‘Bodies of seeing’

A video ethnography of academic x-ray image interpretation training and professional vision in undergraduate radiology and radiography education

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Dedication

I dedicate this thesis to my parents – John and Julie – in gratitude for their unconditional love and patience. To my brother Paul, I am grateful for all of your acts of kindness over the years.

Abstract

This thesis reports on a UK-based video ethnography of academic x-ray image interpretation training across two undergraduate courses in radiology and radiography. By studying the teaching and learning practices of the classroom, I initially explore the professional vision of x-ray image interpretation and how its relation to normal radiographic anatomy founds the practice of being 'critical'. This criticality accomplishes a faculty of perceptual norms that is coded and organised and also, therefore, of a specific radiological vision. Professionals' commitment to the cognitivist rhetoric of 'looking at'/'pattern recognition' builds this critical perception, a perception that deepens in organisation when professionals endorse a 'systematic approach' that mediates matter-of-fact thoroughness and offers a helpful critical commentary towards the image. In what follows, I explore how x-ray image interpretation is constituted in case presentations. During training, x-ray images are treated with suspicion and as misleading and are aligned with a commitment to discursive contexts of 'missed abnormality', 'interpretive risk', and 'technical error'. The image is subsequently constructed as ambiguous and that what is shown cannot be taken at face value. This interconnects with reenacting ideals around 'seeing clearly' that are explained through the teaching practices and material world of the academic setting and how, if misinterpretation is established, the ambiguity of the image is reduced by embodied gestures and technoscientific knowledge. By making this correction, the ambiguous image is reenacted and the misinterpretation of image content is explained. To conclude, I highlight how the professional vision of academic x-ray image interpretation prepares students for the workplace, shapes the classificatory interpretation of ab(normal) anatomy, manages ambiguity through embodied expectations and bodily norms, and cultivates body-machine relations.

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Glossary of Terms

Anterior Posterior (AP)	Anterior refers to the 'front' and Posterior refers to the 'back'. Putting this in context, the AP radiograph is a back view of body part, where the x-ray source is positioned so that the x-ray beam enters through the anterior (front) of the body part and exits out of the posterior (back), where the beam is detected.
Arthritis	A disease causing painful inflammation and stiffness of the joints
Aspirate	The sound you make with an exhalation of Breath.
Axilla	Armpit
Azygos fissure	A normal anatomic variant of the RUL due to invagination of the azygos vein and pleura during development in the foetus.
Cardiomegaly	Abnormal enlargement of the heart
Cardiothoracic surgery	When a specialist (cardiothoracic surgeon) operates on the heart, lungs and other thoracic (chest) organs
Clavicle	The collarbone
Clinical placement	An hospital environment that provides clinical situations to students under supervision.

Costophrenic angles	The two places where the diaphragm meets the ribs. On a CXR (normal) each angle can be seen as a sharply-pointed downward indentation.
Diaphragm	The dome shaped sheet of muscle and tendon that sits at the base of the chest. It serves as the main muscle of respiration and plays a vital role in the breathing process.
Endotracheal Tube (ET)	A flexible plastic tube that is inserted into the trachea (windpipe) to help a patient breathe. The tube is then connected to a ventilator, which ensures adequate exchange of oxygen and carbon dioxide.
Hemipelvis	Either left or right half of a pelvis (plural hemipelves)
Hemithorax	One side of the chest
Hickman line:	A central venous catheter most often used for the administration of chemotherapy or other medications, as well as for the withdrawal of blood for analysis.
Hila	The root of the lung that contains the pulmonary veins and arteries that supply blood to the lungs[1]
Intensive Therapy Unit (ITU)	Specialist hospital wards that provide treatment and monitoring for people who are very ill. Also called Intensive care Unit (ICU).
Lungs	The lungs are located on either side of the

[1] Or hilium (pleural)

	Heart. and are separated by fissures into lobes.
Left Lung: lobes	The left lung has two lobes: Left Upper Lobe (LUL) and Left Lower Lobe (LLL).
Left lung: Fissure	Separates the LUL from the LLL.
Lucency	Something is less dense (i.e. blacker)
Mastectomy	A surgical operation to remove a (one) breast
Meniscus sign	A (curving) meniscus is a useful clue to the presence of fluid in the pleural space and indicative of a pleural effusion.
Naso Gastric Tube (NGT)	A plastic tube that carries food and medicine to the stomach through the nose and down the throat.
Opacity	The quality of lacking transparency or translucence, often used in reference to 'whiteness'.
PACS	Picture Archiving and Communication System
PICC line	Peripherally Inserted Central Catheter. Used to give fluids, medications, nutrition and/or take blood samples for testing.
Pleura	The double-layered membranous lining of the thoracic cavity that covers the lungs.
Pleural cavity	The fluid-filled space between the two layers of the pleura, and provides a space for the lung to expand against during inhalation
Posterior Anterior (PA):	Posterior refers to the 'back' and Anterior

	refers to the 'front'. Putting this in context, the PA radiograph is a front view of body part, where the x-ray source is positioned so that the x-ray beam enters through the posterior (back) of the body part and exits out of the anterior (front), where the beam is detected.
Primary placement	General Practice (GP) placements occurred in Phases one, two and three.
Pubic rami	A group of bones that make up a portion of the pelvis. Pubic rami fractures are the most common pelvic fracture pattern. Associated with individuals over 60 years.
Pulmonary Artery	The artery carrying blood from the right ventricle of the heart to the lungs for oxygenation
Radio-opaque	(of a substance) opaque/not able to be seen through X-rays or similar radiation: *radiopaque stones in both kidneys*.
Right Lung: lobes	The right lung has three lobes: Right Upper Lobe (RUL), Right Middle Lobe (RML), Right Lower Lobe (RLL).
Right lung: Fissure	Separates the RLL from the MUL and RUL
Sacroiliac joint	The SI joint is the joint between the sacrum and the ilium bones of the pelvis, which are connected by strong ligaments. It is strong and supports the spine.
Sclerosis	Abnormal hardening of body tissue
Secondary placements	'Hospital' placements that comprise of clinical

	rotations in phases two, three, and four namely through specialty attachments.
SOBOE	Shortness of breath on exertion. Used to describe difficulty breathing when engaged in a simple activity like walking up a flight of stairs.
Specialty Registrar (UK)	A qualified medical doctor who is receiving specialist training.
Sternotomy wires	Designed to facilitate sternum closure after cardiac or thoracic surgery. Usually made of stainless steel or titanium.
Subspecialty	"Subspecialty", as used in this thesis, refers to training undertaken as an integral part of the structured training programme, which is intended to lead to the award of a Certificate of Completion of Specialist Training (CCST) in clinical radiology.
Symphysis pubis	A cartilaginous joint that joins the left and right superior rami of the pubic bones in the pelvis.

1 Introduction

Physicist Wilhelm Röntgen's x-ray image of his wife's hand in 1895 – penetrated by electromagnetic radiation that showed a contrast between the opaque bones and the translucent flesh – captured the imagination of the medical profession as a novel way of seeing. The application of this technology (with much refinement) introduced a new approach to diagnosis and treatment through the practice of *diagnostic imaging*[2] (Kevles, 1997). One hundred and twenty-three years later, x-ray is still the first line of investigation for the majority of patients coming into the Accident and Emergency departments (A&E), Minor Injury Units (MIUs) and radiology services in the United Kingdom. The range of x-ray examinations is quite broad, including x-ray images of the musculoskeletal system (MSK), chest (CXR), and abdomen (AXR) with MSK images entailing the broadest approach to examining a variety of differing parts of the body treated separately (upper and lower limbs, pelvis, hip, spine, neck, back, teeth, head).

X-ray images are often identified as the product of x-ray radiography, that is, an imaging technique that uses x-rays to view the internal structure of the body.[3] Radiography allows x-rays to detect a range of problems, in part because the energy from the x-rays (a type of x-radiation) is absorbed at different rates by different parts of the body being imaged. Those x-rays that pass through to the other side of the body are 'detected' by an electronic detector (used instead of a film) producing an electronic image composed of x-ray scattered tissue or what might otherwise be understood as 'shadows' formed by the objects inside the body (Pasveer, 1989). Problems that may be detected using x-ray include a range of bone fractures/breaks, tooth problems, scoliosis, non-cancerous/cancerous bone tumors, lung

[2] Diagnostic imaging is defined as the production of images of the internal structure of the human body that enables the diagnosis of trauma and disease.

[3] Along with radiography (plain x-rays), there are four other x-ray imaging modalities, such as: computer tomography (CT), mammography, angiography, and fluoroscopy. This thesis focuses on plain film radiography. However, the use of CT and MRI can sometimes be found in professionals' accounts as providing essential diagnostic information (i.e. 'further imaging') and for particularly acute concerns ('severely ill patients').

problems (e.g. pneumonia), dysphagia (swallowing problems), heart problems (e.g. heart failure), and breast cancer (NHS, 2018). This translates to patients who are admitted for x-ray imaging at the formal request of General Practitioners (GP) or when an incident occurs that is potentially harmful (for instance, a pelvic injury sustained in equestrian sports) and requiring people who are able to interpret the meaning of shadows and streaks in the image.

X-ray images have been central to the diagnosis and treatment of patient conditions since the 1930s with many techniques being developed throughout the 20th century to enhance the visibility of different body parts (Kevles, 1997). X-ray images and their interpretation for patient problems are now firmly embedded within clinical medical practice and have become "a part of routine patient care" (Howell, 2016: 341). Historically, x-ray image interpretation has been the preserve of the medical profession and domain of radiologists with radiographers omitted from expressing an opinion on images largely as a result of a medical division of labour (Larkin, 1978; Barley, 1984; Snaith and Hardy, 2008). However, a shortage of radiologists, increasing imaging workload, and changes in government policy has meant that restrictions on the interpretation and reporting of x-ray images have steadily extended to allied health radiographers (Reeves, 1999; Price, 2001; Brealey, 2003; RCR, 2012; Winter and Linehan, 2014). Whilst ultrasound signaled a new role for radiographers in the early 1980s in the form of producing, interpreting, and reporting results to patients and clinicians, the work of Berman et al., (1985), Cheyne et al., (1987) and later Renwick et al., (1991) pointed towards the feasibility of radiographers assisting clinicians in the interpretation of x-ray images. This assistance came in the form of abnormality detection and what become known as the 'red dot' system.[4] Consequently, since 1987 efforts have been made to train qualified radiographers in variations of the red dot system, taking advantage of their knowledge of radiographic anatomy and exposure to various abnormalities in the physical craft of x-ray image production (Brealey, 2003).

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[4] Where a radiographer places an adhesive 'red dot' onto an area of the film determined to be abnormal Introduced as part of the Radiographer Abnormality Detection Scheme (RADS) in 1985 aimed to alleviate the increasing pressures on the radiology workforce (Berman et al., 1985).

Since 2009, roughly all of radiographers *in-the-making* accessing undergraduate diagnostic radiography degrees in England and Wales are trained in x-ray image interpretation, provided with education required to 'red dot' or 'comment' upon an x-ray image upon qualification. The term 'radiographers in-the-making' is my own. I use the term 'in-the-making' because the students are in the process of 'making it' as professionals and make valuable contributions in clinical work as early as the first month into their degree. Nineteen out of the twenty-five (n=19/25; 76%) HEIs in the UK that provide pre-registration radiography degrees delivered image interpretation modules, although this figure is response rate-biased, focusing on the nineteen who opted to participate in the study (Hardy and Snaith, 2009). The uptake in image interpretation modules has dramatically increased annually in Higher Education Institutions (HEIs) since the development of a formal education programme for radiography in 1996 (Prime et al., 1999). This differs from medicine and medical education in UK medical schools, where the uptake in x-ray image interpretation is currently low and it is unclear how much radiology teaching is required to develop sufficient interpretive competencies (Bhogal et al., 2012), although other countries, such as Canada, have reported a decrease in the undergraduate medical school curriculum (Dmytriw et al., 2015).

The decrease in UK medical schools' uptake of formally structured x-ray image interpretation training may be attributable to the increase in a new generation of medical sub-specialties (an increase in sub-specialties is known to have overcrowded the curriculum and increased the competition for space), the treatment of radiology as being "adjunct" to the core elders of medical school curriculum (such as medicine, surgery and pediatrics), and the perspective that radiology may be more appropriately covered in the clinical years (i.e. during clinical placements in radiology departments) (Chowdhury et al., 2008). The decrease in Canada, in contrast, is perhaps attributable to a dependence of training based on clinical 'rotation' and to medical students who are "not interested in specialising in radiology" (Dmytriw et al., 2015: 223). In terms of the UK, interpretive training is being delivered on clinical radiology rotations in UK hospitals (Phillips and Golding, 2010; Bhogal et al., 2012). However, it is unclear how much exposure medical students receive, including their participation in practical procedures such as image production or ultrasound (Phillips and Golding, 2010), although one report has indicated that medicals students are "feeling inadequately exposed to radiology" (O'Brien and Shelmerdine, 2012).

Nonetheless, the lack of coverage in UK medical schools and clinical placements has coincided with an x-ray image interpretation increase in the diagnostic radiography degree in England and Wales as part of modern undergraduate education (Wright and Reeves, 2017). Since 2013, diagnostic degree programs in principle have changed to meet the Society of Radiographer's (SoR) policy of phasing out the 'red dot system' and replacing it with Preliminary Clinical Evaluation (PCE), so that medical staff (such as junior doctors) would have more key information to make a diagnosis (SoR, 2013). PCE, also known as 'commenting' on some common categories of film,[5] is defined by the SoR as the ability to "make informed clinical judgments and decisions, and communicating these in unambiguous written forms to referrers" (SoR, 2013: 3).[6]

According to SoR (2013: 10), PCEs "must have recorded reports" in order to facilitate communication of one of the following: 1) the image is normal/normal with an anatomic variant; 2) the image is abnormal where its location is described using "standard anatomical, physiological and pathological terminology"; 3) the image appearances are "complex" and require either a consultant radiologist or radiographer opinion; and 4) a preliminary evaluation has not been provided. This summary of the PCE, in particular, highlights the importance of anatomical terminology in terms of spelling out the trouble of abnormality (in both its location and appearance). Alongside this, SoR then goes on to state the importance of using technological terminology in references to the image stating: 1) the projections/techniques undertaken; 2) if artefacts are evident in the image; 3) relevant clinical details; 4) patient identification details, 5) the name/status of the person providing the PCE; and 5) the date and time at which the PCE was completed.

In this instance, we can start to see see how seeing and saying is interwoven with both anatomical, scientific and technological terminology in such a way that image appearances are in demand for descriptive detail. This criterion is increasingly important to consider as a means to reduce ambiguity as the SoR (2013: 11) warns: "informal and verbal systems of communication are best avoided" highlighting how informal communication systems "are

[5] Mainly, but not limited to: CXR, AXR and MSK.

[6] The second distinct role in reporting is 'Clinical Reporting' where radiographers "produce diagnostic reports in defined fields of practice after the successful completion of postgraduate training") (SoR, 2013: 3).

inconsistent with delivering reliable outcomes for patients and referrers and for attributing accountability for errors" (SoR, 2013: 3). PCE has been particularly important within the field of A+E medicine, as the majority of diagnostic claims concern junior doctors who are first in line to interpret x-ray images to help in the early diagnosis or exclusion of fractures and disease (Guly, 2001). Throughout chapter four we will see how the learning of anatomical and technical or, rather, technoscientific terminology lies at the heart of their radiological gaze and later in chapter five how they build on this through descriptions or classifications of abnormality.

In addition, a report conducted by the Royal College of Radiologists (RCR) claims that in 2014, the overall error rate[7] varied from 3-30% in the observation and interpretation of medical images. According to the report, of the 3-30% errors that occurred during x-ray image interpretation, the common cause of errors were categorised as 'cognitive' (lack of knowledge) and 'perceptual' (observation or interpretation errors,[8] ambiguity of wording or summary of report) and resulting from the influence of 'system' errors (inadequate, misleading or incorrect clinical information, poor imaging technique, excessive workload or poor working conditions). The proportion of radiological error on radiological reporting in the UK has stayed steady for almost seventy years. Since 1949 until 2014, the errors in radiologic interpretations of plain radiographic (as well as CT, MR, ultrasound, and radionuclide) images hover in the 30% range (Berlin, 2014). Leonard Berlin (2014) claims, however, that an estimated 60-70% of these errors are *perceptual* in nature. He suggests this is because professionals in-the-making are not being sufficiently trained in the 'subtlety' of findings when missing the lesion or abnormality can be due to low contrast or limited difference between adjacent radiographic densities.[9] This matter will actually be elaborated on in chapter four although it is a common thread that runs throughout the thesis.

While this may adequately explain how a subtle lesion or abnormaliy can be missed, it is inadequate or insufficient regarding its task of explaining how 'obvious' lesions or abnormalities can be missed: "the missing of an overt lesion remains as much a mystery and

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[7] Clinically significant

[8] For example, 'false-positives'

[9] That is, similar in colour, or have many shades of grey

enigma today as it was 61 years ago" (Berlin, 2014: 81). It also perhaps reveals how perceptual errors, despite the enormous technological progress of the last century, continue to remain elusive for the human eye and brain. Cognitive or reasoning errors have been sorted out, yet perceptual errors remain; the latter is the most pressing move in medical image interpretation education. Thus, despite this investment in bringing forward the cognitive work in training/image interpretation, the rate of perceptual errors has not fallen, but the number of cognitive errors has decreased, which may have otherwise continued were it not for the increased acknowledgement of radiological errors, improved medical education and more complete patient history/clinical findings to the clinician (Berlin, 2014). Brealey (2003) makes a critical point about cognitive and perceptual errors – the former occurs when the observer fails to correctly describe the content of the image, while the latter when the observer identifies the abnormality but misinterprets what it is.

However, there have been some major radiological errors in the clinical reporting of CXRs, since junior doctors have to formally interpret images. According to the Care Quality Commission (CQC, 2018), over 20,000 CXRs at an NHS Hospital trust in England had not been adequately interpreted, 40% (*n* = 8,000) of which were not reported. Of the 8,000 non-reported CXRs, there were "three serious incidents", where patients came to significant harm when signs of lung cancer were missed. The cancer could possibly spread (in two patients) due to inexperienced junior doctors reviewing the images and a shortage of radiologists or appropriately trained clinical staff to report on the CXRs. This concern for the connection between junior doctors and a lack of training has been well studied for over twenty years by testing and other means of scoring 'competencies' or 'performances' associated with successful image interpretation.

From the first study in 1989 until more recently in 2013, a number of studies have documented deficiencies in junior doctors' competency in the interpretation of CXR images (Gardner, 1989; Guly, 2001; Jeffrey et al., 2003; Eisen et al., 2006; Boutis et al., 2010; Satia et al., 2013). Consequently, studies are increasingly turning their attention towards measuring medical students' interpretive ability hoping to identify learning objectives (Scheiner et al., 2002; Kilicaslan et al., 2003; Jeffrey et al., 2003; Brazeau-Lamontagne et al., 2004; Dawes et al., 2004; Eisen et al., 2006; Halaas et al., 2007; Huang et al., 2010; Boutis et al., 2010; Sendra-Portero, 2012). Most of these studies point towards a lack of teaching and/or poor technique in interpretation as the source of these interpretive deficiencies. Much less, however, is said about the equally significant anatomical components of these deficiencies and the influence of image production on the appearance of anatomies. This means the role of image production, exposure factors and their effects on how different anatomies attenuate radiation are either not mentioned or in the background and underestimated. This is surprising considering how good knowledge of normal radiographic anatomy and knowledge of x-ray image production underpins competent image interpretation and preventable diagnostic errors (Peterson, 1999; Perez et al., 2015).

In comparison, research on radiography students' performance on x-ray image interpretation lags well behind research on medical students, although a growing body of work is being developed for the benefit of UK Government and the SoR (Manning et al., 2006; Nunn and Nunn, 2011; Nocum et al., 2013; Wood et al., 2013; Winter and Linehan, 2014; Buissink et al., 2014; Wright and Reeves, 2017). Most of these studies highlight strengths in a range of interpretive skills and attribute this to having successful retention of radiographic anatomy, the ability to correctly identify normality, and differentiate between normal variants and potential fractures. Furthermore, while this research has made great strides in sorting out interpretive performance in response to certain stimuli, there are still inherent absences in establishing how these performances are learned in the first place. Taking both litertaures into account, the research question I seek to address here is:

> *How do professionals in-the-making learn to see and interpret x-ray images in the initial stage of professional learning?*

Nonetheless, it is clear how x-ray image interpretation begins in academic settings, separate yet somehow converging with the clinical workplace setting. This thesis is dedicated to a video ethnographic exploration of x-ray image interpretation training and development of professional vision in academic settings. Whilst studies have explored clinical imaging departments and uncovered aspects of undergraduate learning embedded in professional work practices (Polanyi, 1958; Barley, 1984; Saunders, 2008, 2009), I focus exclusively on academic departments or classrooms and those accessing formal instruction at the university, as part of undergraduate degree programs.[10] This is because academic x-ray image interpretation tuition is important enough to be explicitly included alongside taken-for-granted or deft tuition in the clinical workplace, which remains a neglected area and almost completely outside the purview of sociological research (until now).

1.1 Previous research

Training for medical image interpretation has previously been the exclusive subject of healthcare education research, mainly drawing on methods for evaluation and assessment closely related to, but distinguishable from social research. However, a large body of research can be classified into two core and interrelated categories of training for x-ray image interpretation. First, a proliferation of studies evaluate the problem solving of professionals in-the-making and if they do or do not correlate with successful interpretation of x-ray images (Cockshott, 1971; Clarke, 1981; Dussault et al., 1983; Cozens, 1987; Edeiken-Monroe et al., 1988; Blane et al., 1989; Locksmith et al., 1992; Peterson, 1999; Charlin et al., 2000; Ekelund and Langer, 2004; Chew et al., 2005; Subramaniam et al., 2006; Thurley and Dennick, 2008; Belfield, 2010; O'Connor et al., 2016). Whilst many of these studies understand learners' comprehension of x-ray image interpretation training as a result of learners' use of cognitive scripts/schemas, others identify training as an intricate interplay between the acquisition of cognitive and perceptual skills rather than the memorised use of scripts (Morita et al., 2008; Krupinski, 2010; van der Gijp et al., 2014; van der Gijp et al., 2017; Kok et al., 2015, Kok et al., 2017; Sheridan and Reingold, 2017).

As a structured teaching technique to learn or improve problem solving, scripts are often referred to as 'systematic approaches' in healthcare education, a 'step-by-step' approach to interpreting radiographs so that images are scrutinised and comprehensively searched in order to stop missed findings (Eaton and Cottrell, 1999; Eisen et al. 2006; Delrue, et al. 2011; Kok et al., 2015). The importance of systematic approaches to interpretive work have not

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[10] Most importantly for this thesis, I define the 'academic' as a formal education setting in which people (as learners) are being educated in university classrooms by professionals. Work on student learning in academic image interpretation practice is non-existent.

gone unnoticed in social research of image interpretation and will be discussed later in chapter two (e.g. Saunders, 2008; Sandell, 2010; Rystedt et al., 2011; Winter and Linehan, 2014; Friis, 2017). Although a reliance on such heuristics or 'rules of thumb' carries a "risk of systematic errors" by influencing cognitive bias (Dawson and Arkes, 1987: 186); it is particularly noteworthy because it draws attention to the "memorability of an event influencing the perception of its probability" something that is warned about in chapter four (Dawson and Arkes, 1987: 183). This corresponds to professionals in-the-making perceiving learning to see as rooted in cognitive psychology (Eaton and Cotrell, 1999; Charlin et al., 2000; Linaker, 2015a), and professionals' training as being a balance between 'analytic' and 'non-analytic' modes of reasoning[11] such as pattern recognition (with the latter being performed through the former) (Crowley et al., 2003; Eva, 2004, 2009; Norman et al., 2007; Kok et al., 2015), but also how case-based teaching can be mainly viewed as an opportunity for learning from errors, and training as more uncertain or difficult, rather than a way of getting the correct diagnosis (Gunderman, 2005; Gunderman and Burdick, 2007; Ravesloot et al., 2017; van der Gijp, 2017).

For Kok et al., (2017) research on diagnostic reasoning in medical image interpetation suggests it is best to start teaching students non-analytic methods first because it underpins the development of a cognitive schema that is crucial for systematic reasoning (Kok et al., 2015, 2017). This foundation of a non-analytic mode of reasoning marks the beginning of medical image interpretation training for radiology educators (Kok et al., 2017) and is administered for the benefit of learning pattern recognition (Eva, 2004, 2009; Norman et al., 2007). Importantly for this thesis pattern recognition has come to be used for the significant body of work that relates to a gestalt[12] form of 'problem solving' in the field of radiology education beginning in the 1960s: a "'instance-based categorisation,' in which expertise

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[11] According to Eva (2004) non-analytic reasoning refers to unconscious/automatic rapid reasoning, whereas analytic reasoning refers to deliberate conscious/controlled reasoning.

[12] According to Friis (2017: 2010) "gestalts are something that stand out against a background and enables us to identify patterns". However, Friss stresses how seeing these patterns is based on a specific intentionality of particular relevance: "it is the interaction between perceiver and the perceivable object, which results in a perceived pattern or gestalt". Put simply, perception is accomplished because people are trained to look for them and seeing what that pattern or object *is* is directed by that person's interest in finding them.

derives from rapid pattern recognition mechanisms that help experts match the case at hand to previously encountered examples" (Crowley et al., 2003: 41). Kok et al., (2015: 191), a team of cognitive neuroscientists and researchers in radiological pedagogy, write that pattern recognition is referred to as a method of non-analytical reasoning because of its reliance on memory: "a physician quickly recognises the diagnosis because of the similarity to cases seen in the past". Furthermore, this literature highlights how professionals use the word 'pattern' when talking about normal anatomies to organise their perception and not abnormal anatomies (although, at times, there is some slippage, such as Donovan and Manning [2006]).

However, not all members of this 'problem solving' community were aligned with the idea that perceptual processing developed before cognitive processing – indeed Lesgold et al., (1988) put less emphasis on perception, suggesting that visual expertise is mainly the function of 'cognitive inference'; "that is, given a set of findings (perceptual features), one has to determine which diseases are consistent with those findings." This movement endorsed a foundational criteria that emphasised the correlation of vision and cognition in forming and evaluating diagnostic decisions – for example Lesgold et al. (1988) emphasised thinking (as cognitive inference) and how vision and cognition correlated in visual diagnostic reasoning when analysing areas of anatomy. Or put simply: cognition builds mental representations which *guide* perception (Lesgold et al., 1988).

Second, a number of studies evaluate the teaching design related to learning image interpretation, particularly concerning the design of classes, modules or other educational formats to undergraduate students. This often translates to evaluating the differences between traditional classroom based learning and new learning interventions using various e-learning methods (D'Alessandro et al., 1993; Erkonen et al., 1994; D'Alessandro et al., 1997; Maleck et al., 2001; Ketelson et al., 2007; Pusic et al., 2007)[13] such as computer based learning, blended learning, online/virtual learning, or web-based learning. Several studies claim professionals in-the-making perceive their retention of radiographic information lies in establishing face-to-face communication, since it provides a high level of student-teacher

[13] Once called Computer-Based Education (CBE)

interaction for solving case presentations (Subramaniam et al., 2004; Ekelund and Langer, 2004; Belfield, 2010; Linaker, 2012; Venter, 2016).

Others simultaneously report on how professionals experience difficulty in delivering face-to-face teaching and encourage independent or self-directed learning (SDL) as supplements to didactic-style instructions in classrooms and lecture halls (Lesgold et al., 1988; Belfield, 2010; Linaker, 2012). Independent curriculum components, however, are now frequently drawn from the increasingly available and comprehensive online and software-based e-learning tools (Pinto et al., 2011, Zafar et al., 2014), including programs to assist with the recognition of anatomical structures in medical images (Khalil et al., 2008), programs that replace traditional lectures with 'virtual lectures' (Sendra-Portero et al., 2013), and programs that 'blend' with the traditional classroom learning environment (Kourdioukova et al., 2011a; Howlett et al., 2011).

This stems from a need to balance both the necessity for didactic teaching, greater participation in class and independent learning (Shaffer and Small, 2004; Zeiler et al., 2001), a conflict between the time professionals have to teach on radiology rotations and the time required for other duties (Robinson and Voci, 2002; Branstetter et al., 2007; Pusic et al., 2007; Nadeem et al., 2009, 2013; Mahnken, 2010; Oris et al., 2012; Linaker, 2012). It also deals with the difficulty of delivering the common risks of imaging investigations and the procedural/limited aspects of imaging technique[14] (Subramaniam et al., 2005; Sendra-Portero et al., 2013; Jacob et al., 2016), how professionals in-the-making may not fully develop three-dimension mental extrapolation (Allen and Roberts, 2002; Shaffer and Small, 2004), and the differences between professionals and professionals in-the-making regarding what constitutes a positive and beneficial learning experience in 'hot-seat' teaching, reflective of Socratic inquiry[15] (Roberts and Chew, 2003; Zou et al., 2011).

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[14] Although medical students are taught about "indications and limitations of basic [radiographic] technique", the "practical application" of this knowledge is restricted in medical school (Jacob et al., 2016: 481).

[15] "A pedagogic technique in which a teacher does not give information directly but instead asks a series of questions, with the intention that students come to the desired knowledge in the process" (Zou et al., 2011).

Taken together, these studies show how the design and dissemination of x-ray image interpretation training has triggered contradictory messages of delivering radiographic information to, and prompting anatomic, scientific-technical, and perceptual difficulties for, professionals in-the-making. This means when learning radiographic information about x-ray image content professionals in-the-making must problem solve frequently based on the teaching design grounded in cognitive psychology and disembodied individualized information (Gegenfurtner et al., 2017; Gegenfurtner and van Merriënboer, 2017). Moreover, most studies are subsumed as assessment tools that play an anchor role in whether interpretive performance is 'better' post the learning innovation (Scheiner and Mainiero, 2003; Pusic et al., 2007, Khalil et al., 2008) building on a medical school's competency-based curriculum (Gunderman et al., 2003). Such extensive research not only highlights the effectiveness of different educational formats in improving abnormality detection, problem solving ability, and radiographic anatomical knowledge of undergraduate students (Linaker, 2015a), but also reassures university departments that students are learning what they (university) teach in order to contribute to a reduction in error rates and litigation related to a missed abnormality (Berlin, 2007).[16]

Nonetheless, whilst the studies cited above provide a substantial contribution to knowledge, there are some criticisms. First, bodily and material aspects are missing from the literature, such as those of medical students and radiography students learning to see or misinterpret images. Additionally, and most unique to this study, is the inclusion of radiographers in-the-making who continue to generate a severely undersized literature. It is surprising that researchers have not given greater priority or presence to radiographers in-the-making, as they play such a key role in the Government's long-term plan for a sustainable NHS given.[17]

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[16] Interestingly enough, there have also been some recent attempts to disseminate image interpretation training of medical students and junior doctors, at an individual level, by creating phone apps, podcasts and posting content to online channels (e.g. YouTube). Perhaps this is to address their limited exposure to image interpretation training.

[17] Following the Government's review of public spending on October 20th 2010 George Osbourne[17] announced how the NHS could save £7.9 million annually if the number of reporting radiographers increased (HM Treasury, 2010).

Second, research is often based on retrospective "end-point" (Garfinkel et al., 1981: 137) evaluation and biased towards studying medical students or junior doctors (e.g. Jaffe and Lynch, 1993; Gunderman et al., 2003; Torre et al., 2005). Focusing on medical students, data is mostly collected via questionnaires (e.g. Locksmith et al., 1992; Merhar, 1995; Peterson, 1999; Jeffrey et al. 2003; Mahnken et al., 2011), surveys (e.g. Kourdioukova et al., 2011b, Oris et al., 2012; Sendra-Portero et al., 2013), or more problematically, professionals speaking for medical students (e.g. Jaffe and Lynch, 1995; Nadeem et al., 2013). Most of these also devote attention to the simultaneous collection of pre-post[18] data designed to assess change in interpretive knowledge before and after the teaching initiative (e.g. Blane et al., 1986; Pusic et al., 2007; Sendra-Portero et al., 2013). Whilst these studies ask 'medical' students questions to evaluate information on the strengths/weaknesses of the teaching design (i.e. 'learner satisfaction') and pre-post test whether it was effective in enhancing their knowledge/skills (i.e. 'learning outcomes'), evaluation forms are mainly multiple choice with closed-ended questions ('yes', 'no', 'maybe'), with little or no room for elaboration via open-ended questions that could emphasise depth of the descriptive details.

These evaluations of student responses and their statistical analysis, a static method that has survived for over fifty years because it reinforces the presumption of a 'scientific method', is both contradictory and inadequate for the collection of data on the *processes* and *interactions* that train and discipline professionals in-the-making who are learning to see. This approach has lasted for some time regarding radiological instructions on student learning of medical image interpretation and it might well take 'competence' as the underlying force behind its movement. Thus, students have been tendered research that restricts the researchers' access to a narrow range of interactions, events and relationships and thus provides a lack of depth to the research on the process(es) of learning how to see (or *not* for that matter).

This assessment of the teaching design, by de-contextualising situation specific training activities and relying on memory that is readily recognised by studies as cognitive psychological or individual (Plummer, 2003) neutralises and makes aspects of meaning-making practices in training activities invisible. This focus on perceiving vision as an

[18] The contrast between the periods 'before' and 'after' the learning intervention to show change

unproblematic form of registering with the external world as well as interactions between people continues to support the prevailing assumptions that it is disembodied (Styhre, 2010).

There are some exceptions in the form of ethnographic and qualitative research. The projects identified belong to the ways of seeing related to radiology and tend to focus on the development of imaging technology such as x-ray (Pasveer, 1989), ultrasound (Yoxen, 1987; Blume, 1992), MRI (Joyce, 2006; Dussauge, 2008), tomosynthesis (Rystedt et al. 2011), while other research has focused exclusively on the integration of new imaging technologies in radiology departments and upon existing work practices (Barley, 1984; Joyce, 2008; Burri, 2008; Saunders, 2008; Wood, 2012; Reed et al. 2016a). Other studies have tended to focus exclusively on the relation between medical images and visual expertise (Polanyi, 1958; Hartswood et al. 2002; Måseide, 2006, 2007; Sandell, 2019; Friedrich, 2011, 2015; Winter and Linehan, 2014; Ivarsson, 2017; Gegenfurtner et al. 2019). Most of these studies, however, concentrate on situations of seeing in clinical and research contexts in which the centrality of visual expertise has been trained to professional or *qualified* status. There are very few studies addressing professional-student interactions related to medical image interpretation (Polanyi, 1958; Barley, 1984; Saunders, 2008, 2009; Zou et al., 2011; Gegenfurtner et al. 2019).

However, they are overly narrow and, more critically, they are backgrounded in the narrative, where (medical) students' contribution to image interpretation is minimal. In a rushed teaching arena, the dyadic relationship among students and professionals provides only a glimpse into interaction and active participation, with Saunders (2008: 51) preferring to focus on how often medical students are subject to enactments of hierarchy when they learn alongside radiologists and clinicians who comment more on radiographic appearances. This focus on the way in which learning to see is situated in clinical work posits a part-for-whole selection that gravely reduces any holistic views on the learning of professionals in-the-making. The clinical setting, in turn, is only part of the university qualification and professional training around undergraduate image interpretation. Having said that, the role of ethnography in researching undergraduate learning remains restricted in clinical settings. It is essential that sociologists turn their attention to this dearth in studies of image interpretation training (this includes ethnographic approaches to university-workplace transitions). Looking at the way images are introduced in academic contexts might illuminate the process at work when images are removed from their sophisticated technologies, patients, and clinical contexts.

Third, studies on x-ray image interpretation training fail to discuss the *process* of learning and subscribe to cognitive psychology components of visual expertise or gestalt theory (i.e. the perception of patterns/signs) more generally. Although exceptions are identified (e.g. Gegenfurtner et al. 2019), there is limited empirical research conducted via video or ethnographic observations of academic settings. They have not dealt with how x-ray image interpretation is accomplished within the processes of initial training and the claims that training fosters a belief that learning to see is an autonomous activity that does not go beyond the individual mind (Ivarsson, 2017).

This criticism extends to analyses on biomedical training practices more generally (i.e. not limited to medical image interpretation training) and how standards around visual expertise are enacted within healthcare education (Prentice, 2013; Gegenfurtner et al., 2017). Studies have suggested biomedical and anatomic education, despite being widely endorsed and embraced, promotes clear attention to 'what to see' and 'what not to see' (Friedrich, 2010; Prentice, 2013). Many studies, however, frame visual expertise as a solo or independent activity. Although these studies contribute to building up the independence of learning and endorse the autonomous development of visual expertise through the application of gestalt principles, there is a shared understanding within the healthcare community that these standard sources have less and less to say (Zafar et al., 2014; Friis, 2017). A major and recent observation has been provided by Zafar et al., (2014), who have attempted to review e-learning in radiology education and concluded that it was not sufficient to prove that online learning enhanced or improved the students' interpretive performance (for example, Pusic et al., 2007; Mahnken et al., 2011).

There is an indication, however, that healthcare research is changing form and style with attention to the learning of visual expertise being social and materially mediated. In part because of the success of Problem-Based Learning (PBL) in responding to challenges in western healthcare education (Stevens, 2009), research on visual expertise in image interpretation training has come to be treated as a watershed in scientific techniques (Kok et al., 2017; Gegenfurtner et al., 2017). Gegenfurtner et al., (2017: 99) argues that the dominant tag of 'visual expertise' has often remained in cognitivism, which denies the skillful use of the body; 'visual expertise' uses "a system including the self, other human agents and non-human mediators" to make expert professionals. The cognitivist-laden 'visual expertise' starts to break down when one observes who and what makes up the visual. By employing visual expertise unfairly within a cognitivist interpretation of perception (one that focuses solely on the interaction between the brain and the eye), such studies obscure how social processes contribute to expert performance (Gegenfurtner et al., 2017). This argument is summarised in Donovan and Manning's (2006: 10) thought-provoking statement:

> We simply do not have a definitive answer to what makes a good radiologist (or reporting radiographer), possibly because we have yet to fully understand the processes of learning, reasoning, knowledge, perception and conceptualisation that underlie proficient image interpretation.

From a more critical perspective, the inability to 'let go' of the scientific method (Reeves, 1999) for researching medical image interpretation training has led to a limit that understandably frustrates radiologists' and radiographers' active meliorism. According to this view, ethnographic and interaction-based research need not represent the inadequacy of evaluation-based research, but may be beneficial in its complementarity. In the light of this awareness from healthcare professionals, this study is timely and necessary to confront the conceptual limitations and healthcare 'overreach' that continue to impede meaningful discussions of image interpretation training.

1.2 The current study

This research – a video ethnography of undergraduate training for x-ray image interpretation – seeks to address the gaps cited above and emphasises the lived nature of visual cognition that differs from the work going on "under the skull" (Garfinkel, 1963: 190). Specifically, I explore the professional vision of radiologists and radiographers and how x-ray image interpretation training is 'done'[19] (Garfinkel, 1967) in the taken-for-granted teaching

[19] 'Verbally' and 'gesturally', initially. This will be clarified in chapter two ('Theoretical foundations').

activities of the university classroom, a place where particular belief systems, professional standards, and competencies are accomplished (Hafferty and Castellani, 2009). A video ethnographic analysis of routine teaching events shows the fluid, complex, and multiple ways in which bodies of seeing give meaning and position in biomedical training.

This study was conducted across two UK higher education settings: 1) Woodfleet, a large polytechnic university in a leafy suburb, and; 2) Bridgestock Hospital, a large NHS teaching hospital attached to a medical school of a red-brick university in the urban area of a large city. My employment of a triangulated approach to data collection meant I spent over forty hours making observations and video recordings of undergraduate training in these settings, generated e-mail correspondence with seven professionals, and analysed audio-video recordings including anatomic handbooks/learning resources allocated to professionals in-the-making. Before I continue, two clarifications are required.

First, I will not turn to video data exclusively concerning professionals in-the-making interacting with images. While their experiences, perceptions and coming-to-see are limited in the literature, I mainly explore professional forms of seeing and reasoning (Goodwin, 1994) between the expert and the image and their "methods for making those same activities visibly-rational-and reportable-for-all-practical-purposes" (Garfinkel, 1967: vii). This is because training is largely driven by professionals and the knowledge of those learning to see is either absent or limited at this time. However, this study does not ignore the fact that in certain social settings professionals in-the-making are called upon to learn for themselves in order to enhance the learning objective of the class. However, this individual engagement is far from 'learning by themselves', as professionals in-the-making interact in a network of peers, images, visual media, and materials (as well as professionals) 'in order' to see. Furthermore, I choose primarily to focus on the 'gap' between professional and student and explore its implications since, as stated earlier, it has very rarely become the object of attention and subjected to critical social analysis in the context of undergraduate image interpretation training.[20]

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[20] This observation highlights another area for further study: professionals in-the-making functioning as important sources of tacit learning themselves. An attempt to start engagement with such learning within image interpretation education is illustrated in chapters four and six.

Second, I draw on observed video recorded training practices of two different communities of practice (Lave and Wenger, 1991). Whilst both communities differed according to the environment and specialisation, the interpretive challenges raised were reflected in both communities. Indeed, training in both settings deployed different and similar pedagogical methods to attain a similar result and so my arguments are closely translatable. However, this is not a comparative study that exercises a normative constraint on its participants for "comparative politics and the like" (Hymes, 1972: 50). There are two good reasons for this. First, making a comparison might present the narrative as a competition between the two professions. Doing so might raise the problem of tension and the "conflict" or "socio-political aspects" that existed between radiologist and radiographer in the past (Price, 2001); that is the former's continued attempts at restricting the autonomy of radiographers in giving diagnostic reports on images (Larkin, 1978; Price, 2001).

Second, radiographers at Woodfleet were teaching newcomers in the *initial* stages of their allied health degree, whereas radiologists at Bridgestock were teaching novices in the *latter* stages of their medical degree (a degree that had previously exposed medical students to radiographic anatomy in anatomy courses and other specialties). Whilst many comparisons can be made, I did not want to give off the idea that this thesis is a comparison between the two professions and should not be read as implying competition or incompatibility with one another.

Ultimately, I present an antithesis of the statistical and comparative methods pioneered by researchers in the performance of students and, as I have already noted, beneath the numerical surface processes of learning are always more complex. This thesis is a movement away from viewing cognition and perception in positivist terms. Importantly, I decided to draw on fieldwork in each setting and elicit the detail to get a sense of the bigger picture of x-ray image interpretation training and how ways of seeing intersect with radiological errors and litigation concerns among radiologists (Joyce, 2008; Burri, 2013; Berlin, 2007, 2014; Brady et al., 2012; Brady, 2017). The drive behind this thesis, then, is to address the lack of information on sources of radiological error and how professionals in-the-making overcome some difficulties in learning x-ray image interpretation: "in this, the proponents of practice-based accounts share the same difficulties as their analytical predecessors" (Ambrosio, 2015: 140).

The main focus of this work was on the professionals' bodied practical actions when teaching x-ray image interpretation. I follow professionals' ways, as resources of experience and carriers of 'tacit knowledge'[21] (Polanyi, 1958; Engel, 2008), in and across their communities. I show how their interpretive practices and embodied interactions with images, professionals in-the-making and cognitive artifacts at hand which "make up the lifeworld of a setting" (Goodwin, 2000a: 163), shape and organise visual expertise. By recognising the academic educational setting as a unique environment for studying a "drama of proximity" to the image (Saunders, 2008: 16), I am attentive to how professionals construct and determine image content, how they organise phenomena and shape their detection as to the clinical practices that will follow, and how they perform 'professional vision' (Goodwin, 1994). Following Merleau-Ponty's (1962: 95) dictum, one must unmask the development of skills as they begin to aggregate in formal education settings, until they become "a unity of action that is so reliable that it becomes invisible" (Latour, 2002: 252). I describe how, what, and where professionals teach and to whom, and its consequences for how other bodies participate in learning to 'do' the work of image interpretation (while doing no damage to patients).[22]

This means I effectively illuminate how professional vision for x-ray image interpretation within the established borders of each community of practice is enacted and made sense of from a sociological repertoire that allow a mode of analysis. Emphasis is placed not on the assumption that interior processes of thought control actions or that visual thinking is separate from doing (Gegenfurtner and van Merriënboer, 2017). Rather it examines 'ways of seeing' as modalities one externalises and how those learning to see are located, ideally in 'natural' situations, whenever possible, to learn and practise skills linked to certain "qualities, properties, or features, in short, 'attributes' that the individual [the professional] *is* or *has*"

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[21] More on tacit knowledge in chapter two. However, for now we can understand tacit knowledge as playing a key role in visual expertise and ultimately sets experts apart from novices (Polanyi, 1958), especially in the recognition of relevant patterns including signs and symptoms (Van Baalen, 2019: 71).

[22] Unfortunately, the same cannot be said of patient surrogates (such as anatomic models that mimic patient body parts).

(Hester, 1992: 159). In this case, uncovering these attributes offers insights into the tacit expectations, methods, and skills professionals rely upon, acting as “aids to a sluggish imagination” (Garfinkel, 1967: 38). This dynamic is mainly missing in current analyses on medical image interpretation training in undergraduate education.

Unlike the studies mentioned above that limit image interpretation and its visual expertise to cognitive/individual imperatives as invoked in the cognitive psychology literature, this study views image interpretation and learning of visual expertise as ‘facts’ negotiated and constructed in the content of collegial talk, gesture, and practices of professionals and their early interactions with professionals in-the-making, digital images, materials, and movement through space (Gegenfurtner et al. 2019). This greatly contributes to scholarly research on how learning the interpretation of medical images is a social and embodied practice (Joyce, 2005; 2008; Saunders, 2008; Friedrich, 2010; Rystedt et al. 2011; van Baalen et al., 2016; Ivarsson, 2017; Gegenfurtner et al. 2019) but further extends this analysis by considering how ‘seeing’ is reproduced and distributed in academic degree courses. By taking seriously the formal side of university training that has often been taken for granted, I seek to show the various ways image interpretation is taught and understood, how professionals perform interpretation, and finally how visual expertise is constituted within training activities.

1.3 Thesis outline

So far, I have outlined what is notably absent in previous studies on x-ray image interpretation education, training and research. Presented in the form of previously published research in sociology, radiology, radiography and diagnostic imaging, the introduction helps disclose or *reveal* certain key absences in previous studies. The presentation of what is absent and lacking in existing research will emphasise the purpose of this thesis, why it is timely, and the value of the ‘current study’ as a significant contributor to the training of undergraduate students in x-ray image interpretation. In this case, acknowledgement of what is missing will further animate and build on ideas around the ‘development’ of a professional vision of x-ray images or ‘radiological vision’ (Måseide, 2007). Chapter two outlines the theoretical foundations that present my arguments and intellections. Theoretically my analysis is informed by a sociocultural perspective (Goodwin, 1994) and influenced by ethnomethodology (Garfinkel, 1967, 2002). Chapter three outlines the process of gaining access and ethical approval (that was anything but straightforward), collecting audio-video data, writing fieldnotes, using video analysis software Studiocode to make maps and code data, and the ethical challenges of video ethnography in educational settings. I also propose a parallel between that learning to see and my own learning to see: an ironic stance that means this study was not possible for the untrained eye and was somewhat essential to completing this thesis.

Chapter four begins with a showing of video data. I explore the professional vision of x-ray image interpretation training and how the organisation of that learning accomplishes it as a 'critical' practice. This is interactionally achieved in three ways. First, professionals enact a 'professional vision' (Goodwin, 1994) of x-ray image interpretation, by deploying an entwined cognitivist rhetoric of 'looking at' and 'pattern recognition' to professionals in-the-making in order to learn how to see normal radiographic anatomy. This rhetorical structure takes shape when students learn to look at/recognise normal patterns of anatomies and intensifies when learning its relation to differences in densities/shades of grey; a relation established by the definitiveness and systematicity of a 'coding' scheme. Second, a 'systematic approach', as a step-by-step "system of scrutiny" (Delrue et al. 2011), is endorsed by professionals to ensure that professionals in the-making scrutinise specific anatomical locations in order to not miss or forget anything. Given the risk of missing or forgetting findings, professionals encourage a repetition of this approach to ensure a full and thorough inspection of the radiograph (as well as comprehension and diagnostic accuracy). Third, the 'areas of interest' of normal x-ray images are (offering pedagogical opportunities to expect 'common places for abnormality', anatomic weaknesses/limitations, and reenactments of mechanisms of injury) are presumed to signal suspicion and make such locations known to the viewer. Such training, I would like to suggest, accomplishes a perception of normal in x-ray image interpretation, forming a foundation for x-ray image interpretation, thus, as a critical and embodied practice.

Chapter five explores how x-ray image interpretation is constituted in the hot seat and radiographic case presentations more generally. Professionals continue to be critical in x-ray image interpretation training and induce uncertainty about images, yet, in training, such interpretations become obedient in a "symbolic economy" (Saunders, 2008: 180). X-ray image interpretation training is presented as misleading, but pushes the practice forward as much as it keeps it in check (hinging on satisfaction of search, abnormal signs, and classification). As such, interpretive practice becomes subsumed by a response to discursive contexts of 'missed abnormality', 'interpretive risk', and 'technical error' in clinical domains that are based on growing trends of medical-malpractice litigation. This ensures that images cannot be taken at face value and common reasons for misinterpretation remain within the purview of the soon-to-be professional for a long time (until a shift in perception closes it down). Chapter six shows how training links cultural ideals to clarity and perceived malleability close to hand. This equips professionals in-the-making (and especially radiographers in-the-making) with scrutinising observation to produce and assess the 'technical adequacy' of images, the discourse used by professionals, as *another* type of systematic approach that assesses the technical quality of the image. The assertion that medical images can "show clearly" (Joyce, 2008: 53) anatomical appearances also relates to the constitution of those being tuned to the domestication of the body, which is fundamental to differentiate between normal and abnormal. Whilst the technical effects of radiographs can vary from the significant to the agonistic to the insignificant, the looking that seems to be on its way to misinterpretation is corrected with a 'techno-scientific gaze' in the embodied conduct of professionals. As such, the embodied reasoning and correction to the 'techno-scientific gaze' contributes to the correction as well as the developing of a 'radiological vision', one that is both physical and verbal, in the classroom (Måseide, 2007).

Chapter seven concludes the thesis. The conclusion reiterates the observations and findings in the study and, importantly, their theoretical contribution to the sociology of science and technology (STS) and beyond. I also reflect upon how x-ray image interpretation training plays a central role in reporting acute awareness to common abnormalities, reducing litigation, highlighting typical difficulties and errors in interpretation, whilst simultaneously administrating common sense links to confidence and delivering a commentary, or of depicting, which images are valued (or not). Consequently, I show how x-ray image interpretation, rather than being founded on the transparency of procedures remaining beneficial to precise diagnosis and appropriate treatment, reenacts the technically ideal image to collude in suspicious on guard seeing. Additionally, I offer some recommendations for future teaching practice, namely the experienced technical performance, by medical students, of radiographic practice in action with patients. Whilst suggestions are proposed, they are not provocative: I do not identify features in teaching practices that I have studied that call for better training. Drawing on Lave and Wenger (1991: 15), students are "transformed most dramatically by increased participation in a productive process" where learning is "not a one-person act". My main intention, thus, is to point out that interpretive teaching in academic settings requires considerable 'physical' skill given the absence of patient bodies and imaging technology.

Answering Joyce's (2008: 65) call for analysing how medical professionals learn to see medical image content, coincidentally, addresses a limited insight into teaching and learning in undergraduate radiology (Chhem, 2009) and radiography (Winter and Linehan, 2014). In this thesis, I broaden the call of 'learning to see' beyond medicine, to include allied health professionals who produce, interpret, and use x-ray images. Whilst I invoke the classic staple of medical professions in sociological inquiry, I also extend my analysis to the allied health professions that have largely been neglected in favour of medicine and left those in training mute. Taken together, I have crafted a story that is a crosscut of two professional training worlds in two academic domains and presents important implications for our conceptions of cognitive and perceptual work, pedagogical principles, ideas about the embodied nature of interpretive work, how radiological error *shapes* the constitution of what is seen in images, and how it prepares students pragmatically for a clinical work environment. As training extends to clinical spaces and expands student learning via bodies, tools, and machines, this expansion challenges us to think about the transition to workplace protocols. In part due to continual NHS changes and intensification of medical imaging services, STS research on the topic must continue. Such research that grapples with image interpretation training in academic and clinical settings (as well as *between*) must continue the same way the NHS continues.

2 Theoretical Foundations

This chapter introduces the theory on which the thesis is based. Video ethnography, as Heath (1986) stresses, can "form an archive, a corpus of data that can be subject to a range of analytic interests and theoretical commitments". Ironically, while this study could be recognised as making an interpretive analysis of interpretive practices, it is precisely on this same point that one puts forward arguments that are not primarily grounded in one theoretic perspective. Like Goodwin (1994), my research is in keeping with ethnomethodological concerns about the way seeing is organised and takes forward work initiated by 'laboratory studies', where the goal is an "examination of the methodical way in which observations are experienced and organised so that sense can be made of them" (Lynch and Woolgar, 1990: 37). According to Dennis (2011), ethnomethodological research addressing the methods people use in their everyday affairs, usually 'members' concerted activities, constitutes an "asymetrical and alternative sociology *tout court*". Whereas meaning in social interaction is associated to its *context* ("action, sense and situation are mutually elaborative in situ") for ethnomethodologists, sociologists analysing social interaction argue that meaning depends entirely on "actors' interpretations and understandings" (2011: 350). This ethnomethodological stance and *constitution of context* will be visible in my analysis of professional vision, practical reasoning, and different methods of visual practice as I too argue that 'context' is accomplished in interaction.

However, in spite of this we can say that ethnomethodology obtains its sense from its relationship with sociology and is in fact "reliant upon it in order to define its own identity, programme, and project in that it respecifies sociological accounts of sociological facts" (Elsey, 2010: 12). Furthermore, it is the 'practical matters' such as bureaucratic and organisational issues, as well as patient safety and litigation, that provides an element of the ethnomethodological justification for this thesis as they inevitably play a part in the teaching of professionals (Wenger, 1998). An expression of both disciplines serves as the underlying intellectual apparatus for this thesis and reflects, in turn, how the complexity of academic x-ray image interpretation training cannot be handled by a particular worldview. In sum, what follows is an attempt to manage this complexity, connected to a rich vocabulary for examining social interaction, reflected by the theoretical tools of Goodwin and Garfinkel in this chapter.

Having indicated the complexities of the dynamics that are at issue, I consider drawing from the work of Goodwin and Garfinkel to uncover how students learn to see in academic settings as well as articulate a theory of interpretive learning. This turn to a study of x-ray image interpretation focuses on Goodwin's (1994) notion of 'professional vision' and suggests learning to see includes appropriating a sort of knowledge inside a community of professionals; one that brings visual expertise as embodied practice and conduct into focus (Ivarsson, 2017; Gegenfurtner et al. 2019). These ideas and the emphasis on and meanings attributed to the practices of professional seeing and visual expertise are broadly set out in the chapter. These will then become elaborated upon throughout my analysis as the thesis progresses. Following Goodwin (1994) my objective is to theorise and reveal how medical and radiography students learn to see in professionally relevant ways and how experts communicate visual practices to their students in order to see and understand aspects of image content. Taking an analytical stance influenced by a sociological perspective and founded on ethnomethodology – and in particular Goodwin's concept of 'professional vision' – is helpful for thinking about medical image interpretation as a social practice (Joyce, 2005, Gegenfurtner et al. 2019). Goodwin's concept is especially pertinent here, as it will help consider these learning processes and interactions with people, documentation, and materials encountered in activities of academic x-ray image interpretation training.

2.1 Goodwin: Professional vision

The concept of professional vision derives from Goodwin's (1994) seminal paper of the same name. The work examines how professions have ways of seeing which are organised in professionally work relevant ways within the distinctive interests of the social group. Goodwin (1994: 606) describes how the way in which professional groups 'see' do so by operating the insignia of their profession's craft: the 'theory' that animates the discourse, the 'material artifacts' used as relevant graphic representations (e.g. maps), and that this is all accomplished through 'bodies of expertise' "that are its special and distinctive domain of competence". The process of seeing does require cognition, but this is socially organised and distributed in a "socially situated activity" (1994: 607). Each phase of the learning process is accomplished by seeing bodies and some form of tool being used by the professional for organising ongoing activity in what is essentially the 'situated' or interactional nature of learning. Goodwin's context of professional activity on an archeological field excavation will help us understand this process of seeing. For example, a professional archeologist distributes some form of tool (such as colour categories), which essentially establishes one possible way that the object of interest (e.g. dirt) could be 'looked at'. However, this cognition is constituted through the social deployment of a meaningful activity relevant to the profession, meaning that the underlying cognition of seeing is built within a world or *practice* in which it is situated. The professional archeologist participates in a situated practice; they train a distinct vision in a temporally unfolding process and they nonetheless expect their students "to be able to see and categorise the world in the ways that are relevant to the work, tools, and artifacts that constitute their profession" (1994: 615).

This vision, however, is often not without its challenges and there may be an instance where some features of the world (or *dirt*) can be difficult to see. In order to overcome this difficulty, an additional concept to the idea of situated seeing dubbed the "situated activity system" is introduced. Following our understanding that seeing can be difficult, professionals operate within a "small activitiy system" who exercise something "more than talk" (1994: 613-614). We can see this now in the interaction between the professional archeologist and student archeologist. The activity of 'inscription',[23] which impels the archeology student's act of measuring the length and depth of two different layers of dirt to a piece of graph paper reveals its dynamic character (talk, writing, tools, and distributed cognition).

However, the ability to provide an answer that aligns with the experts is a difficult exercise, meaning that the expert, taking on the role of correcting and aligning the student's inaccurate measurements, eliminates any uncertainties with "not only sequences of talk" but also "body movements" and "the phenomena they are attending to as they use relevant representations". This activity system allows the professional archeologist to notice that her student has failed to locate a relevant point in the dirt (from which it can be measured) before any measurement is uttered and "creates an interpretive environment that will be used by participants to

[23] The work of inscription is important to any interpretive practice and its very process is fundamental to those learning to see. This is particularly true for student radiographers learning radiographic anatomy and will be returned to later in the chapter as x-ray images are also subjected to inscriptions from educational resources (i.e. schematic anatomical diagrams) as part of the labeling the anatomy activity.

analyse whatever occurs after it" (1994: 613). A consideration of this adaptation to error (i.e. the student producing her 'corrections'), Goodwin (1994: 608) contends, is important when analysing the larger social scene, for it leads us to an understanding of cognition to be a "patchwork of situated, disparate, locally organised cultures, in which knowledge is constituted through a variety of social and political processes". The making of mistakes, as well as disappointing the professional archeologist, shows how visual practice is organised, and while those learning to see in an activity system sometimes encounter difficulties, he suggests that professional vision overcomes this through organisational communication and mundane bureaucratic 'expert systems' (e.g. a colour category system).[24]

Goodwin (1994: 627) discusses three ways in which people learn to see via "practices such as highlighting, coding, and articulating graphic representations" which forces "members of a discourse community to become metapragmatically aware of the communication practices that organise their work" (ibid: 622). For example, we can see how each of these three discursive practices play out in the work of archeologists in the situated activity of analysing post moulds: how the colour of soil is being transformed into categories (the *coding practice*), how documentary materials are produced to represent ancient structures (the practice of producing a *graphic representation*); and how differences in the colour of the dirt are made "salient by marking them in some fashion" (the practice of *highlighting*). It is said that all of these practices mutually elaborate each other and inform the development of a professional vision.

This, mutual elaboration, for Goodwin, seems to be based on a basic principle of common sense thinking called the "documentary method of interpretation". First, the "archeologist attempts to locate *features* such as these post moulds by scrutinising the earth as she digs" (1994: 610). A post mold in the dirt, for example, will have its own unique category that is relevant to the profession. Second, the archeologist, once having classified these colour differences as evidence of a pre-exisiting post mold, may then attempt to mark the post mold into existence once it has been found. Here, the traces in the dirt are "coded" into a coherent object; the categorisation is supplemented and linked together with the line that has been

[24] Later on we will see how radiologists and radiographers exercise expertise through their own (and similar) expert systems.

drawn around the mold, a most public event that can "guide the perception of others" and reifies the task of coding and highlighting as visible and having "very powerful persuasive consequences". Goodwin concerns himself with the first kind of practice, the activity that sets the student "a coding problem", that also involves the mutual elaboration of talk and gesture. This framework of action that the archeologist "discursively shapes" from the dirt becomes "the concerns of the profession" (1994: 611).

2.2 How to see and say

Having identified the socially organised modes of seeing where it becomes necessary, upon occasion, to code, highlight and graphically represent or articulate phenomena, Goodwin (1994: 614) simultaneously focuses our attention to the "sequence of talk within which these ostenstive demonstrations emerge". According to Goodwin, one way of managing how seeing is socially organised through ongoing processes of action is to "provide a relevant language game that can be used to make inferences about precisely what features of the complex perceptual field being pointed at should be attended to", such as a patch of dirt or a video screen, on the assumption that there is a "process of socialisation through language" (1994: 614-615).

In pedagogical contexts of medical image interpretation, for instance, Saunders (2008: 208) suggests that seeing and saying is one of establishing a language game of recognition and proper use of terms in a clinical context. It involves the rational use of language as a matter of social convention and negotiation in matters that concern questions of observation, i.e. aims of the various radiological practices in which the ability to "see more clearly" is twined with words to "say more clearly". For Saunders, seeing and saying transposes the observation into a visual language in order to promote a taxonomy (i.e. something classified) when findings and concerns are referenced, especially when it comes to problems of the image such as abnormalities or lesions.[25] This rational use of language has the pedagogical effect of allowing

[25] A lesion is a region in an organ or a tissue which has suffered damage through injury or disease, such as a wound or tumour.

learners to become sufficiently precise in their classifications and ultimately leads them and others to a fairly clear diagnosis (Saunders, 2008).

The language game presented here lambasts imprecision, especially with the problem of the full description of the observation and deviance from the equivalence between appearance and terminology. There must be a saw/said precision. For example, As Saunders (2008) demonstrates in his chapter 'Testifying and Teaching', imprecision is often corrected by colleagues and 'directed' by more experienced members of the radiology community, such as the resident (junior registrar in UK terms) and the attending (senior registrar or consultant in UK terms): "first the resident saw a density and named it: 'mass'. The attending called the density 'effusion' (fluid collection) – thereby indicating that the resident mistook liquid for solid" (Saunders, 2008: 210). Saunders argues that this is just one example of a series of "correctives" and is typical of teaching interactions "aimed at finessing description of findings" (209), this having the benefit of allowing others to see through a process of regular interruption.

These kinds of interruptions (such as the amending of errors, the redirecting of inspections, and the translation of observations into proper terminologies) should ideally be maximized and prompted to direct the learner towards an understanding of the languge as Saunders eloquently argues, "the goal is not yet to name the culprit disease but to develop a verbal representation of a finding, a *description* (emphasis added)". By taking notice of and supporting analyses of the language, I examine how professionals teach students to see and say through the use of specific terms that guide the learner's every move to the point of some form of description that is constructed through talk and action. For Sandell (2010), this process of learning to see and say in the right way, aligns with the 'commmunities of practice' school of thought (Lave and Wenger, 1991) – the idea that 'newcomers' to a profession learn a common language and acquire gradually the capacity see and say (as well as hear and feel) as professionals do.[26]

[26] Sandell (2010) study is on the scanning practices of midwives who are newcomers to the profession.

In saying this, I should emphasise that the community of practice not only provides newcomers or, rather, in my terms professionals in-the-making, with legitimate access to its language it also tends to reify 'situated learning' – a concept that offers a pragmatic view for observing cognition and skills in their making in specific situated practices; it "shapes specific skills of relation, cognition, and perception" (Grasseni, 2009: 10). However, it is important to note that Sandell's (and Lave and Wenger's) conceptualisation of the situated and social nature of learning is stressed through authentic contexts of *practice* or 'on the job' training, usually with hands-on instruction from the supervisor or trainer. This conveys the idea that "knowledge and skills are always part of, reproduced in, and kept up in situated everyday practices by and within a specific group of practitioners" (Sandell, 2010: 31).

We will see this in chapter five when students are invited to participate in 'systematic' interpretive work 'as if' they were learning to see and say on the job and then in chapter six when radiography students learn to produce x-ray images surrounded by materials which stand in as 'props' to represent the physical layout of image production (Goffman, 1959). Although learning to see and say in this thesis is *not* being done in authentic workplace contexts, I will show how professionals - whom "embody practice at its fullest in the community of practice" – are able to reenact or conjure the ongoing authentic activities of their professional work environments *into* the academic or classroom environment. Nonetheless, Sandell (2010) shows how seeing and saying as a member of a diagnostic imaging work community is all about tuning in with the language of the experts. It is a reminder that "language is part of practice, and it is in practice that people learn" (Lave and Wenger, 1991: 85).

Unsurprisingly, then, radiologists attach considerable importance to language: particularly the terms that others use when interpreting, writing reports, and communicating findings to others. A poor grasp of language is a core concern for both professions in this thesis, particularly among the more experienced radiologists who have "begun to point to language and communication practices as a growing problem" which are "keenly felt when radiologists and clinicians exchange reports" (Friis, 2017: 217). Whilst the radiologist brings a sense that terminology in report writing is vital in determining the objects in their perceptual field, radiographers also highlight the importance of information and specific words on imaging request cards when requested by clinicians to image patients (Newton-Hughes, 2015).

These conditions, in turn, reinforce the quest for scientific certainty in their work, the strong objective identification with medical science, even among seasoned professionals whose typical day at work to produce objective claims about nature continue to hold the view that their descriptions of information contained in images are “fairly unproblematic” (Friis, 2017: 213). A notable example of this ‘objective knowledge’ can be seen in the work of Joyce (2005, 2008) who maintains that “language practices” allow radiologists to make authoritative statements about what can be legitimately seen in MR images so that they could circulate findings to others confidently (including patients). Like Saunders (2008), Joyce (2005: 448) highlighted the role of local understandings in a language game in which one radiologist says “cross talk”, to his colleague. Within this context, says Joyce, the term is not merely naming the object, but functions as an order to draw attention to a source of technically distorted “misinformation”: “you get these little white dots [in the image] and you’re like, ‘what the hell is that?’”[27]

The second solution is to offer the student a variety of categories which allows them to describe the phenomena of interest they encounter (e.g. colour, consistency and texture). The alternative presented here is often where language is then supported with additional tools of inscription: a coding scheme may be used to reinforce description with visual representation. In order to generate a precise description of the phenomena in this way, participants are engaged in ‘comparison’ to make sense of the ways in which observations can be compared. Coding, in this sense, is a comparative strategy by which radiologists transform qualitative observations into quantitative labels. It is a commonly adopted coordinating and organising approach used by radiologists to help describe findings from ambiguous medical images (Pasveer, 1989; Prasad, 2005; Dussauge, 2008). It is through an interplay of seeing different parts of the body and comparing these with ‘gold standards’ of human anatomy that the professional becomes a participant in fusing written description with visual representation and acquires the language. For example, Prasad (2005: 305), observes how these efforts are

[27] Some others include the naming of ‘old friends’ and ‘unidentified bright objects/UBOs’ considered as anatomical anomalies that are considered normal for healthy people, yet cause confusion and may lead to ‘overinterpretation’ as abnormal. (450).

accomplished through the use of “body atlases”[28] with normal anatomic images and their pathological variations as part of a wider “cross-referential network” in the process of coming to see pathology and its “closure” (2005: 300).

Similarly, Dussauge (2008)[29] refers to the four ‘comparative strategies’ of early radiologists to interpret x-ray images. These included “comparison of scans of known objects with the object; of scans of the body with established anatomic depictions; with clinical methods; and with other x-ray scans". Whilst my point here is to show yet again another example of a ‘documentary method of interpretation’ (Garfinkel, 1967; Goodwin, 1994) as a basic principle of learning the language (through classifying, describing and visibilisation) I also wish to show “how early radiologists developed methods aiming to reach the early twentieth century ideal of objectivity, stabilising representations in order to fulfill the requirements of mechanical objectivity, which ‘paved the way for a perspectival communication between doctors’.” This way of learning to see and say through familiar professional and bureaucratic knowledge structures not only entrains in fine detail the cognitive activity of those who use them but also legitimises and stabilises uncertainty when communicating some of the objects of knowledge (i.e. radiological findings) to professionals and patients.

A third way of helping others to see and say is by paying attention to the ways in which forms of talking about evidence act out as “demonstrations”. Goodwin (1994: 621) shows how the professional archeologist’s description about the colour of a post mold and linking it to a coding scheme “is not just a statement, a static category, but a *demonstration* built through the active interplay between coding scheme and the domain of scrutiny to which it is being applied” (my own emphasis applied). The professionals’ activity of making inferences about precisely what category should be pointed at emerges as a demonstration, thereby teaching the student not only ‘how to code’ the relevant structure, but also how to *see* the structure. This method of demonstration was similarly adopted by radiologists in a study conducted by

[28] Anatomic atlases involve acknowledging that the textbook has a set of ‘domesticated’ MR images alongside diagrammatic representations that facilitates the visual learning of radiologists (Prasad, 2005)

[29] Dussauge’s (2008) research entails those involved in a NMR tumour study using an indefinite number of comparison strategies to cross-reference histopathological tests of NRM tumours and make them intelligible to others.

Saunders (2008). Cognitive and perceptual difficulties surrounding the diagnosis of CT images meant radiologists often demonstrated to other profesisonals or medical students a model of engaged learning as a type of puzzle-solving exercise, or what he describes as ‘detective story’, where the radiologist draws on prior experiences and discursive practices to search for diagnostic clues. This is an apt description of the kind of detective work that informs the radiologist’s solution for solving cases and the tale in which the “the poetics of detection” is set to operate: “one pass for clue gathering and conjecture, and a second pass of authoritative retelling, review of evidence” (Saunders, 2008: 142).

In specific situations, Saunders (2008: 224) argues that when radiologists first start to gather clues they discover dimensions of the image that are linked to the previous work of their colleagues and their pursuit of pathology. ‘Correlation’, he argues, can be the act of bridging evidence of the image (e.g. proof of pathology) with the radiologist’s as well as other specialised viewpoints from professionals inside and outside radiology (e.g. clinicians). Saunders argues that the first part of correlation for a case presentation includes a concern with formal information devolving from either a patient’s demographics (such as age, gender, race or ethnicity, risk factors) or history of tests (such as blood tests for proteins and kidney function). Moving beyond this process of initial clue gathering, however, the radiologist begins to retell aspects of image content in order to develop a more detailed sense of the correlation. This is done by by drawing upon his/hers and others’ specialist viewpoints. This centres on the empirical belief that correlation is built upon in practice and that the practice of correlation carries with it ‘tacit knowledge’. According to Polanyi (1962: 18) the concept correlation conveys two important components of tacit knowledge. First, tacit knowledge, as something that one often develops from their participation in work, and in doing so their body functions as an instrument shaping a type of “personal knowledge”. Second, because tacit knowledge comprises of both “subsidiary awareness” and “focal attention”, it is also understood as a pedagogical process that generates one’s thoughts, perceptions, and actions, yet it does so by being “the outcome of an active shaping of experience performed in the pursuit of knowledge” (Polanyi, 1966: 6).

This, according to van Baalen (2019), is what Polanyi means by “indwelling” and “dwelling in it”, namely that tacit knowledge works by way of, in Van Baalen’s word’s, “tools or theories” which “become part of our subsidiary awareness, it is ‘interiorized’ to understand something, extending the cognitive apparatus of the knower". One's tacit knowledge, then, not only structures ones thoughts and actions, but, as such, generates the demonstration or shaping of a skilfull achievement (whether practical or theoretical), and by doing so in a way that is often "taken for granted" by and from the person involved in the demonstration (Polanyi, 1958: 282). Rather than manifesting as a "definite set of rules", tacit knowledge, and the actions it constitutes, work as a kind of skill or perception that one develops by being a member of a community that can judge or accredit a distinctive pattern of performance. In this matter of accreditation, Polanyi (1958: 55) writes about the difference in roles between 'master' and 'apprentice' in training and writes:

> By watching the master and emulating his efforts in the presence of his example, the apprentice unconsciously picks up the rules of the art, including those which are not explicitly known to the master himself. These hidden rules can be assimilated only by a person who surrenders himself to that extent uncritically to the imitation of another.

The interactions in teaching contexts follows this model of authority (Saunders, 2008): the advanced expert guides the student's learning in the acquisition of interpretive skills and competencies. Medical students learn how to see through the enactment or demonstation of the expert's body. From this perspective, *seeing and saying* surrounds a tale of sectioned demonstrable tacit knowledges: the first typifies the way clues are gathered as objects of study leading to the formation of conjecture, the second focuses on the intention of "retelling" (2008: 142) where the audience is eager for explanation, and the explanation brings to the fore the emergence of relations in the image (i.e. artifacts, human anatomies, work practices). In the poetics of detection, there is a "recapitulation, of the primal scene of the crime: it is not simply that 'the analyst throws himself into the spirit of his opponent,' but often that the detective must reproduce, bodily, key gestures of the culprit agent" (Saunders, 2008: 143). In a later section of this chapter, we will see how different components of this demonstration are a special form of conduct and told through different components of the body and reported utterances, such as gesture and facial expressions. These effects of demonstrations transition outside the body, initiating "reenactments" (Tutt and Hindmarsh, 2011), particularly when professionals are keen to consider the complications and uncertainties they face (more on this later).

From this position, *learning to see and say* is based on the poetics of detection during which professionals enact “tacit knowledge and judgement” (that is, the knowledge of how to see in their visual detection and reasoning without thinking about what they do). This means they know as a matter of ‘doing’ (Saunders, 2008: 129). Certainly, this stance, with the radiologist as detective and the medical student as trainee detective, highlights a gap in tacit understanding between them, during which professionals maintain both their position of authority, organisation, and their coordination of actions over interpretive work. According to Joyce (2005: 446) the concept of tacit knowledge is crucial to the practice of a radiologist’s interpretation of medical images. The existence of a community, or even a group that allows them to acquire tacit knowledge by participating in the production of images is crucial because it “creates an understanding of the instability of MRI examinations, countering the definitiveness and certainty constructed by common rhetorical practices”.

Not only does it allow them to be surrounded by taken-for-granted patterns, assumptions, and rhetorical practices that equates the image within the realm of objectivity and transparency, but the pervasive influence of discursive practices – the most obvious example is highlighting the “cross talk artifact” – highlights how the imaging of the body is actually a volatile process. This has the effect of “countering the definitiveness and certainty constructed by common rhetorical practices” (Joyce, 2005: 446). Because this point positions the radiologist and technologist[30] as tacit observers participating in the local knowledge and situated practice of imaging examinations, they can see and depict culprits or non-culprits with greater certainty. This is perhaps the most important point of the thesis: that tacit knowledge of the image production process slays the dragon of uncertainty.

However, I extend this observation by showing how a tacit knowledge of normal anatomy helps to consolidate, reify and work alongside scientific and technological fluidity of image production. This is what I mean by *radiographic anatomy*. In her ethnography of anatomy and surgery education, Prentice (2004: 166) identified how the situated and physical skill of learning normal anatomy lay the foundation for a tacit knowledge that came to define a surgical perception - a “muscular gestalt accompanied by knowledge of anatomy and

[30] ‘Radiographer’ in the UK sense.

pathology". In the anatomy laboratory, this tacit physical knowledge is anchored in the "act of sculpting anatomical forms from dozens of varied and opaque patient bodies" (2004: 166). Moreover, in this process of learning to articulate normal anatomies – making a connection between their *hands* and the anatomical model (e.g. a material pelvis) as well as cadavers – these trainee surgeons came to "embody techniques intended to prevent slips, techniques that range from continual repetition of anatomical architecture to bracing one's wrist to prevent the hand's natural tremor from interfering from one's own work" (2013: 260). Importantly for this thesis, Prentice (2013: 117) points out that this personal, iterative and sensory process allows learners to "gradually embody complex procedural knowledge and eventually, clinical judgement".

Like the trainee surgeons, we will see how radiographers and their students at times rely on anatomic material guidance for the interpretation of x-ray images. In doing so, the material anatomy provides another physical realm for learning to see and say and participates in producing a *radiological* perception. Anatomical architecture of the material model embodies in itself a set of features, textures, or cavities (which is in itself a set of strict rules) for finding one's way in an otherwise uncharted or ambiguous radiograph (Fountain, 2010; 2014). Prominent here has been the work of Kenny Fountain, for whom an important part of the value of material practices in medical education is its capacity to embody anatomical information. What these various uses of material resources – as well as visual information in textbooks or images displayed on computer screens – recognises is the power of people to embody features or patterns through: "observation (the act of looking), visual evidence (what one sees in the body), haptic experience (the act of touching), and anatomical-medical knowledge (what one labels the body) to identify as anatomy those objects on display" (Fountain, 2010: 49). This insight is not new. As Fountain (2010) has noted, the 19th century conception of western medicine emphasised its social, haptic character: "by the eye, by the touch, by the measurement from some fixed point, by line, or by percussion" (Fountain, 2010: 50). The capacity that pattern recognition can be generated by different forms of tacit knowledge is, however, distinctive.

In this thesis, this form of material practice strongly influenced the radiographer's delivery of learning to see and say radiographic anatomy and assisted in the foundation of a particular pattern of anatomical orderliness. On these grounds "the appraisal of order is an act of personal knowledge, exactly as is the assessment of probability to which it is allied" (Polanyi, 1958: 37). This exhibits the view that material and visual evidence (used alongside language or 'labels') are useful tools for developing an embodied relationship to underlying features of parts of patterns in medical images (Polanyi, 1958; Engel, 2008; Friedrich, 2010; Fountain, 2010, 2014).

This compendium of embodied anatomical, scientific, and procedural knowledge bears close resemblance to the radiographers and radiography students in this thesis in relation to learning to see and say normal anatomy and how anatomy can be seen in the radiograph, contributing to the critique and uncertainty of the image. This intertwining of tacitness and caution that professionals work with chimes with the findings of others on anatomical learning: "the tacit knowledge serving as an anchor, the explicit awareness serving as critique and corrective" (Sennett, 2009: 50). I will go on to argue that this tacit combination of anatomical and procedural orderliness produces a special type of knowing or *conduct* of images. Not only does this open up sequences of certainty but it can also be used to identify disorder or deviance in the image – which might be reasonably self-evident or unproblematic (Nyce, 2009) – often acting as a deliberate ploy to present the myriad (or differential) interpretations of the image. This is arguably linked with the wobbles, the uncertainties and errors that can also be applied to the process of medical image interpretation.

2.3 The art of uncertainty

In these methods, the notion of certainty is vital or present, as in the corrections. The power of the description, coding, correction and story-telling function to 'translate' and apply sign phenomena (i.e. the nature of an appearance). In these approaches, the model of language is used to eliminate doubt and certainty. However, what makes image interpretation training stand out from the rest of professional vision narratives, is that the foundation for seeing in x-ray images is also shaped by the deliberate desire to draw attention to the person's *uncertainty* of the image that counter common misinterpretations, missing information and bias (Hartswood et al. 2002; Saunders, 2008; Rystedt et al. 2011). Research by Gunderman (2005: 801) shows how radiologists bring a certain "art of uncertainty" in teaching case presentations by conveying the "degree of uncertainty inherent to each case and, where appropriate, acts to reduce this uncertainty". The logic of uncertainty is antithesis to the model of medical science training in which professionals present material as simple facts, thereby "squelching any scepticism". Instead of being imbued with scientific facts, for example, Gunderman (2005: 801) portrays 'good' interpretive practice as not entailing "right" or "wrong" answers: "this creates a false expectation on the part of the learner that every case has a correct answer, in light of which all other answers are more or less wrong". In his book, Saunders (2008: 244) addresses this logic of uncertainty and contends that radiologists in pedagogical contexts constantly reinforce this technique of uncertainty in interpreting CT images until initial ambiguity and conjecture have been "whittled away", creating a unique opportunity for learning. Similar to the analysis of Gunderman, Saunders (2008) remains apprehensive of medicine's narrow model of problem solving and its threat to diagnostic expertise.

Moreover, there are suggestions that the prevalence of uncertainty induces a space for making error or disagreement between learners who view the tactic as a learning opportunity rather than a sign of failure: "the good radiologists learn as much or more from their mistakes as they learn from their success" (Gunderman and Nyce, 2002: 299). Instead of being imbued with a hunger for certainty, Gunderman (2005) sees his teachers as actors portraying scepticism, curiosity and creativity of image content where they can help learners to make the most of uncertainty and learn from associated tales of risk and error and is contrary to some radiologists who claim that "it's all there in black and white" (Nyce, 2009). In CT suite, Saunders writes of how radiology educators shaped the deliberate ploy of 'intrigue' and types of recognised error that warn against 'disguise', the classifiably 'tricky' and the 'obviousness' of findings (Saunders, 2008); activities suggesting medical images cannot be taken at "face value" (Coopmans, 2011).

Because the concept of face value is universally accepted, it may have a comparable role as a point of reference. For example, the concept of face value provides the framework for the article 'Face Value: New Medical Imaging Software in Commercial View' (Coopmans, 2011), which provides a thorough example of start-up company members (engineers and scientists) attempts at generating interest in selling their prototype mammography software but also to protect what they considered to be commercial secrets. Coopmans (2011: 158) suggests that the concept can be used to imply "a gap between appearance and reality; the notion that appearances do not always map on to reality, although sometimes they might", for example by arguing that the ambiguity of the softwares visual interface becomes salient in different ways depending on the audience. Similarly, I will use the concept of face value through my analysis of interpretive training to refer to the ambiguity of x-ray images and suggest that the gap between appearance and reality entails vast increases in performances of tacit knowledge, uncertainty, and caution that hails from experts' experience. Additionally, these acts of "revelation and concealment" are supplemented by members "who know the software well", implying their tacit involvement and discursive work in developing the image processing software and how this is key to the dynamics of seeing, saying and *showing* (2011: 156).

The concept of face value, therefore, calls for a closer look at the effects of intrigue in teaching contexts. It also depicts the more formalised methods professionals use to enforce the idea that each image requires a double viewing: firstly, through a 'systematic approach' (Sandell, 2010; Delrue et al., 2011; Kok et al., 2015; Kok et al., 2017) and secondly through the 'review areas'. It also outlines the process of enacting 'artifice' of medical images from clinical cases or problems – created by the utterly unique culture of radiographic practice (Strudwick, 2014) – and its subsequent deployment in teaching.

2.4 Embodied conduct

Goodwin's (1994: 628) work deals principally with the "discursive practices" of a community of professionals in order to "build structures in the world that organise knowledge, shape perception, and structure future action". The concerted practices he identifies can be understood as a type of 'embodied conduct' that is special and distinctive of its community,[31] a thought that builds upon Garfinkel's (1967) preoccupation with the "observability of organised activities in actual occasions with situated particulars of talk and conduct". For example, recalling the previous discussion on how the professional archeologist uses her body to make relevant measurements in the dirt, we saw that learning to see occurs within an

[31] It is important to note how the specific embodied conduct of professionals would never have occurred if the student did not show her/his (lack of) embodied conduct. This 'lack of', 'inadequacy' or 'poor performance' of embodied conduct is an important point and will be drawn out throughout the thesis.

ordered activity that "presupposes the ability to locate where in the dirt measurements should be made" (Goodwin, 1994: 612). Because Garfinkel's ethnomethodology concerns itself with naturally occuring talk or language, social interaction and practical human action, it appears close to Goodwin's (1994) preoccupation with 'organisational work'. Admittedly, crediting a close relationship between Goodwin and Garfinkel has a tendency to naively subsume ethnomethodology with sociology and uncritically take for granted the tensions between the two positions.

Nonetheless, Garfinkel (1967) in examining the professional procedures of jury deliberations in negligence cases[32] demonstrates how jurors engaged in 'practical reasoning' and how it was a manifestation of their common sense reasoning and everyday rationality. Everyday contexts not only provided a context for understanding negligence cases but also to ascertain what kinds of *conduct* were accepted and valued. As Maynard and Manzo (1993) point out, jurors rarely changed their reliance on common sense reasoning despite being instructed to adhere to official and legal criteria for guilt. Their common sense reasoning helped the jury to arrive at their knowledge and 'justice' of the defendant through the practical reasoning displayed by jury-room negotiations, rather than reliance on decontextualized laws or procedural rules.[33] Dennis et al. (2013: 52) describe how Garfinkel's detailed empirical analysis of juror deliberation identified these activities of practical reasoning as "socially situated aspects of ordinary conduct". This practice of practical reasoning indicates how enacted 'conduct', in the sense of embodying one's own specialised or *personal* knowledge and making it witnessable in the world for others, reveals the strongly structured normative social order commonly routinised and "taken-for-granted" in settings in which people operate (Garfinkel, 1967: 8). Displays of talk and conduct are viewed as methodical, indexical, and accountable (as well as reflexive) in interaction, while any indexical expression and indexical action from this tends to be demonstrably rational and relative to the user of which the word

[32] After his study of jurors, Garfinkel (1967) consolidated his theory of ethnomethodology by analysing the practices of clinical staff selecting patients for psychiatric treatment and sociology students coding the contents of clinical folders.

[33] In discussing matters such as 'witness credibility', 'adequacy of testimony', 'motive', 'plausibility and relevance of evidence', among others.

is concerned. In other words, "everyday talk is thoroughly indexical, that is, dependent on context" (Dennis et al. 2013: 51).

The expectation of routine, "a necessary condition of social action", exposes how talk and conduct is accomplished "only for all practical purposes", using "organisationally demonstrable sense, or facticity, or methodic use, or agreement among 'cultural colleagues'" (1967: 10-11). In their "process of becoming a juror", jurors learn to act as a "decision-making body" who in their activities of coming to an agreement amongst themselves become socially recognisable – i.e. deciding 'the facts' among alternative claims – thereby making these matters of fact visibly rational and reportable for all members of the jury and other interested parties in the courtroom setting (1967: 112). Garfinkel (1967: 104) identifies how society, by establishing what is a "healthy respect for the routine features of the social order" informed the jurors common sense logic that the jurors possessed and embodied in their decision-making. As Macbeth (2003: 242) argues, this pragmatic ambition is in process of shaping routine action from *afar* to local orders of competent practice, bringing into focus the character of practical reasoning that takes place from *within* (original emphasis).

Such an attribute for Hindmarsh and Pilnick (2002: 151) is 'embodied conduct', a knowledge that people draw on that "cannot be recovered from a training manual or other formal description of the work". An individual with a form of embodied conduct, he claims, is identified in "actions and activities, such as lifting a mask, moving a trolley, releasing a gas valve *within particular local contexts of action* can be used to infer a trajectory, that is, a sense of what will happen next and its consequences for collaborative involvement" (161). Those who have 'embodied conduct', are able to maintain the order of a professional medical performance and are said to impute a wide range of competent displays by constituting a case presentation or region of interest in which they can draw on and engage in a problem solving process influencing perceptual judgement.

Accordingly, Ivarsson (2017) shows how radiological reasoning is made publically available to others when radiologists struggle to see or overcome their analytical problems. The work of radiologists and radiophysicists – as the they attempt to express their understanding of new tomosynthetic images - "involve interesting forms of embodied conduct", while representing "what things accountably *are* (as anatomical structures)" and "formulating difficulties pertaining to the very *process of diagnosis".* This way of highlighting conduct is promising at least for the reason that it chimes with Joyce's (2005: 449) analysis of interpretive work where "interpretation troubles" are "made visible in discursive practices when problems arise". Needless to say, embodied conduct comes from being not only uniquely, but familiar and interconnected to the image (and patient) on a *personal* level. This idea of personal, tacit, or *embodied* knowledge, as my thesis shows, is deepened with immersion and attachment to the processes of learning normal anatomy in the context of learning about image production practices.

Whilst this focus on analysing embodied conduct for explicating practical actions and practical reasoning is in danger of backgrounding the importance of talk or language, there is no doubt that organisational interactions are full of coordinating ensembles of talk and embodied conduct. It was Garfinkel (2002: 109), after all that reminded us that we should not reduce interaction to just talk, as conversation analysts can be prone to talk by privileging the transcript (Elsey et al. 2017) and emphasises how the coherences or 'just-thisness' of things cannot be understood without detailed embodied aspects of their status. Zimmerman (1999: 198) makes this sentiment increasingly more explicit: "talking is *doing*; speech, one kind of bodily movement (vocal cords, auditory apparatus), is interwoven with other bodily engagements with objects and other people in the extensive and extended course of practice entailed by an emerging sociality" (original emphasis). Thus, the very constructive analysis of embodied conduct recognises that embodied conduct not only *supplements* speech, but they are *reciprocal* with the use of peoples terms 'segmenting' with the accompanying action (e.g. a 'gesture'); or as Hindmarsh and Heath (2000a: 1864) argue: "the talk reflexively works on behalf of the gesture". This role of embodied conduct as a method for reenactment and the composition of different forms of gesture, and how these come to signify practices of seeing and analytical work, are discussed in the next two sections.

2.5 Reenactments and procedural knowledge

By formulating his theory of practical action as "organisationally situated", Garfinkel's (1967: 11) work identifies how individuals are offered methods used by members to explicate what is already known and shared so that they can uphold the standards of thought and norms of conduct in accord with the actual activities of their collective. In their capacity as members to a specialised community, members “produce, accomplish, recognise, or demonstrate rational-adequacy-for-all-practical-purposes of their procedures and findings” (1967:8). These demonstrable methods - making use of practical reasoning about the indexical details of their observations - offer a set of normative features that exist as a tacit scheme of interpretation for actors and should be understood in terms of constructing sense in the social setting or context of manifestation (Garfinkel, 1967). According to Tutt and Hindmarsh (2011: 234), these demonstrations, commonly marked by indexical relationships, are products of context based on “mimetic” strategies. This “representation” and “imitation” tactic embedded within the local material ecology of the activity bestows audiences, those who are witnessing or experiencing the speaker, with relevance for the work at hand: “the design of enactments should not be thought of as a simple reproduction, but rather as a version of action that selects, and often exaggerates, certain features. Nevertheless, they must bear resemblance to be persuasive”. This application attends to the ways in which phenomena can be made visible either because it is unavailable to or hidden from the recipient. Through these interests, according to the authors, ‘reenactments’ are deployed to make visible or to make tangible something visible in the scene – reenactment in which talk and embodied conduct is central to the analytical work in these contexts.

This study positions how reenactments as “embodied demonstrations of past events or scenes” (Tutt and Hindmarsh, 2011: 211) as especially important when professionals tackle ambiguities of the image and places great importance on professionals to share their tacit applications of a “given sight style” that is learned from collective as well as individual clinical work routines of diagnostic seeing in the image (Friedrich, 2010: 187). The point here is that reenactment and the drawing out of personal experiences and community stories – a type of correlational ‘retelling’ (Saunders, 2008) - is important for this thesis because it not only helps prepare students for a “specific capability”, but also to give them a sense of the possible trajectories of image content available in various communities” (Wenger, 1998: 272).[34] In the

[34] This is particularly important as ways of working with images change in different clinical contexts. While I highlight the tacit learning of students and how clinical placement creates possible trajectories of learning, a full analysis of this reaches beyond the walls of this thesis and requires a start to explore further aspects of x-ray image interpretation training.

current study this entails paying attention to the ways in which professionals reenact the image and how this practice draws on their embodied and situated reasoning of certain images (more on this later in 'radiological vision'). Thus, in these ways of 'reenactment' professionals bring others closer to the nature of its original reality and determining the true nature of its content (Saunders, 2008; Ivarsson, 2017).

Like Tutt and Hindmarsh (2011: 214) I consider how reenactment – through gesture, tools and 'cognitive artifacts' such as anatomic materials, signs/representations (Måseide, 2007: 202) – can also animate learners' 'imaginations' in regards to anatomies and procedural lessons of image production (Saunders, 2008, Ivarsson, 2017).[35] The use of demonstration lays bare social and technical limitations (as well as their advantages) associated with the use of x-ray imaging technology. In Ivarsson's (2017: 24) work on the development of a new x-ray imaging technique to detect cancer nodules in the chest (Tomosynthesis), the procedural knowledges about how to describe the x-rays and how the production of x-rays affected the resulting image exhibited in what he calls "production procedures"; "through which the body of the patient is coordinated with the skilled body of the practitioner".

Ivarsson's example of production procedures exhibits the professionals' subjective understanding of the patient's involvement in the image making process and their ability to formulate these procedures using their own body to aid the understanding of others. Ivarsson's concept is helpful to develop an understanding of how such technical knowledge is embodied, that it plays out as a demonstration to help others organise reasoning, and that it is enacted by their body that involves the hands, eyes and other materials in the environment. Rather than limiting the analytical gaze to certain groups of actors in the present, patient relations and how they are mediated via the technology are here envisioned as embodied and disciplined according to the organisational protocols stipulated by the imaging system. Simultaneously the technical efficacy of different attempts to assert control over patient agency has not always portrayed as happening in a space of 'docile' bodies either. Within the

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[35] Although a "radiological imagination" has been featured in sociology before, it is very much in the background of Saunders's (2008: 230) analysis, particularly in teaching CT image interpretation; for example: "she forces all at the viewbox to *imagine* what such a lesion would look like – a unique and potentially grotesque prospect" (emphasis added).

concept of production procedures, the particular positioning of the different actors involved in the routine procedures of imaging can be understood as "con-forming bodies" (Wood, 2012, 2016), and these bodies having an influence on the resulting image (and its overall interpretability).

Wood (2012, 2016) offers an approach to understanding the act of medical image production as not only influencing the embodied rationality of imaging professionals informing human-machine relations but also how both professionals and patients come together, configure, and co-produce the image. In her comprehensive ethnography of how Cone Beam Computed Tomography (CBCT) is integrated into radiotherapy departments, Wood (2012) provides a fascinating account of how bodies and machines co-create images. What she calls '*con*-forming' the CBCT image did not only require the standardised imaging procedures and the protocols of positioning body parts for the targeting of diseased cells, but also the social and material involvements such as the radiotherapist adjusting the patient's body part from outside the treatment room by remote control. Only a dynamic of conforming the patient body, extending through and making use of the material setting of the environment, achieved the correct bodily arrangement for precise cancer treatment. Wood thus lays out the control over the patient body as a means to shore up the authority of images and the disciplining practices in the process of image production.

Research in the domain of image production thus focuses on control and organisational arrangements. Whereas popular accounts often assert that medical imaging procedures either enable transparent images or objective features, this field of research requires us to approach the relations between actors becoming visible, all becoming 'core participants' in the image (Joyce, 2005, 2008; Wood, 2012, 2016). Conceptualising procedural knowledge as a "sociomaterial assemblage of patient, practitioner, imaging system and healthcare context" (Wood, 2016: 779) rather than a truly objective or value neutral one – much in the sense of Rachel Prentice's (2013) understanding of anatomical and procedural knowledge – this work analyses the procedural and technical skills in their embodied demonstration to students in academic settings. But since this work is interested in ordering the patient body, it is also sensitive to persisting risks and errors and their influence on the production of these images. For example, there are "inter-fraction" movements (i.e. discrepancies of patient positioning by professionals) and/or "intra-fraction" movements (i.e. patient movements, such as breathing and tumour movement) (Wood, 2016: 772). Of the work on CBCT imaging, discussed above, Wood addresses the conforming images most explicitly by looking at how radiotherapists and radiographers embark upon producing images of 'good patients', in the sense of establishing "what is in place and what is out of place" (Wood, 2012: 290).

In her analysis, Wood (2012: 289) acknowledges the work of Mary Douglas (1966) whose analysis of dirt, in terms of 'matter out place', emphasises pollution as anything "which is likely to confuse or contradict a system of categories". With regard to the analysis of pollution, Douglas's (1966) work emphasises a culturally determined standard or notion of what people expect to be 'ideal' (as a set of ordered relations or 'natural' types), and so any disruption or contravention to that order becomes treated as 'polluting' phenomena (as especially dirty, or especially abhorrent). In an analytically similar vein, Wood's (2012, 2016) analysis of cone beam imaging examines the principles whereby the contents of images are made ordered and distinct. In a thoroughly situated perspective, Wood (2012: 290) notes that patient anatomy and bodily functions (such as waste) becomes 'matter out of place'. The placement of the cone beam equipment shifts the boundary between what is in place and what is out of place and "reveals disorder (i.e. it doesn't fit in with the order as directed in the protocols" (2012: 290). A full rectum, or rather faecal matter out of place, in other words, is not appropriate in the work of cone beam imaging. There are, therefore, expectations that the patient needs to fulfill (i.e. empty their bladder/rectum) where "if the patient does not act there will be no treatment for that patient today [...] and if the patients 'lie' […] the scan will show up this misdemeanor" (2012: 291).

The equation of the image with a misdemeanor is certainly grounded in standards of normative expectations, yet since diseased or deviant anatomic behaviour – for example if a patient presented with a tumour were imaged – can also be marked as matter out of place, Douglas's concept may prove useful when analysing pathology or trauma. As Douglas (1966: 94) observes: "granted that disorder spoils pattern; it also provides the materials of pattern. […] We recognise that it is destructive to existing patterns; also that it has potentiality. It symbolises both danger and power." I take this to imply how disruptions to patterns of normal anatomies do not only imply disease/abnormality but also how the "instabilities" of image production (Joyce, 2005) have the potential to give *false* appearances of disease/abnormality. As I make clear throughout this thesis, this gives rise to effects of "artifice" and opens up potential for misinterpretation, where at times professionals take advantage of such artifice and reenact the potential for wobbles, uncertainties, and errors in interpretation during pedagogical encounters (Saunders, 2008).

I hope to extend this scholarship on production procedures to consider how embodied demonstrations and reenactments (via tools, representations and artifacts) are useful as thinking tools for seeing and perceiving aspects of image content absent or 'back-stage' to clinical settings (more on this later). In addition, I will show how reenactments of imaging procedures bring to life details about the patients "mechanism of injury": how they have injured themselves (e.g. "fallen down the stairs"), what they have ("inversion injury") and the level of pain experienced by the patient and their level of mobility (Newton-Hughes, 2015: 79). By taking the role of the envisioned patient, I will show how professionals reenact imaging procedures, injury, and relevant context of the injury that would constitute types of radiological risk and error *as* embodied demonstrations.

2.6 Gesture and repair

Research on gesture, within the field of sociology, anthropology, and STS, spans over at least thirty years. Especially anthropological engagements with the sign languages of deaf people in New Guinea and of bereaved women in aboriginal Australia (Kendon, 2004) have brought insightful analyses of the uses of gesture and their social implications for order, meaning and communication (Streeck, 2009). As Streeck (2009: 2) argues in his eloquent introduction of the gesture's importance to human understanding:

> "The skilled, mindful bodily practice of gesture unfolds its full potential as a universally available resource from which people can manufacture understandings – of each other and of the world they share. Moving the limbs, one party can articulate for the other how some part of the world ought to be seen".

Far from claiming to be exhaustive in my own sense making of existing literature on gesture, I order analytical ties to the analysis of gesture in the practical dealings with medical (e.g. Rystedt et al. 2011; Ivarsson, 2017) and scientific images (e.g. Myers, 2007; Alač, 2008; 2011; Koschmann et al. 2011; Gegenfurtner et al. 2019), and at times within broader social contexts of medicine (e.g. Prentice, 2013; Mondada, 2014) and dentistry (e.g. Hindmarsh et al. 2011). Whilst analysing gesture as being choreographed with accompanying talk, I ask in what way the various approaches to gesture – which I understand as "forms of hand shape and movement, including pointing, waving" (Nevile, 2015: 130) – are used as 'methods' to conduct interaction and organise radiological reasoning, a process that "seeks to *explicate* what is already known and shared within a targeted group" (Ivarsson, 2017: 13): how do professionals address the multiple (perceptual) issues the participants are orienting to?

As Ivarsson (2017: 17-23) points out, seeing, understanding and radiological reasoning of medical images can be attributed to indexical forms of talk (e.g. words such as 'this', 'that', 'here') and indexical actions (e.g. 'gesture' and 'gaze'). In this "context of the self-reflective situation set up by the team", Ivarsson (2017: 22) shows how radiologists display professional forms of embodied conduct in the form of different types of 'gesture' that are closely amalgamated with anatomic materials, technological concepts and vernacular talk. Ivarsson stresses that these gestures are not some type of "general phenomenon" but instead are seen as "specialised embodied conduct indexical (i.e. uniquely fitted) to projected images, practical actions, or specific-locations in patient-bodies." It is important to recognise that there are distinctive differences in gesture – for instance Streeck (2009) has distinguished six "ecologies of gesture" and two of these are most relevant in the context of radiological practice (Ivarrson, 2017).

Two types of gesture are explored that play different but important roles in making appearances visible within interpretive practice, with radiologists using gesture to: (1) "select and elaborate features and significances of the *world within sight*", and (2) sharing gestures that "evoke phenomena that *are not present* and depict imaginary and abstract worlds" (2017: 15). Ivarsson claims that gesture works as a form of practical problem solving and techniques for managing perception, where problems are made more vivid by demonstration or illustration, resulting in the remedying of perceptual or cognitive difficulties. There is an increasing emphasis on gesture, on the interaction between the expert and space, and on issues of perception in professional vision research. The use of talk and movement in (personal) space that includes the management of perception have become key phenomena of interest to those studying imaging practice.

Thus, Gegenfurtner et al.'s (2019: 284) video recordings of radiologists communicating subtle and lesser contrast radiographic information to medical students revealed their methods of "highlighting gesture" mediated by local tools (e.g. a wooden stick) that helped "structure the visual field into what is relevant and what can be perceptually ignored" (Gegenfurtner, 2019: 284). Saunders (2008: 19) observed practices of 'pointing' that were indexed with the cursor, claiming the cursor as a "prosthetic extension from hand to screen, a gesture"; Alač's (2008: 494) work of neuroscience laboratories examined types of 'shearing gesture' and 'frozen gesture' indicating that the gesture is about making salient the features in the image, but also how gesture can "participate in the interpretive act as an embodied enactment of *change*" (e.g. changes in the properties of magnetic fields as a result of changes in blood oxygenation); Rystedt et al. (2011) discovered how radiologists supplemented their comments of tomosynthesis images with an "encircling gesture with a laser pointer" as a method to "instruct everyone where to look".

The important point that gesture is used in the practical activities of radiological practice relates to gesticulation as *pragmatic* or 'pragmatic gesture' (Kendon, 2004) as a performative function that assimilates the pragmatic aspects of talk or utterance: "they not only furnish recipients with visual displays of pragmatic aspects of communicative acts, but at the same time give the speaker feedback about his or her own communicative intentions" (Streeck, 2009: 182). The emergence of pragmatic skills go hand in hand in the learning of language and communication and are tied to each other in ways that finely tune the audience to the speaker or object of attention, for example through 'presentation gestures' or 'pointing gestures'. Like Kendon (2004) I support the idea that pragmatic gestures and their rhetorical power in functioning like speech acts are examples of 'manual' gestures; the idea that gesture is a visible action of any body part when coordinated with talk or as part of talk. However, there is another dimension to this 'manuality' that is of greater importance. The fact that there as so many gestures to be analysed, he argues, is a clear indication of how we use our body, and especially our hands, as primary modes of engagement with the world or as Merleau-Ponty (1962) might put it: a "vehicle for being in the world". Our body combines perception and action and is at the very core of our sensory experience of objects that are our focus and our active making of the world (Streeck, 2009). Again, this reminds us of the archeologists who are engaged in the process of transforming their sensory experience of objects (an actual bit of wet dirt) into formal, abstract *types* (e.g. the 'brown to dark brown' of 'subsoil' and 'plow scar' and the 'dark yellowish brown' of 'lower plow zone') of descriptive colour that helps to organise their perception (Goodwin, 2018: 196).

These practical actions and practical reasoning then, not only sums up all the elements that seem to be of importance to being connected to community of practice, but also bears resemblance to our "repertoires of manual action" that we encounter in our tactile contact with the world and its objects, indeed insisting on a range of actions that our hands routinely perform (Mulder, 1996; Streeck, 2009). For example: "changing position" (e.g. lifting, drawing, shaking), "changing orientation" (e.g twist, spin, rotate), "changing shape" (e.g. smooth, pinch, fracture), "contact with the object" (e.g. grasp, grip, hold), "joining objects" (tighten, wriggle, wrap), and "indirect manipulation" (e.g. whet, set, strop). All of these give rise to an underlying tacit practice or 'doing' and previous experience with the world, factors that interact with and transcend physical features or elements of a thing or environment and give rise to different hand shapes (Kendon, 2004).

Without aspiring to provide an exhaustive treatment of gesturing with hands, my interest is in showing actual instances of gestures that appear to have pragmatic *and* semantic functions in both enactments and reenactments of x-ray images and their content. As such I will call upon an analysis of gestures and their specific properties, the "maximum gestural excursion" as Wagner (2014) puts it, only when necessary - such as the beginning and ending of "gestural phase" (Kendon, 2004) and their temporal coordination with speech (e.g. quickly, slowly) for the establishment of understanding which the professionals deem useful in order to make sense of something.

Responses to the talk and gestures of professionals have been noted, but less attention has been drawn to the talk and gestures of *students,* which occur under the gaze of and in the presence of the competent professional. There are aspects of talk and gestures from students– particularly in moments when they watch professional practice entranced, enchanted and are called upon to see and say for themselves, staring at the image confused, anxious and uncertain. Importantly, professionals acknowledge the talk, utterances and intonation of their students, alert to the confusions, uncertainties, and misinterpretations of situated (embodied) conduct. Goodwin (1986) highlights that speakers in their attempt at finding a word, do so by themselves and, usually, do not require help from others. However, when the individual fails to find this word or 'self repair' (for example, through hesitation and pause), it leads and invites others in for collaboration to help produce the word needed, thus making their faulty performance overt by "cutting off their utterance, restarting it, interrupting it again", employing such devices until they are satisfied with the "sought-for-word" (Streeck, 2009: 108).

Goffman (1971) identifies these interactional moments as 'broken down situations' where rules of talk and 'conduct' are broken and individuals run the risk of becoming discredited: "one with an obligation, who should have governed himself by the rule; the other with an expectation, who should have been treated in a particular way because of this governance" (1971: 343). He adds that these breaking down situations are especially prescient in pedagogical contexts when students fail to live up to the expectations of their teachers. These features of repair, he stresses, are also characteristic of 'ritualistic' behaviour that produce and reproduce 'social order'. According to Goffman (1971: xii), face-to-face interaction establishes the means of a "social order", which can "benefit almost all of its participants individually, often equitably" causing individuals to "come together and voluntarily agree to abide by certain ground rules, forming a norm-generating coalition, the better to free attention from unimportant matters and get on with the business at hand". Conforming to the norms enforced by an authorised agent affirms the social bonds of membership and relatedness, and anyone incapable of paying homage to these rules is seen as a person of "improper performance", in the extreme, someone considered in our minds is a 'slight', a 'violation' (1971: 63). Social order is especially visible in classrooms: "where those in charge can foster a parental impression: that the individual has the option of adhering to to the rules or concealing violation" and how those doing neither will be "plucked out of his situation and made to pay the consequence" (Goffman, 1971: 105).

Powell and Powell (2016), among others have reviewed this break of face-to-face interaction with respect to classroom communication, and how those deemed to be conflicting with what the teacher defines as 'correct' are at risk of being caused to look foolish. In a similar vein, Brandt and Tatsis (2009) believe that the process of learning mathematics requires structured interaction and that the participants' involvement in collaborative problem solving requires the actor to 'save face' when their answers are threatened, an interaction ritual described by Goffman (1972) as 'face work'. In much Goffman inspired research, these strategies often occur as part of a person's 'front-stage' interaction where 'actors' are able to portray a set of rules and manage how they want others to see them.

Goffman's (1959: 128) dramaturgical approach states how the 'front-stage' audience is segregated from a 'back-stage' audience, illustrating why people behave differently in different settings and how these different regions define behavior and meaning: "back-stage conduct is one which allows minor acts which might easily be taken as symbolic of intimacy and disrespect for others present and for the region, while front region conduct is one which disallows such potentially offensive behavior". In this sense, the front-stage is where the "set social interaction plays out" and in the case of a typical teacher/student interaction it is the "setting of the classroom when it is used for a lesson" (both teacher and student *know* what type of interactions are expected of them), the 'back-stage' is where the formal environment ends abruptly when the bell rings to end the lesson and the front-stage gets broken down "as the students talk amongst themselves, make phones calls, and begin to eat their lunch" (Brown and Dickinson, 2013: 66).

Brown and Dickinson's (2013: 67) analysis of Life Orientation Lessons[36] in South Africa draws on Goffman's work to explore how teachers maintain order and repair 'problematic' aspects of teaching sex education to male and female students. Through Brown and Dickinson's work, we come to see the relevance of analysing the "interaction order" and how through Goffmanian concepts, "we can come to an understanding of the production of encounters, roles, responsibilities, 'normal', and 'ordinary'" (vom Lehn and Gibson, 2018: 317). Brown and Dickinson's (2013: 67) study of sex education or 'sex talk'[37] in the classroom focussed on how teachers had to manage the gender relations present in the community and how topics of sex and sexual desire could be discussed. Here the concept of 'back-stage' had an important role in mitigating these issues; this was particularly so when young men dominated the formal

[36] A curriculum objective in the South Africa that guides secondary school students to make informed decisions about their health, environment, subject choices and career and are based on the problems of the area (e.g. drug use, teenage pregnancy)

[37] A curriculum objective in the South Africa that guides secondary school students to make informed decisions about their health, environment, subject choices and career and are based on the problems of the area (e.g. drug use, teenage pregnancy)

orientation of the lesson and female students could not always take advantage of the teacher's approachability. Paying particular attention to the interactions conducted in the classroom, Brown and Dickinson (2013: 67) draw on Goffman's work to show how the front-stage and back-stage are less divided or blurred by encouraging female students to stay behind in the classroom. In this way, female students could approach the teacher "if they had a problem that they did not want to divulge during the lesson, in the front-stage setting" which had now opened up as an intimate and confidential space. Such movements by these teachers are what Goffman (1959: 146) might call 'protective practices', such as employing "tactful inattention" to avoid embarrassing the student.

In a similar vein, Streeck (2009) notices how these utterances that are in need of 'repair' often occur as some part of mastering a practice, where talk and gesture is used to help learners correct or repair faulty performance. He adds that these gestures combined with verbal utterance may add to thinking and problem solving and parallels closely with what is observed in sign language. In his studies of gesture from 1980 onwards, Kendon (2004) analyses the sign language used by deaf people, and in doing so (through the use of video recordings) identifies gesture as a situated social practice emphasising that the body is a semiotic resource that produces signs. More recently, Streeck (2009: 204) builds on this work and broadens the notion of gesture as a "*craft,* comprised of practices and skills (emphasis added)" in the sense that it is about the "practicalities of situated communication". Moreover, he considers one particular direction that such debate has led – focusing on the intimate connection between hand and head rather than construing it simply as a code or a part of language. Having discussed the features depicted in professional vision – such as embodied conduct and gesture – it can be easily suggested that the presence of medical image interpretation training results in a specific type of vision in the bodies of radiologists and radiographers. Previously, the task of detection, typically the act of correlation, highlighted the central processes of diagnostic intrigue and was the most important product of pedagogical and testimonial practices in conferences and reading rooms. In the next section we shall see that this is indeed the case. Thus, it prompts me to go deeper into my studied phenomena to understand radiological vision in teaching contexts - a faculty enrolled in the organisation of cognition and the proper constitution and perception of image content (Måseide, 2007).

2.7 Radiological vision, x-ray images, and 'problem solving'

The work of Pasveer (1989:374), among others, maintains that x-ray images have played a large part in the cognitive and practical organisation of medicine, since x-ray images inevitably raises a rhetorical status of professional seeing "though only the expert can properly interpret all the shadows which may be seen by the x-rays". It is the discursive rhetoric of radiological testimony, for Saunders (2008: 148), which offers expert interpretation in clinical settings, a site of teaching diagnostic judgement including lay detection, where conjectural reconstruction, abductive reasonings, assumed special importance". Each judgement, he insists, determines the acceptability of 'diagnostic' findings, adding up to a selective detection process in which "abduction is thinned, unto pattern recognition". Ivarsson (2017: 12) similarly contends that visual expertise in radiology helps professionals to select, shape and articulate representational objects in ways that render these professional objects available to others brought about by the "enacted production of radiological reasoning".

He contends that x-ray images initiate a brave new world of meaningful actions and problem solving, a form of problem solving riddled with reported troubles of perception and understanding. For Ivarsson, the complex nature of radiological seeing and reasoning, believed to be grounded in deep forms of cognitive processing, institutes the cognitive model of radiology in which "it has been portrayed as a solitary practice where for instance the position of the radiologist's eye in relation to the image can be examined for the ways that it will impact on the detection of pathologies" (2017: 13). Thus, x-ray images, the likes of Pasveer, Saunders, and Ivarsson claim, makes it possible for professionals to identify and eradicate the 'social' processes, reflecting a prevailing culture which views anything in relation to medical images as a type of "cognitive apprenticeship", even adopting a cognitive stance on visual perception and expertise (Gegenfurtner et al., 2019).

For Måseide (2007: 203), the production of x-ray images are characterised by an "ontological ambiguity", in which radiologists are confronted with the task to "replace ambiguity with certainty" and to "generate a shared and objective radiological vision among the users of x-rays". He suggests that in modern medicine, hospitals function as expert organisations and warrant a way of working that is conducted through expert processes "consisting of different kinds of expert systems". Attractively phrased, medically orientated expert systems in favour of getting medical work done (such as accomplishing a diagnosis), Måseide adds, shape problem solving as the "production and reproduction of a medical order conforming to the professionalised and institutionalised order of biomedical problems", a way of giving professionals information that is supposed to create order through "bureaucratization and other principles of management" (2007: 201). But, as Måseide and other sociologists like Saunders claim, it is also regulated by situational requirements and restraints, playing out a complex social process influenced by principles regulating social interaction. A professional's process of problem solving, according to Måseide, is an instance of a small 'activity system' rather than individual cognition, this defining the 'distributed cognition' of radiologists as experts "who collaborate with other professionals, but also with equipment, technology, representations, discursive forms and other signs" (2007: 202). Saunders (2008) and Van Baalen (2019) allude to this notion of 'distributed cognition' and how medical institutions establish behavior that cognitive and 'embodied' radiologists must practice during medical image interpretation.

This, for Måseide (2007: 202-203), renders the possibility of conducting image interpretation in relation to "signs, marks or representations", explicitly making the patient's body "visible in a medically relevant manner" and "regulates the problem solving activities". He suggests that what counts as evidence is a "local, interactive phenomenon", reflected by radiologists imposing an emergent "organisation of medical work as it relates to medical sign systems" (2007: 203). Problem solving as part of this interactional activity with x-ray images, Måseide claims, "provides actors with resources necessary for conducting and continuing their interactions". This matter of *conducting*, is a term Måseide borrows from Garfinkel (1967) and expands upon, is the supposed practical accomplishment of situated talk and conduct for the task at hand – conducting in this manner derives its serious sense as instructed enterprise or the power to direct conduct. Subsequently, when the hospital offers radiologists regular and diverse conferences, for Måseide (2006, 2007) and Saunders (2008, 2009) among others, it is already, by definition, discursively organising the observation of clinical symptoms and signs. That these conferences are spaces that show how no single doctor had the total competence to solve common problems, Saunders (2008: 201) advances, is developed in "teaching conferences", a further opportunity for radiologists to come together for reviewing 'local' case presentations, where "such gatherings are frequent and intensified and yoked to specific pedagogical agendas". In his analysis, Saunders (2008: 272) noticed that there are three stages to teaching case presentations, if a radiologist has not seen the image previously: first there is the "discovery phase of solo image inspection (autopsis)", second a "presentation phase" and the third is termed as a 'parsed phase' because radiologists tend to unpack the components or image content into a "period of orienting display for colleagues" one that constitutes a "reconnaissance of findings, a focus on key findings, and a differential diagnosis, ideally leading to a consummating diagnosis".

Importantly for this thesis, it also highlights the complexity of the phenomena involved and that it requires multiple methods for making relevant distinctions when learning to see like a professional. Using the ancient rhetoric of "autopsis", Saunders (2008: 16) describes the ways by which it "pertains to testimony of the eyewitness", this relating to seeing for oneself and *saying* what one has seen. It is this autopsis, according to Saunders, that is a mode of personal knowledge (twined with hearing and pointing) and comprises the "fragility of seeing, the perils of poor seeing". Viewed by Saunders as launching a description for radiological findings and as enrolling others in the act of attention, radiological descriptions are also perceived by Måseide (2007: 217) as constituting one major component of problem solving, namely the application of a "script that directs the radiological presentation". According to Linaker (2015a: 10) radiologists teach medical students through the use of algorithms or 'scripts' that are based in cognitive psychology, and what this resource provides is access to prestored knowledge that will improve their ability to develop search patterns fused with correct terminology.

The danger of this, Linaker adds, is that by gratifying students' desire to create a predetermined "search pattern", problem solving inevitably "may not be effective for individual patients". The increasing use and systematic approach of cognitive scripts for interpreting x-ray images, in short, is distinguished by Linaker as at risk of "memorising generalized patterns", namely, not embracing the finding in its context and therefore not generating a modified script. Saunders (2008) similarly contends that scripts are applied to a "specific x-ray" but it is "situationally realised" through a collective understanding of the problem at hand. It is the process and emergent act of following the script that makes the radiologist visible as a "professionally competent and active participant in the creation of radiological vision" (2007: 216). For the likes of Måseide and Saunders, then, radiologists in teaching contexts embrace the object of viewing and generating context for their audience to bear witness is a social event – their style has a performative function of pre-established order and 'objectivist' way of seeing: a vision that is equipped with expert systems, gesture, convincing representations and twined with the rhetorics of persuasion against the ambiguity of shadows. Accordingly, x-ray images are tantamount to a process that is importantly situated in the real-life world of clinical settings and, most importantly for my analysis, all x-ray images are particularly ambiguous for those learning to see outside these environments. As Strudwick (2014: 146) points out, x-ray images are "cultural artefacts" that accomplish the objectives of upholding the technical and scientific norms and standards of the radiographic community where radiographers "appear to take pride in their images if they are optimal". As I examine throughout this study, professionals' embodied conduct of normal radiographic anatomy and image production animates classroom teaching. I show how these tacit forms of knowing not only exposes the ambiguities of x-ray images but also seeks to disambiguate them in the process of 'seeing as'.

2.8 'Seeing *as*' and multimodal interactions

Ambiguity, which I understand as belonging to the domain of image production, brings into play the ordering work of professionals as a means to communicate and reproduce a particular way of seeing. Scholars in this domain ask how experts can find ways of reducing or removing the ambiguity of scientific or medical images (see for example, Lynch, 1985b; Amann and Knorr Cetina, 1988; Myers, 2007; Alač, 2008; 2011; Vertesi, 2014, 2016). For example, in her work on how a NASA[38] team crafted and interpreted images of Mars, Janet Vertesi (2016: 97) stated that photographs of the planet's surface were highly ambiguous and scientists analysing these images found ways of making these images meaningful to their discipline. In doing so, Rover scientists used methods of "digital image manipulation" to resolve these ambiguities in order to disambiguate the photographs, without which "they would not come to see the compositional or morphological details of the Martian terrain that interest them" (2016: 9).

[38] National Aeronatics and Space Administration

To show this, Vertesi presents us with a suitably ambiguous image of 'Cape Verdi' (a crater rim) where mission scientists used visual and verbal tools to make salient features they were interested in seeing. For instance, geomorphologists interested in Cape Verde's stratigraphy demarcated it *as* a cliff face (annotated with lines to demarcate different units in the cliff), whereas soil scientists highlighted compositional differences of soil types and demarcated Cape Verde *as* showing the tones and textures of soil. The case in point illustrates the ambiguity of the image: Vertesi shows how scientists might *see* Cape Verdi *as* a stratified cliff face on Mars (i.e. a true colour image of the cliff face to reveal striations[39] and stratigraphy[40]), or *see* it *as* composed of different soils (i.e. a use of different colours to demonstrate compositional differences in the soil). This practice of seeing images of Mars, deploying Wittgenstein's (1953)[41] concept of 'seeing as', documents how the team can see the same Martian features differently using different image processing techniques to achieve different purposes; this skill of *seeing as* that Vertesi (2014, 2016) identifies is essential to scientific practice.

In addition, Vertesi (2016) highlights the how the distribution of images among the team of scientific observers produced "shared visions" of the Martian terrain that served not only to develop a "shared vocabulary" (of spatial and temporal naming conventions) to plan the Rover's next location, but to help scientists and engineers communicate effectively (2016: 120). The organisation of this shared site of exploration and experience resonates not only with with work on "distributed cognition" (Hutchins, 1995) but the shared "sight styles" across radiologists in a clinic working with medical images and diagnostic tools mentioned earlier (Friedrich, 2010); a shared sight style contributes to a "shared mode of thought" that is essential for establishing a sound diagnosis in radiological practice (Van Baalen et al. 2016; Van Baalen and Carusi, 2019; Van Baalen, 2019).

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[39] Marked with striae, a linear mark, slight ridge or groove on a surface

[40] A branch of science in Geology that ordes rock strata

[41] Wittgenstein (1953) states that seeing is always 'seeing as…': when people stop saying, 'I *see* a duck' and start to say, 'I *see* it *as* a duck'. In other words, by taking advantage of the widely cited ambiguous drawing that could depict either a duck or a rabbit, Vertesi shows how the duck-rabbit example can be compared to seeing Cape Verde *as* a cliff face or, see it *as* composed of different soils. Thus, the crafting of the drawing shows how people (for whatever reason) are complicit in informing a change in the organisation of the visual experience, and are particularly good at making this complexity meaningful to others (Vertesi, 2016).

While Vertesi's (2016) work highlights the array of sophisticated imaging and visualisation techniques used by Mars Rover scientists, her analysis shows how the scientists attending to these images of Mars requires attention to their *bodily* engagement with computers and other tools or instruments for seeing Mars *like* a Rover. According to Vertesi (2016: 22) they "acquire an embodied sensitivity to the robots' capabilities, mediated through Earthbound visual transformations". The team's embodied attunement to the Rover's experience on Mars - informed by their experiences or social order on earth (much like the Jurors common everyday informed knowledge mentioned earlier) – reveals how embodied gestures, narrative, forms of talk and visual practices contribute to their visual sense making of ambiguous images *as well as* playing a central role "in reproducing the team's collective orientation". Similarly, Myers's (2007, 2008, 2015) work on protein crystallographers[42] shows how students used interactive computer graphics technologies to generate and visualise the intricate molecular structures of proteins and in doing so developed a personal form of embodied relationship with the complex 3-dimensional objects on screen. Drawing attention to the "body work" of modeling in structural biology, Myers (2007: 244) showed how an intense relation between model and modeler (and mind and body) was generated and highlighted how "modes of embodiment, affect, and performance" helped "solve" the complex structure of proteins and enzymes (Myers, 2007: 21).

When analysing these images, scientists do not only *look at* the objects on screen but *also* manipulate them. Scientists do not only draw on internal mental images privately conceived but *also* a number of external representations, using various material objects/tools or their own and other bodies. As is demonstrated in Alač (2008, 2011), the scientist's dynamic interactions with these external sources provided by the environment are efforts in the organisation of "multimodal" communication. For Alač (2014: 62) – as well as others, such as Goodwin (2018), Koschmann et al., (2007) and Streeck (2009) – these multimodal interactions "point out that talk, as well as bodily conduct that engages with material elements in the setting, participates in the social accomplishment of social activities" and undoubtedly include "talk, gestures, posody, visual orientation, and facial expressions". For Goodwin (2018), we can see this "multimodal organisation of action" come into play when the

[42] Undergraduate structural biology students

professional archeologist uses talk, tools (trowel, category system) and subtle body movements to make makes visible structures in the dirt to help produce a profile or *map* about the site of excavation. This multimodal approach to scientific representation and removal of ambiguity in classifying phenomena (that tends to foreground or background phenomena as part of this process) reveals the "complexity" of the phenomena that these scientists are dealing with (Goodwin, 2000a).

Importantly for this thesis, attention to the unfolding dynamics of multimodal communication moves beyond the mind and engages the body with the external environment. The body and its interaction with tools, materials/artifacts, and resources shows that medical decision making and rational approaches to problem solving or clinical reasoning are not not purely cognitive exercises that draw on "symbolic mental representations" (Berg, 1997: 27) but also draw on and are informed via multimodal semiotic means (such as talk, bodily conduct, gestures etc.). Whilst this thesis largely focuses on professional multimodal interactions in the academic environment, it is mostly done in contexts of demonstration and making matters observable and reportable (i.e. shaping cognition at a distance, albeit in the situated field). However, at times, some of their multimodal communication is also in organising students to acquire forms of tacit knowledge in the classroom and advising students to respond and acquire the salient features of external material phenomena.

We will mainly see this in chapter six when radiographers advise radiography students to engage in a variety of tactile interactions with plastic anatomic models to help craft adequate and optimal images. According to Prentice (2005: 857) this tactile engagement with external (anatomic) materials reinforces the concept of "haptic learning" to help (medical students) make visual and tactile distinctions among anatomical features. For Prentice (2005: 849) this "cognitive feedback loop – the work that happens between hand and mind – takes up the question of what we learn through our bodies and how what is transmitted to the body gets interpreted and learned". From this vantage, we can start seeing how the overarching aim of these studies innovates an approach to a socially distributed "embodied cognition" that lies at the development of a professional vision (Prentice, 2005; Alač, 2011; Goodwin, 2018). From this perspective, cognition is embodied "by our bodies locking us causally into relations with our immediate environment", supplementing and enhancing studies based on multimodal communication" (Hollan et al., 2000: 177).

2.9 Professional vision and x-ray image interpretation training: My study

The points illustrated above will prove useful in examining x-ray image interpretation training and subsequent professional vision of radiologists and radiographers. In *Practices of Color Classification* (2000b: 62), Goodwin remarks that in the person's process of systematically describing the colour of dirt brings him into a "historically constituted architecture for perception", yet one begins to learn how there are "several different ways of identifying the same colour". This multiplicity of possibilities, for Goodwin, is viewed as potentially ambiguous to a learner and constitutes the "cognitive and perceptual uncertainties that these students are grappling with" (2000b: 33), exhibiting a major obstacle that must be overcome. This leads to his embodied "activity framework", a movement of support "lodged within a hierarchy of displays being performed by the body" of the person doing the action and that talk and the body "mutually amplify each other". Upon finding the correct category and a sense of the way the earth should be looked at, the vision of the archeology student is radically changed, a shift that has "important methodological consequences", a method that shapes them to become an archeologist in a "community of competent practitioners" (2000b: 20).

Though Goodwin's (1994; 2000a; 2000b; 2018) discussion is predominantly limited to student archeologists in archeological field excavations, his work proves useful when considering the professional vision of medical imaging professionals teaching students x-ray image interpretation training. He demonstrates how newcomers to a community of professionals are embedded in the "organisation of visual practice", this coming from "tools that structure the process of seeing and classification, and documents that organise cognition and interaction (2000b: 168). In a study conducted by Saunders (2008: 304) on radiological practice in a CT suite, participants similarly viewed how pedagogical exchanges involved the "cognitive work of detection" because they wanted to "organise the attentions and routines of workers" yet these cognitive skills, modes of knowing or judgment that conveyed an appearance of system or scientificity become appreciable to others in misunderstandings and like the detective "must reproduce, bodily, key gestures of the culprit agent".

In this thesis, the analytical centre of attention is on professional vision, and, hence, how professionals help learners see, describe, and make sense of images (Goodwin, 1994). I explore how professionals, as actual members of a specialised work community, produce both physical actions and words pertinent to the 'ambiguity' of x-ray images (Måseide, 2007), as well as always make these relative to specific circumstances, in a work-relevant way to which they act. This restates the empirical concern of ethnomethodology to "the study of practical actions", where members are "engaged in serious and practical work of detecting, demonstrating, persuading through displays in the ordinary occasions of their interactions the appearances of consistent, coherent, clear, chosen, planful arrangements" (Garfinkel, 1967: 34). These assertions about practical experiences and 'methods' of understanding, which arise in the course of members' engagement within a situationally restricted "radiological vision" (Måseide, 2007: 203), identify what professionals must do to communicate their knowledge in order for new members to learn how to 'see' and 'interpret' x-ray images. This treatment of seeing and understanding particular kinds of information in image content from a practical vantage point captures the interactional nuances of highly 'specialised' (and highly tacit) bodies in academic settings. In so doing, I identify ways in which professional vision can shape the multimodal semiotic repertoire of professionals maintaining a shared perception and in accordance to methods that they use on which seeing/saying depends at Bridgestock and Woodfleet.

This professional vision broadens to the analysis of conduct and pragmatic gesture (Kendon, 2004). Embodied conduct performs particular forms of gesture for organising ways of seeing, that is, how professionals use gesture as a tool as a way of organising reasoning and making sense of images 'in order' to grasp what is being seen (Goodwin, 1994; Streeck, 2009; Ivarsson, 2017; Gegenfurtner et al., 2019). This is important when considering gesture at Bridgestock and Woodfleet. Indeed, professionals embody conduct and make the achievable details of their work available through the interactive organisation of gesture shaping students into the normative features that govern performance in their community (Lave and Wenger, 1991). For Goodwin, this orientation for making phenomena conditionally relevant and thus creating an interpretive environment used by participants allows the researcher to come to terms with how peoples' interactions with images and each other are deployed through actions of multiple "semiotic fields" which "mutually elaborate each other". The allows us to "focus on signs-in-their-media, i.e., the way in which what is typically being attended to are *sign* phenomena of various types (gestures, patterns, graphic representations, bodily orientation, etc.) and are said to have "variable structural properties that arise in part from the different kinds of materials used to make them visible (e.g., the body, talk, documents, etc.). One example provided by Goodwin involves the three different semiotic fields used by archeologists for competently seeing a relevant structure in a territory being mapped. On such occasions, the archeologist can conjoin use of the three 'semiotic fields' by using the material map, the place on the map indicated by a pointing finger, and the moment-by-moment accompanying talk that takes into 'account' what archeologists show to one another.

It is said that "interpreting 'marks, indicators, signs and symbols' is inevitably what sociologists and social scientists must do in order to carry out the corpus status of their studies of ordinary actions" (Garfinkel, 2002: 97). However, Garfinkel (2002) in making a distinction between ethnomethodology's program and formal sociological analysis (FA) argues that the researcher – as ethnomethodologist – is "not in the business of interpreting signs" per se because a focus on signs assumes too close a relation to textbook or *formalised* knowledge and seems to downplay how meaning is conveyed in practice. This attunement to the work of signs is a perspective that ignores their local, *in situ* processes of coming-to-be (McHoul, 1998), with Garfinkel (2002: 97), in particular, stressing how "enacted local practices are not texts which symbolise 'meanings' or events". In this sense, the prerogative of the researcher is *not* as 'formal analyst' after the fact of practical actions; rather I am interested in the "property of practical actions through and through … their self-revealing (or self-accounting) properties" (McHoul, 1998: 20). In so doing, I explore how professionals' ensembles of talk and embodied conduct as different kinds of sign systems feature during the discovery phase of a teaching case, as primordially situated in processes of learning to see.

In particular, the study by Saunders (2008) shows how, in pedagogical exchanges, the clinical correlation of an imaging case devolves into a process of *correction*[43] to understand image content, that is, how certain students require some level of correction to reduce their cognitive and perceptual uncertainties in the academic setting. Since the body is in action with

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[43] As we will come to see, much of this correction is not so much about correcting misinterpretations between normal and abnormal anatomies, but correcting misinterpretations of normal anatomy, such as that of challenging imaging conditions that have the potential to distort the appearance of normal anatomies and making them appear abnormally deviant to the uninitiated.

the image, I understand this is not just accomplished through verbal or pictorial interaction, but through embodied reenactments and gesture which also "provide various pieces of information that are systematically missing in the talk" (Nishizaka, 2017: 113) – this is particularly reflective of ethnomethodology which tends to include the body's role in the clarification of meaning (Garfinkel, 1967).

Following this, Vertesi's (2014, 2016) use of seeing as - as well as drawing *as*, and seeing *like* - is particularly prescient for this thesis, because at the heart of the Rover team's scientific practice is their duty to visually communicate the features of Mars to a public audience. This centers on the idea that "the public had to be taught how to see them" (2016: 97) but also how seeing as *does not always* have to rely on image processing techniques to disambiguate the otherwise ambiguous image. I will go on to argue that radiology and radiography professionals also participate in 'seeing as' practices that are done through their embodied and multimodal (re)enactments of the x-ray image.

In this chapter, I have identified the key theories informing my approach and explicitly highlighted how video ethnographic footage opens up substantial opportunities for paying close attention to people's situated and embodied activities of seeing. These situations and embodied activities are accomplished through the deployment of discursive practices. Video ethnographic fieldwork is 'inductive', in the sense that the researcher resists analyses that are shaped by theory, but instead attempts to build up an understanding of the world using the data. This approach appears to underlie a research methodology suitable in relation to the 'origins of ethnomethodology' and prompts creating novel categories and concepts (Lynch, 2007). However, this is not to say that fieldwork ignored fieldnotes and their role in mediating between the observation of the interaction and the video footage. In this sense, the researcher does not ultimately create theory from the video alone, but rather draws on the observations recorded in the fieldnotes, codes these notes in an analytic fashion, and develops explicit theoretical positions (Emerson et al., 1995). Overall, I maintained an inductive and flexible posture that needs not suppose any restriction regarding the ways in which professionals show aspects of their work performed before an audience made up of those learning to see - such as through the interplay of verbal/non-verbal utterances, gestures and body movements, and the information on screens (Greiffenhagen, 2008).

With reference to the concepts above, I explore and draw out the ways in which radiological practice is “known and shared” amongst the participating professionals (Ivarsson, 2017: 20) and how people organise what they see through embodied multimodal interactions in a local educational order. Furthering Goodwin (1994; 2000a; 2000b; 2018) and Garfinkel’s (1967, 2002) pursuit of studying people’s engagement with their work, my research fleshes out the specific socially-distributed processes involved in seeing images in a work-relevant way, that is, the ‘ordinary methods’ used to display and detect a particular object which “are occasioned; they are ‘hidden’ in and as their apt and familiar efficacy; they are only available to practitioners; and only to their vulgar competence, they are done unwittingly” (Garfinkel, 1981: 140). Interested in the “translation” processes of medical image content (Joyce, 2008: 64), this research is a story of how x-ray image interpretation gets ‘done’ in academic training (Garfinkel, 1967) and how academic settings are a place where professionals organise, (re)enact, and occasionally contest parts of the image being examined.

Do professionals in this study similarly use cognitive scripts or systematic practices to underpin the objective character of their descriptions? Do professionals witness perceptual and cognitive difficulties and then discursively ‘correct’ these through different kinds of semiotic phenomena? Do they embed students in ‘activity systems’ and if so, what do they do? How does ‘seeing as’ come into play in removing the ambiguity of x-ray images? These considerations, and the method of discursive practice to an ambiguous conjectured situation instigated by aspects of the professionals’ “embodied actions”, that is, a performing resource “tailored to the distinctive requirements of their work situation”, will be reflected upon when making sense of the findings (Goodwin, 2000b: 22)

This chapter provides a foundation for the concepts in this thesis and sets up the methodological agenda for the following chapter (chapter 3), namely the idea of using video as an analytic resource to unpack the ways in which embodied conduct organises knowledge, shapes perception, and structures future action and unfolds *in situ* (Heath and Hindmarsh, 2000).

3 'Everything is situated': elucidating methods

Chapter three discusses my entry and access to the field as a video ethnographer, *what* was recorded and *how* it was recorded, the analytical affordances of video as well as its limitations in the field. In navigating these, that is, self-monitoring the use and conduct of video alongside controlled observation, in-the-moment coding and fieldnotes, I also take into account not only what video seemed to reveal in the teaching practices, but also the challenges of video recording. This sets limits to my own limitations of seeing and to my analysis, and draws attention to the requirements of developing some form of competence or 'adequacy' in the work under study (Garfinkel, 2002). In this observation, I propose a parallel between those learning x-ray image interpretations in this study and my own learning. Video ethnography allowed for differential access to video recordings of different professionals teaching practices in field settings as they were performed. Probing this approach, I describe my entry to the field and how observational data was generated during six months of fieldwork at Bridgestock (a NHS teaching hospital of considerable size near the city centre) and Woodfleet (a large public University whose allied health training facility is located in a popular area away from the city centre).

With a focus on the role of the STS ethnographer's body as part of the learning process – its sociologically trained otherness situated in radiologic pedagogy that is performed best in darkness, I will reflect on how professionals and students perceived me during the fieldwork. Subsequently, my analytical strategy engages with what Adele Clarke (2003) calls 'situational analysis'; a theoretical approach that upholds material contributions and reflexivity to data collection and aligns with my theoretical positioning throughout this thesis. A final point fleshes out the problems and (im)practicalities of the video ethnographic craft. Despite considerable effort on my behalf to remain backgrounded, the spatial and physical layout of the classrooms, flow/movement, modes of light and interruptions often revealed my presence, giving me away.

Foremost in my approach I put forward the intersubjective elements of reflexivity. In my role as video ethnographer I offer a critique about developing kinds of relationships between professionals and students affected by video recording, including necessary ethics and responsibilities. As video recording in training and professional settings involves the intrusion into space and privacy, fears about how footage is used (for example, to publicise evidence of incompetence and error) are commonly expressed (Iedema et al., 2006). Working with video during fieldwork also engendered empathic "deep" reflexivity that offered a better insight into the researcher-researched relationship that cannot be exercised in the same way through the "explanatory" after-the-event reflexivity of writing (MacDougall, 1998: 89). This florescence of methodological self-consciousness elicited 'deep' data from the participants: it demanded exploring one's sensitive attention to interactions in and around video recorders and forced me to become self-aware of the excessive exposure and proximity. Rather than hide behind video recorders, I often flitted among the participants to adjust the position of the tripod, the focus and iris settings and, in some instances, I was 'called out' from behind the video - therefore I weave a discussion of reflexivity or *being* reflexive during fieldwork and its effect on the participants, on the field, and on the fieldworker.

Reflexivity in this sense is my attempt to show how the researcher can be 'written in the text' accepting that both researcher and research*ed* shape the encounter, as if shaping both the construction of knowledge and displacing or sharing the analytical privilege of the researcher (Lynch, 2000). At the same time, however, Lynch (2000) points out that reflexivity's role in enhancing objectivity (e.g. by 'bracketing' the subjectivity of the researcher) or raising false claims of objectivity has no particular benefit because objectivity is neither assumed nor pursued in such research. In this sense, being reflexive has a much less 'radical' epistemological character than we initially perceive because being aware of one's own subjectivities, our participants and phenomena that we attend to is also *always* present throughout any research agenda. Reflexivity, then, is an "unavoidable feature" of the way we do research and therefore "it is impossible to be unreflexive" (2000: 26-27). Nonetheless, I agree with Lynch (2000) that there are different modes of reflexivity (e.g. methodological self-consciousness) and that being reflexive has no apparent advantage unless it is potentially useful, in this instance I recognise myself as being a self-conscious reflexive researcher who critically interrogates his own position (and others): so as to not stress participants or disrupt the process of learning while video recording.[44]

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[44] I also apologise in advance for any "epistemological hubris" that comes from it (Lynch, 2000: 47).

3.1 Video ethnography between two sites

This study is based on fieldwork conducted at two UK sites: Bridgestock and Woodfleet. Bridgestock is a NHS teaching hospital with a medical-radiology department and Woodfleet is an allied health-training faculty at a Higher Educational Institution (HEI).[45] Before I outline an exploration of the methodology for collecting data on participants, I turn to a discussion on being given access to conduct video ethnographies and how accessing the hospital setting differed sharply from university access. As access conversations with medical school staff had revealed, x-ray image interpretation training in the medical curriculum tended to be integrated within clinical work as part of a specialty-specific rotation in radiology in Bridgestock teaching hospital. This meant there was no formal radiological education in the medical school. Progress around access to teaching in Bridgestock's radiology department and securing some kind of formal training was gradual. This involved addressing questions about whether the study required NHS ethical approval (because medical students were trained in a NHS teaching hospital) and whether I could dissolve or circumvent training in clinical contexts. This duty to inspect the study for NHS ethical approval was notably protracted and for the sake of space and "economy of description" (Heath et al. 2010: 121), only a focus on key details will be presented here.

Video ethnography follows the tradition of its counterpart, ethnography, with its focus on the everyday organisation of life in different settings, communities or cultures (Heath, 1986). However, it differs from the traditional "pen and paper style of data fixation" (Schubert, 2002: 4) in the technical demands of using video-related technology. Video ethnography has frequently been used in healthcare settings as part of projects exploring clinical identity or professionalism in medical practice (Heath, 1986; Heath and Hindmarsh, 2002; Iedema et al., 2006a, 2006b, 2007, 2016) and bedside teaching encounters (BTEs) (Rizan et al. 2014; Elsey et al. 2014; Elsey et al. 2017), and usually contains a 'reflexive' component that allows clinicians to view selected footage reflexively discuss their practice so that they can learn from patients and/or staff experiences (Iedema et al. 2013; Gordon et al. 2017). Most notably, given my interest in aspects of talk and bodily conduct these studies draw on ethnomethodological concerns and demonstrate how medical practice (such as professional

[45] A former Polytechnic that achieved University status in the early 90s.

forms of seeing and reasoning and diagnosis) is accomplished through the interplay of talk, bodies, materials and use of tools and technologies where the "contextual or situated character of practical action and interaction is placed at the heart of the analytic agenda" (Heath et al. 2007: 110).[46]

However, gaining access to conduct ethnographic fieldwork on NHS property is a complex, problematic and lengthy process (Reed, 2007).[47] As Reed (2007) explains, access is hampered by the lengthy NHS ethical review because it is caught up in a system designed to evaluate clinical research involving participants, which is often high-risk and which looks at 'outside' researchers with suspicion. While academic settings are neither high-risk[48] nor high-tech settings, access to Bridgestock was anything but straightforward: as far as I could gather, stakeholders and key professionals[49] were in the dark as to whether this study required or did not require an NHS ethical approval. Concerns around access were further compounded by my use of video recording as the main method of ethnographic inquiry and as the source of empirical data. Gaining access and permission to video record pose difficulties in relation to the physical entry/exit of settings and the establishment of trust between the key gatekeepers and the participants (Heath et al., 2010) - a distinction provocatively expressed by Cassell (1998: 89, emphasis added) as "getting *in*" to the setting and "getting *on*" with the participants.

In terms of 'getting in', part of the video ethnographer's preparation requires talking to those associated with the setting and seeking official access to what is initially inaccessible. This often involves navigating across "preliminary meetings" with a variety of key professionals responsible for the setting and interactions that decide whether the study is worthwhile and whether the researcher is sensitive to general concerns they hold (Heath et al., 2010: 15). Under such circumstances, there is a customary preference for granting access if the

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[46] This emergence grew from the limitations of audio recordings in conventional ethnographic fieldwork that neglected the body and gestures, as well as the visual and material aspects embedded within the interaction (Heath et al., 2010).

[47] Specifically, UK hospitals in the NHS.

[48] Absent of NHS patients.

[49] Medical and nonmedical professionals.

participants benefit from the research findings (Wolcott, 1995) or if the study has educational or clinical benefits (Harrison, 2002). Preliminary meetings often require the ethnographer to provide reassurances that she/he is competent[50] to undertake the study.

Outside of this, the video ethnographer must perform the usual duties ascribed to him (such as analysing research and policy documents, completing forms, making phone calls), but also anticipate other sources of information involved in preparing themselves for the vagaries of video in the field. This includes (but is not limited to): video training, booking and purchasing equipment, testing equipment, testing software,[51] enlisting the assistance of video operators and becoming familiar with the setting.[52] Needless to say, fieldwork begins even before access is granted and one 'steps over' into the field. According to Douglas (1994), fieldwork begins as soon as the researcher is immersed among 'role players', who, because of their close interactions with the participants, are seen as part of the community being investigated. For Emerson et al., (1995), fieldwork is a period of naturalistic inquiry into the social activities of a particular group (as well as the location and the rules by which they abide) that can be elaborated upon for an external audience, shared with those on the outside. In the present study, 'fieldwork' is a contentious term, but perhaps the term 'ethnography' is the most contentious.

Ethnography is often viewed as interchangeable with fieldwork, where the researcher, for methodological reasons, is primarily immersed in a period of prolonged 'participant observation' due to its inherent exploratory focus (Emerson et al., 1995). However, in recent years, ethnography has moved beyond this methodological rubric of deep immersion and participatory inquiry, given that many ethnographers nowadays are 'unable to commit sufficient time in the field' (Bryman, 2012). Regardless of time or degree of observational inquiry, it is important to recognise that ethnography, at its core, is still a process of writing

[50] These meetings consist of questions put forward by gatekeepers to assess the competences (as well as acceptable demeanour) supporting the researcher's proposal, weaving the 'sociology' of their project with the knowledge of the disciplines in the field.

[51] I organised a one-day training session with a representative from the video analysis software Studiocode.

[52] I attended three separate social research courses that provided hands-on instructions and tutoring in video camera use. This included the difficulties and pitfalls of video recording in the field.

down and recording the social life of people[53] going about their everyday ways as well as *learning:* "what is required to be a member of that world, what they experience as meaningful and important" (Emerson et al., 1995). Whilst the ethnographer's attention is on fieldwork, the researcher is involved in work prior to this. In what follows, I provide a quick discussion on University research ethical approval, where I articulate the different dimensions of ethical approval for both field sites These deliberations allowed me to gather how I could satisfy the concerns about video recording and develop a sense of trust among the gatekeepers by making connections, exercising considerateness and understanding the learning community.

3.2 University research ethical approval

The University research ethics process allowed me to perceive the demands on medical and radiography students and engendered empathy towards their educational commitment. This helped refine the study and develop research ethics documents to address professional concerns. A breakdown of the two applications (for each profession) to the University Research Ethics Committee (UREC) outlined: *what* video data would be recorded, *where* video recording would occur, and *how* participants would be recruited.[54] Applications also addressed concerns around anonymity as well as other research related information, such as methods (Appendices 1-2). The radiography application was submitted to the UREC's online application system (May 2015) and approved in early June 2015. The radiology application was submitted two months later (July 2015) and approved mid August 2015. Submission culminated with both applications being approved with suggested amendments, mainly in relation to issues of transparency (e.g. enhancing the clarity of the information sheet) and anonymity (e.g. whether true anonymisation/confidentiality could be achieved). After approval was granted by UREC, Ms Shortwood (medical school administrator) subsequently 'posted' the study on the medical students' online learning environment: ATHENA.[55] Ms

[53] A social world that is often previously unknown.

[54] 'Preliminary fieldwork' (Caine et al. 2009) helped me develop a sense of where to position the audio-video equipment to capture the teaching activities. While preliminary fieldwork was important to me in order to gain access to the research settings and establish trust between my participants, I have decided to omit it from the thesis as it would merely overload the methods with superfluous details.

[55] Athena is the Managed Learning Environment for the University of Bridgestock Medical School. It is a bespoke

Shortwood then helped identify the medical students on rotation, four at Bridgestock, and emailed them on my behalf about the study. The email contained a short message (intended as a 'personal invite') that I had prepared myself (Appendix 3), with attached information and consent forms (Appendices 4-5). This recruitment strategy was intended to give a 'heads up' to the medical students about the study, offering awareness about video recording and to prevent them from being taken by surprise. I soon realised that this strategy was problematic and I will come back to this issue later.

3.3 Fieldwork

Contact was made with Dr. Collins (WURD radiographer) and Dr. Maxwell to identify when I would begin to collect data at Woodfleet and Bridgestock. A third meeting with Dr. Collins and Mr. Hearken, who had been invited, discussed the dates for the 2015-2016 intake and what teaching was available to record. It was explained to me that the delivery of the x-ray image interpretation training would consist of both formal lectures and small group tutorial sessions. A tabulated teaching timetable was emailed to me to establish *where* and *when* teaching occurred and with *whom*. Mr. Hearken also advised me to contact module tutors a week before the tabulated teaching date to ensure there were no room changes. Mr. Hearken explained that Woodfleet University was where x-ray image interpretation training 'started' for undergraduate students. Similarly, Dr. Maxwell identified Bridgestock Hospital's radiology meeting room as the 'main' place for delivering academic content and the 'first time' medical students would receive formal radiology tuition as part of their degree. As such, it was established that x-ray image interpretation training was a practice that occurred between two different professional communities on two different sites. Because university approval had outlined two different settings, fieldwork was dictated as 'multi-sited' from the outset. This approach corresponds to the expanding wave of "multi-sited ethnography" that examines multiple sites ethnographically, instead of the traditional single or local sites of observation and participation (Marcus, 1995). The fact that these professionals share the radiograph as their 'domain of professional scrutiny' (Goodwin, 1994) in two different settings showcases

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e-learning platform for medical students at the University, providing electronic resources for the undergraduate medical degree (MBChB), including course structure and GMC guidelines.

the complexity of x-ray image interpretation training as part of a wider pedagogical and institutional network, defying the notion of a single site study.

By focusing on the training practices around x-ray image interpretation between different educational settings, a multi-sited ethnography provided me with a lens through which I was able to "follow people, things, metaphors, plots, biographies and conflicts" (Marcus, 1995: 106). This particular methodological approach to fieldwork, which includes following 'the thing' as well as following 'the people', allows me to explore the ethnographic object in the multi-sitedness of the field (Johnson, 2004). During fieldwork, I entered a variety of academic settings (classrooms, seminar rooms, offices, lecture theatre) and clinical departmental settings (reporting room, ultrasound, x-ray). Given my restrictions on anonymised images and the focus on 'academic' training, a vast amount of video recording and observations of teaching activities was confined to two academic settings: Bridgestock Radiology Meeting Room (BRMR) at the Bridgestock Hospital Radiology Department (BHRD) and Woodfleet University Radiography Department (WURD).

Whilst this style of video ethnographic fieldwork undertaken at two different institutions benefitted my analysis of interpretive training activities, it proposed a complementary and comparative insight into two professional ways of formative development. The conviction that one's professional vision relies on the "work environment" (Goodwin, 1994: 609), calls into question the material environment and the ways in which professionals use the setting to organise ways of seeing and understanding.

Not surprisingly, conducting such a multi-sited study undoubtedly allows for a rich analysis or "thick description" (Geertz, 1973: 6) of the interpretive training activities, where the use of video, in turn, moves beyond the textualist limitations of Geertz (Atkinson et al., 2003). This ethnographic detail, achieved through the ethnographer's eyes and video, further magnified by visualisation tools to make embodied semiotic engagement 'more visible', provided a visual record of inexhaustible insight and richness into the social and material contexts that constitute radiological vision. Following from this sense of radiological vision, I bring our attention to a description of the two main social and material settings of my fieldwork.

3.4 Bridgestock Radiology Meeting Room (BRMR)

On arrival at the Bridgestock Hospital Radiology Department (BHRD), medical students often sit or stand in the radiology waiting room among patients, waiting to be introduced to the radiology lead. After a brief introduction, the lead mobilises a corridor walk of the public domain that familiarises the students with the layout of the department and the location of the sub-specialty rooms for rotation teaching. This departmental induction ends on the other side of the public corridor; 'off the path' of patients, the other side is a network of corridors that lead to the departmental offices used by radiologists and radiology administrators outside the patient realm. In between the two offices rests Bridgestock Radiology Meeting Room (BRMR), the final destination in the departmental induction. Upon entry, the extreme smallness of the room, cluttered with too many chairs, conveyed a 'darkroom' used by plain film photographers that housed a computer workstation, six tables (some on their sides against the wall). There appeared to be seating for about eight people. The four walls of the room were beige and grey; the wall space behind the workstation was covered by a large LCD screen that almost spanned the entire wall and a narrow whiteboard on either side used by the radiologists to chart productivity targets. The wall the side of the door had a dimmer switch (rather than a more abrupt light switch) to alter light levels. The wall opposite the door was occupied by two windows, both of which always had steel blinds pulled down. From the two windows, there is a striking view of the steamy outside: a topographical estate of mechanical ventilation systems and a panoptic vision of the hospital's 'inside'.

A corner at the back of the room moved further back into its own private space that disrupted its rectangular laterality. This indent, which resembled a dark cove, was used as a storage area for boxes full of obsolete 'plain films'. The dumped boxes of dusty x-ray films remind us of a bygone era where film-handling chores, storage enterprise, and massive film management were part of the labour of x-ray production (Saunders, 2008). Behind the boxes there is a desktop computer with a high-resolution monitor and devices (keyboard and wireless mouse), the latter resembling a 'trackball', an ergonomic alternative to the conventional mouse. Despite its training purpose, the absence of learning materials in BRMR showcases competence and professionalism. It appears anatomical models and apparatus are not required in the workplace.

BRMR is mainly used as a space for clinicoradiological and Multi-Disciplinary Team (MDT) meetings to discuss 'interesting cases' as potential follow-up investigations for the department and to confirm the diagnosis for the 'active cases'. Alongside MDTs, radiologists use the room to gather, share, present and discuss information in meetings around audits, discrepancies, and management. BRMR also doubles up as a space for Specialist Training (ST) in radiology, for both radiologists and medical students, on their rotation in the radiology department. ST radiologists opt to undertake undergraduate teaching duties and are administered[56] BRMR as the locus of formal teaching. They participate in a complex system that combines clinical work and formal rotation teaching.

Although BRMR was allocated to professionals as a fixed domain of core and substantive formal teaching, it was not immune to time constraints and the demands of the surrounding clinical environment. The very large role of work duties carried into BRMR accelerated the pace for introductions, teaching (for example, hurried students in hot-seat sequences), and left case presentations unfinished. Upon entry to BRMR, professional-medical student greetings were highly formal: quick and quiet as the professional balances learning the students' names with the demands of setting up the PowerPoint Presentation. The fact that this space is termed the 'meeting' room – a word associated with business, work, pressure, time constraints, and hierarchy – is evidence of the blurred professional boundaries in medical education. This is especially evident when the students quietly enter the room, sit down, and await the 'greeting ritual' (Goffman, 1967).[57] Medical students appeared accustomed to the immediacy of teaching as greetings were prompt or, in most cases, absent. Moreover, BRMR and its professional connotations contrast with the less serious or playful atmosphere and mood of classroom settings across WURD.

[56] The radiology administrators are involved in the organisation and delegation of teaching commitments.

[57] Upon entry to the room, professional-medical student greetings were highly formal: quick and quiet as the professional balances learning the students' names with the demands of setting up, such as, dimming the lights, switching the workstation on, loading the PowerPoint Presentation on the LCD, and in some cases adjusting the chairs/tables - and for me to finish setting up the video equipment.

3.5 Woodfleet University Radiography Department (WURD)

Woodfleet University is located a mile away from Bridgestock Hospital, a setting that trains allied health care professionals. A large department on a leafy university campus, Woodfleet University's Radiography Department (WURD) employs professional radiographers to train individuals in a three-year undergraduate degree in diagnostic radiography. The degree is primarily devoted to training individual students in the practice of producing radiographs of diagnostic quality. WURD has established close training links for radiography students across a number of teaching hospitals, where students are selected to participate in clinical placements throughout the course of their degree. As indicated by the degree, the department facilitates the training of radiograph production and optimisation. The main hazard associated with imaging patients is the x-rays, which can become harmful if radiation exposure on the anatomy being imaged is too high. For this reason, there is a digital x-ray suite where students learn to perform the positioning technique and produce x-rays using a 'phantom' skeleton rather than themselves. In a separate room, on the same corridor, there is an image interpretation suite, where students evaluate the 'technical adequacy' of the images taken in the x-ray room, as well as 'real' images on the PACS. As indicated by the radiation protection protocols, the x-ray room and the image interpretation suite are separate, although both entrances share the same 'vestibule'.

What is more, radiographers in-the-making have to minimise the movements of patients' bodies to avoid radiological error that inadequate positioning and movement may cause. When radiographers, in the image-making process, do address patient positioning, their primary concern is to produce radiographs of diagnostic quality. The assessment of whether the image is 'technically adequate' for diagnostic purposes is realised at the end of the production process, or later during its interpretation. In addition to the image making and technical evaluation process, radiography students also attend radiograph image interpretation classes. WURD contains five rooms for professionals to teach image interpretation: a computer room, and four other classrooms where, while all slightly different in layout, the walls were animated with anatomical posters, as well as old light boxes and x-ray tubes that were once features of analogue radiographic work.

The 'computer room', where radiographers in-the-making were given anatomical models to help label the radiographic anatomy in the PowerPoint slides, is a small L-shaped room containing a now obsolete light box, an x-ray detector (or 'cassette'), nine desktop computers, a large LCD screen, anatomical posters, three tables littered with anatomical models, and an x-ray grid. The anatomy was presented to students in a large green 'bone box' (Fig. 1). The bone box contained anatomical models of the upper and lower limbs, thorax, abdomen, shoulder, spine, and pelvis. These model bones allow for familiarisation, measurement, and positioning of students' own bodies and the comparison of patient anatomy in the radiograph. The other four classrooms were all fairly similar in size to each other, either having numerous anatomical posters on the walls and scattered models of internal body parts (like before) or particularly drab in appearance.

When attending x-ray image interpretation classes in WURD, radiography students patiently wait outside and chatter with classmates until the professional appears guiding them inside. If the professional is inside, the classroom quickly fills with the muffled din of between twelve to fifteen students, most of whom are young females, aged between 18 and 25. The chatter is anywhere from playful (critiquing films, Saturday nights) to more serious (assignments, assessments, and revision) and continues inside as the students locate their chair of choice. In WURD, students either sit individually on a chair that has its own table or sit in twos at tables arranged about the room - with the exception of the computer room – and sit facing the professional. Those who are first to enter classrooms migrate towards the back wall, sitting furthest away from the large LCD screen or projector screen used for teaching.

In most rooms, radiography students encounter one large LCD screen, placed on each wall, displaying the x-ray image simultaneously. Here lies the force of multiplicity in the process of learning; the same version of the image spatially distributed across the room, which allows students to see the case presentation and brings them closer. From radiography students' point of view, multiple LCD screens enforce the idea that the image needs attention and it becomes an 'education of attention' (Gibson, 1979; Ingold, 2001), allowing students to focus or 'tune' their perception so as to participate in whatever way necessary. This invites us to consider how environmental features, such as the media layout and space of the rooms contribute to and help discipline a professional vision.

3.6 Professionals in Bridgestock and Woodfleet

The table below specifies the professionals that participated and consented to the study and generalised information on their role. Notably, the table is particularly gender-biased, with six of the seven professionals video recorded being male.[58] Professional specialties (e.g. neuroradiology) have been omitted to further protect the anonymity of professionals. Furthermore, the small number of professionals recruited onto the study may relate to concerns around video recording, along with professionals' willingness to anonymise images.

Table 1. Professionals in BHRD and WURD

Name	Hospital role *Department of Radiology*	University role *Department of Radiography*
Dr David Maxwell	Consultant radiologist	-
Dr George Saury	Radiologist (ST4 registrar)	-
Dr Ben Delichon	Radiologist (ST2 registrar)	-
Dr Simon Clyde	Radiologist (ST4 registrar)	-
Mr Adam Hearken	-	Senior Lecturer in Diagnostic Radiography
Mrs Valerie Campbell	-	Lecturer in Diagnostic Radiography
Mr Jim Richards	-	Senior Lecturer in Diagnostic Radiography
Dr. Jeff Collins*		Senior Lecturer in Diagnostic Imaging

**This professional was not involved in image interpretation training after a change in the teaching timetable.*

WURD is run by the course leader (Dr. Effie Hammer) and employs four professional registered radiographers (Mr. Hearken; Mrs. Campbell, Mr. Jim Richards, and Dr. Jeff Collins).

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[58] It is difficult to establish whether the dominance of male members is standard for the professionals in this domain or whether it just happened to be the case for this study. Due to Dr. Maxwell's recruitment strategy this was not easy to recognise: staff were recruited on the basis of proximity and on whether they had put together anonymised case presentations.

At the time of the study, Mr. Hearken and Mrs Campbell worked part-time in local teaching hospitals. At BHRD, Dr. Maxwell is the undergraduate lead for the medical student radiology rotation. BHRD employs ten consultants and twenty STs across the department. Apart from Dr. Maxwell, BHRD professionals are not paid for teaching, or for preparation. Undergraduate teaching is fitted in between clinical commitments or 'free time', such as lunchtimes.

Figure 1 'The bone box'

3.7 Data collection

Six months were spent in the field collecting data. Forty-one hours of audio-video data are supplemented with fieldnotes, field observations of professional-student interactions, and e-mail correspondence with professionals. This multi-method approach to data collection was fitted to accommodate the complexities of healthcare training that straddle the 'classroom' and 'clinical' environment, reflecting the workplace or clinical training as a composite of healthcare education as a whole. As Johnson (2007) reminds us, large elements of the skills required to be a healthcare professional are commonly located in work-based settings as part of work practice through observation/participation, often colloquially termed "at the coalface" (Hyde, 2009: 119). This would imply a destabilising or disruption of the data collection process. Four times throughout the first year, radiography students travelled between university classrooms to clinical-practice placements at local teaching hospitals. Out of the 45 weeks, radiography students spent 13 weeks (29%) of their degree being trained on the university campus, primarily in classroom settings. For purposes of comparison, 27 weeks (60%) are spent on clinical placement throughout the first year of their degree. An obvious observation that emerges here is that radiography students spend more time training in clinical practice than in the classroom.[59] The other time away from the university is spent on time allocated for personal study/reading and revision for assessments and exams (4 weeks/8.9%) and interprofessional learning classes (1 week/2%).

Relatedly, disruptions to data collection were also encountered following medical-radiology rotations.[60] Throughout a typical seven-week radiology rotation, four groups of medical students spend one-week (5 days) training in the department. The seven-week rotation is punctuated by a week free from teaching duties; this was a rallying call directed to professionals in the department, whose shoulders carried the weight of clinical targets to make sure workload did not fall behind. This meant that after a week of data collection in Bridgestock I had to put my fieldwork on hold, as during this week long hiatus I was distilled from the field. This also questions whether weeklong radiology training is enough for medical students and supports previous concerns by medical students and their radiology educators who claim that training is "often sporadic and disorganised" (O'Brien and Shelmerdine, 2012: 2). Most of the professionals I talked to – both radiologists *and* radiographers – agreed that this was not enough time to train medical students in x-ray image interpretation and all they needed to know.

There was then another fortnight hiatus or *'breathing space'* (as one radiologist put it) until the beginning of the next rotation. Clearly, medical students are likely to recognise the bulk of degree training in clinical practice. At the time of the study, medical students were in the second year of a two-year clinical training programme that extended the basic clinical

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[59] Appendix 10

[60] Appendix 11

competencies of the previous programme otherwise known as a 'phase'.[61] According to Ms Shortwood (Medical school administrator), there are approximately sixty medical students per radiology rotation, subdivided into four large groups across four local NHS teaching hospitals. In Bridgestock, approximately fifteen medical students were expected on each rotation, rotating in five groups of three every fortnight.

This model of healthcare training illustrates the reciprocal relation between university training and clinical training, a co-constitutive relationship that challenges the ethnographic practice of medical and radiography education. No ethnographies have been carried out that follow undergraduate image interpretation training from classroom into clinic, and vice versa: this may in part be due to difficulties in accessing and navigating a complex model of healthcare training, not simply to a professional vision that is 'best' explored in clinical settings.[62] It further shows how a prepared (video) ethnographer, aware of the sociological dimensions of professional practice, can *miss* data that provides teaching interactions in academic settings. For instance, it became quite clear that the 'clinical' knowledge acquired during placement/rotation enhanced students' understanding of teaching interactions in academic classroom settings. The observations, made by radiography students, in particular when returning from their first clinical placement questioned, or, more accurately, disputed tacit aspects of professional claims to radiographic practice.

Traditionally, STS ethnographers acquire ethnographic understanding of a professional domain by interacting with their participants (this has been given the more appropriate STS-like moniker 'participant comprehension')(Collins 2004). However, the healthcare training model above can disrupt the geometry of researching the early shaping of the 'raw' professional into the qualified clinical professional, not only in the early years of the profession but during the transition between settings, such as returning to the classroom after clinic.

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[61] The first year of this phase (Phase 3a) was based in primary care (GP surgeries), whereas the second year of this phase (Phase 3b) was based in secondary care (hospital settings). The main feature of phase 3b was the opportunity to train and rotate among a range of medical sub-specialties.

[62] It is a commonplace understanding of professionals involved in healthcare training that time spent in clinical placements leads to a significant understanding of practice, including their professionalisation.

This also raises some wider issues, whereby it problematises the ethnographers' understanding of teaching interactions and interpretive practice. From the ethnographer's perspective, if data collection is regularly paused to accommodate the clinical, observations tend to be less informed which calls into question the validity of the periodic ethnographic observations and the authenticity of the study as an 'ethnography'. Clinical placement and limitations to access essentially led to the premature closure of fieldwork and "early saturation" which 'cut off' my access to other academic settings. Because of this the thesis cannot be regarded as "strong ethnographic work" (Charmaz and Mitchell, 2003: 168), although I hope it allows enough 'ethnographic sensibility' in its analysis for current or former professionals to critique (Elsey, 2010). It must be noted, however, that time away from the field allowed me to re-enter the field with a better grasp of anatomical language, allowing me to converse with the participants on the topics in a more relevant way.

The decision to conduct a video ethnography and to use video data to explore teaching interactions is grounded in the theory that has been developed to understand the training of professional vision, as outlined in chapter two. The use of video ethnography is a departure from what is sometimes thought of as the qualitative researcher's over-dependence on interview data, which has led to what some commentators have dubbed 'the interview society' (Atkinson and Silverman, 1997). Rather than collect interview data, my strategy of following x-ray image interpretation training between two professions resonates in ethnomethodology. Whilst this approach claims social life is the product of a person's lived experience, it is also used to help point out the methodic activities people (re)produce 'from within' (Hester and Francis, 2000).

Ethnomethodologists see ethnography and especially video data as the most analytically rewarding way to analyse the methods used by people within settings that structure the world of that community (Goodwin, 1994), that is, how the person's everyday practices of ordering and making the social world intelligible are 'done' by natural interaction. This tendency to video record 'naturally occurring' interactions relevant to professional practice within the participant's natural setting is central to the video ethnographic inquiry (Heath, 1986; Kendon 2004; Heath et al., 2010; Pink, 2012). Furthermore, video data can be, as Goodwin (2000b: 6) suggests, an appropriate method to "maintain as much information as possible about the setting, bodily displays and spatial organisation of all relevant participants, their talk, and how events change through time". I proposed video as my primary source for data collection because I was interested in providing a detailed description of the spatial-material features of the learning environment and the nuances of talk and body in learning 'to do' the practical work of a profession. Like Goodwin (1994: 626), I do not view seeing "lodged in the individual mind", isolated from the conditions that create context, but rather as a process that situates people in ongoing patterns of interactions with both humans and nonhumans (such as external materials relevant to the practice). As Peräkylä notes (2005: 869), researchers that use 'naturally occurring' empirical material (such as video recordings or written text) are "in more direct touch with the very object that he or she is investigating". In this respect, it is better to video record professionals' teaching practices and students' learning image interpretation rather than to ask participants to tell us what they are 'doing' (Peräkylä, 2005). To be clear, the video data captured is of the methods that the professionals deploy to organise their perception in a "work-relevant way of seeing", thereby producing the orderliness of their activities with the majority of the image work I examine being x-ray images of the chest (Goodwin, 2000a: 169).

Further, it can be said that this raises questions about the representation of voice and analytical privilege of the social researcher: whose voice do I represent the most and how can these voices be presented in a fair and robust manner in the researcher-researched relationship? It is clear that social researchers have a privileged position in their observation, analysis, and representation of participants; a standpoint that generates epistemic privilege to legitimate claims to ethnographic insight (Raheim et al. 2016). It is suggested that this privilege is likely to have profound interpretivist implications in examining a social question or behaviour, particularly when we begin to view, absorb and interpret the 'voices' of data that run the risk of potentially opposing perspectives between the researcher-researched (Raheim et al. 2016).

Pink and Mackley (2012), sensitive to dominant and silent voices argue that one way of defending against analytical privilege is by "placing practices at the centre of analysis, and indeed affording them analytical privilege", a theoretical commitment to a foundational principle in sociology: the idea of a theory of *practice* where individuals are not "the source of meaning and normativity", rather "practices are the source and carriers of meaning, language, and normativity" (Schatzki et al., 2001: 12). However, Pink and Mackley (2012: 3.4) argue that placing practice at the centre of analysis “tells us little about either individual variation or the multisensory, social and material environments of which practices are a part” and in doing so puts forward the proposal that ‘collaborative research’ will help defend analytical privilege because it can “open up ways of knowing as they are inscribed in embedded clips, in relation to our written argument” (2012: 1). In Carrol and Iedema’s (2008) work video recording how clinicians in local intensive care units (ICUs) conducted their practices, collaboration was encouraged through the use of ‘video reflexivity’ which rested upon the idea of engaging clinicians in reviewing real-time footage and allowing them to feedback their communication difficulties. In keeping with the ‘reflexive turn’ in social research – problematising the researcher as the ‘one who knows’ through the way researchers collect, interpret and textually render data (Pollner and Emerson, 2003) – I considered including video reflexivity component into the data collection process, allowing participants to have an iterative and active role not just in foregrounding particular events or perspectives but also by intensifying one’s apprehension of what has remained in the background (Carroll and Iedema, 2008).

This process, ultimately helping to shape types of questions, what activities to follow, and the spaces and relationships the researcher finds themselves in ultimately stands in stark contrast to purely observational approaches (Pink and Morgan, 2013). For example, a video reflexivity component would have helped provide insights into professionals and students’ own definitions of teaching practice and factors affecting their understanding, thus ‘privileging’ their view. Unfortunately, I decided to omit a video reflexivity component to the research due in part to burdening participants with expectations of intense involvement, arising more from the demands of their degrees than from any desire from the participants themselves.

Additionally, I did think about asking the students to view and participate in the coding of video but I was cautious of time and the demanding responsibilities placed on students who both balanced academic commitments with clinical placements. Nonetheless, I still attempted degrees of collaborative research which will be discussed later in this chapter, particularly in the form of writing a ‘light bulb’ moment with students and by involving professionals in viewing, commenting on and verifying written work via email correspondence. I express these as an attempt to address analytical privilege and as a sign of trust that continually reassures that my participants had some degree of control throughout the research process.

3.8 Video recording

The vast majority of the data is taken from video recording professionals teaching undergraduate students how to interpret x-ray images in radiography and radiology education. These training sessions took place at BRMR and WURD. As such, BRMR and WURD data was collected through video recordings and other academic training worlds (e.g. medical school lecture theatre) were video recorded less often. In total, I video recorded thirty four teaching sessions (twenty-five in radiography and nine in radiology), in which image interpretation with radiographs was being done absent from x-ray imaging technology, the patient's living body, and fellow practitioners. Whilst the arguments in this thesis come from video footage, it does not mean I let the video recorder do all the work. The possibility of 'doing nothing' and relying on the video camera as the main method for observation has been challenged in the context of collecting data on interaction (Goodwin, 1981; Schubert, 2002; Heath et al., 2010).

Rather than simply using the video camera as a 'stand alone' method, its operation was often overseen by the researcher[63] looking through both the lens of the video camera and the digital screen display as part of video-mediated observation.[64] Video-mediated observation via the screen display, in particular, allowed me to view the aesthetic quality of the video being recorded in real time and made it possible to address aesthetic features (such as light/darkness and exposure).[65] Such actions were necessary throughout fieldwork for the establishment of 'good quality' footage, so as to see the images as they appeared to the participants and to follow movement and focus in on embodied actions in settings. Often, I adjusted the zoom to 'get closer' to the ways participants interacted with images and to focus in on subtle or obscure anatomical details.

[63] Video recording was not always done as a 'solo' activity. At times I required assistance (more on this later).

[64] A built-in tiltable LCD touchscreen

[65] Data collecting in dark rooms is a difficult practice for the video ethnographer to master. Digital video cameras do have autonomous automated exposure settings. This helps reduce the over/under exposure of recordings. However, I often considered this problematic, as it often determined a different exposure to what I wanted. I also had to come to terms with the disruptive potential of exposure changes during analysis.

I also routinely used the zoom to defeat the 'whiteness' of radiographs that became exaggerated on the display screen - phenomena that was otherwise invisible to the 'naked eye' (Schubert, 2002). The 'whiter' the radiograph, the more difficult it was to capture its features in an aesthetic sense, and risk losing a subtle anatomical detail that was otherwise visible to the 'naked eye'. The whiteness was partly due to radiographs that had been overexposed when they were made or whitened by the presence of (abnormal) fluid as well as bursts of light from outside intruding and piercing the dark rooms or to professionals adjusting the light while teaching. By recalling Burri's (2008: 50) observations of professionals discussing the importance of "aesthetic features" at radiological conferences, I too was concerned with the aesthetic features of images through fieldwork and collective strategies. As we will come to see, my actions to achieve satisfactory aesthetic quality are not too dissimilar from the participants I am studying: a role that paralleled with the radiographers' by setting up technical equipment (e.g. cameras, tripods, cables, laptop), 'collimating' the lens of consenting bodies, and adjusting 'exposure' settings to get the best possible picture.[66]

In addition to video mediated observation, I spent the rest of my time away from the video camera's display screen in 'direct observation' (Drury, 1995) of the teaching practice – a naturalistic methodological technique that observes participants' interactions during their usual activities without being actively involved in the activity going on.[67] This mainly involved writing fieldnotes. Whilst my activity was limited for reasons regarding disturbing teaching practice and participants' learning, remaining fairly restricted in substantial movements and refraining from asking questions focused observations, which intensified efforts to observe 'seeing as a process' *in situ* (Goodwin, 2000b; Alač, 2008). This approach takes the form of a self-conscious reflexivity, taking into consideration my role and my relationship and responsibility to not disrupt the learning process. This clearly poses a challenge to conventional STS ethnographies interested in people's practice in which the methodological idea of participation and immersion is endorsed to "actually understand what they are doing"

[66] I find it ironical that I was operating visual technology and involved in a type of image-making craft.

[67] This should not be confused with 'non-participant' observation, where the researcher goes to great lengths to be unobtrusive during data collection and finds interactions with participants problematic for the 'validity' of data, as if to yield a singular 'truth'.

(Tosoni and Pinch, 2016: 16). Fortunately, Schubert (2002: 4) reminds the video researcher that 'participating' should not be taken literally, but as a technique that allows us "to get closer to the field".

However, there were occasions when I became an active participant, although this was restricted to teaching sessions organised into smaller groups, that were more informal and relational, such as classes that formed into 'breakout groups' or 'round robins' that allowed students to learn among themselves, computer screens, and materials. As a result, I sometimes found myself in the action of 'passing bones' to students and answering questions about the study or tempering concerns around video recording (more on this later). At other points, I was called upon by the professional and flushed out from behind the camera as a resource to support a point being made about the 'barn door obvious'[68] or became an active member of the class, playing with model bones that gave me a basic feel of *knowing* the normal.

Because these actions were infrequent, my observational approach allowed an intensive immersion into the learning process being recorded and sharpened real-time editing that I would not have done if participating. An observer, then, will suffice: I do not need to take part in the field activities because my video-work means the situation is still achieved (Schubert, 2002). In doing so, the video camera recorded information on the "largely unspoken processes of apprenticeship and an education of attention" (Grasseni, 2004: 13) which professionals and students, in both settings, took for granted, a tendency that neglected and understated the social phenomena in founding their professional vision..

As I have shown, video recordings of interpretive training activities in academic settings comprised the bulk of my data, but how exactly was the video data collected? As noted earlier, Mr. Hearken (WURD radiographer) provided me with a teaching timetable that tabulated all of the image interpretation classes of the first year. Similarly, Dr. Maxwell (BHRD radiologist) handed out a radiology rotation timetable that tabulated fixed and non-fixed times for teaching sessions, as given to medical students at the beginning of the departmental induction

[68] The point being that the abnormality was 'obvious' to see even to the untrained eye (more on this later in chapter five).

and to myself when I first accompanied them around BHRD and into the subspecialty expertise rooms. Diffracting ethnographic fieldwork across settings, I video recorded the teaching sessions dedicated to specific images (shoulder, pelvis, spine, chest, abdomen, CT head). I became involved in these sessions the same way the students did: the teaching timetable provided me with all the interpretive training I could attend.

In addition, the teaching timetables with their focus on specific types of images, allowed me to develop a 'map' of the two field sites, providing me with an opportunity to see the images and continued to be important analytically. In the first instance, the physical home of the professionals and images were mapped, along with their interactions with students. Mapping both field sites was an ongoing process, which was reflected upon and amended as the study progressed. The initial map seen here, however, can be viewed as the first stage in the 'situational analysis' approach (Clarke, 2003), and what comes to be known as the "messy/working version" (Figure 2) of the situational map; providing important background context for data collection and analysis (ibid: 2003: 561). I will speak more about map making later in the chapter. But, for now, it is necessary to continue to explore the intimacies that shape the researcher's relationship with video recording.

Outside of teaching sessions, my routine after video recording would consist of looking at my fieldnotes, transferring the audio-video data from memory cards onto external storage devices,[69] creating nomenclatures to label files containing data, reviewing audio-video data for sound and image quality, then returning the equipment back to the University's audio-visual services. I also spent much of my time away from teaching activities learning "to think anatomically" (Good, 1994: 73), like the participants in the study.

In addition, the ethnographic constraints of being omitted from clinical practice - where nearly all learning is done – markedly limited my grasp, orientation, and comprehension of what the participants saw. This observation is a critique of my analysis on the teaching activities that perform or the materials that enact anatomical or technological phenomena. Even when the radiography students returned from their first clinical placement, I found

[69] Three external hard drives: (1) Lacie rugged 2TB Thunderbolt drive; (2) G-Tech G-drive 1TB external; (3) G-Tech G-drive 1TB external); and (4) a cloud account (150 GB).

departmental protocols to be a significant feature of the radiographic technique and image production, an observation that corrupted my understanding of academic teaching interactions.

A month into the fieldwork, professionals presented their own ways of teaching case presentations, not in their head as a hidden cognitive process, but rather as a visible bodied activity that drew on their body and the environment as semiotic resources for the organisation of seeing and situated learners in institutional discourse (Goodwin, 1994; Goodwin, 2000a Lave and Wenger, 1991; Wenger, 1998). Rather than assess and evaluate professional competences or the best ways of teaching within some kind of 'best practice' framework, I asked what practices professionals do to train and organise practices of seeing, how these practices are accomplished, and in what type of community or 'work life' they are embedded (Goodwin, 1994).

Professional-educators, "as representatives of the institution and upholders of curricula demands, with an identity defined by an institutional role" (Wenger, 1998: 266), are treated as active practitioners, who value inventive, creative practices in the world, restrained, that is, not freed from contributing to organisational goals through practices that are prescribed to newcomers (Wenger, 1998). Thus, it is important to take into consideration the professionals' accounts of what is talked about (as in verbally) and the work that is done via the body (as in gestures), but also what they *use,* which powerfully supports the teaching practice and illustrates how such professional ways of seeing is done or situated in the display of meaning and action (Goodwin, 2000a).

Heath et al., (2010) preserve this sentiment**:** those ethnographers using video do so as part of studies of situated practical action and interaction. These matters of *doing* image interpretation in educational settings are about representing existing features of the imaging workplace where medical images and medical imaging technology (and modes of visualisations) are present. This awareness, modeled on the relations professionals have at workplace practice, makes seeing and interpreting graspable to the uninitiated eye.

Thus, with a focus on seeing/interpreting[70] as an embodied and material aspect of communicative situations at Bridgestock and Woodfleet (Ivarsson, 2017), data collection became exploratory so as to unpick the human and nonhuman elements in the everyday activities of interpretive training. Indeed, this methodology involves paying attention to multiple "semiotic resources" (Goodwin, 2000a) that shape professional vision, such as the field of the computer screen, and the ones inhabited by materials and bodies (Alač, 2008) that characterise the work of image interpretation training. I explore how professionals train students in practices of seeing, how image content is made 'seeable/interpretable', how professionals introduce uncertainty in case presentations, how students are warned about radiological error and litigation, and how seeing is 'corrected' in pedagogical exchanges that are aimed at finessing descriptions of a finding (Saunders, 2008).

When the radiography students dispersed for their fourth clinical placement it was around the same time as the radiology department welcomed a *'vacation'* in teaching duties (a two-week break before the beginning of the next rotation), the limits of data collecting helped decide that I should leave. In addition, I had amassed seventy-six 'raw' videos and seventy-seven 'raw' audio recordings[71] that together became over a terabyte of audio-video data, meaning massive storage capacity was needed.[72] Inevitably, the storage capacity increased as part of the editing/analysis through techniques of video 'stacking', audio syncing, and code creation. While HD memory cards are relatively inexpensive, the back-up storage devices are not. In effect, this limited the possibilities for further fieldwork.

Although events were recorded on memory cards and 'backed up' once, I was aware of the data loss (and the loss of self) through corruption/distortion or damage and this meant back-ups were 'on-going' through four storage drives (three external hard drives and one online repository). Despite the cost of storage space decreasing (Dicks et al., 2005), the HD video, audio files and other visual media (PowerPoint presentations with radiographs, photographs,

[70] I use the term 'interpret' rather than 'read' to avoid some of the connotations implied by the word 'read', as explained later in the text.

[71] See Appendix 12 for a breakdown of the total hours of audio-video recording for each group.

[72] The large lecture theatre in the medical school required the use of a third audio recorder (a boundary microphone).

and anatomy diagrams), the cost of backing up soon added up. In retrospect, the dispersion of the participants came at a good time, as I was becoming inhibited by the cost and the intensive labour in storing and producing the files but also by the drive to write and 'get on with the analysis'.

3.9 Fieldnotes and Zooming

I was able to write fieldnotes during the teaching sessions. Classrooms and meeting rooms were the ideal settings to construct fieldnotes – inscriptions that allowed me to blend almost imperceptibly with the students – and structure a 'shared interactional space' (Suchman, 1987). Often, however, there was the need to attend to the video equipment during fieldwork. This meant that on many occasions, I moved out from my 'armchair' to behind the video camera in order to follow and aestheticise the interactions. For instance, I regularly left my fieldnotes to adjust the zoom function to pick up subtle or obscured image content that the previous adjustment was unlikely to capture on the computer screens.

Zooming has been understood as an effective practice in video recording interaction. For example, reflecting on research on board the oceanographic ship, Goodwin (1993: 194) pointed to the zoom function of video recording and argues that he "wanted a record of the computer screens they were working with". Here, Goodwin is actually endorsing the zoom as being "invaluable for subsequent analysis" (ibid: 194). Although such actions inevitably 'arrange the field' and raise suspicions that the camera is made to 'lie' (Banks, 1992), they show that the researcher is always "implicated in the social life that he or she seeks to account for" (Dicks et al., 2005: 32). As a consequence, fieldnote writing was interrupted and ultimately unbalanced my understanding of 'what was going on' during the teaching interactions.

At other times, my capacity for making fieldnotes was undermined from the very beginning of the classes because of locked or occupied rooms which prevented me from entering before the participants.[73] On such occasions I was afforded little time in the technical labour of setting up the video equipment and rushed to decide on analytical choices (camera angle, shot composition, sound quality). In these instances, I lost a sense of the "primal occasion" for writing ethnographic fieldnotes (Emerson et al., 1995). Although I became adept at recognising, knowing and making adjustments, I remained uncomfortable with having to attend to video equipment because the very idea of 'moving' and 'configuring' the video recorders unavoidably entangled me with the technology, connoting the idea that I was monitoring and part of a wider surveillance system. The researcher having to adjust the video cameras on these occasions can be accused of sacrificing observational rigor and its relationship to memory, yet I was still confident of my 'ethnographic authority' (Atkinson, 1990), because the cameras continued to film.

In what is probably the biggest advantage of video, I was not overly concerned that my manual attempts to adjust and tailor the video would cause me to miss events. The interconnection between the video recordings and writing fieldnotes added to the "analytic description" (Heath et al., 2010: 125): both the video and fieldnotes provided a description of the settings, the activities and the materials relevant for image interpretation training, As such, the construction of fieldnotes of people and materials can be said to overlap and reinforce each other.

3.10 Email correspondence

There was email correspondence with four radiologists and three radiographers (n=7). Although email correspondence was not intended as a research method at the outset, it soon became important for overcoming any challenges to my analysis of the data and providing insight into the teaching practice in general. This may come as a surprise, but the experiences

[73] Even with a clear understanding of where to position the two video cameras beforehand, locked doors to rooms or rooms that were occupied by other healthcare professionals/students hindered me in the preparation of the video equipment, and most fundamentally, writing fieldnotes at the beginning of the lessons. In such instances, I was delayed by a number of circumstances that were out of my control. During fieldwork, I often found myself waiting outside locked rooms and on one occasion outside the building.

of professionals' teaching medical image interpretation are absent across sociology, radiography, and radiology. The emergence of email as a qualitative tool for seeking further information and the quality of the data produced has transformed it as an often used method of inquiry with participants who are classed as 'difficult to interview face-to-face' (Meho, 2006). The fact that professionals are highly busy individuals in overwhelmingly demanding environments shaped my decision to use email correspondence rather than attempt face-to-face interviews. For example, in addition to teaching commitments, radiologists had clinical workload and personal study time for specialty training, whereas radiographers were burdened by requests for after-lecture help, out-of-hour help, mentoring, postgraduate supervision duties, assessment/exam marking, and employed to teach the other two year groups.

In addition, email became a valuable resource to maintain trust. Given two-week periods in between video recording, new groups of medical students and often month-long gaps with the radiography students, opportunities to build rapport and establish trust were limited. The use of video required me to build enough good rapport with the participants for there to be a genuine exchange of teaching interactions and openness for students to ask questions on events during learning. However, the gaps between the teaching sessions essentially increased the distance between researcher-researched and severely limited the opportunities to build rapport and trust. Because of this, maintaining trust among professionals and their students was an ongoing challenge during fieldwork.

Nonetheless, in order to confront a subject area that is absent (a video ethnography of academic medical image interpretation training, its situated constellation, and where the part of interpretive practice is about analysing the formation of professional vision), I mean to draw upon an array of video recordings, observations, fieldnotes, and email correspondence. These methods interweave and form the basis of my fieldwork. At the beginning of fieldwork, email correspondence with professionals was used to confirm whether teaching rooms had changed and to gain insight into the teaching formats of forthcoming classes.[74] The

[74] At this stage in the fieldwork, email correspondence was not included as a research method on the UREC proposal (outlined earlier). As a consequence, I sought retrospective ethics approval from UREC who approved

importance and usefulness of email as a method for seeking information was also recognised when professionals sent teaching materials, such as PowerPoint slides containing case presentations and curriculum documents.

As time went on, email correspondence with professionals did not stop and proved to be a valuable tool to check my observations of video data. The process whereby professionals verified or refuted my observations of image content happened when I needed them to confirm exactly 'what was going on' during teaching interactions. This was most important when radiologists imagined an image with multiple and differing possibilities of the abnormal – the practise of differential diagnosis. To the sociological outsider, this type of quick and improvisational choreography in the teaching practice posed a challenge, as it drew on the *a priori* clinical knowledge and medical students' imagination.

Bloor (1978: 547) claims it is a common pitfall for social researchers to ultimately rely on observation for ethnographic knowledge because it raises "the hoary old problem of drawing the correct inference from all the competing inferences that could be drawn from one's data". Similarly, I argue observing the interactions - wherein professionals offered no means of distinguishing between the real or imagined to the 'outsider' - produced different versions of the abnormal from exactly the same image. For Bloor it is strictly the "richness of the data" (Bloor, 1978: 547) in observation-based ethnographic research that may lead to problems of inference. Drawing on STS sensibilities, it shows the volatility and instability of medical images and how interactions with images enact multiple ontologies (Mol, 2002; Måseide, 2007). This matter of 'respondent validation' to overcome my own misinterpretation will resurface later in the chapter and will be discussed again in more detail.

Email correspondence was also attempted with radiography students to collect key accounts of radiographic practice experienced during clinical placement that was crucial to the process of seeing for 'the first time'. The decision to collect these accounts was modulated to the way in which I noticed the profound influence that clinical placement had upon students' capacity to see and interact with images in academic settings. As opposed to a disquiet with regard to

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that the additional data collection method of using email correspondence as data was a 'minor revision'. This was approved on 14/12/16 (Appendix 7).

answering questions inherent in training before placement, radiography students, partly as the result of observing and participating in radiographic work in hospitals, seemed to *know* answers to questions upon their return.

Whereas there was a certain expectation of radiography students benefiting from the content and placement of radiographic instruction, there was an element of surprise about how much was learned, internalised and embodied upon their return to university teaching: clinical placement helped constitute an ideal cultural setting for training both the process and the product of diagnostic imaging (as well as situating students in relation to the habits of the culture in terms of meaningful embodied actions). My observation was instantly recognised by Mr. Hearken who described it as a *'light bulb moment'*[75] - an example of the 'folk' terminology and situated vocabulary of the setting through which people have a shared understanding (Atkinson, 1990). The 'light bulb moment' was when people came to realise what was an important part of the learning process and how this made them understand. According to Atkinson (ibid: 168), folk terms are usually embedded in data and sometimes "taken over by the voice of the ethnographer and used as descriptive terms in their own right".

Because the term was tied to learning in clinical-practice contexts, I noticed its rhetorical value and mobilised it as a device for enabling and encouraging radiography students to email me about any 'light bulb moments' when learning in practice. Similar to the 'penny drops' phrase in everyday discourse the 'light bulb moment' immediately resonated with the radiography students. Although students acknowledged my request, it provided me with only one student response.[76] In other words, the method ultimately failed in my challenge to receive individual accounts of students' own learning. Methodologically, one must reflect why email correspondence with student radiographers was unsuccessful. With such a busy

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[75] Mrs. Campbell emailed the 'light bulb moment' task and the conference abstract to the radiography students on my behalf. It is important to note that both professionals on 'either side' were engaged fully in the study often going beyond their academic roles by assisting me in purposes of fostering trust and recruitment.

[76] Not only did this female student confirm the empowering role that 'on-the-job' clinical training provided radiography students, it confirmed how clinical experiences profoundly shaped teaching and learning interactions in academic settings.

schedule - and sometimes as demanding - as the professionals themselves, my method was another ‘task’ that added to their educational commitments. Because of its main function as a confirmatory device, email quotes are not at the centre of analysis, although its consequence as an empirical material to verify observations cannot be underestimated.

As a consequence, this is a context-sensitive thesis, where the majority of the quotes are exchanges situated within naturally occurring teaching interactions. I rely on a montage of written descriptions, participant exchanges, email quotations, and video screenshots as a situational arrangement of data sources that attempt to closely connect and situate the audience (you) into a way of seeing. Video screenshots represent key interactions that support my arguments in the context of teaching and learning, as the text unfolds. In the case of video, I also wanted to finally end the perspective that pattern recognition and the cognitive process of rote memorisation underpins learning image interpretation – a scientific perception that may be a key obstacle to the integration of the *social* in imaging-based curricula. Cognition and perception is shaped *socially* and through ongoing *social* practice (Goodwin, 1994).

Video recordings allow for an in-depth exploration of social life and generate a visual record of detail and context, allowing researchers to “delve into questions that will reveal what matters to those people in the context of what the researcher is seeking to find out” (Pink and Morgan, 2013: 352). Despite the seductive power of video recordings as ‘facts’ (Pink, 2004) that provide the researcher seamless visual access to this embodied world, I would maintain that email correspondence should not be discounted as a method. This approach mirrors Flick’s (2002: 226) claim that qualitative research is inherently multimethod in focus, where the combination of multiple methodological practices (‘triangulation’) should be used to capture data. The key here is that email correspondence, in conjunction with observations and video recordings, allowed me to delve even deeper into a not so straightforward elicitation of video footage, issues of analysis (e.g. misinterpretation during differential diagnosis), and the complexity of human social relations with materials. In effect, multiple methods do not allow us to ‘see’ the obvious truth (or untruth) or to apprehend any objective reality. Rather, a combination of multiple data sources captures ‘as much of reality as possible’ so that it enhances the researcher’s capacity to understand the participants more fully in the contexts and situations under study (Goffman, 1983).

E-mail correspondence with professionals was conducted after I had left the field. This was because of three reasons. First, I needed to watch, edit, and analyse the footage to identify the issues attributed to my misunderstanding about image interpretation before professionals were recruited for email correspondence. This meant I was only able to confidently seek clarification about the teaching practice once the video data was edited awaiting analysis, or I had deviated from the editing process because something attracted a sizable interest. The latter, indeed, considers the editing/analysis debate as an unavoidable aspect of using video for research as both are inevitably combined (and as a welcome diversion from editing!). Miles and Huberman (1994), for instance, talk about how the iterative viewing of video clips during the editing process of a new research project helped them notice 'codes' that resonated with previous analytical work.

Second, I wanted to foster a relationship of trust with professionals. During fieldwork I felt trust was often compromised by my short time in the field, the long periods of time between teaching, and a sense of video surveillance. After video ethnographic fieldwork, adding face-to-face interviews to the study would have been an invasive stretch of surveillance and was likely to give the impression of assessment. In this case, the impression of challenging and confronting the professionals' teaching practice in image interpretation, or even their skill. Emails presented the advantage of allowing trust to develop between the participants and myself so I could attach screenshots of video footage and pieces of writing to professionals to elicit their feedback.

Third, professional training operated in busy environments and staggeringly busy schedules. Anticipating that I may have difficulty finding time to schedule interviews due to the professionals' demanding workload/teaching schedules, email correspondence allowed them to respond to questions in their own time (at times and in places that were more convenient). Since communication was conducted via email, regardless of how long it took professionals to respond,[77] communication within this context represents a 'back-stage' area (Goffman, 1959).

[77] Expectedly, one of the disadvantages of relying on emails for information is when "participants fail to respond within a period of several days" (Hunt and McHale (2007: 1417). According to Hunt and McHale (ibid) participants who stop or do not respond to emails put the researcher in a quandary, because the potential for questions to remain unanswered may occur. Another problem of non-response is the issue of bias from the

This gave professionals 'time for reflection' and drew on previous experiences and materials related to the core of the question. As time passed, email correspondence turned into an ongoing dialogue with professionals and could be described as a 'quasi-interview' format due to the textual construction of ethnographic knowledge (Atkinson, 1990: 143). Email correspondence, conversational in nature, was a mix of short and long answers, and explored in detail topics that needed to be covered. Spontaneous emails to professionals were avoided, despite the temptation that questions could be answered anytime. Rather, questions were developed over time with regard to the editing/analysis of the videos, both alone and in conjunction with the transcription. Appendix 8 contains a variety of questions that were asked through email.

When email correspondence proved fascinating and merged into the conversation, I asked participants if some of their responses could be used for the study. Like video data, I reiterated that participants would remain anonymous and that they had the right to refuse the inclusion of email correspondence in the study. Over email, participants whom I sensed valued the study, did not refuse the email information being used, particularly as it opened up insight into their own teaching. It was during this time that UREC approved of the method, and allowed me to include it on a new consent form that was subsequently dispensed to professionals halfway through fieldwork.

During emails, professionals showed eagerness to answer questions and were open to sharing information about their profession. In contrast to this, participants in teaching contexts became somewhat guarded in their interactions, feelings, and comments. This implicitly reflects one of the major themes of ethnographic research (the themes of 'mistrust', 'surveillance', and 'exploitation' are intertwined), further complicated if we realise that people behave differently in front of video cameras. At this stage, I must introduce the idea that people's talk may mean one thing but their body language may say otherwise. I now reflect on why rapport building and trust were ongoing throughout fieldwork.

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perspectives of those who do respond (ibid). Rather than attributing 'non response' to the participant's lack of trust, non-response was attributed to the professional's everyday responsibilities.

3.11 'Getting on board': professionals, students, and a pain in the neck

During fieldwork at Bridgestock Hospital and Woodfleet University, professionals and students were predominantly suspicious of being video recorded. As noted earlier, it is not easy for a researcher to access and video record in educational settings, since participants, not unreasonably, may be reluctant to have a "potentially permanent record of events that can be replayed, reviewed, analysed, re-analysed, and shared" (Hackling, 2014: 1). Below, I offer five ways that I attempted to build rapport and effectively establish trust.

First, two gatekeepers championed the study: Dr. Collins (Woodfleet) and Dr. Maxwell (Bridgestock). Because both gatekeepers held senior positions and were valued as 'authoritative sources' at their respective institutions, their endorsement legitimised my presence to the professionals involved in delivering the training. This affiliation imbued me with credibility and protected status to convince professional trainers to 'get on board' with the study and they, in turn, assisted me in the recruitment of students. During fieldwork, the professionals' personal and professional qualities helped quash student concerns regarding video recording (*'you'll soon forget it's there'*).[78] Dr. Maxwell often took up this role and voiced *'pretend he's not there, he's a nice guy'* – though, upon reflection, my niceness can be seen as calculated and exploitative, an argument I will return to in later pages. Second, I dressed in accordance to the differences in dress between radiology and radiography for the purposes of 'fitting in'. In radiography I was smart without over-formalising my appearance, although the degree of formality increased when meeting radiologists and medical students, in part because of the workplace environment. I soon realised my smart and professional appearance may have swayed Dr. Maxwell's decision in allowing me to participate in the departmental induction for passing as a medical student (*'you look like a medical student anyway'*).

A third means of fostering trust relates to my student status. Whilst I was a researcher, occupying a powerful position over participants, I attempted to use my status as a student to disrupt and normalise this power relationship. One way of doing this was to turn up to teaching sessions early and attempt small talk (chit-chat) with professionals and students. This strategy, often referred to as 'breaking the ice', resulted in talking about the weekend or

[78] Mr. Jim Roberts (WURD radiographer)

identifying topics of interest (e.g. sport, educational commitments, employment/career). One might state that the timetables allowed me to know where and when participants arrived; however, this was not always the case with medical students, whom I would often find waiting among the public outside radiology reception (front-stage), or sitting on the mint green seats in the corridor where the radiology offices were located (back-stage), or wandering aimlessly around the department (front-stage). At times, Dr. Maxwell would utilise my role to know the whereabouts of medical students, if they were not at reception, and to bring them to his office where he waited.

Walking with Dr. Maxwell also presented further opportunities for rapport, by sharing our personal physiotherapy stories and the fact that we were both in considerable discomfort due to our respective muscular pains. Dr. Maxwell complained of a *'frozen shoulder'* (a musculoskeletal problem common among radiologists at times of high workload and an effect of high productivity), whereas I winced about acute neck tension.[79] On the morning of the 'labeling the anatomy' round robin in the computer lab, it was imperative that I disclose my neck tension to the radiography students for fear that it would cause them to feel uncomfortable.

Fortunately, this disclaimer (apology) resulted in a collective sympathy (*'awww'*), with some expression of mirth. I played up to this neck pain throughout each of the four-hour long classes, attempting to massage myself from muscle stiffness and welcoming expressions of care. In Bridgestock, I was usually stationed or anchored on the mint green seats in the corridor, waiting for the meeting room to vacate, allowing medical students the chance to see me as a student first, before seeing me as a researcher. In Woodfleet, the doors to the rooms were predominantly open. Although this allowed me to prepare the recording equipment in advance of the session, it hampered my efforts to talk to the radiography students, even when students themselves made efforts.

Fourth, I increased my efforts to build trust with the participants by sharing data, and by involving professionals in viewing, commenting on and verifying written work or video

[79] My physiotherapist had explained that this acute tension (the inability to move the neck) was stress induced, an effect of high workload.

screenshots. It is not only a matter of what I wanted to gain from the study, but what the participants could gain from it. For instance, I engaged professionals in reflecting upon teaching (*'it is horrible reading a transcript back of your own verbal diarrhea, did I really say 'pneumothorax can do a big one'??! Ha ha, I don't know what that means'*) as well as being 'collaborative partners' in future research publications. The value of the email cannot be underestimated here, allowing me the opportunity to participate in 'data sharing' with professionals. Pink (2004: 14) shows how 'giving away' data (video footage and edits) was valuable in enhancing transparency between herself and participants, allowing trust to develop, whereby participants furthered her access and increased her time in the field. Email also offered the opportunity to share data with radiography students by sharing a conference abstract (Appendix 9).[80] Again, the purpose was to interact with the cohort and create a sense that my study was important, which I hoped would settle the 'naturalness' of teaching and learning interactions. In sum, sharing data with the participants allowed me to foster trust and allay suspicions because it showed participants the "kinds of data I was collecting and the issues I was exploring" (Heath et al., 2010: 20). The sharing of data and examples of ethnographic writing three months into fieldwork entail rapport as an ongoing and constantly negotiated practice.

A final means of fostering trust was being invited by professionals to talk to students at their introduction to the course or rotation. In radiography, Mr. Hearken (WURD radiographer) invited me to attend the 'course welcome and introduction', in which the whole year cohort – fifty-four in total – of first year diagnostic radiography students were introduced to the professionals and provided with an overview of the degree's course content. After each of the four radiographers had introduced themselves and presented a brief module overview to the students, I was also invited to introduce myself. This opportunity helped preserve the immediacy of trust and impress upon the students that I was part of the 'club', in order to better guide them towards recruitment. I moved out from standing alongside professionals at the front of the class to talk about the study, and offer information about anonymity. After the talk, I decided to distribute information sheets and consent forms because it would benefit the students, and that any concerns regarding video recording could be communicated to

[80] Mrs. Campbell emailed the conference abstract to the radiography students on my behalf.

professionals in confidence. Rather than asking for consent in the 'meet the staff' session, I welcomed students to further inform themselves about the study using the information sheet and mentioned that the consent form should be returned to Mrs. Campbell (WURD radiographer) at any point before the beginning of fieldwork in a week's time.

This helped foster a sense of mutual trust. Such an arrangement contributed to the belief that 'getting on' with the professionals would ease my 'getting on' with the radiography students. Moreover, the arrangement also gave students a sufficient amount of time to read over the information sheet and email the radiographers (or myself) if there were any reservations or concerns. This tactic was vital in building trust as part of preliminary fieldwork – what I mean by 'trust' is vis-a-vis a willingness to be video recorded and secure consent for video recordings.

Similarly, Dr. Maxwell (BHRD radiologist) suggested that I attend the departmental induction as an attempt to get closer to potential participants for the purpose of recruitment. This did not involve data collection as such, but rather an attempt to lay the foundation for rapport building and recruitment through the sharing of experience and place (*'it is just a brief tour around the department, but you are welcome to join us'*). The induction was an exercise in following Dr. Maxwell around BHRD on a corridor walk. Walking around involved the need to be aware of teaching locations in routine academic and clinical contexts. As a reference point, walking around with research participants is recommended by sensory ethnographer Sarah Pink (2012: 38) as a means of learning about the "social, sensory and material elements" of the environments that are involved in shaping identity. The end of each induction often finished outside BRMR, opposite the administrative offices, where Dr. Maxwell opened up a space for me to talk to the students about the study. Anticipating that some medical students may feel uncomfortable with video recording, I reassured the students in a brief 'show and tell' at the end of the induction.[81]

Conversations of reassurance about video resonated with medical students who expressed a level of familiarity with being recorded and part of a research study. I attribute this

[81] There is a departmental induction to the radiology department at the beginning of every group's rotation.

familiarisation and willingness to participate in the study to the circulation of research projects throughout the medical curriculum.[82] This opportunity to talk at reception or on the mint green seats of the corridor proved especially valuable for participant recruitment. As I had anticipated, some medical students stated that they had not seen the study on ATHENA nor seen the email, but appreciated the plan to inform them in advance. It was here that the information sheet and consent forms were distributed allowing some time (24 hours) for assimilation before video recording. Furthermore, the 'show and tell' allowed me to see how medical students felt radiology was seriously undervalued in the curriculum and were quick to see the value in the study in informing teaching practice as their previous experiences of radiology teaching *'was not that good'*.

3.12 The ethics of video ethnography: mass surveillance and suspicion in academic settings

Despite the participants' consent and my efforts to build rapport with them, I was unsure whether trust had been established. Indeed, during fieldwork, Mr. Hearken (WURD radiographer) immediately corrected 'rude slang' for anatomy and quickly removed bodily interactions from radiographic anatomy if the students understood it as sexual in nature (e.g. hands on patient's breasts). Although these quick juxtapositions always made students laugh, it is difficult to say with complete confidence whether Mr. Hearken's actions were deliberate and intentional for his own rapport building, or whether, because of the video cameras, he reacted much like a deviant youth would to levels of surveillance. As time passed, however, the latter interpretation became more profound; I soon got the impression that professionals had a moral identity at stake and regarded the presence of video recorders as surveillance. Noting this example, it is important that the researcher become attuned to 'ethics in practice', taking into account that ethical concerns emerge at all stages of fieldwork, as opposed to the 'procedural ethics' that occur during explicit and formal ethical approval (Guillemin and Gillam, 2004: 261).

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[82] Phase 3b medical students would have been involved in several undergraduate research projects by this time through their engagement with peers and medical educators within the medical school or with other disciplines such as sociology.

Heath et al., (2010) claim that video-based research inevitably raises moral and ethical issues; we must balance our participants' concerns and wellbeing as well as collecting data. We become aware of everyday problems yet we allow this to remain unarticulated, and we are exposed to certain characteristics of individuals and matters that may appear controversial that can be subsequently exploited. For Pink (2004), the use of video is 'exploitative in nature', drawing parallels between video ethnographic researchers and ethnographic documentary filmmakers. Elsewhere, Pink (2012: 17) also draws our attention to the "symbolic violence that can be done to the integrity of daily practices" by researchers driven to understand social reality under the guise of a theoretical examination. Whilst Bryman (2012) reminds us that exploitation can be reduced and that researchers can *give* as well as receive (emphasis added), I recognise the exploitative dimensions of conducting social research and that fieldwork ethics are complicated and elusive when using video.

With its potential for capturing recorded activities and preserving situations (deepened by researcher specificity), I noticed some participants silently resisted the presence of being video recorded despite having 'consented'. This became apparent to me while I was filming, as participants either removed themselves from the shot or, at the very least, obscured themselves from view.[83] On other occasions, participants looked directly at the video camera in a way that suggested they were 'caught out' or that privacy was disrupted, regardless of whether there was a researcher behind the camera or not. I soon realised that consent was rather an act of politeness and, perhaps, a matter of duty for the participants to show respect for the researcher and participate in the study on which their consent was based. While these issues are not a novel departure from ethical concerns raised in video ethnography as a whole, they gave me the impression that participants recognised their responsibility and commitment to the project by presenting themselves as 'professional' and 'competent' participants. This brought me to the conclusion that the presence of video recorders (and myself) stopped participants from behaving *naturally* and perhaps heightened barriers of 'professionalism'. This both seemed plausible and likely, as healthcare training is subsumed by 'competencies' subject to scrutiny and assessment (Atkinson and Delamont, 2009: 47).

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[83] From the participants' perspective, it is impossible to know whether their removal has been successful although one can approximate.

From this perspective, it is possible that professionals may have been concerned about making themselves available to the researcher who has the ‘power’ to scrutinise, or even, criticise their methods and expertise. On the one hand, it acknowledges that professionals carried a ‘regulated’ body that does not end as soon as they leave the workplace. On the other hand, it is a body that, under such circumstances, is strategically managed to shield them from scrutiny, an adjustment that recalls Goffman’s (1959) ‘presentation of self’ and how professional training might have been ‘staged’ for the video camera. Of course, such a claim is forged further when assimilating observations of professional training with rehearsed jokes[84] and stories, as well as theatrical metaphors including ‘props’ (model anatomy), ‘scripts’ (hand-outs), ‘staging’ (dimming of lights) and even ‘costumes’ (scrubs). Similarly, if professionals were wary of the video recorder and if it made them behave less naturally, I considered what was staged on occasions for my own benefit (Hammersley and Atkinson, 1995: 130-131). Two professionals in particular were quite willing to exaggerate bodily actions in order to satisfy the researcher’s objectives and the values associated with qualitative research, especially when I reiterated that it focused on ‘the body’ and that video made tangible professional vision. Although professionals could be accused of ‘selling the drama’ and perhaps contributing to deficiencies in qualitative research, it was appreciated because of the demonstrable effects it had on the learning process. On the whole, professionals were highly reciprocal and accommodating to the study.

Despite being careful not to appear as ‘surveillance research’ to participants, a notion influenced by Armstrong’s (1995) ‘surveillance medicine’, I noticed that the technology could over-formalise the settings and disrupt the natural attitude of everyday image interpretation training. Although I set out to approximate the naturalness and authenticity of teaching interactions, such deployment of recording technology allowed this to reverse – video ethnography resembled an exercise in controlled experimentation: rather than having a natural quality, such a set-up became artificial. Upon reflection, the participants’ suspicions were perhaps made worse due to my overdependence on recording technology.

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[84] Joke repetition became clear when the same joke or gaffe was repeated to different groups of students in ‘round robins’ that delivered the same content.

At times, the placement of the audio recorders often felt like 'setting traps' as my preference was to capture as much data as possible. My propensity to make sure 'nothing was missed' and the greed of data collection adversely 'denaturalised' the setting. For instance, on occasions, the radiography students removed the audio recorder from its set position and placed it somewhere else. I recall a mature female student at the beginning of a shoulder II class moved the audio recorder from her table onto a table the other side of the room.[85] Despite having consented to the study, her behaviour, however, suggested otherwise. On reactions like these I decided to leave the audio recorders wherever participants moved them, because it would be extremely violating if I were to put the recorder back to its original position. Vakul and Niha, who decided to consent to the study, depict a clear anxiety of being recorded or are at least unsettled by my quest to record and preserve everything:

Niha:	Amar do you wanna do the next one? [Pushes keyboard over to Amar]
Amar:	Yeah go on then [Coding: Copies and pastes a text box in the radiograph]
Vakul:	He's got the camera, I'd like to get it right out of my face!
Niha:	*Shhh!* [Gesture: Points at audio recorder]
Vakul:	It's *alright man, we're not gonna get marked down or anything [speaking to the audio recorder*] 'oh hello, you alright?' it's natural, he doesn't want us to- be normal [*speaking to the audio recorder*] 'you alright, mate?' be normal. Uh, what is it 'proximal'? [Coding: Types 'proximal phalanges' in the text box] [Highlighting 1: Inserts arrow from the anatomy to the text box][86]

The importance of the 'introductory lecture' is exemplified by Vakul who explains to Niha that the study was not one of assessment (*'not gonna get marked down'*) helping to naturalise the learning process, notably by continuing with the labeling activity (*'be normal'*). Alongside verbal concerns, I became highly sensitive and aware of the students' bodily behaviour to the cameras: eyes looking uncomfortably in the presence of the video cameras; movements away from the fixed shot that was being recorded; and re-positioning the audio recorders away

[85] As students walked in, another mature male student pointed at the zoom audio recorder. Fortunately, this participant did not touch it.

[86] This is also an opportunity to draw your attention to the coloured text in the square brackets that have been used to analyse the data. A different colour stipulates and presents a 'practice of seeing' (Goodwin, 1994). This will be talked about in more depth later in 'method of transcription'.

from the action. I took these as signs of aversion to video recording.[87] By comparison, medical students on the whole appeared to have no objections to the video cameras in BRMR. Out of nineteen medical students, one male student (in Dr. Clyde's AXR seminar in BRMR) looked at the rear camera and conveyed uncomfortable body language; however, this was not noticed until after I uploaded the video and reviewed the quality of the data later that day. Up to this advanced stage in their training, it could be said that medical students are used to being observed, assessed, examined, critiqued and even probed in matters of medical education.

Similarly, there was a sense that participants objected to fieldnote writing. The very fact that I was writing fieldnotes alongside video recording only increased suspicions about the study. For example, one mature radiography student commented that I gave the impression of grading their work during a class where students gave presentations. In contrast, keeping the radiography students 'on board' with the study was an ongoing and constantly negotiated practice. Sharing the conference abstract helped to negotiate a fit between data collection and the suspicion of students.

I admit that my data collection process was one of gluttony and of contradiction: although I set out to conduct a naturalistic style of video recording, my preference for using multiple recording technologies increased the impact of 'being there' and ultimately enhanced the analysis. Furthermore, the decision to include 'fieldwork voices' (Dicks et al., 2005) in the methods narrative helps establish a closer relationship between the researcher-researched in the field, an approach that is central to video ethnography. According to Pink (2004: 3), this relation is recognised as 'deep reflexivity', because the author reveals the importance of the participants 'guiding' their work, thus emphasising the subjectivities of the participants (as well as of the researchers) in producing the video. This approach lies at the heart of what Clarke (2003) calls 'situational analysis' and will be talked about later.

My most serious problem, however, was adhering to the notion of informed consent with the medical students. Despite the promise of medical school administrators agreeing to email students and 'advertising' the study on my behalf ('snowballing' medical students on the

[87] Of the five radiography students who did not consent, four were female, whereas the male student was of ethnic origin and whom I later found had withdrawn from the course.

radiology rotation mailing list), it did not automatically guarantee students had been informed about the study in advance. Relying on medical school administrators to email medical students and, even more specifically, on students to read the information sheets meant it was possible for some students to enter a research zone and know nothing about the study or its methods at the time of the teaching.[88]

It was through realisation of this recruitment strategy that I felt uncomfortable with uninformed students being distressed, and the effect on group dynamics, building trust and sabotaging the 'informed' recruitment consent. I considered the difficult position in which I would place students as they entered BRMR settling down to the video equipment without prior knowledge about the nature of the study. Unfortunately, this approach manifested as a female medical student, unaware the radiology lecture was being 'filmed', saw the presence of the video recorders as a violent intrusion of privacy and bad practice for one in a research position.[89] Interestingly, the student validated the need for this research and recognised its significance, mainly voicing how poorly it is taught (*'except for this one'*).

The large lecture theatre carried the additional implication of having a large number of medical students (n=75). Despite being introduced to the medical students by Dr. Saury (BHRD radiologist) and giving the students a brief talk about the study (as well as having enough information sheets and consent forms to dispense to the students[90]), I had seven responses with six consenting to being video recorded. Because it was difficult to know who consented, I had to omit the teaching activities that involved students as a way of meeting the ethical requirements of the study.

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[88] This strategy had two limitations. First, it was highly dependent on a medical school administrator to email every group on rotation four. Second, it depended on whether medical students – who at this time were busy with clinical-educational and employment commitments – checked ATHENA or emails.

[89] This female medical student, understandably angry, demanded that her identity be removed from the video. The inclusion of participants' personal feelings and emotional reactions is considered a core component of ethnographic research (Goffman, 1989).

[90] This number was disclosed to me in advance by a medical school administrator.

Another problem for video-based research is the obligation to protect the participants' anonymity and to keep the data confidential. The former task involved providing pseudonyms for the participants and blurring out materials, information on screens, or technology that made the settings identifiable, further preserving participant anonymity. Video research raises the question of whether true anonymity can be achieved at all, as the participants – despite having pseudonyms – are instantly recognisable to those who know them. Those students who did not consent to being video recorded took part in the training activities and were still part of the research process. Since video ethnographers have a duty to omit those who do not give consent, I wrote down their names and omitted them from the shot. However, this procedure could not always be maintained as these students would move into the shot or would be accidentally recorded on the wide shot of the fixed video camera. As a consequence, great care has been taken to identify these students while reviewing the video footage and then excluding them from the analysis.

Nevertheless, anonymity is an enduring and unsolvable problem for video ethnography, and it is impossible to avoid. In addition, the collection of audio-video data inevitably led to a large corpus of data that needed to be stored on an external hard drive with two other 'back-up' hard drives.[91] Such a strategy is a safeguard against data loss and also a challenge for confidentiality. As Asan and Montague (2014: 5) point out, video data introduces "more risk to overall confidentiality" and should "be stored on a secure storage without links to other identifiable information". Although file names were assigned with nomenclatures which also served to mask identifiable information, one of the study's external hard drives got corrupted and had to be sent for repair at the University's equipment support service. Despite these problems, I hope my video ethnographic account of the x-ray image interpretation training at Bridgestock and Woodfleet is an accurate portrayal and provides a common digital-analogue for analysis.

[91] The hard drive of the laptop was relatively small (249.8 GB) and, due to limitations of the hard disk's size, analysis was undertaken using the external storage capacity.

3.13 Studiocode and video analysis: coding, map making and the situated perspective

I used video analysis software Studiocode as a research tool to help analyse video footage. Originally developed as a video analysis tool to annotate or code the performance of sportspersons in sporting events, Studiocode leans towards the annotation of real time monitoring, tracking and analysis of performance-based professions (Rich and Hannafin, 2009). Once branded as a sports package the software has branched out to other domains of empirical research including teacher education, medicine, speech pathology, science, and mathematics (Rich and Hannafin, 2009).

In a review of video annotation tools for education research, Rich and Hannafin (2009: 54) highlight how Studiocode allows the user to "create and apply a set of codes to selected portions of the video". In so doing, the analyst as *bricoleur* creates codes and code sets which appear as 'buttons' that can be applied to video footage (see Figure 3). Once the button is pressed the code then appears and populates on the timeline (see Figure 4). Indeed, it is one of the strengths of these analytical commitments that Studiocode has sustained interested in educational research, particularly in examining the typology of teaching practice and classroom-based instruction in order to engage teachers in reflective analysis of practice and support teacher learning. For example, Ibrahim-Didi et al., (2017) used Studiocode to analyse the commonalities and differences in embodied representations that influenced scientific meaning in multimodal communication so that they could "offer suggestions for teachers to effectively use embodied approaches" (Ibrahim-Didi et al., 2017: 218).

Similarly, Prusak and Dye (2010) used Studiocode to analyse the different teaching methods of novice teachers in elementary physical education to understand their competency in delivering instruction (for example, seeing whether students were compliant or non compliant when asked to 'freeze' as well as 'making partners', or 'splitting the class' when instructing students to move). Each of these studies used Studiocode as a means of analysing the "methodic character of practical action" and the "practical accomplishment of human activity" which rests upon a social organisation that enables the intelligibility of "practice, procedure, practical reasoning and the like" (Heath et al., 2010: 83). This focus on peoples' methods or practices allows for in-depth analysis of "how talk – what is said, how it is said, and the sense and sequential import it achieves can be embodied within, and dependent upon, the participants' orientation to and engagement with features of the immediate environment" (Heath et al., 2010: 92). In principle, indeed, the researcher may find themselves coding a very diverse repertoire of methods – coding spoken discourse and discursive practices, including interactions with tools, technologies and the material environment (Heath and Hindmarsh, 2002).

In recent years, this focus on the array of methods and bodily conduct have become widespread and has overlapped with ethnomethodological studies of situated practices of looking and telling or 'ways of seeing' in clinical practice, particularly in the work of surgeons and training surgeons in the operating room (Hindmarsh and Pilnick, 2002; Heath et al., 2010; Koschmann et al., 2011; Mondada, 2014). There has been some attempt at using video to record imaging practice; and a number of ethnomethodologically influenced research has produced visual accounts of different types of instructions and practical decision making in contexts of radiology (Rystedt et al., 2011; Ivarsson, 2017; Gegenfurtner et al., 2019), obstetric ultrasound (Nishizaka, 2014) and neuroscience (Alač, 2008; 2011).

One of the benefits of using Studiocode is that it offers "simultaneous, real time annotation and recording" where researchers are able to connect the video recorder to their laptop (Rich and Hannafin (2009: 63). [92] From this perspective, real time coding is more adept at capturing activity or events with the purposes of providing immediate feedback and evaluation. Consequently, Studiocode using researchers 'straddle the fence' between academic and applied research, acknowledging that their research forms the basis for intervention as a method for evaluation and assessment (Heath et al., 2010). Such research acts as a medium for reflection with potential for the redesign of teaching practice, based on the assumption that the "order exhibited by the objectified actions … allows the action to be understood". In this sense "audio-visual data encompasses meaning patterns that reflect the meaning of the situations represented" (Knoblauch and Tuma, 2011: 420-428). This Studiocode-influenced 'evaluation work' not only works as a reflective tool to assess teacher competencies and

[92] In my case via an UltraStudio Mini Recorder that 'captured' the live feeds of the video recorder and transferred it in real time to the Mac. One output of this device is to be connected to the Mac with a Thunderbolt cable, whereas the second output from this device needs to be connected to the HDMI input of the video recorder.

characteristics (Prusak et al., 2010) but also generates "self-evaluative feedback without necessitating an external evaluator" (Dye, 2007:9). However, my form of coding prioritised the situated practices of 'looking and telling' with no obligation to provide immediate feedback. From this analytical standpoint, real time coding did not suit the methodological 'interactionist' framework of this project. It also allowed me to minimise any potential disruption to teaching, given how I was always standing or sitting by one of the video recorders to adjust the zoom (Heath et al., 2010).

Studiocode's interface provided me with 'stacked' on-screen video recordings (Fig. 4) to establish connections and disconnections between the participants situated in interpretive practice training. The main benefit of this was that it provided me with repeated viewings of the participants *in situ* and the possibility to compare and contrast a substantial body of visual data, on which codes and analysis are based (Heath, 1986; vom Lehn and Heath, 2006). Familiarisation with the literature allowed for an inductive approach to coding, an analytical process augmented by fieldnotes and e-mail correspondence, but one that also drew on reflections about professional vision (Goodwin, 1994). The importance of interrogating video in a comparable way lies not just in the fact that it constitutes connections/disconnections, but also in that it led to the first phase of analysis and the creation of a 'messy' situational map (Clarke, 2003: 569): a resource that captured and annotated observations of training that organised a "quick and dirty relational analyses" between sites.

The first phase of analysis involved the initial process of observing video footage of x-ray image interpretation training between radiology and radiography (as the two field sites) and giving temporary labels (or *codes*) to particular phenomena. This includes coding or labelling the range of actions belonging to participants with a specific focus on the interactions between: 1) professional and image; 2) professional and student; 3) student and student. In each of these interactions, the coding of how the material environment was used by participants as a resource in coordinating bodily motion and conduct also took place (Heath et al., 2010). This initial labeling approach helped identify preliminary or temporary codes from the data and specify the nature of the relationship between 'things' and elicit what may be going on in the data (Clarke, 2003).

The generation of these preliminary codes allowed me to develop a 'dirty map' of the two field sites, providing me with an opportunity to see the types of images that were of primary importance to professionals. In the first instance, the physical home of the professionals and images were mapped, along with their interactions with students. Mapping both field sites was an ongoing process, which was reflected upon and amended as the study progressed. The initial map however, can be viewed as the first stage in the 'situational analysis' approach (Clarke, 2003) and what comes to be known as the "messy/working version" **(Figure 2)** of the situational map; providing important background context for data collection and analysis (ibid: 2003: 561).

Clarke says situational analysis is a means to renovate and regenerate grounded theory, so that the "researcher becomes not only analyst and bricoleur but also a cartographer of sorts" (ibid: 571). Clarke (2003: 553) provides us with cartographic devices she calls 'situational maps', to help navigate 'messy' or uncertain situations that accommodate the multiplicities, ambivalences, contradictions and relationalities in the analysis of the social process ('action') – a supplement to the pure 'basic social process' that is typical of grounded theory. This attempt to deepen the analyst's understanding of relations and action between human and nonhuman elements in social interaction has been described as one of the more methodological aspects of the 'theory/methods package' (Clarke and Star, 2008). This package has been extremely useful for generating ideas or concepts on the social processes that contribute to expert performance (Covington and Barcinas, 2017) and is an approach inspired by the interpretivist and constructionist tradition – a social research epistemology that has often been a "sound approach to qualitative analysis" (Clarke, 2003: 553) and the concern of interactionist sociology.

3.13.1 Figure 2: 'Messy/Working' situational map of x-ray image interpretation training and embodied conduct analysis

I have decided to present both the 'messy/working' and 'ordered/working' maps as described by Clarke (2003) for purposes that indicate the construction of chapter headings and subheadings. Figure 2 is the messy/working map and presents data on the professionals' academic settings. *What is this map telling us?* First, it includes an analysis of the relations among the human and nonhuman elements drawn as different coloured arrows to represent the discipline (**purple for radiography professionals/students**, **orange for radiologists/students**) and their interactions with types of images and material sources. The map is made up of different coloured boxes: the **blue boxes** represent image interpretation of specific x-ray images/body parts (upper limb; lower limb, spine, shoulder etc.), the **red boxes** represent image production (systematic approach; technical adequacy; imaging technique etc.), and the **green boxes** represent the materials handled in the stream of training. I use the messy/working map to visualise the role of humans and nonhumans and their relations in channeling the flow of teaching from professional bodies and other material resources.

The map demonstrates not just the complexity of x-ray image interpretation training, but also the three 'vortices' where interpretive training drew attention to potential error and where professionals needed to intervene to correct misinterpretations. For instance, and with reference to Figure 2, the blue circle (dotted) in the bottom-left of the map is labeled 'radiographic anatomy vortex': this is where misinterpretation occurs due to a lack of knowledge of normal radiographic anatomy and its variants. The red circle (dotted) at the top of the diagram is the 'missed abnormality vortex': this is where missed abnormalities occur due to a lack of systematic approach. Then there is the green circled (dotted) 'image production vortex' where students with limited knowledge of the image making process and radiographic techniques are unable to see clearly or understand image content. These vortices represent professional concerns and therefore raise the need for students to engage in the direction of social structure or situated experience of professionals (Wenger, 1998). Analytically, an overview of these vortices served to highlight the most common sources of professional concerns and prompted me to explore any mentions of such concerns by participants. This allowed me to track the training practices in more detail and generate the 'ordered situational map' (Figure 3).

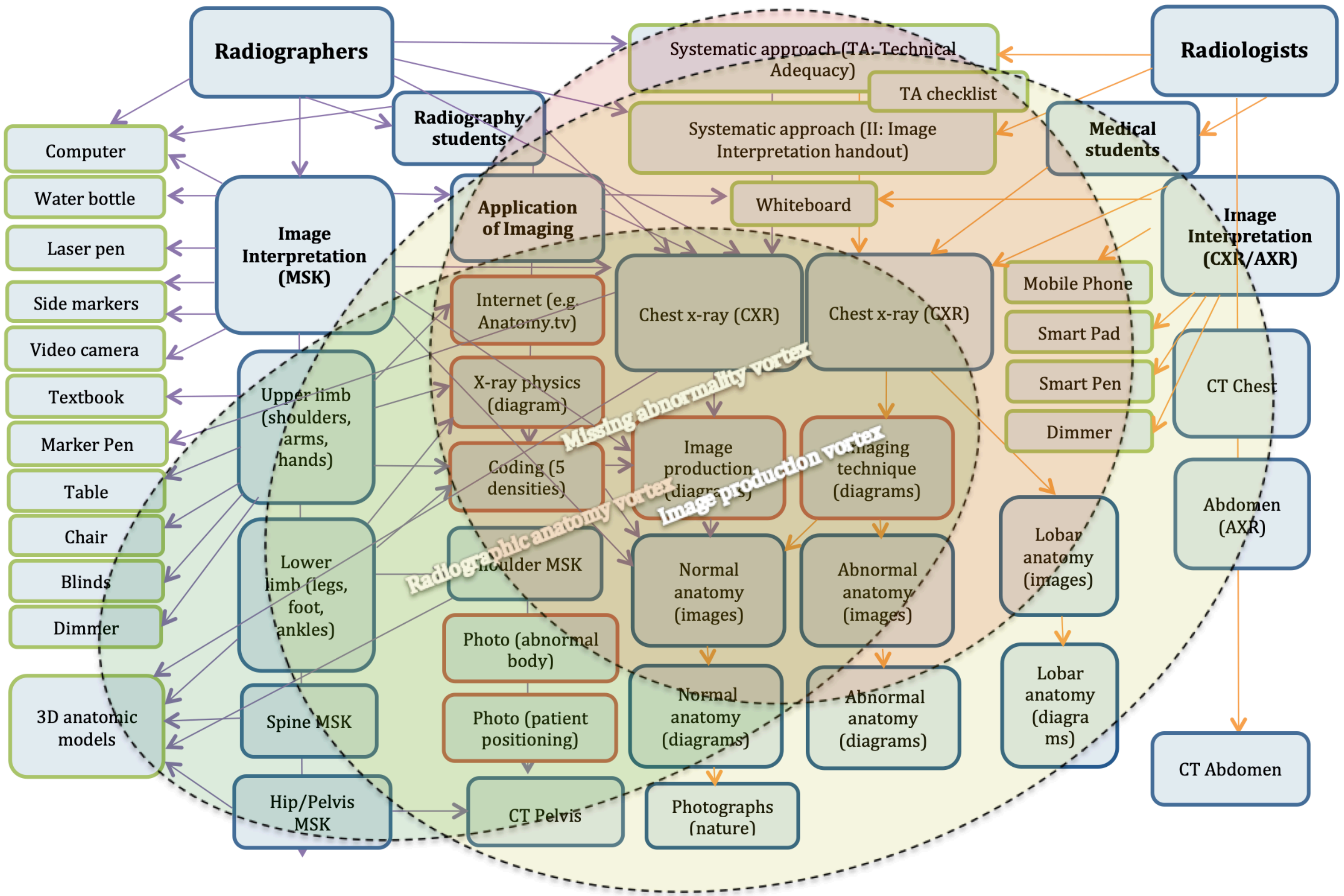

Figure 2 The 'messy' situational map

3.13.2 Figure 3: 'Ordered/Working' situational map of x-ray image interpretation training and embodied conduct analysis

The findings of the messy situational analysis map were used to inform the building of the 'ordered' map to frame and organise all of the discourses related to the training situation conducted by professionals. The ordered situational map allowed me to move beyond the humans/nonhumans and their interactions with images and materials and include the more discursive elements of professional training and the setting that produced them. In doing so, the 'messy' and 'ordered' situational analysis mapping identified three thematic concerns enacted by professionals as he/she facilitated students learning to see in academic settings. It is here that the structuring of data chapters began around the radiographic anatomy vortex (Green), the missing abnormality vortex (Red), and the image production vortex (Yellow). It was particularly the missing of abnormality that drew attention. Missing abnormality and its concepts was highly significant for understanding how professionals think about, conceive, and define the nature or 'logic' of their teaching. Rather than the student being presented with normal or abnormal images, training was structured so as to bring forth the various images where most radiological error is known to have risen (Figure 3 and Table 2).

The normal radiographic image is the initial object of knowledge where professionals provide a foundation for anatomical understanding. It is here that students receive pedagogical advice on how best to acquire a relative alliance of normal anatomy, which can be accomplished either by 'looking at' radiographic anatomic textbooks that provide 'patterns' of normal anatomies or by physically learning the anatomy (i.e. 'pattern recognition'). It is also here that the x-ray image is introduced as ambiguous and looking at it passively without taking into account knowledge of (normal) radiographic anatomy is most manifest. Lack of knowledge of radiographic anatomy may be manifest with a lack of knowledge of normal patterns, normal variants, optical illusions, and five x-ray densities that compose the image (i.e. the internal structures are reflected mostly by x-ray density). The advice here is that by having a comprehensive understanding of normal anatomy (and its variants) and the basics of x-ray physics professionals in-the-making will be able to build a close relation with the normal and its shades of grey. The purpose? To be alert to deviancy that might be present. In this case, the students also learn to look at normal images where they can make out differences in changes to anatomic density or make out whether the anatomy is leaving its typical or usual place either through rotation, movement or normal variance.

But it is here that ‘looking at’ / ’pattern recognition’ is sometimes undermined and professionals draw upon talk and interesting forms of embodied conduct as resources for aligning the novice gaze, improving judgment, and even forgetfulness. The systematic approach adds to this conduct by providing a ‘run through’ of specific anatomical structures and ‘thoroughness’ to the image by paying close attention to the heart and mediastinum, lungs and pleura, soft tissues, and bones. This is then followed by re-checking four specific anatomic locations referred to as the ‘review areas’ (diaphragm, heart, hila and apices). Many of the lessons that take place here are of well-defined expectations of what these anatomical structures *should* look like and what these structures *should not* look like. This offers the students something important for seeing and reasoning – a body – with which professionals use constantly to conjure up how image content should be seen. By teaching the students what to expect, professionals teach them the “competent deployment” of practice (*coding*) of professional vision (Goodwin, 1994: 626). But unexpectedly the relationship between bodies, images and radiological error was starting to emerge. Here, common interpretive pitfalls were starting to become unpacked in the academic setting and it is where interesting forms of embodied conduct come to the fore for purposes of seeing/interpreting, critique and repairing misinterpretations.

A second analysis of the ordered situational map highlights professionals’ concerns of missing abnormality. This is a variegated thread, as I address missing abnormality in both chapters four and five. First, I address the missing of abnormality in chapter four upon which the practice of the systematic approach operates. Here, I address how a systematic approach is introduced as an ordered tool for learning a ‘structure’ and in intensifying their knowledge of key (normal) anatomical areas. Whilst anatomic scrutiny may be the principal engagement of such a skilled practice, related concerns about missing abnormality arise, and on a more practical level concerns about the visual expertise of medical students who may be unfamiliar with image production.

Second, I observe how a systematic approach shades into concern with a selection of abnormal images.[93] But again, an abiding impulse of criticality emerged during practice, none

[93] As explained by Mr. Hearken in his interaction, reported in chapter five.

more obvious than 'satisfaction of search'. In this case, it is depicted as providing awareness to the perceptual error of 'satisfaction of search' where the detection of a ('barn door') obvious finding can interfere with the detection of other abnormalities, particularly the more subtle or hidden lesions. This includes the continued application of a personal or tacit systematic approach for checking the review areas afterwards as they relate to the CXR. Professionals often drew on satisfaction of search, in particular missing or 'not seeing' the more subtler or hidden abnormalities – usually explicitly through the systematic approach. This is where professionals – in their rhetoric and discursive practice – endorsed a system for scrutiny based on specific anatomical areas to increase the novice's chances of being piqued by subtle findings. This was combined with professionals highlighting the difficulty of the task at hand and how such conspicuous findings would be easy to miss.

The CXR is very important to both sets of professionals. The CXR opens up a greater space for multiple interpretations and responses (Krupinski, 2010; Delrue et al., 2011). This also includes a wide range of concerns related to the sociotechnical work or "instabilities" of producing medical images (Joyce, 2005: 446). I will go onto argue that the nature of these concerns reaches more into the pitfalls of image production where certain appearances of (normal) radiographic anatomy are multifacted and become misleading. Hence the pressure of making technically adequate images impacts on radiographers, and key pedagogical events endorse the production of both primary and secondary images to reduce uncertainty in the interpretive and decision making process.

In CXR image interpretation training with medical and radiography students, pedagogical exchanges are stimulated and guided by a variety of common abnormalities that can be found among patients: these are likely to be pneumonia, pleural effusion (meniscus sign), collapsed lobes (e.g. sail sign), pneumothorax, pulmonary fibrosis ('net-like'), soft tissue tumour, hilar lymphadenopathy (swollen lymph nodes/'bumps'). Important also is radiographic density, technical adequacy, lines/tubes, and limitations of imaging technique (e.g. patient rotation). These concerns are influenced by the political/economic composition of NHS standards and regulatory frameworks (such as the 'never event' policy and Radiation policy) or professional community (such as undergraduate curriculums and standards for learning about 'discrepancies' or 'commenting'). Technical adequacy is very important to professionals primarily so it can provide the interpreter with a high quality or optimal image that enhances their confidence and certainty. Technical adequacy can take many forms, such as removal of artefacts, correct use of side markers, radiation exposure, appropriate attenuation of body parts/anatomies, positioning and inspiration, and image post-processing. However, the pursuit of a technically adequate image is not so straightforward and any initial observation of abnormality comes with cautionary phrases directed towards image production, suggesting that even calls on abnormality cannot be considered in isolation from image production (Joyce, 2005). It is through this complexity that those who are learning to see (i.e. the uninitiated) are more likely to "overcall" (Renfrew et al., 1992) – an example of a common overcall in this thesis was when a patient had rotated during image production and the student misinterpreted this as possible disease or malignancy. This means a lack of knowledge over the limitations and risks of imaging technique fuelled the greatest uncertainty leaving students at risk of radiological error (i.e. misinterpretation). The purposeful selection of these images that presume some diagnostic uncertainty is considerably deepened by the absence of the patient situation and incomplete contextual information.

Technical inadequacy and poor imaging technique are a well-recognised pitfall for interpretive practice (Brady et al., 2012; Holt and Goddard, 2012; Brady, 2017). This was supported throughout video data, fieldnotes and email correspondence with professionals. With technical inadequacy and poor imaging technique came reconstruction and ostensive demonstration of image production and the embodied practices whereby this was achieved. There were also expectations of good and bad imaging technique and the difficulty of positioning and inspiration mainly predetermined by the condition of the patient (Delrue et al., 2011). These types of interactions appeared to blur the boundaries between human (professional and patient) and machine and make the embodied relation more precise to clarify anatomies and reduce ambiguities. It is clear that this part of the analysis reaches into the common interpretive pitfalls of novices – who are themselves inexperienced in image production and rely on the professional's body as a discursive resource to give them a glimpse into image production.

The third area of concern is composed of the image production vortex. This is where interesting discourse emerged about the technically adequate and optimal image, including an awareness of the limitations and risks of imaging technique. There is close connection with good and bad radiographic techniques, standard and secondary views, 3D anatomical models, measurements, image manipulation skills, and a systematic approach to critique 'technical adequacy'. Important also are magnification/size distortion, patient rotation, foreshortening, elongation, incorrect side markers, poor imaging conditions, lines, tubes, artefacts, and incorrect imaging request form. This includes a wide range of gesture, rhetoric and visual representations that support the practice of imaging technique and it encourages the scrutiny of 'areas of interest' as expectation that the students will see something from that body part. This is where professionals continuously re-orientate and explore limitations of specific imaging technique (the term 'imaging technique' is often used interchangeably with 'view' or 'projection') alongside the strengths of specific imaging techniques. In doing so, they provide a critical, scrutinizing gaze towards specific images, naturally connected to good and bad examples of imaging technique. This vortex also places expectations on radiographers to produce technically adequate or optimal images manifest in policy requirements and expectations of the professional community. For example, the radiologist requires adequate, clear and optimal radiographs in order to 'see clearly'. To be able to clearly distinguish the inner structures of humans is of paramount importance to imaging professionals (Dussauge, 2008). This understanding is typically embodied and reinforced by the professionals' experience of image production; a practice that provides them with the ability to classify, sort out, and discriminate limitations and risk of medical images.

The professionals support the assessment of technical adequacy before a search for pathology and the production of secondary and/or additional imaging to increase the scrutiny of anatomical and abnormal signs to actors. However, the radiographers offer a more detailed consideration of the technical practices and implications of the image. They also, however, send students messages about the profession's expectations of the skills that they should develop. With it comes a wide range of bodily information that combines development of technical skills with procedural knowledge. These accumulate to form sensory and spatial skills as "higher level abilities" for intuition and judgment (Prentice, 2013: 5). The expectation here is that the better ones sensory and spatial knowledge (wrapped up in bodily, technical and procedural knowledge) their gaze will be more confident and alert to confusions between findings and technical errors or interpretive risks. This is where concerns around subtle and hidden findings and patient rotation remain important.

The ordered map captured relations between sites, with the interrelatedness of human and nonhuman elements organised and annotated as *codes.* According to Clarke (2003: 554), this map is a sophisticated framework that centres on "elucidating complexities – the key elements and conditions that characterise the situation of concern in the research project broadly conceived". This translates as being situated in the context of x-ray image interpretation training, which builds a professional vision. The researcher undertaking video analysis is undoubtedly overwhelmed by the depth and intensity of the video recordings (Pink and Morgan, 2013), particularly when one focuses on the *processes* of learning to see (Goodwin, 1994). This gave me a sense that everything is situated – including myself.

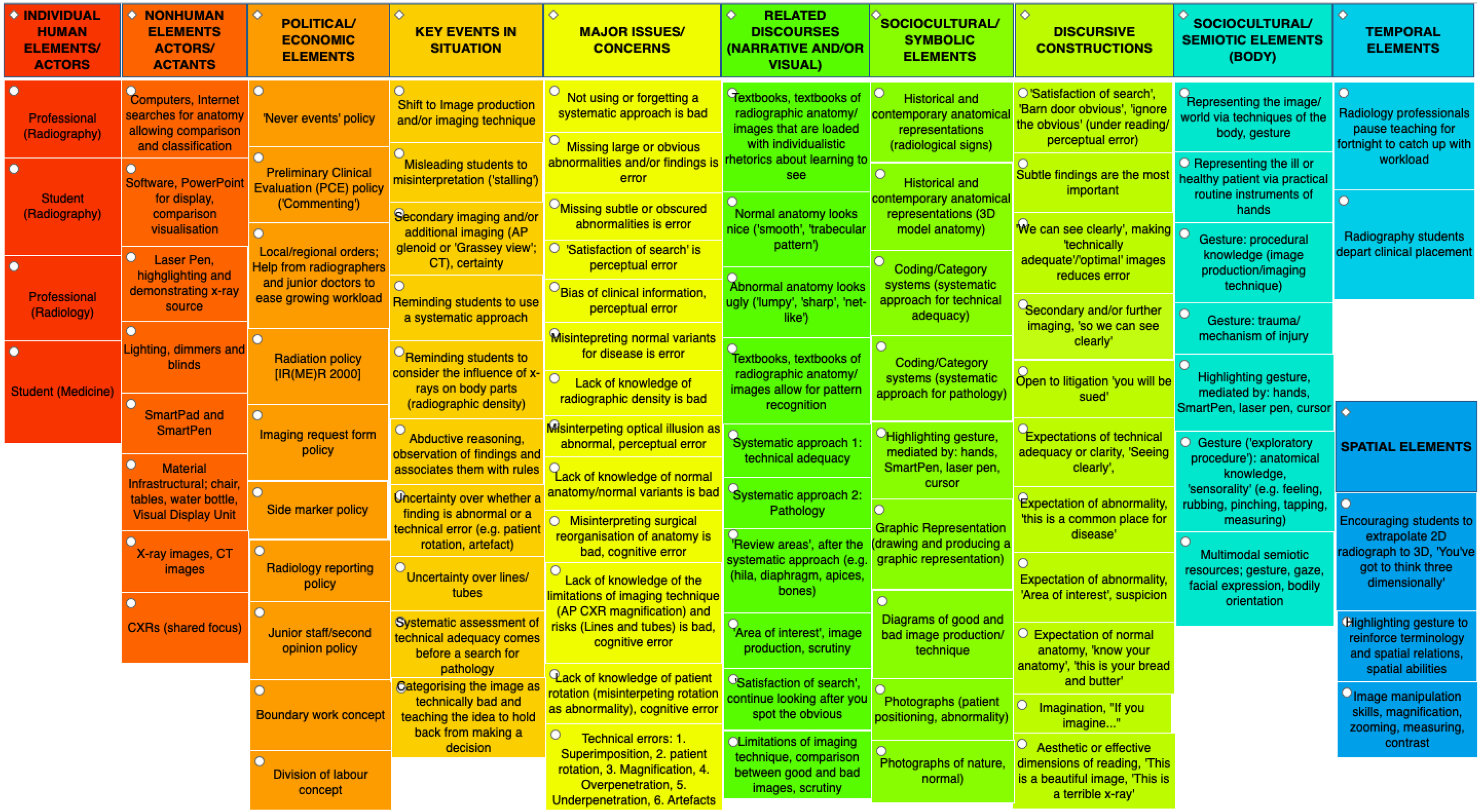

Figure 3 The 'ordered/working' situational map

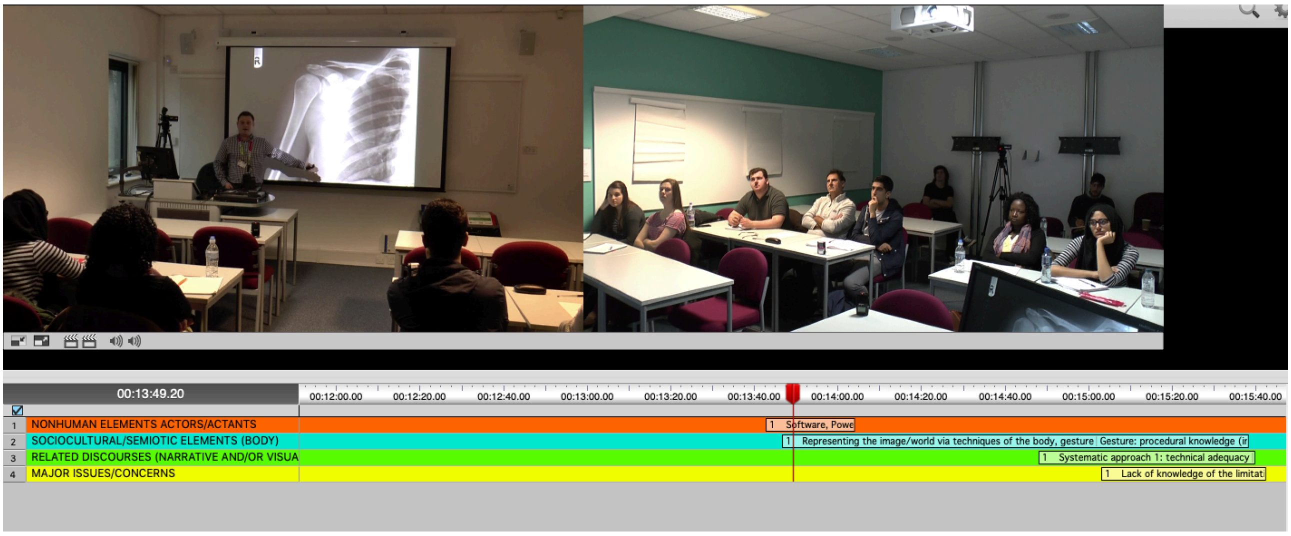

Figure 4 Coding using Studiocode

The analytic codes and categories generated and elicited from the 'ordered/working map' were then explicitly integrated to form a table of the substantive areas that became the focus of the research project (**Table 2**). This grounded theory approach became sensitive to commonality and the complexities of x-ray image interpretation, aiming to improve patient safety and reduce litigation by preventing **radiological error** (Manning et al., 2005; Pinto and Brunese, 2010; Donald and Barnard, 2012; Holt and Goddard, 2012; Berlin, 2014; Van der Gijp, 2017; Brady et al., 2012; Brady, 2017). And, this really comes as no surprise: the anatomical and technical features of the medical image help constitute an ideal and expected image for image interpretation (and diagnosis). However, while the goal is to always try and produce this type of ideal, it is all the more important that professionals-as-educators train students about the impact the real-world setting has both for the process and the product of x-ray interpretive practice. My analytic account proposes this value as an attribute of both communities of practice and over time it became a *pattern*[94] that emerged from the data which consequently affected the behaviour of professionals (and eventually their students). This is where the three main 'vortices' of interpretive training overlapped and drew attention to potential errors and risks and where professionals encouraged students to be critical of image content and to take nothing at face value. This predilection towards being critical in x-

[94] The irony is not lost on me that I was also learning to see via pattern recognition.

ray image interpretation was attributed in part to the fact that x-ray images were 'ambiguous' and is subject to conscious reflection in ways that draw out misleading aspects, thereby facilitating a heightened awareness of "face value" (Coopmans, 2011). The idea of "face value" which "facilitates the simultaneous tracing of technical and social material and metaphorical ways in which visual images come to matter" (Coopmans, 2011: 170).

Table 2. Three main concerns that professionals have during training

1. Lack of knowledge of normal (radiographic) anatomy	
Lack of knowledge of normal anatomy and its variants (concern)	*a. Limited normal pattern recognition* *b. Limited knowledge of anatomical language* *c. Misinterpreting normal variants that mimic pathology (Risk)* *d. Lack of knowledge over the surgical reorganization of anatomy* *e. Difficulty extrapolating from 2D to 3D*
Optical illusions (Perceptual error)	*a. Mach band (Risk)* *b. Background effect (Risk)* *Silhouetting (Risk)*
Lack of knowledge of subtle and obscured normal anatomy.	*a. Haptic* *b. Sensorality (feeling, rubbing, pinching, measuring)* *c. Spatial and technical language*
Lack of knowledge of radiographic density	*a. Difficult to distinguish normal from abnormal structures and material elements* *b. Difficulty of appreciating contrast difference*
Lack of knowledge of systematic approach	*a. Risking the ability to know the details of anatomy* *b. Not giving the anatomy a complete and comprehensive* *c. Lacking better coordination of anatomic learning and looking*
2. Missing abnormality	
Not using or forgetting a systematic approach is bad (cognitive error)	*a. Forgetting a comprehensive analysis (Risk)* *b. Not checking the 'review areas' (Risk)* *c. Not looking behind the anatomy*

Missing abnormality due to 'Satisfaction of search'	a. *Focusing on the 'barn door obvious'* b. *Missing subtle abnormality/findings*
Missing abnormal due to limited knowledge of radiological signs or clinically relevant findings	a. *Sign systems* b. *Eponyms* c. *Differential diagnosis*
Missing abnormal due to poor imaging request form (system-related error)	a. *Wrong side requested/imaged* b. *Wrong area requested/imaged* c. *Wrong patient*
Missing abnormal due to bias of previous knowledge (Perceptual error)	*a. Bias of mental picture, expectation* *b. Bias of clinical information, expectation*
Missing abnormal due to bias of clinical knowledge	
Missing abnormal due to technical errors (system-related error)	a. *Inadequate collimation (Risk of missing abnormality outside the area of interest)* b. *Overpenetration (Risk)* c. *Underpenetration (Risk)* d. *Magnification (Risk)* e. *Patient rotation (Risk)* f. *Not removing artefacts (e.g. necklaces)*
Seeing the abnormality but not knowing what it is (cognitive error)	
Missing abnormal due to satisfaction of search (under reading error or perceptual error)	a. *Not looking for other possible abnormalities* b. *Missing subtle lesions*
Missing abnormality due to lines/tubes/artefacts	*a. Lines/tubes/artefacts obscuring the anatomy*
3. Lack of knowledge of the limitations of imaging techniques and interpretive risks	
Lack of knowledge over secondary imaging	*a. Foreshortening* *b. Elongation* *c. Inadequate views (to see joint space)* *d. Not seeing joint space (Risk)* *e. Not seeing subtle or obscured anatomy (Risk)* *f. Missing parts of the anatomy (Risk)*
Lack of knowledge over lines/tubes	a. *Missing lines and tubes* b. *'Never event'*

Challenging imaging conditions	a. *Seriously ill patients (risk)* b. *Imprecise image* production (Risk) c. *Difficulty inserting lines/tubes in the right place*
Magnification (Perception error)	a. *AP Chest* b. *Patient movement away from detector* c. *Patient rotation away from detector*
Distortion (Perception error)	*a. Patient rotation closer to the detector*
Exposure to more radiation	*Radiation policy [IR(ME)R 2000]*

3.13.3 Method of transcription

Even when video is the main data source, transcribing audio recordings played an active role in the analysis and involved 'two rounds' of transcriptions: first, a professional UK transcription company transcribed the talk from audio recordings. Second upon receiving these transcriptions, I added to the talk by using video footage to transcribe participants' professional vision when they interacted with other bodies, images and materials. As Goodwin (1994) points out, everyday professional practice goes beyond talk, to accommodate gestures, bodily conduct, visuality, and the material elements of the setting. The outsourced professional transcription allowed for a 'quick' and 'deeper' route' to analysis: the completed transcripts served as templates and allowed more time to further excavate information about participant bodies, such as prosody, facial expressions, and visual orientations (Alač, 2008, 2011). All the participants appear in this text with carefully transcribed 'micro-processes' and 'micro-differences' between them, intact for a deeper understanding of both teaching and learning. Interaction at such an "intense microlevel awareness" brings us closer to our participants' subjective experiences and is retained to articulate embodied intuition that captures subtle information about the performance (Cartwright, 2015: 263), not only about problems participants have in learning, but also what others do to help when these subtleties are picked upon.

Transcription of video was not based on any previous transcription conventions but rather in light of Goodwin's work (1994) and the knowledge derived from my ordered situational map

(Clarke, 2003). This means the excerpts from video footage are transcribed according to the complex character of *professional vision* (Goodwin, 1994) and my phenomena of interest embedded in the 'ordered' framework (Figure 3). Each excerpt illustrates how the participants (both professionals and students) talk, gesture, and interactionally engage their bodies as they attend to images, materials and each other (Alač, 2011) within the specifics of the three modes of practice used to accomplish professional vision: coding, highlighting, and graphic representation. Transcription focused on situating these practices with respect to their textual landmark and where they appeared in the transcription. This operation was generated using a combination of text and colour to mark how the text should be read.

For example, when a participant uses a body part (e.g. hand) to make image content perceptually salient against an ambiguous background (the **highlighting** practice), the extract is represented by means of red text in square brackets included in the talk (*'what's this carpal bone called? [Highlighting: lasers hamate bone]'*). Often, when the highlighting gesture is used to depict or represent image content (for example the carpal bone, above) it is mediated by mobile physical objects by using the mouse (i.e. cursor movement), keyboard commands, and laser pens. Highlighting is done in various ways: in my attention to practices of highlighting and rhetorics of looking I simply mark these as highlighting as exempla so as not to distract from extracts and overburden you (the reader) with too much detail. Highlighting 1 and Highlighting 2 chimes with Ivarsson's (2017: 15) analysis of highlighting gesture in radiological practice: Highlighting 1 is to refer to highlighting that selects, elaborates, and makes salient features "of the world within sight" (i.e. that are present). Highlighting 2 evokes "phenomena that are not present and depict imaginary and abstract worlds".

To identify **coding**, I colour the text green in the extracts. My identification of coding practices is based in part on matching the image with a previously coded/labelled educational resource belonging to the work community of radiology and radiography. Coding resources come in different discursive forms and can also be based in part on number matching, colour matching as well as textual matching. For example, radiographers used the coding of x-ray densities displayed on the Visual Display Unit (VDU) in the application of imaging (AoI) classes. By understanding the five x-ray densities, they employ the location of x-ray densities to a specific destination on the radiograph or anatomic models bones. In this sense, coding, is based in part on matching the image or material with an established organisational system upon which the "worker views the world from the perspective it establishes" (Goodwin, 1994: 609). When viewed this way, professionals perform the coding system and it becomes an interesting form of professional vision. This episode will be examined in detail in chapter 4 ('the professional vision of x-ray image interpretation training'). Professionals in-the-making also learn to code this way in interaction with software based visualisation tools: in the 'labelling the anatomy' activities students consider the location of anatomic structures and features alongside schematic images for which anatomy has already been coded (for example, [*Coding: Carries creates a 'text box' on the AP view of the lower leg and types in 'tibial tuberosity'*]).[95] Visualisation tools also provide varying 'contrast' views where students engaging in contrast enhancement of the anatomy under scrutiny are able to distinguish between different types of soft tissues. This practice is supposed to mimic the real-world application of (digital) contrast in the post-processing stage of radiographs that simultaneously prepares them with a taste of workplace visualisation technology (i.e. PACS). In this thesis, a coding scheme is a type of cognitive resource used to control perception and to help analyse the image in scientific terms.

When **graphic representation** is identified as the mode of seeing, I employ the **colour orange** as an indication of the creation of a new visual representation. This often includes 'drawing as' (Vertesi, 2014; 2016) and sketching something that is neither present or visible on the image. Like Sandell (2010) I understand medical images *as* graphic representations, but I am concerned with the use of domain specific representations in a map-like fashion similar to the work of archeologists (Goodwin, 1994). However, as we will see, the representation of image content is not always drawn in or marked and professionals can use other types of tools to represent content (e.g. mouse cursor). Again, adopting the perspective of physical radiological reasoning (Ivarsson, 2017), I make a distinction between ***present*** ('Graphic representation 1') and ***non-present*** representations of phenomena ('Graphic representation 2').

Along with these three modes of visual practice I also include gestures that operate as embodied or enactive demonstrations of reality (i.e. 'out there' in the workplace) created to

[95] This will be explored in detail in a forthcoming article: 'Have a feel for it and you'll just see that this is normal': Pattern recognition and sensory knowledge in learning radiographic anatomy.

organise and represent content. Here I employ the **colour blue** in the interpretive activity of professionals to represent different types of hand gesture. Given their manual nature, these gestures are grounded in a set of verbs proposed by Mulder (1996) and include gestures that change position (e.g. pull, depress, thrust, shake, shift), changing orientation (e.g twist, rotate), change shape" (e.g. smooth, pinch, fracture), contact with the object (e.g. grasp, grip, hold), joining objects (tighten, wriggle, wrap), and "indirect manipulation" (e.g. set). All of these give rise to an underlying tacit practice or 'doing' and previous experience of practical action with the world, factors that interact with and transcend physical features or elements of a thing or environment and give rise to different hand shapes (Kendon, 2004; Streeck, 2009).

3.14 Learning to see (for myself) and its consequences on analysis

Whilst this study was based on undergraduate x-ray image interpretation training, I also entered the field with the expectation of being trained. This expectation, intended as a route to ethnographic knowledge, would guide my observations and help me understand the means and processes through which students learn. As Grasseni (2004: 14) claims:

> [There is] a parallel between the process of apprenticeship that a visual ethnographer has to undergo, and the process of education of attention that is required of anyone participating in a community of practice.

Grasseni's statement describes how the use of the visual in ethnography can aid in training the ethnographer's eyes, and effectively (to some extent), appropriate our participants' 'ways of seeing' (Berger, 1972). In a way remarkably similar to Grasseni's (2004), this parallel corresponds to my own approach. Ethnographers once drew on this as a challenge to the balance of closeness and detachment (Maier and Monahan, 2009). However, for Pollner and Emerson (2003), this is problematic, since being close is analytically productive, as well as being a requirement for the collection of meaningful data. Distance and attempts to keep it have been described as an essential part of fieldwork: holding ethnographic distance as both theoretical and practical is documented as advantageous (Gold, 1958). This risks making field descriptions appear 'objective' and imposes degrees of detachedness towards the participants, an account that curbs both our engagement and understanding of the practices involved in a sociological study. The formation of STS as a field of enquiry was meant to tackle this analytical objective and "create distance from idealized descriptions of scientific procedure" (Coopmans et al., 2014: 2) – I follow this long-standing tradition.

Undertaking this study required great closeness, intimate acquaintance with observations of situated practice, and a serious commitment to learning to see like a professional in order to support my analysis. In this way, seeing 'like'[96] a professional would ultimately build my vision. My raw and uninitiated recruitment of both social worlds steered my eyes, pulled my body, and seduced me into the reflexive relationship between talk, embodied conduct and materials through which situated learning is recognised (Ivarsson, 2017). As such, I uphold the notion that there is a relationship between my participants learning to see, and my own learning to see. Indeed, I embraced the idea of my own learning to see as a practice that was somewhat essential to completing this thesis: this study was not possible for the untrained eye. Indeed, there is an oscillation between the fieldwork in this study and Goffman (1989: 125) who insists that fieldwork involves:

> Subjecting yourself, your own body and your own personality, and your own social situation, to the set of contingencies that play upon a set of individuals, so that you can physically and ecologically penetrate their circle of response to their social situation, or their work situation.

Despite being somewhat of an outsider, my learning to see was realised during moments in fieldwork when radiographic anatomy 'came into view' through talk, embodied conduct, visuals, and (re)enactments. For instance, I recall seeing anterior ribs for the first time in a CXR image interpretation lecture. To the untrained eye, posterior ribs are more visible than anterior ribs, as they are situated at the front of the radiograph; however, anterior ribs are much less obvious as they are behind the lungs. The anterior ribs appeared once the radiographer started highlighting each anterior lung in the right zone. I believe my *starting to*

[96] Here, I make a distinction between seeing *like* a professional and seeing *as* a professional and reflects back to the earlier discussion on 'unique adequacy requirement'. The former is a broadly performative orientation that tends to focus on and having just enough education to perform as my anatomical, technical and understanding of image interpretation was limited at the time. The latter privileges 'expert' knowledge and is in sync with the competent performance of the tasks conducted by the professional (i.e. qualified).

see began when the radiographer highlighted the posterior ribs before highlighting the anterior ribs, where each rib was numerically counted. As if by magic, the anterior ribs appeared before my eyes 'out of nowhere'. Thus, direct observation of the teaching interactions renders the work of 'seeing' not only graspable, but also publicly shared and perceivable (Alač, 2008).

A second means of learning to see was when professionals and students allowed me to materially grasp what could otherwise only be conveyed in a radiograph, that being a PowerPoint slide of the radiograph referred to as a 'case presentation'. As seeing was inherently based on learning radiographic anatomy, I found myself like the newcomers to radiography: I had to find my own way of learning – *way finding* involved intuitive processes of registering touch and pressure (whether purposeful or accidental) with human bones using my senses. Much like the novice archeologist forensically fumbling through the dirt, I made use of my senses to help proximate my body with the surface of three dimensional (3D) model anatomy to notice bony features. Here, seeing becomes a material theory of learning allowing us to consider how the materiality of objects is just as essential as talk, bodies, and human interaction in building vision or distinct 'ways of seeing'[97] (Fountain, 2010, 2014; Prentice, 2013).

This learning appeared alongside its radiographic counterpart on the LCD screen, allowing me to import these senses onto the image and recognise its bony features. This movement or 'acts of coordination' between bodies and the work onscreen is said to ultimately establish a physical connection between professionals and the otherwise distant patient to help 'translate' important bodily features (Alač, 2014): a merger that calls attention to the senses, the sensual body, and the embodiment of meaning as an ethnographic domain (Good, 1994). With regard to way finding in task-oriented seeing, similarities and differences between model anatomy and radiographic anatomy were much more about getting my *body in* than about getting my *eye in*.

[97] Coincidentally, one of the current enthusiasms in STS research is the notion of *materiality* in scientific practice. In line with current STS scholarship, materiality is concerned with notions of embodiment, tools, objects, technologies, and environments that shape scientific work (Coopmans et al., 2014).

However, this did not happen much and, as such, I often relied on online educational resources to repair my 'not knowing', an example being the 'radiology masterclass'[98] website for anatomy training across multiple imaging investigations. PowerPoint images from professionals (through email correspondence and ad hoc illustration), my use of my own body, and pulling up images and schematic diagrams from websites, all supported my learning and shaped my radiological eye. At times I often emulated professionals' and students' 'methods' (Garfinkel, 1967) in the video to make sense of what was being seen.

Trawling through images and searching my bones – I regularly probed the bones underneath my flesh to lead and inform my training off-site – allowed me to reconnect with the training and constantly reminded me of the radiographer's words: *'you have to build that image into your memory'.*[99] At times it felt like I was part of the ethnographic narrative. While tackling the problem of how to see radiographic anatomy I recalled Garfinkel's (2002) dictum that ethnomethodologists must immerse themselves in the situation being studied and make efforts to satisfy the 'unique adequacy requirement'. However, when fieldwork is not what most people generally participate in (like ordinary talk, cycling, walking) and when located in "specialized populations" (e.g. science, engineering, aviation), unique adequacy is hard to achieve. Thus, I identify my unique adequacy requirement as 'weak', where "the analyst has enough to recognise, or identify, or follow the development of, or describe phenomena of order" (Garfinkel, 2002: 175). Simply put, I know enough to understand what is going on.

Another aspect of learning to see was that it aided the analysis: radiographic anatomy constructed as everyday patterns/signs was most useful for seeing and it influenced my choice of images to be used for analysis. This is the intention of assigning the anatomy its own pattern/sign: to make normal/abnormal visible to students through the resemblance of familiar shapes recognised in society.[100] In other words, professionals drew attention to anatomy with these shapes as ontological ideals influenced by their common sense knowledge and everyday understanding of the world (Garfinkel, 1967). This has clear parallels with

[98] http://www.radiologymasterclass.co.uk

[99] Mr. Jim Richards (WURD Radiographer).

[100] Particularly everyday/familiar objects and nature.

“ideal types” in scientific collecting practices of cross-referencing (Beaulieu, 2002) and is therefore grounded in “pictorial objectivity”, as discussed by Daston and Galison (1992).

The composition of anatomy as everyday patterns/signs effectively draws attention to the everyday as a reference point. After all, radiologic patterns/signs function as a pedagogical resource between communities, facilitating newcomers’ or novices’ visibility to *see in* images. The representation of anatomy as everyday thereby developed my own radiologic vision and helped me see, even as a non-member of either profession. This is evident in how radiologic anatomies became pictorially linked to the text in the fieldnotes, as something that can be written and understood. (Ab)normalities that do not have ‘patterns’/’signs’ often have a metaphoric value, where figurative language provides another means of similarity (Lakoff and Johnson, 1980; Fountain, 2010, 2014). The everyday, it seems, is as important for professionals as it is for the ethnographer.

Many of the radiographs that have been used in this thesis have been carefully selected for their ‘patterns’/’signs’ for presentation and analysis (both acting as a stimulus for a type of audience for whom x-ray image interpretation is outside of their profession). However, this risks a drift towards interpretive simplicity and reinforces a negative stereotype of image interpretation training as a ‘sign alignment activity’ only, one that might reflect unfavourably on professions. My intention here is not to trivialise; healthcare professions work in hectic clinical environments, too hectic to spend long periods of time over images and are depicted as having unrealistic workload targets. These aspects provide good reasons why professionals rely on signs in medical images, because these offer specific ‘advantages’ in clinical work.

According to Burri (2012: 53), the way “visual signs” are composed in images benefits the communication between professionals, allowing one to grasp information in a very short time, as well as heighten persuasiveness with patients, as “visual information is many times more effective than textual communication”. Questions around the selection of such radiographs for the presentation of the thesis demonstrate the difficulties (sociological) outsiders face when researching professional practice. These choices are expanded in the case of medical images without ‘patterns’ or ‘signs’, in which the researcher’s demands increase because images become more difficult and problematic to analyse/present. And so, for the purposes of clarity in the analysis, my role is to provide a world that ‘makes sense to people’; a tactic that crafts a clear analytical account by 'cutting [yourself] to the bone' (Goffman, 1989: 127). Much like the vast labour of professionals basing case presentations on official institutional and organisational texts, this thesis features selections of images in order to better analyse and produce a version for both the researcher and the audience.

In another sense, the readers of this thesis, like the students in this study 'learn what they need to learn'. There is also the other issue, that video ethnography is essentially interpretive. Whilst video takes into account the full range of contexts and perspectives in the ongoing interpretive search for situated meaning (Erickson, 2006), the researcher is essentially involved in the *interpretation of the interpretations*. As a consequence, the video ethnographic data is interpreted and not presented 'objectively' – there is no objective eyewitness in understanding how image interpretation training shapes how and what students come to perceive. How are we able to interpret the meaning our participants gather, particularly when students are also involved in explicating? How are we to truly know what matters or what distinguishes an eye blink from a wink? As Geertz (1973: 9) puts forward in his discussion of providing a 'thick description', the researcher is always at risk of "explicating explications. Winks upon winks upon winks." Such a view may somewhat mislead the analysis, as, when constructing the ethnographic 'text', we are always explicating, involved in continuously cultivating participants' meaning. Here, I may be accused of being lured into the misinterpretation of subtle and nuanced interactions that have implications for the analysis, particularly when it comes to matters of misleading in training (e.g. the professional's intentional act of misleading students).

At almost every stage of the analysis, it was important to make use of multiple camera angles and ethnographic data sources, as well as playback and zoom, 'to be as accurate as possible' when it came to interpreting situations that had a certain level of complexity. Here, there is no objective product constructed by the neutral observer. This, however, does not mean that its research findings are limited. Although there are limits to what can be known, being interpretive allows us to 'grasp from within' and to access embodied accounts and individuality (Hammersley and Atkinson, 1995: 2). Aware that the interpretive style of the research draws on criticism, by treating participants as passive rule-following "cultural dopes" (Garfinkel, 1967: 68), through which it claims that the authorial voice of the researcher speaks for his or her subjects, this thesis is designed not just to voice the participants through 'text' but to voice them through 'video clips'. More importantly, perhaps, this helps establish a greater correspondence between the participant and the analyst's views of the world (Bloor, 1978). This is not to say that my interpretive problems stopped here.

Certainly, 'image interpretation' opened up the possibility for the misinterpretation of radiographs. After a short period of analysing the interpretive practice, I realised that I needed professionals to confirm aspects of image content in case presentations when abnormal anatomy was seen through the lens of differential diagnosis. This process was used by radiologists to accomplish rather complicated accounts of abductive reasoning in which misleading information or highly ambiguous images were used to formulate a different or *differential* diagnosis. Despite the fact that I used observation, fieldnotes and video to see and critique what was going on I was still unaware of the existence of a solid diagnosis attributable to some images. This made my analysis somewhat ambivalent. Here, the limitation that I did not observe nor even participate in anatomy training and image making became evident, as radiographic anatomy was crucial to any understanding of x-ray images. Although these were not specifically image interpretation in the normal vs. abnormal sense, having a grounding in normal anatomy and image production would have sharpened my analytical lens and curbed misinterpretation, especially in matters of 'superimposition' (overlapping of bones and tissue that misleads interpretation), 'optical illusion' (making the anatomy appear as a false shadow), or 'size distortion'/'magnification' (caused by inadequate positioning, rotation, or movement in image production).

Alongside such analytical difficulties, there were some practical ones. Video recording could be difficult and frustrating. I could spend a considerable amount of time maneuvering the recorder and adjusting to the light and darkness. Teaching sessions in radiography were often chaotic and loud, setting up and removing the equipment was done in haste, the recording equipment was heavy to carry. While I accrued as much information about the teaching rooms beforehand (via e-mail), it still did not fully prepare me for recording in these settings or 'reduce the stress' of data collection (Stevens et al., 2017). Without going into details about the complexities of setting up the recording equipment (and indeed myself) in these settings, setting-up drew on improvisation and spontaneity rather than pre-determination. In addition, on three other occasions I enlisted the assistance of a 'second pair of hands' (and eyes) to help video record.[101] Behind the scenes, I also had to miss two training sessions: once, because they happened at the same time, and the other was when fieldwork overlapped with a pre-booked video course in Southampton as part of my own PhD training.

3.15 Conclusion

This chapter details research ethics and fieldwork, where the two main sites of video ethnography were located (BRMR, WURD). In becoming a reflexive researcher along the way, I intermix discussions of field relations, the adoption of methods, video camera work, and the ethics of video ethnography. These principles of methodological conduct were shaped around the early stages of x-ray image interpretation training located across 'non-clinical' sites, the focus being on an academic engagement of x-ray images that refers to organised and ordered ways of 'seeing' and 'interpreting'. However, this ethnographic study that I was conducting in academic contexts actually involved and *evolved* around the clinical. The study of the development of professional vision over time demanded me to move beyond the 'non-clinical' and academic organisation of interpretive practice to the diffuse contexts of 'clinical' activity that further mediated this vision. Like most ethnographies that "portray the round of life in a social setting" (Barley and Bechky, 1994: 86), this study falls someway short. Because the academic and clinical are interconnected and ultimately cannot be understood without one another, this 'round of life' provokes the creation of an ethnography that can straddle both academic and clinical settings. Going forward, I encourage future ethnographic work at the sites of clinical placement where patients, professionals, technologies, and apparatus are involved in x-ray image interpretation training.

As part of my description about the principles behind my methods, I describe a video-based methodological approach to capture the professional vision of x-ray image interpretation training between two different professions at different sites. Such an approach to data collection is useful for capturing 'situated' aspects and experiences of place that are key to

[101] Interestingly, assistance in the ethnographic fieldwork is often talked about in terms of methodologies, rather than humans.

building professional vision, as well as all the different forms of communication and representations that people bring together to create meaning. Here, the utility of the video moves beyond talk and writing to accommodate gesture, body, and place (and space), particularly in settings with complex interactions often mediated by materials or technology (Goodwin, 2000a; Alač, 2008).

With the help of 'situational analysis' (Clarke, 2003), I am able to recognise all of these human and nonhuman elements through processes and practices, to organise my analysis of professional vision as embodied conduct. Eliciting and analysing messy and ordered situational maps, the constitution of radiological error started to emerge not just as providing students with images that were open to multiple interpretations, but as selecting images that were open to misinterpretation. This resonates with the RCRs (2014) report on discrepancies in radiology, which is that when a learning system is in place to understand error, interpretive performance will improve.

In addition, while a situational analysis allowed me to map the various types of images it became clear that the CXR was the only image (at this point in their training) that was shared by both professionals. As a result, the findings of my situational analysis were biased in favour of CXRs and the common forms of radiological error associated with the image. There was common agreement among professionals' previous experiences in x-ray image interpretation that CXRs were the most ambiguous of all x-ray images and more challenging to interpret than MSK images. The CXR, for example, is a complex image of bones and organs for professionals - a complicated internal space of overlapping organs, clusters of bones and soft tissue, as opposed to MSK images where the focus is on bones, joints and soft tissues.

To combat this complexity, both sets of professionals introduced the CXR early on in their training in an effort to build their professional vision from the beginning but also as a means to open the practice to scrutiny, making them more critical early on. In addition to concerns about missing abnormality, the CXR provided added value for teaching radiographic anatomy and the formation (or attenuation) of internal structures and densities (e.g. air). For example, radiography students were introduced to CXRs as early on as the second week of their degree where learning about density was always referred to the CXR,[102] and then, a week later were introduced to CXR image interpretation proper where a greater understanding of density seemed to underpin confidence in, or preference for normal or abnormal. Put simply, Clarke's (2003) semiotic approach postulates that the CXR was of paramount concern and importance to both professionals and their training.

Lastly, having identified the three common concerns professionals had in x-ray image interpretation, a process of tabulation helped me manage this further allowing me to examine these in more detail (**Table 2**). This process also helped me to structure the thesis chapters. Because of the overlapping nature of the three vortices (1. radiographic anatomy, 2. missing abnormality, and 3. image production) there was considerable overlap between the three main concerns professionals had training x-ray image interpretation. Afterwards, I describe how this technologically facilitated attention forms a distinctive professional vision unique to x-ray image interpretation giving rise to distinct forms of embodied conduct in their ability or opportunity to help others see. This presents an analogy between the students' learning image interpretation and that of myself, so bearing similarity to a key aspect of a 'sensory ethnography' (Pink, 2012).[103] Rather than passively supporting the idea that learning to see benefitted the analysis, I then go on to consider some of the analytical difficulties encountered in analysing the participants' activities and interpretations.

In what follows, I present a narrative composed by a multitude of voices that speak both textually and visually. Interested in teaching as well as learning, and in order to see and ease the workload, I reveal how x-ray image interpretation training is embodied, representing an intertwining of local cultural decisions and institutional priorities, technology and aspects of both patient and professional bodies (Joyce, 2005, 2008; Måseide, 2007). The next three chapters show how professionals go about their teaching practice attending to embodied and

[102] The Application of Imaging (AoI) class folded both x-ray physics and anatomy learning together.

[103] Overall, there are two parallels between the participants and i. First, video camera work during fieldwork parallels the work of the radiographer in image production (which provides a backdrop to one of the arguments of this thesis). Second, field observations and writing fieldnotes of teaching practice situated me within the learning worlds of radiography and radiology, and parallel to the learning processes of medical and radiography students.

material aspects of communicative situations to professionals in-the-making. Through the 'visual performance' (Burri, 2012) of video data – a consequence of aesthetic decisions during fieldwork and representational work during analysis – I show that we need to rethink the studies into medical image interpretation training, one that promotes sensitivity to embodiment, materiality, senses and imagination, all involved in learning to see.

4 The professional vision of x-ray image interpretation training in academic settings

In chapter four, I explore how x-ray image interpretation training is conducted and organised. I show how the professional vision of x-ray image interpretation in academic contexts as a back-stage practice contributes to a 'critical' interpretation. I define this critical-interpretive approach as practices that organise and systematise the importance, attention, and scrutiny of x-ray images via the normal. This is particularly common in both Bridgestock and Woodlfeet. For example, at Bridgestock and Woodfleet, professionals in-the-making are offered a 'systematic approach' for the interpretation of radiographic images of chest x-rays (CXRs). Both communities of professionals endorse such a 'systematic system of scrutiny' to those in training in order to establish a correct seeing and interpretation of the chest, ensuring that all areas of the image are scrutinised (Delrue et al., 2011). Whilst they are certainly attentive to pathology, this attention is based on expectant components of anatomy, dependent on the familiar friendly comforts of the normal and its radiographic appearance. As such, the professionals organise their seeing in terms of a specific pattern of inspection that simultaneously makes comfortable the normal ontology of the image.

First, I capture how x-ray image interpretation is founded on normal anatomy and endorsed to professionals in-the-making through the rhetorical testimony of cognitivist psychology, namely 'looking at' and 'pattern recognition', which establishes one's serial attention for organised appraisal. Adhering to these cognitivist-orientated principles not only performs the activity of learning to see normal patterms or *gestalt* as crucial for problem solving, but it also allows radiologists and radiographers, in their professional vision, to form a foundation for a critical faculty of perception by embodying a cognitive relation to the radiographic anatomy at hand (i.e. via the 5 x-ray densities). Second, I explore how professionals structure x-ray image interpretation, where the rhetorical principles from above are reinforced by a systematic approach that commits students towards a fixed deliberation of anatomical areas, ensuring a complete inspection of the image (Kok et al., 2015). Third, professionals describe x-ray images as having specific 'areas of interest' that steer the novice gaze toward common injury sites in order to curb missed abnormalities. This emphasizes both the scrutinizing and analytical gaze of interpretive work. Taken together, such activities contribute to the critical practice of x-ray image interpretation training chiefly designed for, and thus accessible to others in academic settings.

Professional vision considers what professionals (for instance, radiologists and radiographers) do to organise and coordinate the distinctive characteristics of the material world, in ways that shape the cognitive and perceptual orientation and that this is accomplished through diverse forms of embodied work (Goodwin, 1994; 2000a, 2000b; 2003). Speaking on the notion of professional vision, Måseide (2007) claims that in the processual and emergent character of interpreting x-ray images, radiologists engaged in problem solving activities that were discursively generated in moments of uncertainty to conform to what became the preferred medical and moral solution.

Similarly, Joyce (2005, 2008) shows that what counts as professional vision in radiological contexts is inherently influenced by members of the medical community which in turn shapes their rhetorical practices in order to discuss or discursively 'reveal' the inner body. Moreover, for Ivarsson (2017) this professional vision of cultural and bureaucratised action shifts our focus of attention to a locus of embodied conduct and what counts in the *work of finding disease* and of what things accountably *are* (as anatomical structures). As professionals perform their vision for the benefit of their students, professionals draw on their embodied conduct, whose use enacts and reenacts their own version of professional vision: 'radiological vision' (Måseide, 2007). In chapter four, and particularly when analysing the prescribed rhetorics of looking at/pattern recognition, 5 x-ray densities, and systematic approach, I point the Goodwinian lens towards professionals' discursive practices and technoscientific rules, as well as cognitive artifacts (such as density categories and canons of anatomical representation) in order to organise perception and shape cognition.

4.1 'We'll be looking at normal *first*'

This chapter begins by identifying how 'looking at' (or look at) and 'pattern recognition', a transposable educational discourse penetrating x-ray image interpretation and diagnostic imaging more generally, are enacted and reenacted in academic settings and what this accomplishes. The notion of 'looking at' and learning to recognise normal 'patterns' pepper current educational discourses on diagnostic imaging technologies and medical image interpretation. Anatomical textbooks, and e-learning resources in particular, are signaled as essential to problem solving, since they provide professionals in-the-making explicit normal anatomic information and its variants about the human body (Saunders, 2008; Friedrich, 2010), although this may mean overlooking other aspects of learning (Engel, 2008). In line with the cognitivist psychological orientation of this discourse, problem solving is effectively framed as a mental activity. The connection between individual 'perception' and 'cognition' is said to underpin the performance of problem-solving tasks and competent image interpretation, propelled by memorisation and pattern recognition (Bloomer, 1990; Custers et al., 1996; Crowley et al., 2003; Delrue et al., 2011).

As such, the research on the learning to see and diagnostic reasoning of medical images (that is, the honing of visual search patterns and feature/object recognition) is often described in statistical, mechanistic and disembodied terms. At the same time, looking at and pattern recognition (including 'gestalt' and 'symbolic representation', and 'mental representation') as problem solving skills are grounded in cognitive psychology (Polanyi, 1958; Linaker, 2015a; Friis, 2017). In recent years, however, there has been a departure from 'mental representations' and recognition of 'patterns', from professionals storing anatomic representations in the 'mind's eye' with social and material arrangements stripped away, to a model of 'embodiment' in which diagnostic processes (search, perception, cognition and reasoning) are usually assigned "to our physical being, since a part of our professional knowledge is also embodied in our physical being" (Engel, 2008: 185). This logic of embodiment places an emphasis on body and practice, supporting James Gibson's theory of affordances (1977) suggesting that we see things in relation to their possible use, and therefore never as an isolated, detached, *disembodied* observer.

Here, we consider such embodied-user involvement, where visual expertise looks beyond the mind and focuses on the skillful coordination of the body in pragmatic contexts, particularly the role it plays in searching, considering, judging, and interacting with evidence in work relevant ways. Taking this further is Goodwin (1994) who argues that visual expertise or 'professional vision' is not only embodied ('lived in'), but it is socially distributed and materially mediated; researchers working to this end show and tell how such a 'skilled vision' is always “embedded in mediating devices, contexts and routines” (Grasseni et al., 2009: 4). By maintaining this holistic and ecological approach, an emerging critique of embodied conduct has arisen (Koschman et al., 2011; Ivarsson, 2017), with ‘sensorality’ as a recent arrival on shaping search and perceptual skills in learning anatomic details of the body in movement (Fountain, 2010; 2014; Prentice, 2013; Harris, 2016).

One way to understand how professionals refer to looking at and pattern recognition is to analyse the way learning to see is presented to radiography and medical students in undergraduate x-ray image interpretation training. In a setting where the dominance of a cognitive psychology model of learning sublimates the visual expertise under the distinct label of a ‘mental model’ (Prentice, 2013), we must focus on how cognitivism is communicated and talked into teaching practice and how it is effectively deployed, (re)enacted, or demonstrated by professionals during x-ray image interpretation training. At both Woodfleet University and Bridgestock Hospital, radiographers and radiologists emphasise their alignment towards cognitive psychology tendencies when teaching x-ray image interpretation and also when professionals come to focus on the normal anatomical structures that form the appearance of patterns in images. In WURD, radiographers in-the-making are tendered the idea that the act of *looking at* normal radiographs provides the foundation for developing a mental representation of patient anatomy, an individual effort to make one’s way into learning to make distinctions between normal and variant anatomy and between normal and abnormal anatomy (Peterson, 1999; Prentice, 2004).

In WURD, radiographers in-the-making are often instructed to get lots of practice by looking at normal radiographs in textbooks and PACS images on clinical placement. One textbook on radiographic anatomy reads:

> After looking at many normal PA chest films, you will have formed a mental image of what a normal chest film looks like.

This textbook, much like other anatomic literature and educational resources, highlights that professionals in-the-making, *‘after looking at many normal PA chest films’*, will have *‘formed a mental image of what a normal chest film looks like’*. ‘Looking at’ is a common rhetorical device in anatomic textbooks, to which radiographs are often put in the pedagogical sphere, focusing on the mental properties of the individual, rather than the socially distributed or embodied context of training (Prentice, 2004; Alač, 2011). What is at stake here is a description of learning to see as the construction of a mental image of human anatomy.

These ideas about the importance of developing a mental image – and different kinds of mental images – in anatomical knowing can also be found in the professionals' discourse, when they begin to comprehend both the appeal of learning from anatomical textbooks and the grounds for passing this on as advice to professionals in-the-making. Dr. Saury (BHRD radiologist) emphasised that such textbook information will inevitably give beginner's skill a good mental picture of the normal, as he told me during one email exchange:

> You have to have looked at a certain number of that particular imaging study in order to have got a good mental picture of the range of normal in order to perceive the subtle abnormality.

For Dr. Saury, looking at texts of studies of normal imaging and its variations/unremarkable findings generates a perceptual acumen of the normal anatomy at the conscious, mental level. This way of learning about the normal in radiographs can be understood in terms of developing a cognitive stance towards professional problem-solving. Berg (1997: 27) describes how medical professionals constructed physician problem solving as a purely cognitive mental exercise – a view that treats the mind as an information processing system that develops "symbolic mental representations" of problems. This cognitive view of anatomical knowing deemphasizes the role of the body in early anatomical learning. In parallel, this endorsement and the ubiquity of developing a mental picture or 'mental representation of patient anatomy' (normal organs, body fluids, and other structures and how they relate to each other) have long been associated with cognitivist-based studies on professionals' visual expertise in image interpretation (Lesgold et al., 1988; Van der Gijp, 2017).

In addition to this cognitivism, there is the idea about how iteration and continual repetition plays an important role in the technique used to learn the normal. Looking at the terms used in Dr. Saury's (BHRD radiologist) account above, we can see this is overwhelmingly a vocabulary of repetition, echoing what Fountain (2010: 56) observed as "a need for repetition and memorization in order to learn the names and the landmarks". Professionals in BHRD and WURD identify iteration as a way to comprehend and recognise the patterns of normal radiographic anatomy via textbooks and PACS. Each iteration of looking at normal imaging studies, which contiguity affords, captures a consensus moment in the evolving mental storage of normal anatomic information. As Dr. Saury (BHRD radiologist) put it during a lecture in the medical school, *'this is really hard to get your eye in for at the start and you have to just make sure you look each time and you'll gradually get a feel for what's right'*. This pedagogical advice treats learning as a product of individual action that engages with an abstract mental model, playing its part in explication and enabling the organisation of the perceptual field. For Lynch (1985a), this pattern of talk or 'shop talk' is particularly notable for its authoritative role as a specific and established language practice relevant to the work-site competence of the professional domain.

Similarly, radiography students, whose first year is geared towards learning normal radiographic anatomy, are expected to develop their knowledge of a canonical body, one that is as close to normal as possible, together with some knowledge of normal variants, iteratively, with and through looking at anatomic textbooks. For example, a radiographer at WURD argues in favour of iteration as a key part of learning normal anatomy and its variants. In an email he typed:

> By studying the anatomical textbooks and experience the more images you see the more of an appreciation of normal you develop. Everyone's anatomy is different and there is variation from the anatomy books. In fact, there are huge volumes written just on normal anatomical variants alone (we don't expect students to learn all these). The saying I use is; 'how do you expect to see abnormal if you don't know normal?'

Mr. Hearken describes looking at normal anatomy as *'studying the anatomical textbooks',* including anatomic variants in radiographs, where students can see variations in anatomic structures and features. Similarly, *'experience'* is held to be as important, occupying the position that experience means *'the more images you see'*.[104] Mr. Hearken claims this supposition gives radiographers in-the-making a chance to *'know normal'* (including the range of normal) and provides them with a foundation of perception for abnormal anatomy (*'how do*

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[104] This advice also continues to suggest that the ideal of observation-based iteration serves as a necessary background for learning normal.

you expect to see abnormal if you don't know normal?), echoing Dr. Saury's point that learning the normal will allow medical students *'to perceive the subtle abnormality'*. Similarly, Mrs. Campbell (WURD radiographer), who works as a hospital radiographer two days a week, prompts insight that, even in the hospital, there are further opportunities to learn normal anatomy using the PACS images on computer screens because the majority of the images are normal (*'in one day probably take thirty patients and of those thirty patients, maybe five, seven have fractures'*). Both accounts shows how a depiction of experience - that is, experience that focuses on the individual's need of looking at normal images in textbooks and/or via PACS on clinical placement - is shrunk down to looking by professionals, whereas phenomenologically, experience is always the whole body of the person in context.

Merleau-Ponty (1962) describes how people's experience of the world, largely as a means of tactile engagement on the body *from* the world, awakens our nature of perception and the existence of a 'tacit' cogito. In contrast, WURD x-ray image interpretation classes say 'experience', but narrow it down to one factor, shortening the distance between bodily experience and textbook information. The point to stress here is not about experience coming from iteration (although it may), but about the general idea that coming to know the normal is done 'in the head', as opposed to a process experienced by the body 'out there in the world'. Indeed, we might say that it structures the professionals' and students' mental picture of the normal and imposes a semantic overlay in the head through which it becomes possible to see the abnormal:

> We need to look at the anatomy and physiology of the bones in particular that we're looking at, and then we need to be able to *see* normal and abnormal, or recognise normal and abnormal appearances on radiographs. We tend to start with normals. You have to get your vision in [Gesture: hands touch head and extend outwards] so you can recognise it [Gesture: hands touch head and extend outwards], it's like, visual recognition. So, you need to know what a normal looks like [Gesture: hands touch head and extend outwards]. It's fun looking at all the fancy fractures and breaks and everything, but if you don't know what a normal looks like [Gesture: opens space to her left as if to conjure a normal appearance], how do you know that's abnormal? [Gesture: moves space to her right as if to conjure an abnormal appearance]. So, we'll be looking at normal *first*.

Mrs. Campbell's description of learning normal anatomy connects with this idea of generating a mental picture of normal anatomy and in expressing this she enacts this approach (and her own mental schema of the normal) by extending her gesturing hands from her head (*'you need to know what a normal looks like [Gesture: hands touch head and extend outwards]'*).[105] Mrs. Campbell claims this allows professionals in-the-making to *'recognise normal and abnormal appearances on radiographs'*. In doing so, she configures the thinking of the radiography students learning normal anatomy *'to get their vision in [Gesture: hands touch head and extend outwards] so they can recognise it [Gesture: hands touch head and extend outwards]'*). This type of anatomical learning has come to define the rhetorical approach and teaching practices of radiology and radiography educators. Indeed, the nature of teaching and learning to see in a cognitive economy, and the diagnostic reasoning approach in Mrs. Campbell's account is a nice example of non-analytic reasoning which is actually *referred* to as pattern recognition in some circles (Eva, 2004, 2009; Norman et al., 2007; Kok et al. 2015, 2017). Later in the chapter, I will show how this 'non-analytic' organisation of perception is embedded in an analytical, or, rather a 'systematic approach' which acts as an analytical lens to further enhance anatomical scrutiny in order to avoid missing or forgetting findings.

Dr. Saury, Mr. Hearken, and Mrs. Campbell echo some of the central arguments put forward by cognitive psychology in a more general way in which learning to see is based on a wholly independent, objective source of knowledge about the world. The important point in this regard is not that learning normal acts as a frame of reference but, rather, that the acquisition of the normal is itself a critical regulator under specific conditions. This process, in its aptitude, allows a critical gaze to emerge in a distinctive sense to determine criteria for a comparison between normal and abnormal findings. Such a treatment to learning of this sort is often interpreted as a conception of scientific activity that emphasises mechanically obtained objective representations (de Rijcke and Beaulieu, 2014).

Recognising this suggests that objectivity is important for our learning to relate to anatomies and to materials within some overarching normative and external point of view. However,

[105] Mrs. Campbell's hand action is similar to the act of tracing (like an architect placing old house blueprints over new house blueprints), through which it is possible to 'see' the difference between normal and abnormal anatomy by placing the mental picture of the anatomy in her head over the real image.

overly attributing this objectivity to learning to see and knowing glosses over the social process and material contexts, and the interactional and interpretive work that surround them. According to Saunders (2008: 33), in his ethnography of diagnostic work in a CT suite (to which he observed both work *and* teaching practice), learning how to see the normal had evolved from a series of commitments that together moved beyond the visual confines of textbook representation: "norms are not merely objectified sets of limit criteria – though they are often presented thus in textbooks. The normal becomes a structure of the expectant sensorium – an aesthetic device of viewbox practice". Relationships between the aesthetic and the scientific, or between subjectivity and objectivity have been endorsed for many years – indeed throughout laboratory studies research. It is a well-known aspect of the history of laboratory studies that the role of visual representations in scientific activities drew on aesthetic and cultural models as much as on models of 'scientific' research (Lynch, 1985b; Amann and Knorr Cetina; 1988; Lynch and Woolgar, 1990; Latour, 1986; Alač, 2011).

The laboratory studies perspective was fuelled by how specific decisions in laboratory work did "not depend on technical and professional standards alone but also on cultural and aesthetic conventions or individual preferences" (Burri and Dumit, 2007a: 301). The laboratory studies exploration of visual 'representation' – through discourse for instance – highlighted how scientific images were ultimately not 'neutral' products "but the result of a series of specific, culturally shaped sociotechnical negotiations, which imply – like any technological fabrication - processes of formalization and transformation" (Burri and Dumit, 2007a: 301). Equally, the styles of scientific work, the aesthetic production of visual forms and categoristions of image content, and the discourse of modern mechanical objectivity – these all contributed to the styles of biomedical seeing in medical images (Kevles, 1997; Joyce, 2005; 2006; 2008; van Dijk, 2005; Burri and Dumit, 2007a).

Going back to Saunders (2008); what is implied, however, is that image content, or in this case, biomedical seeing of the normal, is informed by a person's aesthetic judgement *as well as* some form of sensory input. In the case of professional seeing, Saunders's analysis of diagnostic reasoning suggests a mental schema of the normal is rooted in an objective-subjective dichotomy which reveals an intellectual harmony of both objective fact and sense-experience. Unfortunately, Saunders (2008: 33) does not elaborate on *how* the normal becomes a "structure of the expectant sensorium", but he does provide evidence of a learning process and advice of general import; "make friends with the normal". Although the method of 'making friends' with the normal permeates the accounts of these professionals, it is not entirely clear what this would look like in the minds of the radiologists. Nor does he show how this aesthetic character of seeing and clinical judgement is shaped or mediated in training.

Saunders (2008: 34) does, however, gives us an understanding of how the anatomy can be coded, how the normal anatomy might be 'classified' and 'labelled' and made visible with appropriate "naming" and "quizzing" exercises. These contexts of teaching summon "clear demonstrations of 'normal anatomy'" and among other points of rhetoric, the fact that learning the normal establishes modes of attentiveness, rhythms of confidence, and comfort in naming for purposes of reference. These teaching skills are driven by a second-nature; knowing in advance accurate recognition of normal findings, and that it provides useful, or at least aesthetic, reasonings. This point echoes the central argument put forward by this thesis in which the standards and litany of the normal offer's foundation for critical analysis – summation of a first level critical perception to defend against a potential hidden enemy.

Moreover, 'normal' and 'abnormal' are examples of members' *categories* of experience and what Goodwin (1994: 609) might call "discrete categories" in that they are individually separate and distinct from each other. If we recall Goodwin's study (1994: 609), archeology students learn to see by using a Munsell colour chart (a colour taxonomy system for dirt) for the purpose of finding the right *category* (colour) of soil. This approach focuses on discrete categories of dirt based on objective content and brings to the fore the practice of categorisation (and comparison) as a "context-free reference standard". Similarly, Mrs. Campbell – whose comparison also represents discrete categorisation – expresses a form of communication *more than* the categorised content by providing background and contextual information about the image context: *'we need to look at the anatomy and physiology of the bones'.* This argument centres on the view that the anatomy and physiology of the bones can be sequestered as *objective categorisations* that pertain to how x-ray images of the bones (i.e. 'Musculoskeletal') are structured or perceived.[106] Therefore the categorisation of

[106] The name of the lecture was called: 'Musculoskeletal imaging 1: introduction to image interpretation' which framed the lecture and its content around the bones of the human skeleton.

normal/abnormal is highly linked to the context of the (MSK) image in which the professional performs, such as upper limb MSK (shoulders, arms, hands), spine MSK, hip/pelvis MSK.[107] Abnormality in this sense is always in reference to bones that are either *'fractured'*, or *'dislocated'*/*'subluxated'* after a *'trauma'* such as a motorcycle accident – this will be discussed in depth in chapter five. We will also come to see how soft tissue/organ-based images (i.e. x-ray images of the *chest*) are categorised as normal/pathological, with 'pathological' referring to *disease*.

At first sight professionals make great efforts to keep this normal/abnormal category pure and distinct (Douglas, 1966); however these boundaries are crossed when: 1) x-ray images contain both broken bone ('abnormal') and disease ('pathological') in the same image; and (2) x-ray images contain disease, yet professionals might show a slippage between pathology and abnormality. Categorisation, in this latter sense, does not reflect a fundamental ambiguity and subsequent anxiety because professionals will always situate the students in the context of disease: professionals could either begin with a testimonial of the disease *as* 'pathology', and move through correlative work, and conclude with 'abnormality' (see chapter five and six) or they could begin to ask disease related questions in hot seat activities. Furthermore, in this discourse, whether it is a bone break or disease does not matter: both are disruptional changes to the human body, are an aspect of ill health or a health problem and *require* intervention. It goes without saying that normal does *not* require any intervention. Although, admittedly, one could argue that disease or cancer would require *immediate* intervention but then again, so would a life-threatening broken bone (e.g. neck, pelvis).

Importantly, the normal/abnormal and normal/pathological categorisation assumes that radiological categorisations/interpretations of the normal anatomy (i.e. with x-ray) is straightforward and trouble free. I argue that this is not the case and in fact, my data will show how learning to see and the categorisation of the normal is just as difficult as seeing/categorising abnormal, if not *more* difficult. The normal images or normal anatomies in this instance are more likely to have highly unstable meanings because, in the words of Mr. Hearken earlier: *'everyone's anatomy is different and there is variation from the anatomy*

[107] For a comprehensive MSK list, please refer to the 'Messy situational Map' in Chapter three (Figure 2).

books'. This 'ontological ambiguity' (Måseide, 2007) of normal radiographs is indeed one of the major concerns of this thesis, opening up medical and radiography to "cognitive and perceptual uncertainties" (just like for the two archeology students at the beginning of this argument) (Goodwin, 1994: 609).

So far, I have argued how a sociological analysis of x-ray image interpretation teaching practice unmasks the rhetorical, organisational, and critical power of learning the normal. However, I will go on to argue how the structuring of this normal 'cognitive schema' – as a mode of non-analytical reasoning (Eva, 2004; Kok et al., 2015) – and the organisation of x-ray image interpretation in general is accomplished as a *social* process. I will argue how the categorisation of normal anatomies are *performed* – which in turn socially effect a foundation of perception with normal range. In an MSK image interpretation class, for instance, Mr. Hearken regularly uses his hands to physically enact and categorise anatomic differences as physical entities in order to shape his students' perception:

Figure 5 PA hand radiograph and laser highlighting the 'hook of hamate'

Figure 6 'Hook of hamate' gesture

Mr. Hearken: What's this carpal bone called? [Highlighting 1: lasers hamate bone]

Nadia: Hamate.

Mr. Hearken: Hamate. Okay. What is this specific little circle? [Highlighting 1: laser circles the 'circle'. (Fig.5)]

Nadia: Is it the pisiform?

Mr. Hearken: It's *not* the pisiform, It's part of the hamate.

Nadia: The hook.

Mr. Hearken: The *hook* of hamate *Head-nods in agreement*.[108] Okay. So your hamate has got like a little hook [Gesture: LH shapes to make a hook] which projects [Gesture: LH motions back and forth, as if hooking around an object (Fig.6)] around the back [Gesture: LH motions back and forth, as if hooking around an object] and that is hook of hamate [Highlighting 1: lasers the hook]. Now if you break your hook of hamate, if you *fracture* your hook of hamate, should I say, that will disappear, and you'll lose that little eye [Highlighting 1: lasers the hook].

Mr. Hearken, interested in the carpal bones of a lateral hand, highlights (Goodwin, 1994) a specific carpal bone in a circular fashion, guiding a group of radiography students toward the preferred interpretation (*'hamate'*). Having highlighted the hamate, Mr. Hearken executes a gesture that resembles a hook (*'your hamate has got like a little hook [Gesture: LH shapes to make a hook]'*). When he utters *'which projects round the back'*, Mr. Hearken's hand moves back and forth twice and, in the process, is hooked, so the gesture resembles a hook joining an object: through this hook, the reference of the hand also changes, from a representation of movement to a depiction of the hook, the small *'circle'* or *'eye'* on the hamate bone [*Gesture: LH motions back and forth, as if hooking around an object. (Fig.6)*]. The left hand is held still for a moment, before it makes a rapid curve movement, showing how it turns around into the rest of the hamate. This is "fictive motion" (Talmy, 2000): it organises perception in terms of motion, even though the described object – the hand radiograph – is static. Throughout this depiction, Mr. Hearken's gesturing body and the movement back and forth in a hooking motion do not constitute a simple requirement of 'looking'. For against the background of an assumed cognitivism, both Mrs. Campbell and Mr. Hearken offer a kind of Merleau-Ponty style

[108] Asterisks indicate expressions. Professional expressions are restless. Constantly using their body through expressions of tiredness (rubbing their face), impatience (unnecessary mouse clicking, finger tapping or hand drumming on their lower limbs), authority (knocking down the mouse, raising their voice), satisfaction (head nodding in agreement at correct or satisfactory answers) and dissatisfaction (hissing, grimacing at poor images). Student expressions include variations of nervousness (exhalation, moving uncomfortably in seats, looking at peers for help) and understanding (head nods).

embodied opposition to traditional cognitivist strategies when explaining where to look and what to see it as.

Despite making these claims that align with cognitive psychology, professionals also enact something rather different, using gestures that make such anatomic information and their recognition publically available (Goodwin, 1994). Additionally, it shows that this approach to knowledge representation and problem solving is too simple. It is true that a pattern is very useful in recognising normal anatomic structures; and a pattern is correlated with a memorised mental picture of the normal. But the pattern is enacted and validated through its performative unfolding – an unfolding that is as "central to human cognition as processes hidden inside the brain" (1994: 628). The gesture typically erasures the cognitive and perceptual uncertainties that these students are dealing with and is crucial to the understanding and intelligibility of the instruction. Thus, despite the evocation of a cognitive psychological approach to learning, the effects of gesture show how imaging professionals also partake in the physicality of an embodied conduct (Ivarsson, 2017). This is particularly effective when professionals perceive the anatomy as having some similarity with the real world or objective familiar to students in everyday life as we can see in the example above.

However, professionals may often go beyond the use of gesture and in pursuit of tactile information to build their pattern recognition of the normal and its variations. Acquiring knowledge through the tactile features of the world becomes a "process of articulating differences in the world", a process that occurs through bodily practice in a material milieu (Prentice, 2005: 841). In the example above, a radiographer, who is in fact interested in seeing the hamate, spoke up to describe this bone as a 'hook' and through the gesture in motion the hamate becomes visible and meaningful. This process is smooth and unproblematic, mainly because he asks the radiography students to *see* it *as* a hook (Wittgenstein, 1953). But what happens when professionals draw attention to unfamiliar features?

In the first week of x-ray image interpretation training, Mrs. Campbell discusses the significance of the trabecular pattern in MSK anatomy, noting that it is indicative of a preconception that the 'trabecular' transpires in the student's perception of the image in terms of its material and texture. Her embodied account is highlighted by an important factor that crucially enhances the potential of the learners' analysis of the trabecular: she provides a term that is interchangeable to a normal surface of a bone (*'smooth').*

Mrs. Campbell:	So, trabecular pattern. Has anybody heard of the word trabecular pattern?
Marco:	I heard it the other day.
Mrs. Campbell:	That's the word for today then, trabecular pattern [Gesture: both hands rub the air in a smooth manual action like a windscreen wiper]. Sometimes you can't see a fracture, but you can see disruption in the trabecular pattern [Highlighting 1: lasers the disrupted pattern on the radius bone]. So, you can see how *smooth* this is [Highlighting 1: lasers smooth pattern on the ulna bone]. So, but then you can see that it's *not* [Highlighting 1: lasers the disrupted pattern on the radius bone]. It's disrupted here [Highlighting 1: halts lasering], the trabecular pattern.

The word *'smooth'* has connotations more to do with learning the pattern through the hands and the tactile experience, than with the perceived value of representationalist positions of cognitivism. Mrs. Campbell's understanding of smoothness comes from translating knowledge of the anatomy's texture, which remains tacit, to her own body. The interaction clarifies that the normal texture of the anatomy on the surface of the bone has become familiar to Mrs. Campbell, allowing her to describe anatomy pedagogy in terms familiar to newcomers. In addition to the term, the crucial facts of comparison, and thus cross-referencing and differential viewing, inform her teaching: *'so you can see how smooth this is [Highlighting 1: lasers the smooth pattern on the ulna bone]. So, but then you can see that it's not [Highlighting 1: lasers the disrupted pattern on the radius bone]'*.

Comparison is commonplace in x-ray image interpretation training and in radiological practice more generally, as initially observed in the work of Pasveer (1989). An example of what comparison might consist of in educational settings and training in particular was provided by Prasad (2005: 296) when he stated that: "a comparison of the images on different planes (axial, sagittal, and coronal) can help in fixing the extent of deviation from what is known to constitute the normal and the pathological". The relevant upshot of Prasad's observation (for our purposes) is that the professional has achieved a closure on abnormality (following the successful completion of the radiography degree), which in part is due to the textural distinction between the smooth (*'so you can see how smooth this is [Highlighting 1: lasers the smooth pattern on the ulna bone]'*) and the disrupted trabecular pattern (*'It's disrupted here [Highlighting 1: lasers the disrupted pattern on the radius bone]'*). Nevertheless, the difference between the two-trabecular patterns as normal/abnormal persists during this description as *'smooth'*: even after her hands reach out to 'rub' the air for smoothness (*[Gesture: both hands rub the air in a smooth manual action like a windscreen wiper]).* Adopting a comparative method in this way can also be said to allow closer scrutiny of the trabecular pattern by professionals in the-making.

But where does this tactile experience come from? And how does it begin? To be able to explore possible differences between bones, and build a tactile gathering of texture, Mr. Harken's comment below sheds some light on the origin of this tactile experience:

> So, what we're going to do first of all is *picks up C1 and C2 model vertebrae from a collection of 3D model bones on the desk* I'm going to hand you the vertebra. So, it's one between three, because I've only got six *distributes models to three students* One, two three *distributes models to three students* One, two three. Just really see if you've got an eye, get a *feel* of what we're talking about. And also, we've got the full anatomy *picks up cervical spine* which you can kind of pass around *distributes the model spine to three students*, just get an appreciation and understanding by mainly laying your hands on the neck.

Supporting radiographic anatomic learning with a *'feel'* (and as we will see later: hand actions that 'pinch' and 'rub') does not constitute 'looking', feeling being translatable to subtly disciplining professionals in-the-making into embodied problem solving. Anatomic instruction then can involve textbooks images *external* to the self (Saunders, 2008), but also gesture and registering the body with some of the world and *internalising* it (Fountain, 2010; Prentice, 2013). Whilst the former is said to be explicit, the latter is considered tacit and implicit (Engel, 2008; Fountain, 2014).

In her study of how medical students train to become surgeons, Rachel Prentice (2004, 2013) notes that surgeons take this tacit level of anatomic learning for granted, particularly once it has been mastered. Whilst not compatible with approaches that draw their ethos from cognitivism, professionals' embodied practice can interactionally constitute (if only momentarily) different kinds of seeing and reasoning by engaging radiographers in-the-making to make meaning themselves out of normal anatomy, often on the basis of their own tactile inspection; for example, telling radiographers in-the-making, as claimed in Mr. Hearken's embodied account, to *'get a feel of what we're talking about'*. In this regard, pattern recognition is a "sensory means of knowing bodies" (Prentice, 2004: 10). This time, looking is not mainly driven by textbooks and prior knowledge of familiar patterns (for example, *'hook'*), it is rather the senses as such, in the subtle material cortex of the surface, which shout out 'pattern' to the informed student (for example, *'smooth'*).

Rather than being elaborated as a problem resulting in intertwined moments of sensory experiences alone (e.g. pinching, caressing, rubbing), such actions are communicated as part of 'looking at', since radiographers' daily connectedness to the body becomes a taken-for-granted aspect of the professional's habitus through years of practice (Berg, 1997); a connection that in some sense makes a radiographic anatomical area equivalent to the body and produces the view that the body is the foundation of perception (Merleau-Ponty, 1962). For instance, having anatomical and physiological skill (particularly of the bones/MSK system) is the *'bread and butter'* of radiographic work and *'this is what you'll be doing all day, every day, so you really need to know this.'*

This process, however, is neither straightforward nor easy. The radiograph is a particularly complex and ambiguous form of anatomical relationship: a two-dimensional image presented on a flat screen. This projection (from a single viewpoint) and orientation calls forth an analytically distinctive form of reasoning that engages in the coordination of not only hands and image but hands and material where a relationship to tactile experience is required to seek out the more obscured and subtle structures or features in the image. Radiographers and radiologists often identify the challenges of looking at subtle or obscured normal anatomic patterns. Mr. Hearken (WURD radiographer), for instance, asserts to radiographers in-the-making that *'you can't really see the PSIS (posterior superior iliac spine) on the x-ray because it's hidden round the back superimposed by everything else'*. Along with citing haptic evidence '*little knobs and bumps and fissures'* (Fountain, 2010) and how appreciating the three-dimensionality of the body and its two-dimensional projection is complicated (Prentice, 2013;

Fountain, 2014), Mr. Hearken encourages radiographers in-the-making to look at x-ray images in tandem with bodies (professional, student), materials (3D anatomic models), and images (radiographs, diagrams). Mr. Hearken suggests to *'go and learn your knobbly bits, because we don't go through bony anatomy again'* and *'it's something that, the pattern of normal, you'll develop over time'*.

This pedagogical advice given by Woodfleet radiographers is similarly expressed by Bridgestock radiologists, albeit without material anatomic models. One radiologist, Dr. Saury, often encouraged medical students in BRMR to *'get your eye in for what normal looks like',* in reference to textbook or PACS images. Coming to see normal patterns in x-ray images is thus actualised through cognitivist and individualist models of reasoning that is said to be based on research inspired by psychological theories (Eva, 2004; Linaker, 2015a; Kok et al., 2015, 2017). This often leads to professionals telling students explicitly, in different ways, '*what does the textbook say? What are the processes we're looking at? What are they called?*' (Mr. Hearken, WURD radiographer).

However, despite the emphasis on learning through textbooks, the 'looking' and the 'recognition' of anatomic patterns, a distinct difference between the two professions emerges when learning to see. This is leveraged in part to radiographers encouraging the use of material anatomic models to help sense the patterns of normal anatomic structures/features and at times erupt into an awareness of their own body.[109] Later in the chapter I will show how these tactile interactions come in handy in deepening a critical appreciation of normal radiographic information. More specifically, I argue how these interactions are useful in helping describe anatomy, spatially locating densely packed structures and features, and seeing hidden or obscured anatomies.

[109] Later in chapter six I will show how radiography students learn to tacitly place these features within one classification or another (person or thing) as part of learning technical and procedural knowledge of image production.

4.2 Professionals' concerns in x-ray image interpretation

This alignment with encouraging 'looking at' and 'pattern recognition', however, sits uncomfortably alongside three main concerns professionals have of x-ray image interpretation: (1) lack of knowledge of x-ray density and the radiographic factors affecting anatomical appearances; (2) missing subtle abnormalities or underreading the image (i.e. false negative errors); (3) x-ray images carry the risk of technical error and procedural limitations, such as body parts lying outside the area of interest and patient movement (rotation or breathing). Whilst the last concern is discussed in chapter six, the first two concerns are addressed in chapters four and five.

X-ray image interpretation in WURD provokes an array of concerns around the nature of radiographic anatomy and crises of not registering image content to the basics of x-ray physics and density scales. The view that anatomic knowledge was coupled with x-ray physics was succinctly captured by one of the radiographers at the beginning of an Application of Imaging (AoI) class:

Mr. Richards: So, what are the actual x-ray images? Now you've done a little bit of the Physics, you know a little bit. All they are is *reads PowerPoint slide titled: 'Silhouettes or densities which are a representation of the structures the x-ray beam has passed through'* so this leg *Picks up 3D anatomical model of leg* you have an imaging plate [Gesture: taps his stomach to enact the detector plate] at the back here and all that we've done is sent some x-rays through the bones [Gesture: LH moves in air to emulate x-ray beam source] and then we just capture them at the back [Gesture: LH hovers over stomach to enact the x-rays traveling through his body and detected on the plate]. How many of the x-rays have managed to penetrate and get through the bone? [Gesture: LH emulates x-ray beam passing through the bone]. So, the difference in the density is partly to do with how thick the bone is [Highlighting: LH points at knee joint] and the thicker the bone or tissue type will absorb more x-rays than something that's less dense, okay? So, like a bit of fat or a soft tissue isn't going to absorb x-rays in the same way, but it's *also* to do with the physical size [Highlighting: RH: caresses shaft of femur bone], okay? So, if you've been with an AP elbow image which you should now be able to, which we looked at yesterday, i'll pass around these arms *distributes some arms from the bone box*

Figure 7 'That little bone in the middle is actually really thin'

[*Using their computers, the students search for the AP radiograph of the elbow in PowerPoint*]

[*Mr. Richards sifts through box and hands out models to the class*]

Mr. Richards: It's just a really good illustration of this. I did tell someone this yesterday anyway. There's one arm

[*Mr. Richards gives one arm to a group of three students at the back of the class*]

Mr. Richards: Okay, so if you look at your AP elbows all of you. Now you can all see there's that black hole right in the centre? Yep? *Picks up 3D model elbow from bone box* So have you all picked up the black hole in your x-rays in the image? What it is, it's these dips here which are called 'Fossa's [Highlighting 1: LH pinches the coronoid/olecranon fossa on the 3D model elbow]. So all dips in bones have a fossa of one kind or another so those *two*, there's one at the front and one at the back are like to do with the movement of the arm [Gesture: Bends arm] but that means that little bone in the middle is actually really thin [Highlighting 1: LH rubs the coronoid/olecranon fossa on the 3D model elbow (Fig. 7)] and it's actually made of really dense bone so just because it's *black*

[Gesture: LH grabs imagined fossa in the air] it's still bone, okay? So, there's not actually a hole in there it's just the x-ray beam hasn't had to go through much tissue. Is that okay? So, don't assume something is black and white or it has to be a certain tissue type, it also has to do with the size, location.

[*Clicks to slide 2: 'Density and Contrast'*]

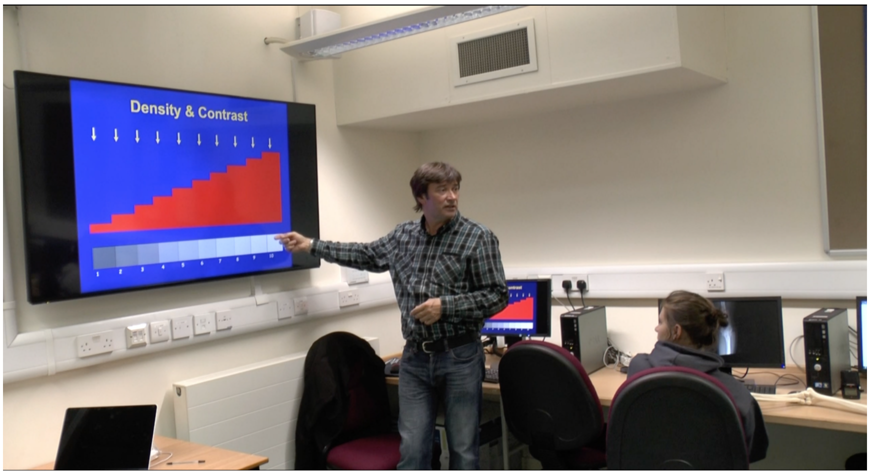

Figure 8 'If you look on here, it's basically saying you can either have something that's very thick or very dense it's going to absorb a lot of x-rays…so it's going to go white, okay?'

Mr. Richards: *So*, if you look on here [Highlighting 1: RH traces up and down a histogram of thick density] it's basically saying you can either have something that very thick or very dense it's gonna absorb a lot of x-rays so you're not going to get the x-ray through the imaging plate so there's going to be no signal, so it's gonna go white, okay? [Highlighting 1 and Coding: RH points at white colour 10 (Fig.8)]. On the other hand, if there's very little tissue to go through or very little absorption taking place [Gesture: fingers clasp together to enact absorption] it's gonna be black [Highlighting 1 and Coding: RH points at black colour 1], okay? But you could find that you got a big thick piece of muscle tissue [Gesture: both hands join together to emulate thick muscle tissue] that absorbs exactly the same *amount* as a thin piece of compact bone [Gesture: RH pinches the air to enact thin bone] so they can be both be given a bit of grey or something. Is that okay?

It is clear Mr. Richards's teaching leans towards scientific details of seeing but on an anatomical basis, informing radiography students about x-ray physics and density or thickness for understanding the appearance of radiographic anatomy. Mr. Richard's embodied gesture at the end of the extract explains one aspect of radiographic ambiguity in which there are two possible ways of seeing the anatomy as both tissue or bone (*'you could find that you've got a big thick piece of muscle tissue [Gesture: both hands join together to emulate thick muscle tissue] that absorbs exactly the same amount as a thin piece of compact bone'*). This, however, is supplemented with a warning that both bone and soft tissue anatomy can be collapsed into sameness *'so they can be both be given a bit of grey or something'*. The training resumes:

Figure 9 'If you can imagine this as being a cross section of the arm, well here, because there's one bone in it'

Mr. Richards: So what we have to assume as well, if you can imagine this as being a cross section[110] of the arm [Gesture and Graphic Representation 1:[111] LH cutting gesture at the distal end of the right arm] well here [Gesture and Graphic Representation 1: LH makes a slight adjustment and moves up to the proximal end of the humerus (Fig.9)] because there's one bone in it, so you've got your soft tissues here [Highlighting 1: RH circles the pink inside the oval] a little bit of air in there, a bit of bone

[110] A surface or shape exposed by making a straight cut through something

[111] **Remember:** Highlighting 1 and Graphic Representation 1 exhibit ***present*** phenomena whereas Highlighting 2 and Graphic Representation 2 exhibit ***non-present*** phenomena ('Transcription methods': Pages 119-120).

> then these [Highlighting 1 and Coding: LH points at the colour spectrum] are how we build up the shades of grey. So where the x-ray beams gone through the skin [Gesture and Graphic Representation 1: Enacting the x-ray beam, his RH touches the fourth arrow from the left and follows it down through the bone and finishes on the spectrum] a little bit of absorptions taken place through the soft tissues and muscle layers and you'll get like a grey colour [Coding: RH touches the grey colour]. On the other hand where its had to go through bone and its struggled to get through there's no signal so it's left white [Highlighting 1 and Coding: RH points at colour white on the spectrum], is that okay? It's a little bit more complex than that in practice because at the edges of the bone [Highlighting 1: RH points at the left side of the bone] the x-ray beam hasn't had to go through too much so actually the edges of this white [Highlighting 1: LH rubs the white] would really be a darker colour, a little bit grey, so this would vary between black and white. Is that alright?

Mr. Richard's example is further expressed by asking professionals in-the-making to *'imagine'* a cross-section of his right arm with the assistance of a diagrammatical visual representation (a cross-cut of the arm as diagram: Fig. 9). He then adjusts to give a more accurate representation of the bone in the diagram by emphasising *'well, here [Gesture: LH makes a slight adjustment and moves up to the proximal end of the humerus] cause there's one bone in it'* and claims that radiographers in-the-making will *'build up the shades of grey'* since the attenuation of x-rays passing through the assemblage of soft tissue, bone and air will result in the radiographic anatomy appearing in varying degrees of grey. He continues:

[*Mr. Richards clicks mouse cursor to change to next PowerPoint slide: '5 densities'*]

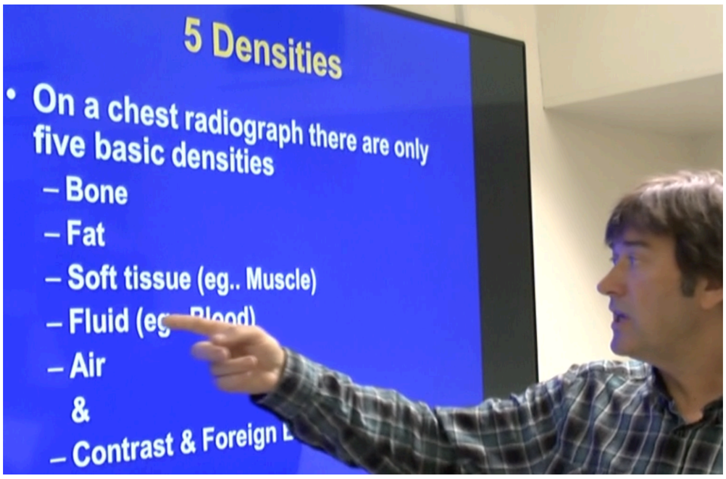

Figure 10 'Fluids, blood and things, are a dark grey'

Mr. Richards: So, having said that, these are the five basic densities, so bone is generally white [Highlighting 1 and Coding: RH points to 'Bone' text], unless it's on your elbows which is quite thin in which case it can be darker and um normally fat would be not quite as white so that will be light grey [Highlighting 1 and Coding: RH points to 'fat' text], so soft tissues would be a mid grey [Highlighting 1 and Coding: RH points at 'soft tissue' text], and then fluids, blood and things, are a dark grey [Highlighting 1 and Coding: RH points at 'fluid' text], and *air* is nearly almost black [Highlighting 1 and Coding: RH points at 'air' text]. So, you can quite safely say that if it's a true black on the image it is air. And it doesn't seem to matter how far an x-ray travels through air [Gesture: LH and RH reenact trajectory of x-ray beam] you can't stop it very easily, okay? Is that alright?

[*Mr. Richards presents the final PowerPoint slide that reads '**Look at** the images and compare them with the bones. Can you work out which part of the bones makes which **patterns** on the image?' and asks the students to start labeling radiographic anatomy using relevant anatomy from the bone box and online sources*]

Mr. Richards cites the *'five basic densities'* of x-rays accompanying each density with its anatomical or material (e.g. air or metal) appearance. Mr. Richards once more supports the differences in greyness as a means of seeing contrast between different anatomical structures, with him advising the students that *'bone is generally white [Highlighting 1 and Coding: RH points to 'Bone' text], unless its on your elbows which is quite thin in which case it can be darker'*, *'normally fat would be not quite as white so that will be light grey [Highlighting 1 and Coding: RH points to 'fat' text]'* and *'so soft tissues would be a mid grey [Highlighting 1 and Coding: RH points at 'soft tissue' text]*. At the end, Mr. Richards outlines the benefits of learning radiographic density for ensuring radiography students can *'work out which part of the bones makes which patterns on the image'.*

Both radiologists and radiographers suggested to their students that a naïve look at the image without taking into account density had the potential for misinterpretation. The perspective here, is that those looking at the image should not lose sight of image content that can be registered to density scales (Saunders, 2008), whereby image content is distinguished from low density material (such as air), very dense material (such as bone or metal) or middle dense material (such as soft tissues). In this training case, Mr. Richards, a Woodfleet Radiographer, is concerned with engaging a small class of radiography students in the basis of x-ray physics. As Mr. Richards identifies how the differences in x-ray attenuation can vary depending on the thickness and density of the bone, he attempts to help them understand it by engaging in a particular cognitive task: the graph indicates which parts of the anatomy are in varying degrees of grey. Not unlike the archeologists in Goodwin's study (1994), Mr. Richards's group has their own "historically constituted architecture of perception" that would enable the distinction of densities. In this process, they learn notions of the normal anatomies mediated by a coding framework of different techno-scientific categories of x-ray radiation but is made meaningful through a situated activity system that also encompasses talk, highlighting gesture, material artifacts (i.e. 3D model anatomy), and graphic information on Power Point slides. In this instance, Mr. Richards can be said to make use of three ways of seeing ('coding', 'highlighting', and the 'articulation of graphic representation')[112] to enhance his students understanding of x-ray physics, to see not only what is shown on the radiograph but also what would otherwise would be hidden because of inadequate attenuation.

[112] For a fuller discussion of these colours in contexts of interpretive practice, please see 'Transcription methods' in Chapter three.

It is my contention that it is only through an understanding of the density and production of x-ray images and methods of engaging in this practice that students can truly appreciate the distinction or boundaries between normal structures. I argue, that this practice of publically enacting the attenuation process and presenting its effect on his own body are grounds for founding a critical look at x-ray images. In addition, Mr. Richards's sequence of gesturing can be said to be a "reenactment" (Tutt and Hindmarsh, 2011) of image production and the attenuation of x-rays depending on the body part/structure. This acknowledges the situated nature of learning and exhibits the "social and cognitive organisation of a profession" (1994: 626) and even as a type of "cognitive apprenticeship" (Gegenfurtner et al., 2019: 282). This is exactly what Amann and Knor Cetina (1988: 164) mean when they say "image analysing talk" is "embedded and entrenched in procedural reconstructions, local experience and in the landscape of the data display". Moreover, these are examples of what Kendon (2004: 158) might call *pragmatic* gestures, a typology of gesture that not only allows us to examine how gestures contribute meaning to utterances (as a type of "semiotic interaction") but a type of gesture whose origin has a practical source and manual significance.

This reenactment of radiation physics, is similarly evoked by a medical radiologist who caresses his hand through the air towards his chest; a performance that invokes previous limitations of x-ray imaging investigations and practical knowledge of x-ray physics:

> The CXR radiology seminar begins. Dr. Delichon sits down in front of his workstation with PowerPoint loaded on one of his two computer screens. The Normal CXR is the first image on PowerPoint and also displays on the large VDU in the darkened room. Chloe and Toya sit down and without an introduction between them the training begins:

Dr. Delichon: So, anatomy. This is a normal chest x-ray.[113] We'll start basic, what's this thing here [Highlighting 1: hovers cursor over lucency], the lucent area not the-

Chloe: The oesophagus?

Dr. Delichon: *hisses* um, could be?

[113] The normal CXR is an important resource for the reader of this thesis (Appendix 14)

Toyah: Trachea?

Dr. Delichon: The trachea. Okay, so in x-rays, do you know how x-rays work on a physics level? Do you know how we create [Gesture: LH caresses the air downwards as if conjuring the x-ray beams] this picture?

Chloe: Is it kind of how much the tissue absorbs? [Gesture: RH fingers extend as if conjuring x-ray beam]

Dr. Delichon: Exactly

Toyah: Yeah

Dr. Delichon: Yeah, so how much it *attenuates*. So, the *more* x-rays that are absorbed by the body [Gesture: both hands grasp the space towards him as if drawing in the x-ray source], the whiter the area is [Gesture: Both hands open as if to release the beams]. The more x-rays that hit the detector plate [Highlighting 1: floats cursor in an area under the left armpit on the detector plate], the blacker it is. So *here* all the x-rays are hitting the back of the plate [Highlighting 1: floats cursor on the detector plate] is black, um here on the bone [Highlighting 1: rests cursor on the left rib cage] less, which is why it's white. So, any *lucent* areas are full of air [Highlighting 1: floats cursor in the lucent space between ribs in the right lung] and any really white areas are bone or tissue [Highlighting 1: places cursor in the white-grey area near the right rib cage], okay? So, the oesophagus could if you've got big air down the oesophagus you're quite right you can get um a lucent area [Highlighting 1: hovers cursor over the trachea].

Dr. Delichon: *More* likely here it's the trachea

Chloe: Mhm

Dr. Delichon: It's very symmetrical. Nice straight lines, it doesn't dilate out [Gesture: both hands open to enact imagined size increase] like the oesophagus would do.

In this exchange, Chloe claims the cursor-highlighted anatomy in question is '*the oesophagus?*' and in doing so answers Dr. Delichon's question with another question. However, Dr. Delichon's hissing effect of his mouth is an audible response to Chloe's answer - a sibilant sound that works to suggest that Chloe's answer about the lucency is imprecise. Dr. Delichon's fusion of hissing (**hisses**) and non-committal response ('*could be?*') directed towards the medical student suggests the professional is not in agreement or satisfied with the interpretation: this allows Toyah to grasp that there may be a margin of error in Chloe's response. Consequently, Toyah ascribes the lucency to the *'trachea?'*[114] which is agreed upon by the radiologist, however, it is not clear whether Toyah knows *why* it is the trachea and *not* the oesophagus as both are median structures in front of the thoracic vertebrae. Chloe's imprecise answer and Toyah's guesswork is enough to convince Dr. Delichon that his students have not taken into account the basic principles of x-ray physics as part of making anatomies *seeable* (particularly radiation exposure effecting the appearance of radiographic anatomy). Hence, the radiologist's question *'so, in x-rays, do you know how x-rays work on a physics level?'* constitutes a key step towards preparing medical students as to the ambiguity of radiographs, but also how the fundamentals of x-ray physics (i.e. how it '*attenuates'* providing differential contrast) in image production overlap into image interpretation.

Like the radiographer in the previous extract, the radiologist attempts to acknowledge the five basic radiographic densities in the image – specifically, that of air, fat, soft tissue, bone, and metal and how the trachea is more likely to be seen because it carries air, which attenuates less radiation - for these reasons it appears black or *'lucent'*. [115] The success of seeing the lucent area as the trachea and knowing why it is not likely to be the oesophagus is paralleled by an understanding of x-ray physics: that tissue absorption or *attenuation* is dependent on tissue thickness and density, and how anatomic structures *attenuate* to produce the radiograph. In other words, the trachea is more likely to be seen because it is structurally wider than the oesophagus and located nearer to the x-ray source - for these reasons the trachea absorbs *more* radiation.[116] However, seeing this distinction cannot be explained by just 'looking'.

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[114] Windpipe.

[115] Disclaimer: It *is* possible to see the oesophagus in 'some' radiographs and it is likely to be visible to the trained eye by appearing darker than the trachea allows (because less x-rays are attenuated). However, the idea of *seeing* the oesophagus problematises the image – specifically of poor patient positioning and raises concerns about vertebrae fractures or displacement of spinous processes.

[116] Disclaimer: It *is* possible to see the oesophagus in 'some' radiographs and is likely to be visible to the trained eye by appearing darker than the trachea allowing (because less x-rays are attenuated). However, the idea of *seeing* the oesophagus problematises the image – specifically of poor patient positioning and raises concerns about vertebrae fractures or displacement of spinous processes.

To help explain this, the radiologist engages with the cursor to highlight (Goodwin, 1994) the transmission of the x-ray beam through the patient and its eventual location (*'hitting the back of the plate'*). Cursor highlighting also serves to acknowledge how physiological density is commonly associated with shades of grey/white whereas its absence is represented by the colour black and captured by the term *lucency* (*'any lucent areas are full of air'*). Highlighting the image content in this way helps in the disciplining of making anatomy *seeable* while, at the same time, helping to *see* anatomy. This strategy to "correct" their vision through highlighting practice sets up a narrative that makes sense of anatomical appearances as visual evidence, working within both cognitive and semiotic aspects of "detection"[117] that develops professional competence (Saunders, 2008: 157). It is as Amann and Knorr Cetina (1988: 133) say, "a slice in the process of fact construction", a conception that is now a hallmark of STS research on imaging and visualisation (Beaulieu, 2002; Joyce 2005, 2008; Roepstorff, 2009).

In the previous example, radiographic density was discussed in some detail to stress how the absorbtion of x-rays between the body's structures allowed the creation of contrast or shadows seen on x-ray images, basically classifying it to the provision of five different types of x-ray density. However, Mr. Richards's (WURD Radiographer) comment on how x-ray images produce *'silhouettes or densities'* points to another problem for those learning to interpret x-ray images. Although the entire culture of radiographers and radiologists was structured around the *'silhouettes or densities'* of x-ray images (Pasveer, 1989; Kevles, 1997), an ambiguity between silhouettes or densities of normal appearances, and silhouettes or densities that took on the form of optical illusions suggested that further caution needed to be taken when it came to x-ray image interpretation. The latter, for instance, has long been mistaken for real disease and resulted in misinterpretation (Buckle et al., 2013). This concern over optical illusion was first raised in the Introduction to Image Interpretation lecture. The optical illusions being discussed below are examples of the 'Mach Band' optical illusion displayed on PowerPoint via a large electric screen (without great loss of detail from the light of the windows):

[117] Or the 'poetics of detection' as Saunders (2008: 142) calls it.

[PowerPoint slide text: *'What can you see (C)? The role of optical illusion*]

Mrs. Campbell: So, what do you see? Do you see a fracture? Or *don't* you see a fracture? Sometimes you look at something and you go [Gesture: RH raises and looks at the open palm as if looking at an x-ray image] *inhales quickly in shock* 'there's a fracture there!' [Gesture: LH points at the conjured image] And then you look at it *squints her eyes* [Gesture: head moves closer to her RH] and you go 'actually, I'm not quite sure?' [Gesture: head moves back and look at the image suspiciously].

Mrs. Campbell opens with an explicit invitation to the students: *'Do you see a fracture or don't you see a fracture?'.* This initial claim, stating that the radiograph can render such ambiguity is followed by a dramatical act of perceptual uncertainty: *'there's a fracture there!' [Gesture: LH points at the conjured image] And then you look at it *squints her eyes* [Gesture: head moves closer to her RH] and you go 'actually, I'm not quite sure?' [Gesture: head moves back and look at the image suspiciously]*. She then explains that this ambiguity, inquiring into the appearance of the bone, has something to do with mach bands and optical illusions via a range of multimodal semiotic means including gesture, gaze, talk, facial expressions and the visual elements of the setting. Amongst this, she raises the point: *'that's part of mach bands'*, including how to see the mach band: *'if you look at it and then look at a different part of it there appears to be grey circles in the middle *looks quizzically at the students* But that's an optical illusion. They're not there'*. This engagement has the potential for generating insights regarding the relationship between density difference and borders of objects. She continues:

[Presses button on keyboard to transition to a slide titled: '*Mach bands and Optical illusions*']

Figure 11 'But that's an optical illusion'

Mrs. Campbell: So, let's have a little bit of a laugh. So, we're looking at mach bands. We'll probably talk about these in imaging science. So, if you look at that *square* *looks up at the slide* and you can see the black squares inside the big white square, okay? If you look at it and then look at a different part of it there appears to be grey circles in the middle *looks quizzically at the students* But that's an optical illusion [Fig.11]. They're not there. And that's part of mach bands. It's an optical illusion.

This situation of seeing, engages the radiographers in-the-making – and specifically understanding by multimodal and embodied conduct, including gesture – in the course of inviting awareness to a particular optical illusion (*'so we're looking at mach bands'*). In the example above, the radiographer shows a white square full of smaller black squares with accompanying text that explains the presence of 'grey spots' between the corners of each black square. This 'depiction practice' (Streeck, 2009) narrowly constraints what recipients expect to see via talk, facial expressions and the textual and visual elements of the setting; an ongoing accomplishment of situated social action (Garfinkel, 1967). Most importantly, however, this was all in preparation for setting up a pedagogical game of optical illusion:

[Presses button on keyboard to transition to a slide titled: '*Mach band*']

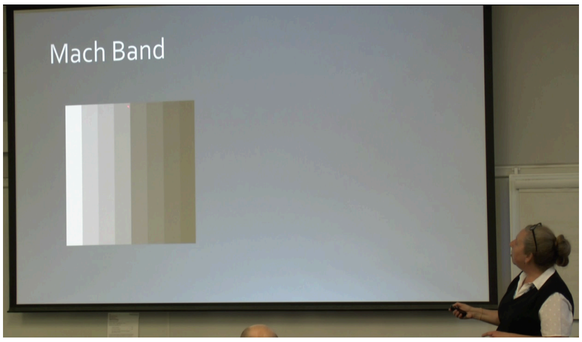

Figure 12 '…or darker on this side [Highlighting 1: Lasers the right side of the 4th band in from the left]'

Mrs. Campbell: So looking at this one *looks at slide*, would you say that they are bands-of-solid-colour [Gesture: RH pinches the air and moves her hand across horizontally as if to depict the mach band on the slide] or would you say they're like a *gradient* [Gesture: RH pinch shape turns to a flat hand that moves across horizontally smoothing or caressing the air] from [*Pauses to pick up laser pen*]. So like this one here, would you say it's darker on this side [Highlighting 1: Lasers the left side of the 4th band in fromt the left] or darker on this side [Highlighting 1: Lasers the right side of the 4th band in from the left: (Fig. 12)] or the same?

Class: Sss-aaa-mm-e *nervous smiles* [Together]

Mrs. Campbell: The same * looks suspiciously at the class*. Some people might think [Gesture: LH and RH sporadically wave through the air as if to enact confusion] it's the same, some people might say it's different.

[Presses button on keyboard to produce a second type of mach band]

Mrs. Campbell: The bands are actually *all* identical, but because they're next to a lighter band [Gesture: both hands emphasise the term lighter band] or a darker band [Gesture: both hands emphasise the term darker band]. The actual *vision*[118] [Gesture: both hands move from her eyes as if depicting some

[118] Again, it's worth noting that the term 'vision' is again used in extension of her head.

externalized retina], the optical illusion is that sometimes it's not quite the same. And of course, we're all looking at various shades of grey.

Like in the previously discussed excerpt, Mrs. Campbell this time invites students themselves to partake in the interpretive work and learning activity by coordinating the movements of her gestures with what is to be seen on the Mach Band (*'would you say that they are bands-of-solid-colour [Gesture: RH pinches the air and moves her hand across horizontally as if to depict the mach band on the slide] or would you say they're like a gradient [Gesture: RH pinch shape turns to a flat hand that moves across horizontally smoothing or caressing the air]*'. Similar to Goodwin's (1994: 614) 'articulation of graphic representation' whereby the archeologists use talk and discursive gestures to demonstrate a "change in slope" in map making, a gestural representation of the bands of gray as a *'gradient'* allows the radiography students to make inferences about the location of illusion. Seeing optical illusions on a band of gray and to be sure of what is being *seen* requires tactical manoeuvre of hand, body, and eyes including the interplay between computational tools, movements of the laser pointer and diagrammatic features on screen (in stock scientific form). However, a pause follows during which Mrs. Campbell uses a laser pointer to make sure the students see what she is referring to by highlighting both left and right sides of the same band for closer attention (*'so like this one here, would you say it's darker on this side [Highlighting 1: Lasers the left side of the 4th band in from the left] or darker on this side [Highlighting 1: Lasers the right side of the 4th band in from the left] or the same?'*).

The radiography students unanimous response (*'Sss-aaa-mm-e *nervous smiles* [Together]')* suggests that they were aware that this was a trick – awareness generated through subtle hints of talk *'a bit of a laugh'* and the warnings of the previous example (e.g. through facial expressions: **looks quizzically at the students**; and through talk *'It's an optical illusion').* In their response, the students did not fall for the trick and gave the right answer – to the uninitiated, both sides of the band looked like different shades of grey, but they were in fact the same grey of the band. Despite giving the 'right' or 'expected' answer, a closer analysis of the students protracted answer and facial expressions – as nervous smiles – suggests they answered in such a way as to convince the teacher that they were genuine and this was the answer that the teacher expected or *ordered*. From my interpretation, it is possible that the students are participating in some form of 'face work' in order to protect themselves due to their inadequacies (Goffman, 1959, 1967). According to Goffman (1959) such a tactic can 'save one's face' by which a person sustains an impression for others to avoid being disgraced or humiliated due to an actor's bad performance. This amounts to Mrs. Campbell repeating their answer albeit with a suspicious gaze and then carrying on without questioning them further (*'the same *looks suspiciously at the class*. Some people might think…'*); a move of "tactful inattention" to avoid embarrassing the first-year radiography students in the first week of their degree (Goffman, 1959: 147).

Nevertheless, Mrs. Campbell's embodied multimodal interaction warns students about the Mach band by teaching them how to see the illusion, suggesting that optical illusions can also be analysed as a social process or performance in action, rather than a perceptual system at work in the mind's eye (Goodwin, 1994; Ivarsson, 2017). When I observed these games, Mrs. Campbell was intent on a complex exercise of optical illusion: attempting to introduce awareness to the fallibility of the mind and the potential for misinterpretation. I interpret this teaching practice as fostering suspicion towards x-ray images – a form of visual resistance to being steered wrong by the ontological ambiguity of x-ray images.[119] She continues:

> [*PowerPoint slide text: 'These optical illusions are largely just a bit of fun. The Mach bands are relevant to plain film radiography because of the potential to produce the illusion of an enhanced/accentuated interface between two structures'*]
>
> It's how your *brain* [Gesture: hands touch head] perceives this. So what we're saying is radiographs *reads from slide* 'because of the potential to produce the illusion of an *enhanced* simulated interface between two structures', so if you're looking at two different shades of gray [Gesture: LH and RH are placed on top of each other to enact a false interface], then these optical illusions you may see things that are actually not there or you might miss things that are there. So, we're not infallible. But that's just to give you an idea that you *will* look at something and you *will* [Pause] I do it. I only work in a little department and I'll put something

[119] There were three examples of optical illusions in total - (1) Mach band illusion (exaggerates the contrast between edges of different shades of grey); (2) The Jesus Illusion (known as 'afterimages' or 'ghost images'), and (3) Anomalous Motion illusion (part of a figure appears to move in a different direction than the rest).

through and I'll go 'oh, look at that!' and someone will go 'no, I can't see that', and then we'll look closer, zoom in [Gesture: RH pushes the air to enact zoom function] *squints*, and go 'oh, actually, it's nothing', and vice versa.

Mrs. Campbell reveals her concern towards optical illusions since *'you may see things that are actually not there or you might miss things that are there'*. If professionals in-the-making do not acknowledge how shades of grey (reflecting the various densities) on the image create the illusion of disease, Mrs. Campbell cautions those undertaking x-ray image interpretation as they could fall prey to *'optical illusions'*. This aspect of optical illusion (i.e. the Mach Band) is a "fictional illusion", leading to both false-positive and false-negative findings in x-ray image interpretation. For example, the mach band may cause someone to see disease when it is absent ('false-positive') or it may cause someone to not see disease when in fact it is present ('false negative') (Buckle et al., 2013). In her study on how learning to produce, see and say the (ab)normal, Sandell (2010: 44) highlights how ultrasound midwives appreciated feedback from false negatives "as a way of learning what needed to be better observed" where such feedback "builds general awareness of what midwives at the clinic might miss, or should look out for". In addition, teaching optical illusions are associated with a process the radiographer calls *'just a little bit of fun'.* Her testimony is both game and pedagogical device: a theatrical means of easing the risk of optical illusion so as not to scare newcomers and propel them away from the profession at an early stage.

The lack of knowledge of radiographic anatomy and density/various shades of grey in the interpretation of x-ray images raises an important pedagogical concern. However, professionals are driven and concerned by a more common problem - how x-ray image interpretation, in their view, can miss abnormalities. Because of this, I focus on this concern throughout much of chapter four. Concerns over missing abnormality among professionals, relating to determining image content during, and/or after medical image interpretation training have been recognised in previous studies (Hartswood et al., 2002; Måseide, 2007; Joyce, 2005, 2008; Dussauge, 2008; Saunders, 2008, 2009; Sandell, 2010; Rystedt et al., 2011; Prentice, 2013; Fountain, 2014; Friedrich, 2010, 2015). Joyce (2008) argues that popular narratives about medical image interpretation say that professionals have access to transparent knowledge about the body and that is understood as eliminating the uncertainty of disease and providing increased visibility of anatomical details. However, this is challenged by Joyce on the premise that professionals' embodied practice demonstrates how each image is not transparent, but instead always raises "interpretation troubles" which are made visible in discursive work when problems such as "underdiagnosis" arise – a term used to describe situations in which the professional interprets the image as 'normal' but others see disease (Joyce, 2005: 449). Similarly, Ivarsson (2017: 18) shows how radiologists in his study reported "troubles of perception and understanding" in determining the location of pulmonary nodules (a growth in the lung which is possibly malignant) in the vagaries of tomosynthesis images. In Woodfleet and Bridgestock, basic x-ray image interpretation is often framed as what Mr. Hearken (WURD radiographer), among others, refers to as the ability to *'spot things and see where things are abnormal, that is the first stage'*:

> Spotting things are abnormal is the most important thing, flagging it up is the most important thing. It's only then with experience and training and knowledge you can start to link what it looks like with what it is. So that's what you need to concentrate on is just being able to know what's normal and spotting things and what it is will come after.
>
> **(Mr. Hearken, WURD Radiographer)**

Mr. Hearken's pedagogical advice is focused on the task of *'spotting things [that] are abnormal'* but of utmost importance is the act of *'flagging it up',* although the fusing of identification and its terminology, such as the abnormality's classification comes with *'experience and training and knowledge'.* Together with Mr. Hearken highlighting how the most important aspect of interpretive practice requires knowing normal anatomy and spotting abnormality (*'being able to know what's normal and spotting things'*), Dr. Delichon (BHRD radiologist) similarly associates the spotting of abnormalities, by asking medical students *'any quick abnormalities you can see?'*, with a focus on *'spot diagnosis'* (*'again, quick spot diagnosis';' *raises voice* this one, spot diagnosis'*). This room for a quick 'spot diagnosis' is where detection takes precedence and arguably highlights the workload and growing demand for MSK images placed on radiology departments (*'generally speaking there is a massive increase in the number of diagnostic exams'*), time pressures (*'there is a legal requirement for images to be reported in a timely fashion'*), and staff shortages (*'there is a massive radiologist shortage, far bigger than a* *radiographer shortage'*)[120]. The following extract highlights this urgency to spot abnormality in greater detail:

> I've just got to kind of prepare you in terms of really *spotting* an abnormal finding early on, because you guys as presumably as junior doctors might be the first and only people to look at the film for quite a while until the radiologist gets round to reporting it, because they'll be busy with the acute CTs, the acute intervention, you know, vascular intervention, that kind of thing, and get round to the plain films maybe a bit later on, and you've got the patient in front of you; if you've got an acutely deteriorating patient in front of you and someone says 'oh, here's the chest X-ray!' you know, it's nice for you to know what to spot and what not to spot ...
>
> **(Dr. Maxwell, BHRD radiologist)**

In this account, Dr. Maxwell typifies medical students as junior doctors. Dr. Maxwell sees medical students as qualified practitioners, who perform medical duties, more specifically, as contributors to the radiological workforce in the hospital. This observation builds on work in medical sociology that demonstrates how professionals in medicine perceive and shape medical students as qualified to intervene in clinical matters (Becker et al., [1961] 1992). Medical students must grapple with the professional responsibility of being seen as a doctor as part of their socialisation into the medical 'system' (Fox, 1988: 96). Dr. Maxwell perceives the medical students as junior doctors and allocates them the role of spotting abnormalities in CXRs across the hospital, mainly *'on the ward'* or *'in A&E'* whereby they interact with patients of varying chest/lung concerns.

According to radiologists and radiographers, however, criticism can be directed to professionals in-the-making who accept CXRs uncritically on account of it being a 'map' of x-rays that illuminate the body on the inside and make anatomical structures visible.[121] They charge professionals in-the-making with not engaging with normal radiographic anatomy and their limited knowledge of radiographic practice, x-ray image production particularly, without understanding how different parts of the body attenuate x-rays (i.e. not understanding density/various shades of gray and having to make a decision on whether something is

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[120] Mr. Hearken

[121] Through variable attenuation (absorbed or scattered).

normal/abnormal). Nonetheless, for professionals, x-ray image interpretation training is about *'being able to know what's normal'* and so, in turn, *'spotting things [that] are abnormal'* (Mr. Hearken, WURD radiographer), and constitutes knowledge of x-ray image production where *'it's important to see how x-rays are taken'* and *'if you've been down to B floor and actually seen some in practice which is really good … because it helps you visualise what's happening when you look in an x-ray'* (Dr. Delichon, BHRD radiographer). By identifying x-ray image interpretation as being based on normal radiographic anatomy, radiologists and radiographers explicitly endorse its learning as a comforting familiarity that underpins a critical perception of radiographs and the ability to detect or spot abnormal findings. In doing so they are effectively learning the first stage of Preliminary Clinical Evaluation or PCE with regards to learning normal appearances, (SoR, 2013). The second step of learning *'what it is'* as Mr. Hearken mentioons above will be discussed in chapter five.

4.3 'Systematic approach' in teaching practice

In this chapter, I have identified one main concern professionals have in regard to x-ray image interpretation and I have also shown how professionals conform to ways of teaching that align with cognitivist notions of looking at and pattern recognition in order to build (and contest) the proper perception of the normal. Professionals prescribe such rhetoric as the route to a cognitive stance on visual perception and expertise (Gegenfurtner et al., 2017; 2019). Saunders (2008) describes how radiologists remain grounded in a cognitive substrate of detection to emphasise the role of detective logic when delivering case presentations, with Kok et al., (2015: 191) suggesting this type of cognitive work is a type of "analytic reasoning" referring to a "systematic deliberation of abnormalities and their relationship to potential diagnoses". In her study on how midwives learn to see routine ultrasounds, Sandell (2010: 38) highlights the importance of the systematic approach: first, it emphasises the importance of following a "structure" when learning to see, and second it ensures that midwives produced all the required images so "that they do not miss anything". This is delivered explicitly in the pedagogical exchange below between Dr. Delichon (BHRD radiologist) and two medical students (Toyah and Chloe) during a CXR image interpretation class. It is an excerpt that is typical of how professionals demonstrate their alignment to the rhetoric of a cognitivist model of learning (looking at, pattern recognition) in the form of a systematic approach:

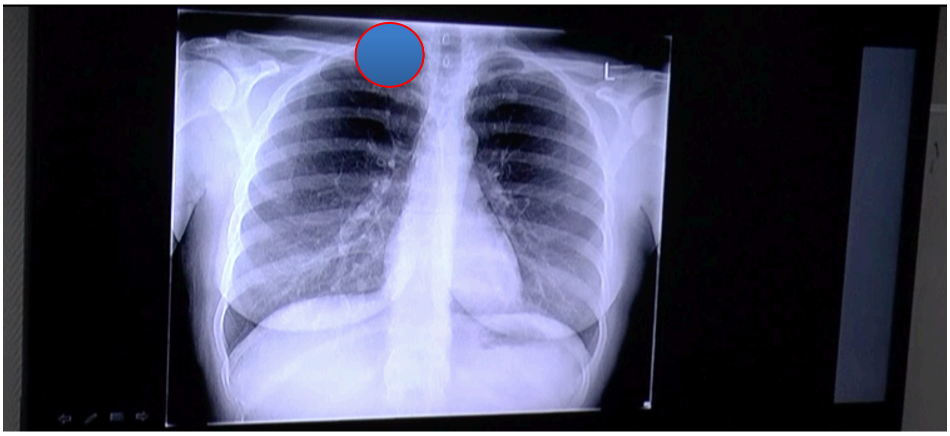

Figure 13 Dr. Delichion using the mouse cursor as a tool to highlight the left apices (highlighted)

Dr. Delichon: So there's loads of different ways to look at x-ray's there's the A, B, C, D, E one where you can start at the top and work down [Gesture: LH slices down through air], start in the middle and work out [Gesture: both hands gently clap and open outwards]. Whichever structure you want to use, that's fine. Develop one now and just keep following it every time you *look at* a chest x-ray. So I start at the top, check the trachea, make sure it's central [Highlighting 1: cursor traces trachea], then I look at the hila [Highlighting 1: cursor traces the left and right hila forming a 'D' shape], then I make sure the mediastinum [Highlighting 1: cursor traces mediastinum] and the heart look normal [Highlighting 1: cursor traces around the heart]. Then I follow out and check the diaphragm [Highlighting 1: cursor highlights left and right hemidiaphragm], then, I look at the lungs themselves [Highlighting 1: cursor highlights the left and right lung pleura]. Make sure you look in the apices because this is quite a congested area with loads of bones overlying it [Highlighting 1: cursor circles the left and right apices (Fig. 13)]. Then look behind the heart [Highlighting 1: cursor circles over the middle of the heart], then I look at all bones [Highlighting 1: cursor traces ribs] and soft tissues [Highlighting 1: cursor traces tissue]. Again look at the breast tissues [Highlighting 1: cursor traces left and right breasts] cause you can often see asymmetry, or absence which can show you previous mastectomy and if you've got a lump in the lung [Graphic Representation 2: cursor circles in lung as if drawing in a lump associated with breast cancer] from a previous mastectomy then you'd probably be worried about metastatic disease so it's

> all things like that you need to look at. One of the first things you should also look at that I forgot to tell you is *lines*, so any metal work, lines so any surgical clips in the auxila [Graphic Representation 2: cursor circles in axilla as if drawing in some surgical clips] any PICC lines that come in or Hickman lines you should always comment on those [Graphic representation 2: cursor moves across the axila as if drawing in PICC/Hickman lines].

Dr. Delichon endorses the idea that the CXR has a particular order for inspection and recommends the A, B, C, D, E mnemonic[122] as a simple, yet comprehensive approach to chest x-ray interpretation. Whilst he does not go into any detail about this approach that guides a complete inspection of the image – at this stage in their training medical students and other non-radiologists are expected to have learnt the A, B, C, D, E approach (Puddy and Hill, 2007) – he offers a distinct alternative means through which the CXR can be assessed. This type of structured systematic (step-by-step) approach to CXR image interpretation is included in much of the educational literature to develop a routine that ensures all areas on the image are scrutinised and to prevent the missing of abnormalities (Delrue et al., 2011; Kok et al., 2015).

However, it is also increasingly clear that deploying the systematic approach for the image is contingent on 'personal knowledge' (Polanyi, 1958) of specific anatomical areas that provided insight about such idiosyncrasies, which he uses to inform perceptual management of the image. The radiologist in this activity above delivers his own focused and deliberate practice emphasising an aspect of formal knowledge that he's changed to suit his own preference in practice. This provides insight into his own idiosyncrasy and a deeply intense personal knowledge, but also 'orderly' in the sense that his exhibited idiosyncrasy can usually be explained (Amann and Knorr Cetina, 1988). In addition, much like the radiologists in Måseide's (2007: 201) study, the decision to use this type of systematic approach is further bolstered by the professional domain where the method (one of many) is a specialty specific "expert system" that has been developed by radiologists to "regulate the problem solving activities" of interpreting x-rays. Nonetheless, in this activity system, Dr. Delichon warns the

[122] A is for 'airways' representing the trachea; B is for breathing representing the lungs and moving out towards the pleural spaces.

medical students about the possibilities of missing further information, by creating a recognisable motion with the mouse cursor that matches the location to a known material element – surgical clips.

His technique of representation depicts the presence of surgical clips (*'any surgical clips in the axilla [Graphic Representation: cursor circles in axilla as if drawing in some surgical clips]'*) and PICC lines/Hickman lines (*'any PICC lines that come in or Hickman lines you should always comment on those [Graphic Representation: cursor moves across the axila as if drawing in PICC/Hickman lines]'*). Interestingly, the acts of graphic representation do not simply generate explicit forms of representation (i.e. lump, surgical clips, lines), but concerns an ability that makes present phenomena of interest that are otherwise absent in the image. This chimes with the idea that people can generate a "synoptic presentation" (Latour, 1986) or "synoptic view" (Myers, 2007) by bringing forth ideas from personal experience accumulated in other places and times. In this thesis, I argue that this interactional enactment and powerful representation of radiological practice deserves attention: they stand in as "proxies" for otherwise absent or missing things, a finding that also plays an important pedagogical role in training student crystallographers (Myers, 2007; 2015). After completing his own personal knowledge of a systematic approach. Dr. Delichon continues:

> And then you always have review areas, which will develop over time. You'll learn the bits that you always forgot to look at or all the things where you missed. So my review areas are: the hila [Highlighting 1: cursor circles left and right hila] because you always miss things in there, always look behind the heart [Highlighting 1: cursor traces heart], behind the diaphragm [Highlighting 1: cursor traces diaphragm], and then up into the apices again [Highlighting 1: cursor traces apices]. So, they're the places that I have a second look and make sure. Yeah bones, you often see parts of bones missing with a big malignant disease [Highlighting 1: cursor traces the left and right humeral head]

Dr. Delichon claims *'you always have review areas which will develop over time'* and *'you'll learn the bits that you always forgot to look at or all the things where you missed'* (presumably meaning that medical students at this stage in their training are prone to forgetfulness, the cost of which is being at risk of missing a structure entirely or deem it not pathological). What is at stake in this forgetfulness is a thorough detection of findings or more broadly, the way in which detection is driven by a critical study of x-ray images. This echoes previous concerns about the "under-reading" of the image (where the abnormality is missed) and is a common source of error in reading CXRs (Berbaum et al., 1990; Renfrew et al., 1992; Delrue et al., 2011; Kim and Mansfield, 2014; Kok et al., 2015; Brady et al., 2012; Brady, 2017). What might be termed as *'review areas'* have been identified and constituted by relations of radiological errors "past, present and future" (Berlin, 2014) – relations that allow for forms of organised visual practices, that facilitate the development of a comprehensive visual search, and that scrutinize particular areas of common error. For the likes of Saunders (2008: 71) this slip of forgetfulness recalls the radiologist who catches him or herself early in launching the "wrong script" where "momentarily she forgot she was dictating a CT instead of an MRI".

Again, it is clear that Dr. Delichon is showing his own personal preference in review areas but one in which the term *'behind'* becomes increasingly important and distinguishes itself from the previous systematic approach. This is emphasised in Dr. Delichon's preference for looking *'behind'* the anatomy in two anatomical areas made publically available by highlighting practice (Goodwin, 1994): (*'always look **behind** the heart [Highlighting 1: cursor traces heart], **behind** the diaphragm [Highlighting 1: cursor traces diaphragm]'*). Dr. Delichon's extract at the end of the account stresses the practice of the review areas, *'they're the places that I have a second look and make sure.'* However, he supplements this with a warning that goes beyond the observation of internal organs and towards a scrutiny of bones that assists in seeing *'big malignant diseases'*. The training resumes:

Toyah:	Do you comment on whether it's adequate penetration and rotation and things?
Dr. Delichon:	So, you should do when you're being assessed? The correct way to do it is say: 'this is a PA chest radiograph of a female taken, whenever it is, whatever her name is- rotation if it's adequate in regards to seeing all the lung fields. Rotation, how do you assess for rotation? Do you know?
Toyah:	*Exhales in frustration and leans forward as if in discomfort* I can't remember. I think it's something to do with the spinous processes? [Gesture:

RH pinches the air and draws imaginary line downwards] like if they're symmetrical or even [Gesture: both hands open space] on both sides or something?

Toyah seeks advice by asking Dr. Delichon whether she needs to comment on *'adequate penetration and rotation and things'*. In doing so, she draws attention back into the technical considerations and once more highlights the technical risks of image production (under/overpenetration and patient rotation). Dr. Delichon, who attempts to become technically immersed in the image emphasises that *'rotation'* must be *'adequate in regards to seeing all the lung fields'*. He then asks Toyah *'how do you assess for rotation?'* in an effort to facilitate reflection on a specific analytic technique and to inform confidence in the examination of phenomena. Toyah's response: **exhales in frustration and leans forward as if in discomfort* 'I can't remember. I think it's something to do with the spinous processes? [Gesture: RH pinches the air and draws imaginary line downwards like if they're symmetrical or even [Gesture: both hands open space] on both sides or something?'* demonstrates once again forgetfulness and evident hesitancy of her own procedure. Coinciding with her talk, Toyah's gesturing hands detail her working attempt to recall the schema set out by previous professionals and possess a type of 'exploratory procedure' (Kirsh, 1995) which are performed for the purposes of gathering information. The training continues:

Dr. Delichon: Yeah. So, you look to see if the spinous processes are aligned straight down the middle. The other thing to look at is the ends of the clavicles [Highlighting 1: cursor highlights the clavicles] and the manubrium [Highlighting 1: cursor circles the manubrium] because you can often see that they're slightly rotated [Gesture: both hands enacts the way a patient would look rotated by having his left hand in front of his right hand] and not in – so you can compare the space in the spinous process [Highlighting 1: cursor rests midpoint between T1-T2 spinous processes] to where the clavicles are [Highlighting 1: cursor rests on medial end of clavicles]') and you can often see rotation [Gesture: both hands enact the way a patient would look rotated by having his left hand in front of his right hand and moves them back and forth (Fig.14)] and that affects the size of the heart or the mediastinum. So, rotation is an important thing to comment on. If you can see all the lungs that's an important thing because often in sick patients they'll be slumped over [Gesture: slumps head over his right shoulder to enact sick patient (Fig. 15)] and you can't see the apex because of their chin. *Penetration* isn't much of an issue with electronic PACS, because you can window and change what you're seeing by changing the window. So penetration is less of an issue. But if it looks really, really white everywhere, it's probably underpenetrated. So, yeah, it's a really important thing to comment on, but I wouldn't get too hung up on that.

Figure 14 Dr. Delichon reenacting the way a patient would look rotated by having his RH in front of his LH and moving them back and forth

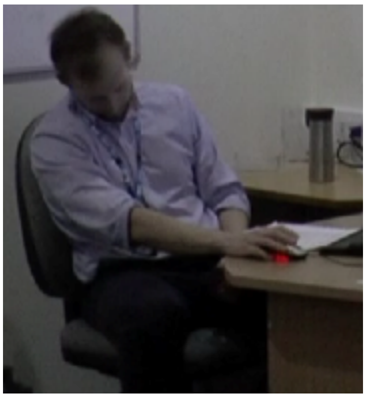

Figure 15 Dr. Delichon slumping like an ill patient

Dr. Delichon agrees with Toyah and gives further specificity of detail to the generality of measuring the spinous processes *'so you look to see if the spinous processes are aligned straight down the middle'*. Dr. Delichon once more emphasises the manual or cognitive aspects of reasoning by comparing and assessing the details of anatomic rotation with the use of a landmark for measurement (*'compare the space in the spinous process [Highlighting 1: cursor rests midpoint between T1-T2 spinous processes] to where the clavicles are [Highlighting 1: cursor rests on medial end of clavicles]'*). Expanding upon his answer about rotation, Dr. Delichon performs two types of patient rotation that make anatomic perception a technique of the body: (1) '*you can often see rotation [Gesture: both hands enact the way a patient would look rotated by having his left hand in front of his right hand and moves them back and forth (Fig.14)] and that affects the size of the heart or the mediastinum*', and (2) *'often in sick patients* *they'll be slumped over [Gesture: slumps head to his right to enact sick patient (Fig. 15)] and you can't see the apex because of their chin'*. Once the radiologist has finished his systematic run through, he invites the group of students to participate in a hot seat activity with emphasis on applying the systematic approach to cases of common pathology, as is demonstrated later in chapter five. After the hot seat activity, the radiologist outlines the benefits of a systematic approach for ensuring they *'pick out the big things, so consolidations, infections, pneumothoraces remember to pick out [Gesture: LH list construction]'*.

There are many acts of persuasion and testimony taking place here between radiologist and medical students. Dr. Delichon's ambition is to rigorously enrol his students in problem-solving by embedding them in a systematic method that is central to their cognitive organisation of seeing (Goodwin, 1994; Saunders, 2008; Linaker, 2012; Gegenfurtner et al., 2017). This action reflects a trend I identified in other teaching sessions at BHRD and WURD. In hot-seat training activities, professionals often deployed systematic approaches to help accomplish a comprehensive viewing of the image so that nothing important was missed (Sandell, 2010). However, Dr. Delichon often participates in the process of 'seeing as' with broad references to how the normal anatomy is expected to look normally *or* if deviated or diseased (Vertesi, 2016). Different possibilities or alternatives of the ambiguous image are often accomplished when Dr. Delichon performs his primary objective of communicating the representational and rhetorical economy of looking at/pattern recognition and expected normal appearance of various features.

This matter of 'seeing as' is founded on patterns of the normal and is something that must be reached and experienced before one is able to talk about and entertain the possibility of abnormality and its classification (Saunders, 2008). In doing so, the systematic approach doubles up as another type of coding practice: not only does it provide structure in order to scrutinise different areas of the body it also, simultaneously organises the perceptual field in a process of classification. For example, he may transform the anatomy into ideal types of what the anatomy *is* (*'the other thing to look at is the ends of the clavicles [Highlighting: cursor highlights the clavicles]'*) or what the anatomy is expected to look like (*'then I look at the hila [Highlighting 1: cursor traces the left and right hila forming a **'D'** shape]'*). In both cases the aim of Dr. Delichon is to indexically align the anatomy to the mouse cursor which renders visible the anatomical structure; his discursive practice is indexical, an indicator of what the anatomy is, or can resonate widely into different categories of normal to meet the demands of anatomy training (Prentice, 2013).

This is similar to Woodfleet, in which x-ray image interpretation is primarily founded on boundaries of normal radiographic information. Radiographers often provide the same (cognitively-based) discursive practice for x-ray image interpretation training during hot seating: they say normal radiographic anatomy can be learned by looking at patterns/normal images, how seeing abnormality is connected to deviations of normal anatomy, how misunderstanding these can result in interpretive errors/risks, and how systematically coding the image for normal patterns can help structure their perception and avoid errors/risks. In doing so, professionals in-the-making can avoid missing abnormalities or forgetting search patterns in future interpretive practice. Such methods allow professionals in-the-making to take comfort in the principle of knowing normal and conveys advice of general import: “make friends with the normal” (Saunders, 2008: 33); in his book Saunders (2008: 33), citing a classic textbook on the fundamentals of radiology refers to the close relation that needs to be built with normal anatomy: “you will find that you build your idea of the expected normal appearance of various structures in various ways…you compare what you see with what you know about normal anatomy. You compare a problem film with one you know to be normal”.

Despite the stability of a structured systematic approach, the practical reasoning of interpretive practice, shaped by the practical realities of radiological risks/errors, delivers a pedagogical approach that is in contrast to the professionals’ cognitivist principles. In the academic setting, my analysis of professionals does not “sublimate bodily knowledge under the visual and cognitivist label of ‘mental model’ (Prentice, 2013: 176). Indeed, the teaching of systematic practice does not simply amount to human cognitive activity, since most advice has the embodied force of prior tactile experience and seeing is mediated by tools and artifacts (such as the mouse cursor and systematic approach). Put simply, professionals’ methods of looking at and pattern recognition – embodied and situated vis-à-vis a complex perceptual field of an analytical visual system an expert uses including the self, other human agents and non-human mediators (Gibson, 1977; Goodwin, 1994; Gegenfurtner et al., 2017) – are very likely to organise knowledge, shape perception and cognition in order to discipline a specific “sight style” (Friedrich, 2010) for problem-solving activities (Måseide, 2007; Saunders, 2008).

This highlights how x-ray image interpretation training is accomplished in the embodied multimodal interactions, cognitive artifacts, and discursive practices of the academic setting. No wonder, perhaps, that I am pointing to how this is made possible within forms of talk and embodied conduct with learning to see as a socially situated activity and seeing as an example of distributed labour (Goodwin, 1994; Måseide, 2007; van Baalen, 2019). Just as relying on explicit knowledge leads to a seemingly 'know-what' or 'systematic knowledge' (Smith, 2001), x-ray image interpretation training is in turn something that professionals *do* with their body, as opposed to something which is looked at only with the eyes shared through print or other formal means (Måseide, 2007; Saunders, 2008; Ivarsson, 2017; Gegenfurtner et al., 2019). This scale of focus takes us to the microlevel of inter-subjectivity and *process*: x-ray image interpretation training is a fact-based and stabilising enterprise, involving the body, multimodal semiotic interactions, (re)enactments, gesture, and non-human mediators such as tools and artifacts. Yet, it is also a practice shared and distributed through the ontological ambiguity of x-ray images, which embodies suspicious and sceptical perspectives that reach towards a critically examining gaze. Since professional vision is enacted and reenacted during embodied conduct, what we regard as 'systematic' is never a stable channel of experience nor a disembodied activity; instead it is always situated in some context and subjected to a variety of common wobbles, uncertainties, or errors some of which are demonstrated so that expected misunderstandings become discursively unmasked for the benefit of learners, anything but a straightforward cognitive task. As Joyce (2005: 449) notes, radiological seeing can be understood with reference either to professionals' objective appraisals of patterns, or to technical practices and political demands of its local context. But, as she reminds us, "the always-occuring interpretive work … is made visible in discursive practices when problems arise".

Rather than focusing on how looking at, pattern recognition, five x-ray densities and systematic approaches are accomplished in teaching practice, I elucidate how these rhetorics of testimony work together to found a critical faculty of perception which in its reflexive act takes account of the cognitive and perceptual uncertainties of everyone else. The rhetorics of looking at, pattern recognition, five x-ray densities, and systematic approach enact and reenact x-ray image interpretation training as a 'critical' component of seeing. In addition, professionals endorse these facets of discourse and deploy them as invaluable pedagogical modes to enact different possibilities for *seeing as* (Vertesi, 2016). Professionals in-the-making are disciplined into skilled, cognitively rich actors who, provided with cognitive artifacts (including 5 x-ray densities and systematic approach) in the classroom setting, are able to shape their own actions but also of their future colleagues and successors (Goodwin, 1994). They are situated and resituated in disciplining discursive practices of seeing and reasoning (Ivarsson, 2017), which sooner or later organises a critical faculty for perception. In their embodied conduct, the professionals discussed above are active in enacting and reenacting an experienced tacit knowledge to professionals in-the-making that represents a social relationship characterised by personal intimacy and intense entanglement with normal radiographic anatomy and procedural implications of image production (supplemented by scientific knowledge of x-ray physics). This is true particularly for radiographers in-the-making, who need to consider their imprint upon the overall composition of the radiograph.[123] Once positioned as active problem-solvers, professionals in-the-making are advised to use a systematic approach and to close the gap between their knowledge of radiographic anatomy and x-ray image production.

4.4 Primary views and secondary views: expecting abnormality

In this chapter I have described how professionals enable different ‘seeing as’ practices and how the ensuing systematic ordering of interpretive work to professionals in-the-making means professionals accomplish critical attention and scrutiny of radiographs. Most of the examples, however, relate to BHRD. In WURD, x-ray image interpretation training also generates a critical approach to radiographs that begins with specific types of radiographic views or projections[124] and the views constraints on seeing. This becomes a critical factor in interpretive practice, purposefully selected to draw attention to views that offer the opportunity to scrutinise common injury sites and reenact mechanisms of injury. Here, radiographic views draw attention to key views, namely a standard view (taken as the primary view) and second view (taken as the alternative view). The standard view and the second view are available in both WURD and BHRD.

[123] And further on down the line, the future diagnosis.

[124] The terms ‘view’ and ‘projection’ are used interchangeably by professionals.

However, standard views and secondary views are mostly presented in WURD, since, as radiographers involved in MSK image production, each view is a matter of the professional's positioning of the patient and imaging technique that offers a different perspective and a deeper scrutiny of the anatomic area of interest.[125] Secondary views presented using normal images have the purpose of excavation; they are associated with enhancing the clarity of anatomic structures/features and are essential in confirming trauma/disease/dislocation (hidden in the detail of shadows). During video recording and away from the 'front-stage' (Goffman, 1959) of the hospital, radiographers often stress to professionals in-the-making, regardless of the body part being imaged (e.g. shoulder, arms, hands), that a standard view is not sufficient to make a diagnosis. For example, in a shoulder x-ray image interpretation class, Mr. Hearken (WURD radiographer) describes his experience of the limitations of having a single standard view for seeing patients with suspected arthritis:

Mr. Hearken:	Typically, the standard projection for trauma would be the standard AP [Highlighting 1: lasers AP radiograph] and some sort of secondary view, so it's the 'Y view' or the 'Axial view', which we'll look at in a minute. The thing about this is when you're doing an AP shoulder, when we're looking for, in terms of trauma, we're looking at the clavicle [Highlighting 2: Lasers expectant clavicle fracture], we're looking at the scapula [Highlighting 2: Lasers expectant scapula fracture], we're looking at the humerus [Highlighting 2: Lasers expectant humerus fracture]. If we were looking for arthritis, what's the *problem* with this projection?
Daniel:	You can't really see the joint space.
Mr. Hearken:	You can't really see the joint space. We've already said that *this* is not a clear projection of joint space, because we can't actually see through it.

[125] Secondary images are primarily associated with MSK imaging, whereas chest radiography is primarily associated with one view (PA). However, when a PA view is difficult to achieve, the AP becomes the standard. This is usually done in emergency imaging conditions when the patient is unable to stand erect. This will be discussed later in chapter 6. Additionally, it should be noted that BHRD medical students are not formally trained in MSK-specific image interpretation. Rather, the radiology rotation focuses primarily on CXR and AXR images.

Although Mr. Hearken associates the *'AP shoulder'* as the *'standard protocol for trauma for shoulder [the standard radiograph]'*, he suggests the AP view is problematic when *'looking for arthritis'.* He attributes this to the *'projection'* element of radiographic imaging, that is the expectation among radiographers that the AP view for assessing the shoulder is designed to obtain a picture of abnormality 'in terms of trauma' and looking only at bones (clavicle, scapula, humerus). According to Mr. Hearken, this becomes a *'problem',* however, when professionals and students are looking for arthritis because the AP shoulder radiograph *'is not a clear projection of joint space, because we can't actually see through it'*. Similarly, Mrs. Campbell (WURD radiographer) establishes a comparison between standard views and secondary views; *'and this one, now you can see them next to each other, you can see the the joint space [Highlighting 1: Lasers joint space on secondary image] very clearly there, so if there's any osteoarthritis there or anything like that then you can see it much more clearly than you would be able to on this one, yeah? [Highlighting 1: Lasers standard shoulder image]'*. Mrs. Campbell further highlights the usefulness of secondary views, since professionals see them exclusively as opportunities to allow closer scrutiny of images by students and help confirm a speculative diagnosis.

Dr. Delichon (BHRD radiologist), similarly brought medical students to a closer scrutiny of a key anatomical area of the chest by comparing a standard view (CXR) of the chest with a secondary view of the chest (Lateral CXR):

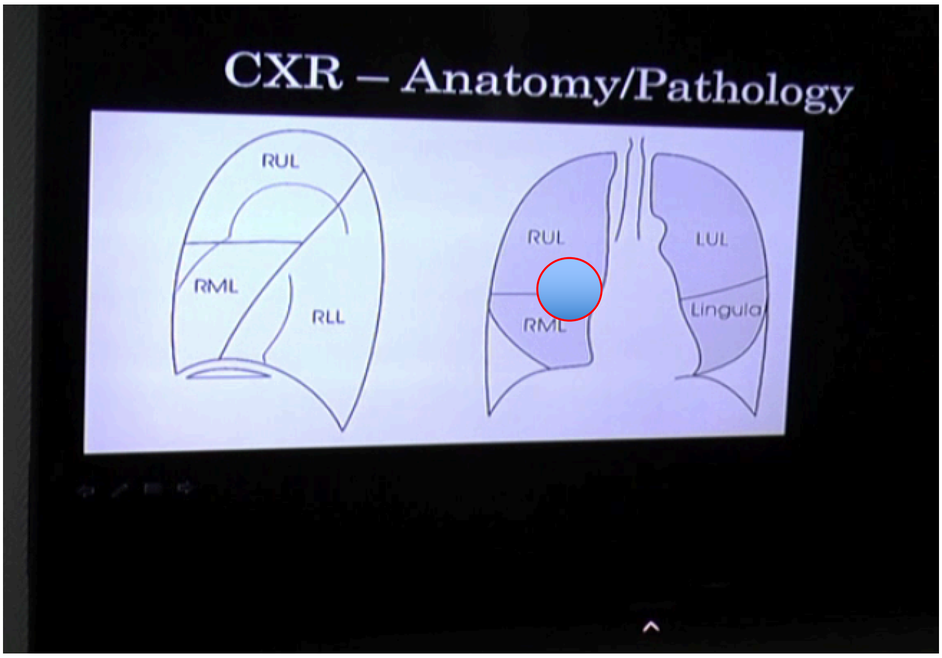

Figure 16 Dr. Delichon using both Lateral CXR (Left) and PA CXR (middle) diagrams.

Dr. Delichon: You may see lateral chest x-rays, but they're not as *commonly* used anymore because we use CT a lot more. But that just shows how far behind the diaphragm the lower lobe goes [Highlighting 1: on lateral CXR cursor hovers over RLL]. So it's really important to try and look behind the diaphragm and actually how superior it goes [Highlighting 1: on PA CXR cursor hovers over highest point of RLL] so sometimes you can see a mass here [Highlighting 2: cursor hovers across the PA between RUL and RML to indicate expectant abnormality (Fig. 16)] and you don't know if it's in the middle lobe [Highlighting 2: cursor hovers over RML to indicate expectant abnormality], the upper lobe [Highlighting 2: cursor hovers over expectant abnormality on PA in RUL], or the lower lobe [Highlighting 2: cursor hovers over expectant abnormality on PA in lower lobe] because it can be anywhere around here [Highlighting 2: on lateral CXR cursor hovers over midpoint of RUL/RML/RLL] so that's why we don't tend to use 'zones'.

Dr. Delichon suggests standard and secondary views – in the form of PA and Lateral diagrams – are seen by professionals as pedagogical opportunities to show *'how far behind the diaphragm the lower lobe goes [Highlighting 1: cursor hovers over lateral CXR at lowest point of*

RLL]'. Despite explicit reference that lateral CXRs are not *'commonly used anymore'*, Lateral images are a good means of establishing a mode of attentiveness to hidden or obscured anatomical areas in which abnormality may eventually intrude.[126] They are learning a diagnostic gaze "not blithely neutral but suspicious, on guard" (Saunders, 2008: 35).

In this instance, the diagram of the secondary view allows the radiologist to remind students that the right lung actually has three lobes (the Right Lower Lobe is *not* visible in the standard CXR); as a teaching point this reminds them to*: 'try and look behind the diaphragm and actually how superior it goes [Highlighting 1: on PA CXR cursor hovers over highest point of RLL] so sometimes you can see a mass here [Highlighting 2: cursor hovers across the PA between RUL and RML to indicate expectant abnormality (Fig. 16)] and you don't know if it's in the middle lobe [Highlighting 2: cursor hovers over RML to indicate expectant abnormality], the upper lobe [Highlighting 2: cursor hovers over expectant abnormality on PA in RUL], or the lower lobe [Highlighting 2: cursor hovers over expectant abnormality on PA in lower lobe]'.* Normal radiographs are so entrenched in abnormal expectation that professionals are able to centre this upon the perceiver, opting to invite students to become alert to the area through the discursive act, by showing a circular motion that overlaps with talk and location. It is an atypical method in that what is highlighted is not the outline of a present object, but a *location* – the location where abnormality is likely to dwell. We must take into account that highlighting gestures are not always achieved with real objects or objects that 'are not really there' (Ivarsson, 2017). In this sense, I draw attention to extending Goodwin's (1994) conceptual apparatus of highlighting which comprises a way of showing and 'seeing what is not there' (*'so sometimes you can see a mass here [Highlighting 2: cursor hovers across the PA between RUL and RML to indicate expectant abnormality (Fig. 16)]'*).

Here, as elsewhere, normal radiographs boast a deep expectation of abnormal and go hand in hand with specific radiographic views/areas of interest. Mr. Hearken claims via email that an

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[126] Whilst a 'Lateral chest view' is talked about as a secondary view, they are currently receding as lateral chest views are more difficult to obtain in practice (i.e. anatomy can be 'cut off'). CTs are increasingly being turned to in order to make up for the potential to miss anatomical areas of interest. Lateral views and the high exposure factors that provide radiation to them are also part of this advancing move towards CT, a topic I return to later in the thesis.

association of radiographic views with abnormal anatomy increases the opportunities for radiographers in-the-making to *'know where they are likely to see abnormalities'*. Even though Mr. Hearken maintains this has a relatively high impact on the efficiency of actually identifying abnormal anatomy, he warns that this is likely to prejudice observations as radiographers in-the-making may *'forget to look for the unexpected/atypical'*. Such uneasiness with expectancy makes it advisable for students to be rigorous in observations, which become *'techniques of satisfaction of search and systematic approach'*, translated as reducing the risk of the viewer's bias towards anatomic regions so that *'we review the entire image.'*

Mr. Hearken's concern extends to both standard views and secondary views together with normal radiographs for x-ray image interpretation. During an MSK image interpretation summary lecture (for OSCE exam preparation), Mr. Hearken (WURD radiographer) claims:

> Review the image, go through it, try not to be *biased*. It's very hard as radiographers, because we've x-rayed the patient, to review it with a clear mind. How many of you have seen a patient, or read a request card, imaged the patient, and have *predicted* what you're going to expect to see, before you even looked at the image? 'That's gonna be normal, there's nothing wrong with it'. Yeah? It *biases* your mind and you're expecting not to see anything, so your mind will think there's nothing there. Once you've looked at it once, well then go back, yeah, and review it again with the clinical information: Where does it hurt? What was the injury? What are the symptoms? So, once you've reviewed it with an open mind you can then go back and review it again with the extra information and all the information that is there for us.

Mr. Hearken warns how x-ray image interpretation can be influenced in the clinical setting, suggesting to students that clinical information *'biases your mind'*. His concerns are shared by other professionals, who caution against having a consensual reliance on clinical information, especially of the imaging request card. The other aspect of students and inexperienced viewers relying on request cards that affect what is seen in images may influence other problems to be overlooked, as they are likely to forget to look for the unexpected/atypical. This cognitive bias is otherwise known as "framing bias", when the observer is unduly influenced by how a case is framed (Lee et al., 2013; Brady, 2017). Reviewing the image with a systematic approach for constraining the bias in seeing is quoted as being the solution to stop this from happening. Mr. Hearken subtly refers to this when advising that students should '*review the image, go through it'.* Much like Mr. Hearken, Mrs. Campbell (WURD radiographer) warns students against relying on the imaging request card, although this is for imprecise information, where it *says 'x-ray right ankle'*, and *'you call the patient from the waiting room 'okay, can you just tell me which ankle hurts? 'This one [Gesture: points to the left ankle].'* Mr. Hearken goes a step further by referring to medical doctors, who, when clinically assessing people, *'might request the wrong image, for example, they might request a hand instead of a wrist',* since *'doctors are not gods, they make mistakes when they're clinically assessing people'*. Thus, the radiographer will, inadvertently, *'miss a fracture because it was on the edge of the film'*.

Similarly, via email, Mr. Hearken suggests radiographs *'in an exam/uni situation',* are assumed by radiographers in-the-making to be 'abnormal' in particular since they *'might be more expectant to see an abnormal compared to a normal*.' In BHRD, Dr. Maxwell (BHRD radiologist) suggests normal radiographs are often contentious and problematic, because, in the case of medical students, *'most people make something up and say something in the right hila region, but there isn't, it's a normal chest x-ray'*. Thus, as well as affording opportunities to control and systematise their observations, exams also allow students (and arguably professionals) increased opportunities to foster expectations of finding abnormalities. Fears among radiography students about imposing abnormality on radiographs when images are normal have been identified (Winter and Linehan, 2014). Despite this, normal images have long been recognised to structure the "expectant sensorium" (Saunders, 2008), with techno-scientific and anatomical expectations interwoven into image interpretation (Saunders, 2008), not least in informing practices of seeing with expectations of normal anatomy and the subsequent "imagining" of abnormality (Saunders, 2008: 230).

I believe there is a potential clash or collision between the novice paradigm as a desired event for abnormality and its workplace context as an unstable event that is somewhat inconsistent with abnormality, and therefore crucial for discerning the 'real' from the 'imagined'. Real/imaginative radiograph boundaries can be strengthened, usually by a 'systematic approach' that helps "discern and stabilise" the objects of imaging investigation (Daston, 2008: 98). I shall give further details about this systematic power of scrutiny over radiographic anatomy in chapter five ('constituting x-ray image interpretation and radiological error in the academic setting').

At Bridgestock and Woodfleet, whilst the true intention behind the professionals' use of normal radiographs can be understood as training radiographic anatomy and good/bad patient positioning, they also explicitly reflect biomedical expectations for sites that are presumed to signal suspicions of abnormality. In guiding professionals in-the-making, professionals play their part in constructing normal radiographs, first and foremost, as a visual and attentive opportunity to recognise particular patterns of normal radiographic anatomy; and yet, through professionals' performance, such forms of knowing can build the "fundamental biomedical assumption that disease is located in the biological body" (Prentice, 2013: 4).

Normal radiographs reinforce the normal as a kind of buttress, but can point to its opposite. In other words, the expression of normal, often through the important role of patterns, can go on to see abnormal anatomy – a durable transition made present in the image through the process of seeing as (Vertesi, 2016). This supports the idea that physicians have a "prior sense of what they would uncover, a 'mental map' of the interior of the body, before actually conducting each action" (Cohn, 2009: 95) and complements the accumulative process of the usual cognitivist representationalist mind-set (e.g. van der Gijp et al., 2014). This delivery of medical assumptions with the abnormal is accomplished in two ways: 1) normal radiographs help teach a 'common place' of fracture/pathology or displacement; 2) normal radiographs offer a chance to reenact mechanisms of injury. This prompts me to say how a radiographic image is not limited to its implications for what is seen as a "real mode" (*modus realis*) of visual information, but also involve expectations in which the discrepancies between 'mental images' and 'reality' interconnect. Since my focus is mainly on MSK radiographs, for the remainder of this chapter I mostly cite extracts taken from WURD video footage of professional and student radiographers.

4.5 A common place

The experienced and expectant implications of interpreting medical images have been identified in previous research. Studies of radiological pedagogy claim that training gives a prior sense of seeing how the anatomy "should be" (Cohn, 2009: 102), helps expectations appear as figments of the imagination which over time guide efforts to see (Polanyi, 1958), has the benefit of providing the viewer with quick visual information to suit the demands of hectic workplace environments (Burri, 2012), makes training seem more 'real' in the absence of 'hands-on' real-life clinical experience (Jaffe and Lynch, 1995; Holt, 2001; Pinto et al., 2011), and is part of the radiological gaze that is not always confident: "it is expectant, searching, somewhat anxious, reassured by friends (the normal, the nameable), alert to confusions between findings and artifacts" (Saunders, 2008: 90). Radiography students can experience these emotions, with expectation and scrutiny often sitting uncomfortably alongside unwanted imagination and lack of confidence during interpretive practice (Winter and Linehan, 2014).

At Bridgestock and Woodfleet, normal radiographs are constructed as useful pedagogic opportunities for expecting abnormal. This point is illustrated by citing the transcription of video footage taken during a normal spine radiograph performed by Mr. Hearken (WURD radiographer), in which the C7-T1 anatomy (an intervertebral disc), located at the very bottom of the neck, is of paramount interest:

Mr. Hearken: We can count from the top down. As we've already said this is cervical vertebra number one, two, three, four, five, six, *seven* [Highlighting 1: cursor rests on each vertebra]. Just about see the top of T1 [Highlighting 1: cursor rests on T1 vertebra]. *So* as in terms of the area of interest we need to ensure we incorporate and include the *entire* cervical spine, and that will normally include, or it *should* include the superior surface of T1 [Gesture: caresses T1 in the air]. Why is that important?

Geoff: Because it's articulating with C7

Mr. Hearken: It is articulating with C7. Yeah. So that means if we can see C1 we're certain, we're *sure* we've got all the cervical vertebra on. You might not know, but what is it about when you go across from one junction of the spine to another? So, from cervical to thoracic, thoracic to lumbar, lumbar to sacral. What happens to the shape of the spine at each of the levels? [Gesture: LH lies oblique in the air to enact an angle suggesting a change in direction]

Geoff: It changes.

Mr. Hearken: It changes direction [Gesture: LH lies oblique in the air to enact angle]. And wherever you get a change in direction there's an inherent weakness, if there's any change in direction of the spine [Gesture: oblique in the air to enact angle] it will always be *weaker*. So, we're thinking about *trauma* in particular, one of the key places or the key areas where you're *likely* to get an injury is at the place where it changes direction, which is C7-T1. So, if we don't include T1 we can't be certain there's not an injury there. *Similarly* in terms of things like osteoarthritis, where is the most weight bearing [Gesture: both hands lie flat and hold imaginary weight] portion of the cervical spine?

[*Silence: no answer*]

Mr. Hearken: C7-T1. It's taking the most *weight*. So, in terms of pathology C7-T1 is also another *common place* to get pathology. So, as a rule when we do the lateral C-spine we always want to include T1. Why is that difficult? Sometimes.

Class together: 'Shoulders'

Mr. Hearken: When someone walks through the door like this [Gesture: waddles forward with shoulder lifted up to his ears and hands by his side emulating a thickset rugby player], big rugby player or a builder – lots of *stereotype* of course – but immediately your heart sinks, because you try to get T1 and you might only get T3 or T4. But sometimes the patient body *habitus* and the way someone is *built* can make it very, very difficult to *get* that C7-T1 junction. So, we have certain techniques and other views we can *do*, which we'll talk about a bit more later on.

Following the observation of the normal cervical vertebra (spine) having seven vertebrae, Mr. Hearken describes to Geoff, alongside other radiography students who have attended the class, how radiographers in-the-making *'should include the superior surface of T1'*, how a change in each junction of the spine *'will always be weaker'*, and how the C7-71 is where *'we're thinking about trauma in particular'*, and how it's *'one of the key places or the key areas where you're likely to get an injury'*. Whilst Mr. Hearken's initial participation in cursor work is attributed to making salient condensed anatomy (Mr. Hearken counts each vertebra *with 'this* *is cervical vertebra number one, two, three, four, five, six, seven'* and highlights each vertebrae *'Highlighting 1: cursor moves down each vertebra each time its number is uttered),* it additionally exhibits how areas of interest, used specifically for galvanizing suspicion to key structures/features, can be organised to what Mr. Hearken refers to as a 'common place' for trauma/pathology.

Later in the lesson, Mr. Hearken draws attention to a specific soft tissue structure in the head and neck (retropharyngeal space). After highlighting the slender location of the retropharyngeal space on the normal radiograph, Mr. Hearken advises the students that *'we're looking for any evidence of swelling* [*Gesture: LH strokes air in association with 'swelling'*] *or increased thickness* [*Gesture: LH strokes air in association with 'thickness'*]*'*. Whilst describing retropharyngeal swelling,[127] Mr. Hearken simultaneously grips the absent abnormality of the soft tissue structures in space, according to its size, to constitute a central feature that summons a common abnormality of the (lateral) cervical spine radiograph in the minds of students.

Here, digital media (PowerPoint) and the physical body are utilised as practical tools in building scrutiny, with highlighting/gesture of normal anatomy into abnormal anatomy (albeit *expectant*) informing a critical visual resource of knowledge and perception. In the expectation of the abnormal, anatomic areas can be constructed as a common place, a productive and artful method where students can build suspicion towards key anatomical areas. This visual and artful treatment of anatomy is one way in which the novice and inexperienced can practice *seeing as* and where expectations make up an economy of one's serial attentions. In BHRD, the normal CXR invites a similar alignment of ritual attention. The video still and transcription below is taken from the closing interactions of a normal CXR between Dr. Saury (BHRD radiologist) and a group of three medical students (Year 4):

[127] Mr. Hearken is likely referring to a 'retropharyngeal abscess', which is usually caused by a bacterial infection.

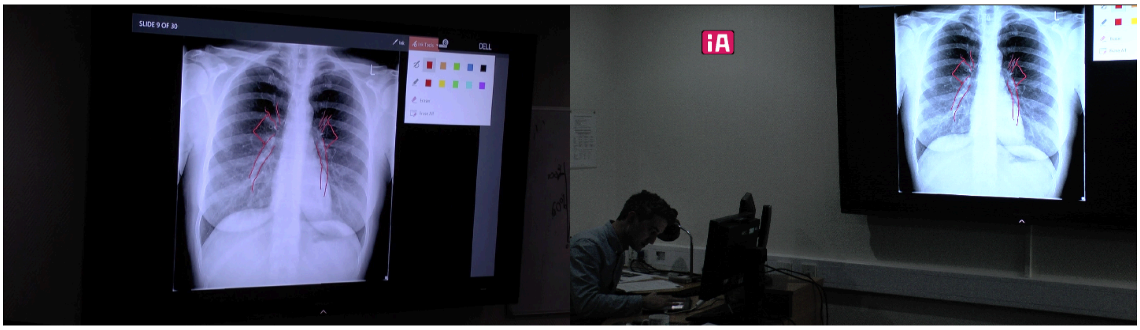

Figure 17 Dr. Saury (via an Android tablet) drawing over the hila on a normal CXR

That's what the hilum *should* look like, okay. *Notice*, you should [Highlighting 1 / Graphic Representation 1: draws diamond between the LLL pulmonary artery and UL vessels (Fig. 14)] have a *fairly* nice lucent diamond in here [Highlighting 1/ Graphic Representation 1: draws diamond between the RLL pulmonary artery and UL vessels (Fig. 17)] where there are fairly few vessels, okay, so that's what a *normal* hilum looks like. Basically everything you see there should be a vessel, a tubular structure, so if you see a tubular structure on its *side* it's a line, if you see it coming towards you, it's a dot, okay, so often you'll see some dots, we got some dots here as well.

[*Dr. Saury opens up a digital palette and replaces the magnifying lens cursor with the colour red*]

Let's just get rid of that [*Deletes highlighting/graphic representation on Android tablet*]

There's a dot here [Highlighting 1/ Graphic Representation 1], there's a dot here [Highlighting/Graphic Representation 1], dot out here [Highlighting 1/Graphic Representation 1], those are very *smooth,* nice circular dots and they're vessels coming out towards us so, on its side outwards, and in between you kind of get an oblique, ellipse sort of appearance. So everything you see there should be a tube, you should be able to make it into a tube.

Figure 18 Dr. Saury drawing in lymphadenopathy and tumours in the right hila review area

> What it *shouldn't* look like, so this is my lower lobe pulmonary artery here [Highlighting 1/ Graphic Representation 1: draws the right hila] and my scraggly upper lobe vessels [Highlighting 1/ Graphic Representation 1: draws present lobe vessels], it *shouldn't* be lumpy, bumpy, nasty, evil stuff [Highlighting 2/ Graphic Representation 2: draws four branching lumps/bumps to represent the appearance of lymphadenopathy and colours them in (Fig. 18)], so this is what lymphadenopathy looks like, okay? Or a big tumor, massive [Highlighting 2/ Graphic Representation 2: draws two large bumps to represent the appearance of two tumours and colours them in] it would *fill* in this diamond where there's supposed to be low density and these just aren't *tubular*, they're lumpy, bumpy things *nods head up and down*, okay, *again* you need to get your eye in for that and you just need to make sure you need to always look at the hila at the end in your review areas and get your eye in for what normal looks like.

[*Erases highlighting/graphic representation via Android tablet*]

Dr. Saury begins anatomy training by demonstrating *'that's what the hilum should look like'* and in effect highlights/graphically represents the two normal hila points which represent *'a fairly nice lucent diamond'.* The explosion of objectivity and visualisation technologies in medical education relies equally on the professional, who must make anatomy meaningful to the uninitiated. In such activity systems, the professionals' semiotic labour and their creative/illustrative dexterity with familiar metaphors and embodied figurative language are used to describe important anatomy (Roepstorff, 2009; Fountain, 2010). Dr. Saury engages in 'highlighting' and 'graphic representation' (Goodwin, 1994), fashioning expectant disease out of symbols forged over the normal anatomy in which the ideal left and right hila are depicted by two equally well-proportioned diamonds. Dr. Saury – in accord with common pathologies expected in the hila – draws in lymphadenopathy [*Highlighting 2 / Graphic Representation 2: draws four branching lumps/bumps to represent the appearance of lymphadenopathy and colours them in (Fig. 18)*] and another hila malignancy [*Highlighting 2 / Graphic Representation 2: draws two large bumps to represent the appearance of two tumours and colours them in (Fig. 18)*]. Whilst 'seeing as/'drawing as' (Vertesi, 2014, 2016), Dr. Saury describes lymphadenopathy as *'lumpy, bumpy, nasty, evil stuff'* and a tumour as *'massive'* together with anatomically abnormal landmarks (e.g. *it would fill in this diamond', 'these just aren't tubular').* Dr. Saury then draws attention to the primary purpose of the image with reference to the normal, its knowledge reducing the prospect of missing abnormality in the *'review areas'*.

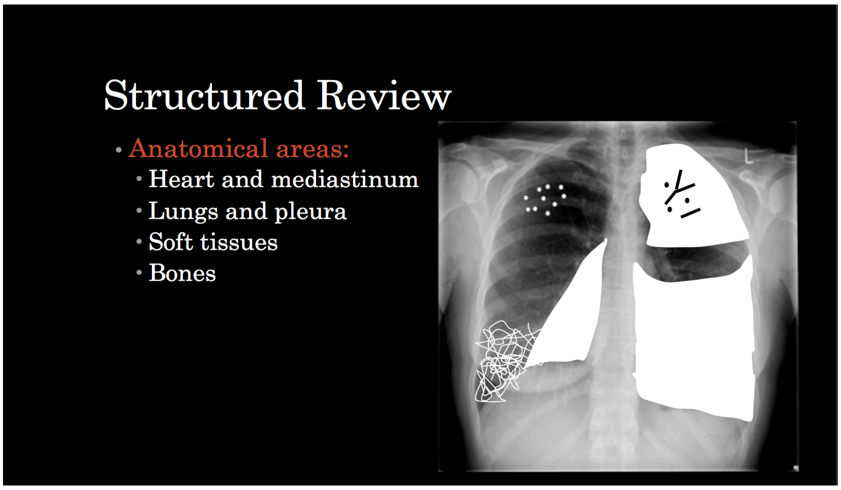

Figure 19 PowerPoint slide of structured review and common sites of lung abnormalities

Similarly, medical students outside of the radiology rotation also have the opportunity to observe another example of Dr. Saury invoking a graphic representation of 'potentially affected' anatomy, crafted via a PowerPoint presentation. During CXR training in the medical schools large lecture theatre, for instance, Dr Saury claims, regarding chest anatomy, that *'there are specific places where we commonly see stuff for various reasons'*. After Dr. Saury draws attention to the diaphragm, he presses a button on his Android tablet to reveal a common pathology above the normal diaphragm displayed via the PowerPoint [Fig. 19].

After Dr. Saury describes it as a *'reticular pattern'* and defines it as *'net like is what reticular means'*, he expands on its visual detail and prescribes how its net-like appearance is *a 'thickening at the interstition between the alveolar spaces'*, which in a normal image *'usually you really just see the vessels on a chest x-ray'* and claims that this thickening is in accordance with *'fibrosis ... because it's scarring, pulls up the diaphragm, pulls down the hila, so you're getting volume loss with fibrosis, in a reticular pattern.'*

After Dr. Saury prioritises the essential components of a normal CXR and intentionally fulfills his duty of teaching normal radiographic anatomy under the rhetorical principles of looking at, pattern recognition, and systematic approach, he establishes what these structures will look like abnormally (i.e. the anatomy's response to pathological deviance). Such prevalent opportunities are arguably harmless in academic-based training, yet they reconstruct the normal radiograph with a common place where trauma/disease usually appears. This reflects how professionals often advise students that they need to clear their minds with regards to the anatomical image they are looking at, even though, as Friedrich (2010: 187) argues, "there are no empty minds in medicine". Dr. Saury's objective, of endorsing a visual memory of specific normal anatomy and expecting its pathological signs, alongside the use of visual aids during teaching, shows how radiographs can become a common place of abnormality as well as ensuring – drawing on Mr. Hearken's contentions – *'predominantly focusing on the anatomy, projections, image criteria etc.'*

Throughout radiographic views, professionals and professionals in-the-making identify anatomy patterns/structures and ascribe these to favourable anatomic appearances (*'so you're looking to see this nice normal trabecular pattern'*; *'roots of a tree at the bottom, then the canopy at the top, so it's like a tree [Highlighting 1: hovers cursor over both right and left apices]'*; *'the iliac crests, so they're dome-shaped structures'*; *'you should [Highlighting 1 / Graphic representation 1: draws diamond between the LLL pulmonary artery and UL vessels] have a fairly nice lucent diamond in here'*), unfavourable anatomic appearance (*'we're looking for any evidence of swelling or increased thickness'; 'lumpy, bumpy, nasty, evil stuff'; 'it's scarring, pulls up the diaphragm, pulls down the hila'; 'does it look sharp?'; 'say tear drops in a spine and everyone immediately goes, ugh, because they're bad news usually'*), and certain strengths (*'so the function or the purpose of these lamina is really protection'; 'so it's a ring-shaped structure to protect the spinal cord which sits directly in the centre'; 'you have a set of ligaments which basically are there for support, for holding the neck in place'*), and certain weaknesses (*'where's the weakest part of the spine? The junctions'; 'the symphysis pubis is a cartilaginous joint and it's bound by a disc of cartilage which basically holds the two hemipelves together, very, very weak'; 'so the next weakest point after that is the sacroiliac joint'; 'pubic rami are very, very thin bones, they are relatively prone to fracture'*).

The description of radiographic anatomy having certain patterns or metaphors corresponds to a "symbolic economy" that shows something familiar in images (Saunders, 2008: 180). During radiographic anatomy training, alongside locating specific anatomical structures, normative-abnormal assumptions and expectations are often communicated as 'common sense knowledge' (Garfinkel, 1967). Nonetheless, the typification and registration of anatomy with favourable/unfavourable appearances, normal/abnormal expectations, and strengths/weakness – accomplished through the coordination of talk and embodied conduct (Ivarsson, 2017) – frames interpretive training as a preparatory accumulation of scrutiny and abnormal expectations as much as it is about in Mr. Hearken's (WURD radiographer) words, *'looking at some anatomy, the standard projections et cetera'*.

4.6 Reenacting mechanisms of injury

Normal radiographs, particularly primary views, are often opportunities for professionals in-the-making to imagine the consequences of specific injuries suffered by a living patient. In WURD, professionals in-the-making are regularly given insight into types of fractures, based on information regarding the patient's injury or, in the words of professionals, the 'mechanism of injury'. Mechanisms of injury are often "reenacted" to help make the trauma visible, constructing conditions of possibility to understand how it changes the anatomy and to see the injury (Tutt and Hindmarsh, 2011). This demonstrative ability and 'alluring narrative modality' (Myers, 2007) – when the patient is not present – undoubtedly stems from radiographic views being reenacted through talk, bodily technique, gesture, and motion, in which professionals dramatically engage in the "retelling" of the image (Saunders, 2008: 142). Accounting for a type of injury during a primary view, for instance, Mr. Hearken (WURD radiographer) claims '*if you know the mechanism you're more likely to be able to predict the type of fracture and where it's going to occur*'. The following exchange is taken from a 'C' (cervical) spine x-ray image interpretation class involving Mr. Hearken (WURD radiographer) and a model of C2 vertebrae:

Figure 20 'Gesture phase 1/3' in the re-enactment of a mechanism of injury (transverse ligament)

Figure 21 'Gesture phase' 2/3 in the re-enactment of a mechanism of injury (transverse ligament)

Figure 22 'Gesture phase' 3/3 in the re-enactment of a mechanism of injury (transverse ligament)

We can see the C2 vertebra [Highlighting 1: rests cursor on the C2 vertebra in the radiograph], the peg, which we're going to talk about in a second, projecting and sitting *inside* the atlas. One of the things that can happen to this ring is that, if you take the C2 vertebra as well

Picks up C1 vertebrae from the table but unable to locate C2 vertebrae

To female student if I can just borrow one of those (in reference to C2 vertebrae)

Sits relatively snugly inside it [Gesture: Fuses C1 and C2 together], but it's held in place by a ligament, it's held in place by a transverse ligament which basically binds the two together [1. Gesture: pushes C1 and C2 together (Fig.20)]. And in certain mechanisms of trauma[128] that

[128] Mechanisms of trauma are further expounded in Chapter Five, where professionals associate mechanisms of injury with specific types of people (boxer, elderly, children) or actions (falling off a horse). This perpetuates

ligament can actually be ruptured [2. Gesture: both hands pull apart enacting a rupture (Fig. 21)] and effectively there's no stability holding the head in place so it can actually effectively rock backwards and forwards [3. Gesture: both hands paddle back and forth to enact instability (Fig. 22)]. One of the things we will look for, and as I said, we'll talk about it in more detail later on in the course, but is this distance between the C1, the anterior part of C1, and C2 [Highlighting 1: cursor moves between C1 and C2 in the radiograph], to see whether it's widened or not. Normal distance is anywhere between two and five millimeters in width.

Mr. Hearken performs a disruptive anatomical movement, during which the radiography students are supposed to see the interruption between stability and instability at the force of the potential injury. Throughout much of the action, Mr. Hearken engages in what Kendon (2004: 143) defines as "gesture phase", namely movement phases in talk or "symbiotic gestures"[129] (Goodwin, 2003), conveying a sense of transition from the normal to the abnormal form. This allows the students to see the components of an injury distributed across a succession of three different hand positions: 1. *'it's held in place by a transverse ligament which basically binds the two together [Gesture: pushes C1 and C2 together (Fig. 20)]'*, 2. *'in certain mechanisms of trauma that ligament can actually be ruptured [Gesture: both hands pull apart enacting a rupture (Fig.21)]'*, 3. *'there's no stability holding the head in place so it can actually effectively rock backwards and forwards [Gesture: both hands paddle back and forth to enact instability (Fig.22)]'*. Prior to emphasising any distinguishable utterances regarding the interruption, Mr. Hearken highlights the normal C2 vertebra to draw attention to specific features of its appearance (*[Highlighting 1: rests cursor on the C2 vertebra in the radiograph]*), which is further reinforced when he joins the 3D anatomical models of the C1-C2 together.

Mr. Hearken symbolically associates the C2 and C1 vertebra in the image to familiar forms or figures in common sense knowledge (*'the peg'* and *'the atlas'/'ring'*), before he enacts the disruption (*'ligament can actually be ruptured [Gesture: both hands pull apart enacting a*

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traditional stereotypes about people reflected by their injuries and helps foster certainty towards classification of the abnormality. For example, arthritis is common in overweight people and pelvic fractures are common in motorcyclists.

[129] Goodwin also refers to this as "environmentally coupled gestures".

rupture Fig.21)]'). This is what Ochs (1994: 161) terms a "dynamic grammar", meaning the words and forms about familiarity, as a means to help establish what normal anatomy is expected to look like and which become metaphorical extensions and outward bodily expressions of anatomical relationships. Mr. Hearken later summons attention to this distance on the image by moving the cursor between C1 and C2 (*'is this distance between the C1, the anterior part of C1, and C2 [Highlighting 1: cursor moves between C1 and C2 in the radiograph], to see whether it's widened or not'*), and then supplements it with a numerical statement that offers another means of assessing whether the vertebrae is beyond its normal distance (*'normal distance is anywhere between two and five millimeters in width'*).

In the classroom, the focus appears to be on performing anatomical expectations and on demonstrating the mechanism of injury. Saunders (2008: 219) identifies demonstrations of illness and injury as "classic appearances" and as a device of exhibiting clinical reasoning. However, there is no published research on the broader embodied demonstrations of these types or examples – how professionals seem to have embodied the sensation from patients during clinical practice, and can re-experience these senses for the benefit of others in teaching contexts. The mechanisms of injury in this context are symbolic and "multi-sensorial" (Myers, 2007: 116), rather than 'classificatory' or an exclusively representational information driven system, yet importance to verbal or written 'descriptions' is still very much the goal (Newton-Hughes, 2015). Such 'demonstration practices' (Goffman, 1974) of trauma and illness emerge in the academic setting. Radiographers reenact the trauma through bodily performance into a drama, by drawing on embodied experience of injury, as well as visible markers of anatomical weaknesses and abnormal images, thereby offering "further testimony to affective, expectant components of radiographic attention, depending on the comforting familiarity of the normal" (Saunders, 2008: 34).

Along with attributing ideal patterns to the radiographic anatomy (ascribing normal anatomical structures to familiar everyday patterns or forms including peg, atlas, and ring), radiographers in-the-making are bestowed a reenactment in which they are allowed to explicate the normal features into some of the abnormal possibilities. Demonstrations of mechanisms of injury are enacted via the process of identifying important anatomic structures/features reconstructing either trauma or disease. In one example, Mr. Hearken points out the *'the path of the anterior ligament, and we're looking to assess it in terms of its* *smoothness, so it should be a gradual smooth arc' [Gesture: RH slowly strokes the air in a linear fashion]*' to which he continues *'so it should be a gradual smooth arc, no steps, no deviations, et cetera, et cetera [Gesture: cuts haphazardly through the air in a bumpy fashion]'.* Here, he constructs a connection between the normal and the abnormal. Again, as part of this drama, he employs a 3D model of the anatomy in question – a type of "cognitive artifact" (Goodwin, 1994: 29) – so as to better understand deviance and violence of a potential mechanism of injury.

4.7 Conclusion

This chapter began by identifying how professionals rely on rhetoric grounded in cognitive psychology when they talk about x-ray image interpretation (Linaker, 2015a; Gegenfurtner et al., 2019). They enact the importance of embedding students within a rhetorical economy of non-analytical reasoning (i.e. looking at/pattern recognition) and analytic reasoning (i.e. systematic approach) where good diagnostic reasoning or interpretive practice is characterised as 'keeping a right balance' between these processes (Custers et al., 1996; Eva, 2004; Kok et al., 2015). Yet, despite these instructions professionals often raise concerns of interpretive practice for students having a limited knowledge of normal radiographic anatomy and the capacity to miss abnormalities. However, analysis of professional vision in interpretive practice shows how during interactions with students, awareness of these issues (often embedded in looking at/pattern recognition and systematic viewing) are 'discursively' shaped (Goodwin, 1994). That is, these three modes of learning to see are organised through a variety of discursive practices meaning that the cognition and perception of professionals in-the-making is shaped 'socially'; "situating such processes not only within the mind, but as visible operations upon external phenomena" (Goodwin, 1994: 610). For Joyce (2005: 440), the rhetorical strategies of professionals talking about medical images are grounds for "shoring up the authority of images as an objective source of knowledge that is crucial to the production of definitions of health and illness", yet these rhetorics are dissolved or seriously weakened when "discursive practices" reveal the limits and many of the "interpretation troubles" facing professionals in interpretive work (2005: 449). At Bridgestock and Woodfleet, similarly, the rhetorical strategies of looking at/pattern recognition and systematic viewing are enacted discursively by professionals with the aim of replacing ambiguity with certainty but in doing so, they discursively unmask the potential sources of errors and risks – for example, optical illusions – in interpretive work. In Maynard's (2006: 109) terms, the articulation of this trouble is not straightforward, nor is it just talked about but rather constitutes an "embodied telling of a seeing", that is, a public challenge "to get perception out of the mind, out of the individual's solitary cognition".

Moving beyond Joyce (2005, 2008) my analysis identifies and explores what this 'authority' accomplishes, namely, that professionals in-the-making are enacted as organised problem solvers and sharing a detective's intention to solve the problem in the image (Saunders, 2008). Professionals can subsequently organise a structured way of learning to see and accomplish it as a situational organisation of a problem-solving activity (Måseide, 2007). As professionals in-the-making/junior doctors are often first in line to see and comment on x-ray images, the realist impulse that seeing must be organised and structured is paramount. Learning problem-solving skills such as looking at/pattern recognition are reinforced and embedded within the deployment of a systematic approach and seeing the problem is therefore constructed as an accumulative organisation of cognition and perception. However, professionals in-the-making are often described as not being attuned to the normal radiographic anatomy of x-ray images and so are often reminded that it serves as a necessary resource to minimise the number of misses. This trend is well documented across this study and the literature, with those learning to see seemingly lacking knowledge of normal radiographic anatomy and the mediated character of medical images (Feigin et al., 2002, Feigin et al., 2007; Magid et al., 2009; Krupinski, 2010; Linaker, 2012; Bhogal et al., 2012; Jacob et al., 2016; Friedrich, 2010; Fountain, 2010, 2014). This means anatomic seeing is far from being simple, with the distinction between machine and human becoming blurred (Haraway, 1991).

Combining the advice of looking at/pattern recognition and systematic viewing for problem-solving, professionals (re)enact opportunities in which training, demonstrated through professional vision and embodied understanding, situates students in ways of seeing that organises their cognition and shapes their perception. Their professional vision, thus, reproduces a critical engagement of x-ray image interpretation (with normal anatomy enacted by the body as a foundation for practical reasoning) and, in turn, providing a crucial 'embodied' component of professional forms of seeing and reasoning.

The second part of this chapter revealed how normal radiographs are constructed as having suspicious sites of abnormality where secondary views allow closer scrutiny of anatomical areas of interest/body parts compared to primary views and, on occasions are given a reenactment of these mechanisms of injury. This accomplishes two things. First, x-ray image interpretation training is enacted and generated as an expectant part of seeing. The enactments of establishing modes of attention to anatomical areas of interest – as well as reenacting how injuries happen to patients – reduces the opportunity to miss abnormalities and hidden abnormalities and, ultimately, the prospect of litigation. Professionals' imperative to fuse expectant anatomical information with a suspiciously searching focused gaze explicitly, and imaginatively, influences their analytical immersion and deepens their critical engagement with x-ray images.

Second, x-ray images – by becoming constructed as places of trauma/pathology and particularly as a chance for training mechanisms of injury through the image – accomplish the expectations of normal anatomy (good) and abnormal anatomy (bad). The inscription of radiographic structures and features of normal anatomy to figurative language and favourable appearances (smooth, nice circular dots, atlas, peg, eggcup, and diamond) constructs ideal patterns of normal anatomic expectations. However, in interpretive work, when a suitable normal pattern is obtained and the professionals are confident in the student's recognition of their identification/description-work, they transition to 'abnormality' (lumpy bumpy, reticular or net-like, sharp, teardrop). This is reflected in areas of interest becoming 'common places of injury' or opportunities to demonstrate 'mechanisms of injury'.

Whilst the former is positioned to reinforce appreciation of normal radiographic anatomy, the latter attempts to make a connection with 'potentially abnormal' anatomy. This point is built upon in chapter five, where I attend to how abnormal anatomy is engaged with and classified within x-ray image interpretation training. In chapter five I identify how abnormal anatomy is made visible, as though saying 'this *is* a fracture and this is what it's called' and how it is used within discursive contexts of 'missed abnormalities, 'interpretive risks', and 'technical errors', where professionals are concerned with the problem of not being analytical, that is, accepting x-ray images at 'face value' (Coopmans, 2011).

5 Constituting x-ray image interpretation and radiological error in the academic setting

Chapter four explored professional vision with respect to x-ray image interpretation training. I have shown how looking at/pattern recognition are used as rhetorics of detection which allows professionals to adopt a cognitive stance on visual perception and expertise. This both grounds professionals in-the-making as problem solvers and embodies x-ray image interpretation as a critical practice, founded upon the learning of normal radiographic anatomy and bolstered by the administration of two types of coding practice (five x-ray densities and systematic approach[130]). These come together to support and strengthen the expert's preferred way of critical reasoning. In addition, I revealed how normal radiographs are testimony to expectations of common abnormality and opportunities to reenact a patient's mechanism of injury. This accomplishes suspicion towards specific areas of interest and the expectation of ideal anatomies and images. The identification of anatomies and images enacts ideas around what anatomies – in relation to medical imaging and anatomical patterns/forms – are favourable (normal) or not favourable (abnormal).

I extend this latter argument in chapters five and six by exploring how x-ray image interpretation consists of seeing and classifying abnormality at Bridgestock and Woodfleet. In chapter five I show how professionals continue to teach x-ray image interpretation training under circumstances of suspicion and critical tractions towards the 'subtle' and 'barn door obvious' abnormalities. However, I show that the larger abnormalities (identifiable as 'obvious' observations) are often cautioned as 'satisfaction of search' during training interactions. This often turns on frequent suspicion from professionals who warn students that obvious abnormalities can distract them from more subtle abnormalities. Whilst professionals put the abnormal in a classificatory system of radiological signs, eponyms and descriptive terms, they simultaneously present the quality of images to show common

[130] Remember, on page 184 the systematic approach doubles up as a coding practice where Dr. Delichon tactically corresponds each anatomical area or review area with a normal category (and at times as a disease state).

difficulties of discerning and seeing. This practice is intertwined with a visual logic that enables students when perceiving visual information to be cautious in calling out abnormality and systematically checking against technical errors and limitations of imaging technique/risks.

This suspicious attitude towards certain radiographs is supported by video footage recorded in BRMR and WURD: 1) the professionals' misplacement of lines and tubes; 2) the surgical reorganisation of anatomy dictates that post-operative anatomy can mislead; 3) Normal variants that mimic pathology; and 4) radiographs which carry the problem of technical error and technical inadequacy related to the creation of the image – the latter exhibited as highlighting the "instability" of medical image production (Joyce, 2005: 445).

In addition, I show how x-ray image interpretation is embedded within pedagogical discursive contexts of 'missed abnormalities', 'interpretive risks', and 'technical errors' which perhaps shape and sustain a means of reducing radiological error and may also help professionals prevent litigation (Burri, 2013). Overall, I argue the embodied conduct and discursive professional vision emerging at Bridgestock and Woodfleet can highlight one reason why radiological errors stay between 3-5% in real time day-to-day interpretation of radiographs (Berlin, 2007; Berlin, 2014; Brady, 2017).

5.1 'Satisfaction of search'

At Bridgestock (BHRD and BRMR) and Woodfleet (WURD), professionals teaching x-ray image interpretation show that they have concerns about professionals in-the-making having a lack of knowledge over normal radiographic anatomy (particularly x-ray densities) and underreading the x-ray image ('missing' abnormalities). The third concern extends to the obviousness of abnormalities and how the obvious can lead to satisfaction of search errors, a failure to think of other possibilities when interpreting radiographs (Berlin, 2014). The troubled concern of professionals falling prey to satisfaction of search in the context of medical image interpretation has been previously documented (Renfrew et al., 1992; Peterson, 1999; Saunders, 2008, 2009; Pinto and Brunese, 2010; Donald and Barnard, 2012; Satia et al., 2013; Reed et al., 2014; Van der Gijp, 2017), although very few studies have included students (Krupinski, 2010; Winter and Linehan 2014; van der Gijp et al., 2014; Kok et al., 2015).[131]

At BHRD and WURD, a number of radiologists and radiographers claim x-ry image interpretation, a practice they are both accountable for, are at times concerned about satisfaction of search and the seduction of obvious abnormalities. At the beginning of a CXR image interpretation lecture, Mr. Hearken (WURD radiographer) cautions students against satisfaction of search and settling upon the 'obviousness' of abnormalities that immediately present themselves to the individual, a warning that serves to continue a critical response of radiographs:

Figure 23 Mr. Hearken endorsing a 'systematic approach' to CXR image interpretation. It also depicts a hand crossing gestures to mark the speech act he is performing (i.e. 'Ignore the great big whopping tumour')

> In terms of image interpretation, it doesn't really matter what we're looking at, whether it's [Gesture: list construction with pen] chest, abdo, MSK, ultrasound, CT, MR, the principles of image interpretation are the same, that if you put up an image [Gesture: raises RH with palm facing his face to enact the image] your brain will be *drawn* to the most obvious abnormality. So if you've got a whopping great big lung tumour [Gesture: RH grabs the air as if grabbing the tumour] that's what your eyes are gonna be drawn to, you gotta *ignore* everything else [Gesture: opens space between hands]. It relates to the fight-or-flight response that if something's coming at you, you're gonna concentrate on that and not everything else that's around you. The same applies with imaging. If you've got something that's very very obvious, you're gonna *forget* or

[131] Saunders (2008, 2009), van der Gijp et al. (2014), and Winter and Linehan (2014) are the only studies to have explored this qualitatively.

> *ignore* the subtleties and you will find that there are times when the obvious thing is not the important thing [Gesture: LH grabs the air], the subtle thing that you *miss* is the bit that's gonna cause problems. So, for that *reason,* when it comes to image interpretation, we recommend that you have a *systematic* approach[132] to the way you look at an image, so you get used to looking at the same images in exactly the same way [Gesture: RH chops through the air] every time. We talk about things called 'review areas' [Highlighting 1: RH uses black marker pen to highlight the text: 'review areas'], which basically means you're looking at every-bit-of-anatomy-on-that-image [Gesture: RH using pen, prods the air seven times to emphasise the words]. And when you have a system that works for you, stick to it and approach each image *puts pen down* I'll stop pointing the pen at you. *Ignore* the great big whopping tumour [Gesture: sporadically crosses hands in the air (Fig. 23)], concentrate on looking at the whole image, and *then* concentrate on the big thing in the middle. This is something we call 'satisfaction of search' [Highlighting 1: finger points to 'satisfaction of search' text on PowerPoint slide]; that by the time we've put that image down or closed it down, or sent it, or whatever, you are *satisfied* that you have searched [Gesture: opens space between hands holding an imagined image] that entire image and you've picked up *everything* there is to see, alright?

Mr. Hearken's rich and embodied communication for medical image interpretation problematises the supposed transparency of images and 'obviousness' of abnormality, where seeing or discerning the abnormal is not a straightforward or easy process. This is in contrast to previous studies which have shown professionals producing and sustaining the myth of transparent images and fully knowable bodies (Joyce, 2005, 2008; van Dijck, 2005). For Mr. Hearken, this rhetoric of transparency is both identified in pedagogical exchanges but also navigated from when it comes to not so obvious or subtle abnormalities. Here, he identifies practices of seeing being between the *'very very obvious'* and the *'subtleties'* which are not apparent to the uninitiated who are likely to *'forget'* or *'ignore'*. Missing obvious

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[132] Appendix 16. The radiographer's systematic approach and the radiologist's systematic approach (chapter four) is almost identical semantically. However, as shown in Appendix 16, the radiographer reproduces the letter 'A'. This merits two types of critique: the first being attentive to 'Technical adequacy', which is intended to make the student critique the technical quality or craftwork of the image, as with the patient rotation in chapter four. The second type of critique is 'pathological' that has become ritualized into the search for disease, such as cancer or tumours, which is part of medical practice and clinical decision-making (Larkin, 1983). I will discuss this technical aspect later on in chapter five and actually constitutes the basis for chapter six.

abnormalities, in contrast, is *'not the important thing'*, leading Mr. Hearken to stress that '*the subtle thing that you miss is the bit that's gonna cause problems*'. Drawing on a structured approach for strategic seeing that was once the preserve of medical radiologists (Larkin, 1978; Barley, 1984), Mr. Hearken positions these problematic abnormalities as prompting a *'systematic approach'* that situates students in a controlled system that organises anatomical seeing during image interpretation. He concludes that a systematic approach will help protect students from succumbing to the error of *'satisfaction of search'* as part of CXR image interpretation.

This mirrors the radiologists in Saunders (2008: 30) who claim that "if you're satisfied with what you find, you miss everything else". During a MSK image interpretation overview and OSCE revision lecture at the end of semester two, Mr. Hearken similarly states: '*our mind is automatically drawn to the most obvious, the barn-door obvious thing, and we kind of focus in on that'* and that *'they will jump out and smack you in the face, they're easy, a six-year-old could pick those up. What about the more subtle ones?'*

Here, Mr. Hearken motions a distinction between 'barn-door obvious' and 'subtle' abnormalities, the former becoming a term for abnormalities that are immediately 'obvious' (that jump out) and easy to see. At BHRD and WURD, radiologists and radiographers construct seeing the larger abnormalities as *'barn-door obvious',* commonly in contrast to smaller or obscured abnormalities which are *'so, so, so, so subtle that you can't see them'*. During a CXR image interpretation hot-seat activity in BRMR, Dr. Delichon (BHRD radiologist) describes these, along with pathology, as *'something nasty'*, *'really subtle and hard to see sometimes'.* In a labelling the anatomy activity, Mr. Jim Richards (WURD radiographer) claimed that whilst no obvious fracture could be seen in an ankle radiograph, the presence of a white joint space between the talus and the fibula *'confirmed that there's something wrong with it'.* Joyce (2008: 40) reports how radiologists have always preferred grey-scale images or shades of grey to multicolour as it provides a "negligible transition" between anatomical structures/features allowing them to identify anatomical subtlety. However, Bridgestock and Woodfleet professionals seem unanimous in identifying subtle lesions or diseases as 'challenging' and show how easily they can be missed in favour of larger abnormalities. During a CXR lecture, Dr. Delichon (BHRD radiologist) suggests that the observation of subtle abnormalities can be made easier for medical students who 'check the apices':

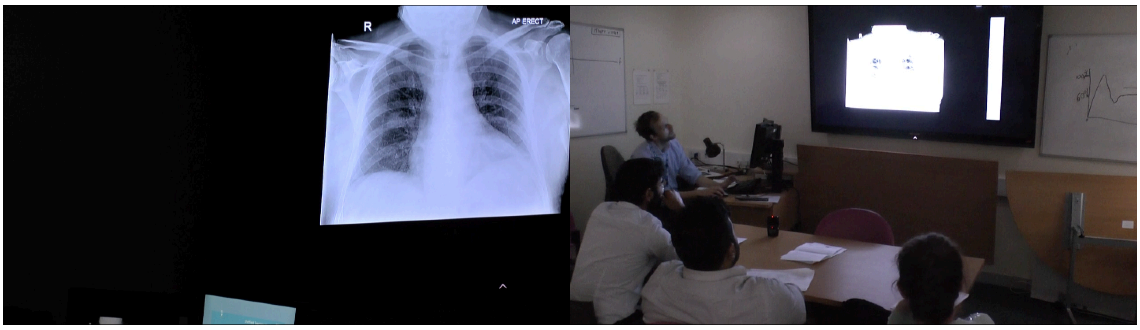

Figure 24 Dr. Delichon presents a CXR in which the patient has a small or 'subtle' tension pneumothorax.

Dr. Delichon: This one's a bit more subtle. This is why it's really important to check the apices [Highlighting 1: hovers cursor over left and right apices (Fig. 24)] again it's hard [*clicks the mouse which transitions forward to a magnified slide of the right lung apex (Fig. 25)*]

Dr. Delichon: But can you see this line here? [Highlighting 1: cursor traces over a faint opaque line under the right clavicle, highlighting a subtle pneumothorax in the right lung apex]

Amit: *tuts* [laughs] *whaat?*

Rehan: *shakes head in disbelief*

Riya: *exhales in surprise*

Dr. Delichon: That's a very small pneumothorax. You can see, sometimes you get lines right underneath them [Highlighting 2: Cursor traces an absent 'composite shadow' which can potentially mimic pneumothorax], the ribs, which are called um composite shadowing[133] but this one's quite a way down [Highlighting 1: cursor traces over a faint opaque line under the clavicle and highlights a subtle pneumothorax in the right lung apex] and you kind of follow it down

Rehan: *tilts head to the left as if following the cursor down*

Amit: Oh, okay

Dr. Delichon: Tension pneumothorax, that's why it's good on a PACS system at the moment, you can *zoom* into things [Gesture: RH presses an invisible button to emulate

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[133] A form of optical illusion: composite shadowing occurs when structures overlay, potentially creating the impression of something different from what is real. Optical illusions and their potential to mimic disease are talked about in chapter four as part of learning to see radiographic anatomy. However, it is different to the 'mach bands' illusion mentioned in chapter four.

	zooming using PACS], you can window however you want to show you these things up a bit better
Rehan:	Mm
Dr. Delichon:	Okay, [clicks mouse button to transition to the next slide] *hisses* umm *looks down at a piece of paper at the workstation*
Riya:	If I reviewed that, like on a night shift, I would *probably* miss that? [Talking about the small pneumothorax on the previous image]
Dr. Delichon:	I think [Gesture: RH points at the LCD] on a PACS screen it's easier to see and I think if you make sure if they're- if the question is: 'short of breath'
Riya:	Yeah
Dr. Delichon:	And you think, and one of your things is I think 'they might have a pneumothorax' then the best thing to do is zoom right up [Gesture: RH moves up in the air to enact magnification on PACS], right up to the apices, right up to like the chest wall and just follow it all the way down and make sure so you can't see any lines. Make sure all the vascular markings [Gesture: RH pinches the air to enact a vascular marking] go out, okay?

Figure 25 Dr. Delichon presents a magnified or zoomed image of the same radiograph (Fig. 24) to help Amit, Rehan and Riya see the subtle pneumothorax.

Dr. Delichon highlights how the subtle or 'tiny'[134] (apical) pneumothorax, a condition where a lung has collapsed because air has pushed on the outside of the lung and made it collapse, is difficult for medical students to see. Although he recognises how students at this stage in their training are unlikely to see the pneumothorax (because of its subtlety), it is an observation that is more likely to be seen through the litany of a systematic approach that takes into

[134] Dr. Delichon used this term to refer to this pneumothorax in another session.

consideration the *'apices'* since the apices are one of the four main areas of concern on a CXR.[135]

Radiologists and radiographers give tacit endorsement to CXR review areas as a means of helping to reveal subtle and hidden abnormalities that are likely to be missed (*'this is the point of the review areas, it's so easy to, you just don't see it because it's white on white'*)[136] as well as being repeated advice students rely on (*'i'll give you a hint, which is 'review areas''*).[137] The review areas are designed to support a second systematic approach towards CXR interpretation. At times, radiologists also instruct medical students to inspect the review areas ('*quickly check your review areas*') despite a 'successful' interpretation. The emphasis on such instruction was set off against the absence of review areas that were forgotten about or utilised as part of the student's initial systematic interpretive work (see previous chapter). The radiologist's interest in asking students to scrutinise the review areas – *even at the end of a correct interpretation and diagnosis* – is a regular feature of radiological pedagogy. It simply puts them back in with a chance of interpreting the image successfully and leaving the radiologist properly satisfied. In addition to guiding the student towards a comprehensive interpretation, the radiologist's systematic approach is intended to render a curriculum objective. It also reflects DoH and NHS Hospital priorities, such as litigation concerns, as it safeguards the student from malpractice in the event of a court case.

When speaking of the review areas, Dr. Delichon (BHRD radiologist) encourages the role of PACS magnification and windowing tools to gain a deeper look into the review areas, particularly when there is nothing obvious or large to see: *'you can zoom into things'* and *'you can window however you want to show you these things up a bit better.'* It is important to note that a large pneumothorax was used prior to or alongside the subtle pneumothorax. This was to give some indication as to the size difference between large/obvious and small/subtle pneumothoraces. For instance, the previous case showed a large tension pneumothorax that was *'clinically easy to diagnose'* and did not require imaging, *'you shouldn't really ever x-ray*

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[135] All professionals claim that lung abnormalities are more common in the four main review areas: diaphragm, heart, hila and apices.

[136] Dr. Saury

[137] Dr. Saury

things like this'. These case presentations were aligned back-to-back to show different forms of the same condition that were often about differences in size and shades of grey in order to spell out the perils of satisfaction of search. Back-to-back images – a core teaching practice for both radiology and radiography professionals – supported seeing differentiation through visual comparison (Pasveer, 1989; Prasad, 2005; Dussauge, 2008). This was a turning point in the observation of abnormalities that were difficult to see and proved useful in the familiarisation of differential conditions. In the case of x-ray image interpretation training, back-to-back slides enforce the reality of the condition and communicate the idea that it can appear anatomically different, as well as more obvious or more subtle. Moreover, these images showed how the larger or more obvious disease could disrupt, distract, or discredit the process of seeing.

BHRD radiologists and WURD radiographers often recommended the use of 'eyes and hands' as a gateway to gather diagnostic information, rather than referring the patient for imaging. Both professionals condemned such referrals and the use of imaging technology because of the severity of the condition and the need to direct patients to immediate treatment. During a shoulder image interpretation lecture, Mrs. Campbell (WURD radiographer) suggests that the patient's condition can be diagnosed and the appropriate treatment can be undertaken without producing the image:

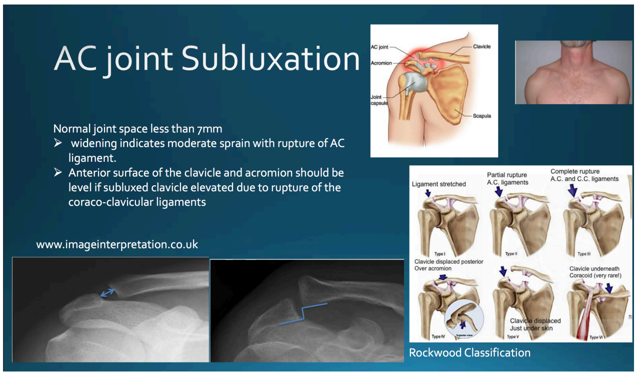

Figure 26 AC joint subluxation slide as part of the shoulder image interpretation lecture

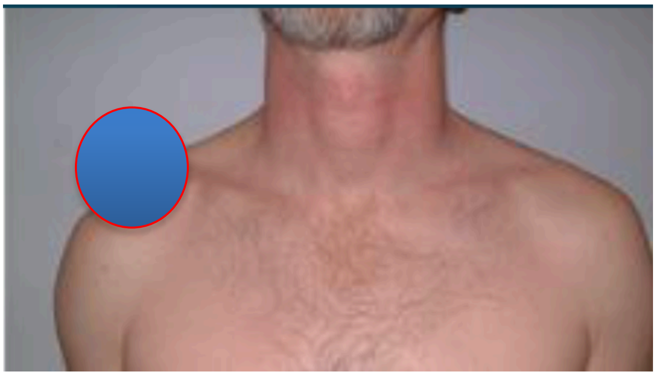

Figure 27 Photograph of a patient presenting with AC joint subluxation in the right shoulder.

Mrs. Campbell:	So, we were saying before we were looking at clavicles. Sometimes the request for a clavicle will be looking at AC joints and that's when they probably do [Gesture: LH and RH touch both her clavicles] a comparison between the two, okay? So, this is

[*Presses mouse button to reveal a photograph of a patient with AC subluxation: (Fig. 27)*]

Mrs. Campbell:	AC subluca-sub-lux-ation. So, I don't know if you've ever seen anything like this?
Nicole:	Noo
Janine:	Ooh, square![138]
Mrs. Campbell:	Yeah? I had a young lad come in and he said 'I think I've hurt my shoulder [Gesture: LH feels shoulder of right arm as if to reenact the patient] [laughs], do you think I've done something?' and it looked like that! [Highlighting 1: LH points to photograph of dislocation on the PowerPoint slide (Fig.24)] '*mayybe*' [laughs]

[*laughs all around*]

Mrs. Campbell:	So, do you need an x-ray machine?
Mary:	No
Mrs. Campbell:	Not really, right, okay.

[138] Janine's comment relies on the general understanding that fractures present themselves as *'sharp or acute, or straight'* (Mr. Hearken, shoulder II, Group 1). This rule was enforced to radiography students throughout the first and second semesters.

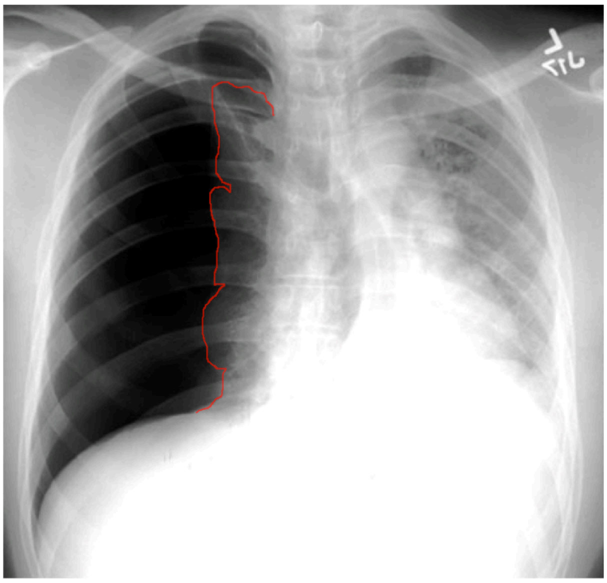

Figure 28 PowerPoint slide of CXR case 8: '18 male acute SOB'. I have highlighted the right lung, which has been, which has been 'squashed down' due to the presence of air ('lots of black') in the right hemithorax.

Mrs. Campbell reveals that *'sometimes the request for a clavicle will be looking at AC joints'* and the radiographers will *'probably do a comparison between the patient's left and right clavicles'*, before concluding that the diagnosis could be known without the assistance of imaging, since the shoulder looks misaligned when compared to the other. Mr. Hearken (WURD radiographer) similarly suggests that reading the imaging request cards bolsters expectations of patient conditions in which the injury can be apprehended before the image is looked at: *'How many of you have seen a patient, read a request card, imaged the patient, and have predicted what you're going to expect to see, before you even looked at the image?'* Likewise, Dr. Maxwell (BHRD radiologist) introduced a CXR (Fig. 28) as *'the x-ray you should never see',* to which Rishi, a fourth-year medical student responded: '*'he shouldn't have had an X-ray ... because this guy had a huge pneumothorax'.* By saying *'the x-ray you should never see',* Dr. Maxwell refers to the circumvention of imaging and immediate treatment because the patient is dying. His description of the patient having *'no breath sounds'* and in *'extreme respiratory distress'* evokes the impression that, in these cases, diagnostic interpretation relies on observation alone. Although the patient should not have been imaged, the radiograph serves as a particularly revealing source for seeing the appearance of the problem (*'lots of black'*), a dynamic that both demonstrates the lung abnormality and disputes the fact that an image was necessary at all.

Given that Rishi was able to see the large *'black'* and *'dark'* area as abnormal and interpret it as '*a tension pneumothorax'*, without assistance from Dr. Maxwell, shows that his trained eye was familiar with tension pneumothorax. The reason for this relates to the attention the image is afforded in radiology education and my own ethnographic observation. During the many moments of my own learning, the tension pneumothorax reported here demanded a critical sort of ontology: tension pneumothorax is often seen as in some sense 'obvious' because black indicates death or dying. One online radiology education website, for example, points out the condition as an urgent matter of health and illness that is easily discernible to the trained eye, where failure to see points to exam failure: "this is the one not to miss. If you cannot diagnose a tension pneumothorax at medical finals you won't find an examiner who will defend you".[139] Nevertheless, Dr. Maxwell is more than willing to use his body to show movement of the right lung and to indicate the location of the compressed right lung. The following transcription provides a brief overview of this dynamic to get at the 'movement' of the lung:

> This is his right lung *here* [Highlighting 1: LH traces the outside of the patient's collapsed right lung], completely squashed down [Gesture: LH pushes across the chest and through the air to enact the pushed back right lung], all this air in his pleural space [Gesture: LH hovers over the blackened right lung and then sideways across the lung enacting pushing] and it's pushing. This is his heart border [Highlighting 1: LH finger traces the outside of the patient's left heart border]; so he really is going to die because you know he's probably losing that input to his heart [...] Um, and it can be maybe penetrating trauma from outside in [Gesture: LH finger prods through the air into the right lung enacting a puncture], it might be that he's got, you know, that and a lung injury, so he's breathing in and it's escaping through the lung into the chest [Gesture: LH finger draws an 'L' shape in the air to enact a second airway access].

Whilst the finger is used to highlight the location of the collapsed right lung and the black hemithorax, the hand animates the direction of air and physically explains why the lung is *'completely squashed down'*. Additionally, Dr. Maxwell draws our attention to a more subtle and invisible interface to *do* representation that does not require the use of the physical environment, using the air as a sketch-based interface. In brief moments the air is made tangible and provides an "imaginary interface" (Gustafson et al., 2013) through which indirect

[139] http://www.radiologymasterclass.co.uk/gallery/chest/pneumothorax/pneumothorax_b

representation can be made. Usually imaginary interfaces are used to access the image, to shift focus and to share attention. This illustrates how the air allows for student participation and engagement, underlying forms of representation regularly generated during teaching practice and student learning. In other words, the air provides an additional dimension that helps depict, measure, control and manipulate the image. This means anatomy, objects, artifacts and (ab)normality are performed through the air, but also *in* the air. Manipulating the imaginary interface offers students an insight into worst-case scenarios, helping foster a "radiological imagination" and a picture of pathological consequences (Saunders, 2008).

The role of the professional is to depict the anatomic body threatened by sources of error and harmful real-world situations, as safe demonstrable phenomena. Conversely, this interface offers a window for professionals in-the-making[140] to learn about the image-making process. This imaginary interface establishes a picture of the practical, social, embodied, and ethical contexts of radiographic work that allows professionals in-the-making to understand that 'seeing the right thing' is entangled with image production. I extend this argument in chapter six by describing how x-ray image interpretation entangles aspects of image-making (e.g. patient positioning and radiographic technique), how medical students and radiography students (at advanced and elementary training stages, respectively) are imbued with this, and how "situated learning" (Lave and Wenger, 1991) strengthens and enhances critical engagement in professional vision. Nonetheless, radiologists and radiographers endorse discourses such as 'barn-door obvious' and 'subtle' as a means to move beyond the obvious and see subtle abnormalities in the radiograph that the novice, in the task of observation, might miss. They are inflecting the warning of being satisfied on the obvious: the 'satisfaction of search'.

The most common problem for professionals, however, is that the satisfaction of seeing the obvious distracts the students from the more subtle findings, cited in one radiology textbook as "dangerous for the patient" (Novelline, 1997: 80). Mr. Hearken is critical of radiography students who settle on the obvious, suggesting that each review area should be checked, since seeing is fixated on the *'barn-door obvious'.* Dr. Maxwell (BHRD radiologist) likewise claims

[140] Particularly those who have not seen or participated in x-ray image production.

that when medical students approach the CXR, he informs them that pathological issues are more common in the review areas with a view that having a structured approach will protect them against *'a conspiracy of little things that kind of lead people up the garden path'.* This advice is frequently followed in CXR classes, since *'there are thousands of pathologies in chests and those pathologies can look like a number of different things'*. Both BHRD and WURD professionals are unanimous in endorsing the review areas to make sure the uninitiated are never satisfied with the obvious, aiming to foster a more comprehensive scrutiny of the radiograph. The following exchange in a shoulder image interpretation class illustrates how radiography students have settled their observation on the shoulder and humerus, presuming that these are the areas of concern:

Mr. Hearken: What about this one? [Gesture: Le Penseur]

[*Silence: fourteen seconds*]

Mr. Hearken: Anything?

[*Silence: two seconds*]

Ebunoluwa: The humerus?
Mr. Hearken: Anything? [Pause] you'll kick yourselves when I tell you!
Ebunoluwa: Erm *shuffles in seat*

[*Silence: four seconds*]

Ebunoluwa: Is the humerus normal?
Radiographer: The humerus I think is normal [Highlighting 1: lasers humerus]
Ebunoluwa: Is it?
Mr. Hearken: What about this? [Highlighting 1: laser sporadically circles the large opacity]
Ebunoluwa: *Aaaah!*
Mr. Hearken: This *was* a lung [Highlighting 1: laser sporadically circles large opacity]. Now full of either tumor or fluid or something, so, last slide, satisfaction of search, alright look at the thing you're interested in and make sure

you look at the whole of the film as well because it will catch you out a lot.

Mr. Hearken's exclamation that *'you'll kick yourselves when I tell you!'* implies that there is something abnormally obvious in the shoulder radiograph. In response to a long silence and Ebunoluwa's uncertain observation about the humerus, Mr. Hearken focuses everyone's attention to the large white opacity in the chest and attributes their miss to 'satisfaction of search'. What is ironic here is that the large abnormality is not barn-door obvious either because their focus was drawn to two review areas (shoulder or arm). After pointing out what is now deemed obvious, Mr. Hearken returns to Ebunoluwa's initial intrigue about the humerus and becomes distracted by a *'little lucency'* in the arm:

Mr. Hearken: Well, actually there is a little lucency in the humerus [Highlighting 1: lasers 'lucency'] what do you think that might be? Does it look like a fracture?

Ebunoluwa Not a fracture, it's-

Mr. Hearken: No, what? Why doesn't it look like a fracture?

[*Silence: three seconds*]

Mr. Hearken: It hasn't got that *blackness* that you often see with a fracture, alright, but you might not see this very very well, but around the [Highlighting 1: lasers sclerotic line], on the edges of this lucency there is a sclerotic *line* and if there's a sclerotic line [Highlighting 1: lasers sclerotic line] around it what does it tell you about how long it's been there?

Ebunoluwa: Is it an old fracture?

Mr. Hearken: Yeah so well it could be an old fracture, but if it was an old fracture it's likely to have been healed**.** Have you come across nutrient lines in bones before? [Pause] No? So, where does the blood, where does the bone get its blood supply from? And its nerve supply? [Pause] Same place as everything else. The way it gets into the bones is through little channels, little passages [Gesture: RH enacts curved nutrient canal] which are called nutrient canals and you often see those particularly in long bones as these long sort of tubular structures which get mistaken for fractures a lot but if you look closely [Highlighting 1: lasers sclerotic edge] you'll actually see they've got a nice sclerotic edge [Gesture: RH enacts curved sclerotic edge] which tells you they've been there a long time, okay? But yeah the teaching point on this one was this great big whopping thing.

[*Some muffled laughs*]

Mr. Hearken attributes the *'little lucency'* as a *'nutrient line'*, described as a canal that supplies the bone with blood, and distinguishes it from a fracture because it *'hasn't got that blackness that you often see with a fracture'.* Interestingly, Mr. Hearken does not problematise Ebunoluwa seeing the lucency. In fact, by returning to the arm – which is not the intended *'teaching point'* – he rather rewards Ebunoluwa's intrigue and turns this incidental finding into another teaching point, thus reshaping the pedagogical conditions of the image. Given what appears as a normal finding, Mr. Hearken takes it as an opportunity to warn the students about superficial resemblance in radiographs: *'as these long sort of tubular structures which get mistaken for fractures a lot'.* During a typical CXR image interpretation class, Ahmed (medical student) is satisfied that there is something wrong with the heart, not only because it appears 'enlarged', but because it appears barn-door obvious:

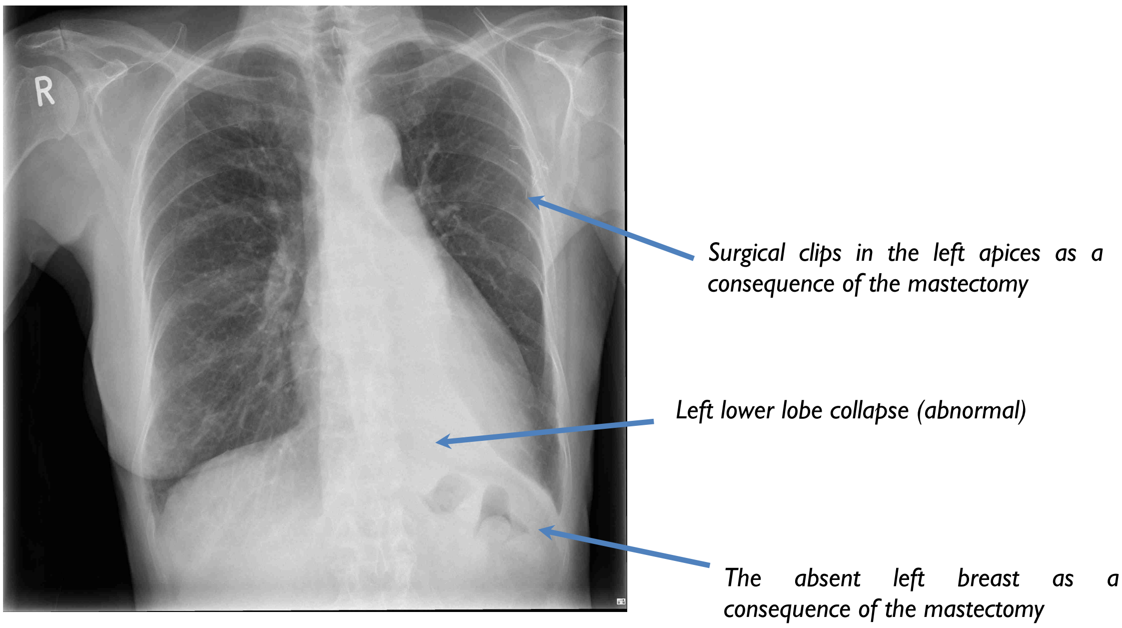

Figure 29 PowerPoint slide o abnormal CXR: 'Left Lower Lobe collapse and Mastectomy'

[*segment omitted*]

Ahmed:	[Fig. 29] Umm [Gesture: Prayer] uh, can't see anything. I don't really know what the diagnosis is unfortunately, the only thing I can see there is the heart's enlarged a bit, I think?
Dr. Delichon:	Yeah the heart's probably enlarged a bit, and then make sure you check your?
Ahmed:	Bone
Dr. Delichon:	Apices [Highlighting 1: cursor circles left and right apices], behind the heart [Highlighting 1: cursor circles over the heart] any weird *shadows* or opacities behind the heart, anything behind the diaphragm [Highlighting 1: cursor circles the left hemidiaphragm], any weird soft tissue shadowing [Highlighting 1: cursor traces the soft tissues of the thoracic wall]
Ahmed:	Mm
Dr. Delichon:	Or lack of soft tissue, the bones all look alright [Highlighting 1: cursor circles over the ribs]. So, as I say make sure you get into a routine [Gesture: RH cuts through the air five times akin to list construction] of going through every stage don't miss anything out and things might [Pause]. *So,* female patient, metal work, see these little linear clips here? [Highlighting 1: places cursor over the clips in the axilla]
Ahmed:	Mm just about yeah
Dr. Delichon:	It's not, it doesn't project *greatly* but they're in the axilla, surgical clips in the axilla, and then looking at soft tissues, we've got a breast shadow here [Highlighting 1: cursor traces around the right, right breast], where's the breast shadow on this side? [Highlighting 2: cursor placed in the location of an absent breast]
Ahmed:	Oh *yeah*, she hasn't got one!
Dr. Delichon:	Okay?
Deepak:	Mmm!
Dr. Delichon:	So, she's had a mastectomy, mastectomy in the axillary *talks under his breath and mumbles the diagnosis* *tuts*

[*segment omitted*]

After suggesting that he *'can't see anything',* Ahmed's comment about the heart means he has fallen prey to satisfaction of search. Although Dr. Delichon agrees that the heart is *'probably enlarged a bit',* it soon becomes clear that this may not be the teaching point and is treated more as incidental rather than pivotal to the image. Whilst Dr. Delichon does not completely denounce this observation, he swiftly guides Ahmed's fixation towards five review areas (*'apices', 'heart', 'diaphragm', 'soft tissues', 'bones'*), in a sequential fashion, through cursor highlighting. After two subtle hints about *'weird shadows'* and *'soft tissue shadowing'*, Dr. Delichon eventually positions the cursor on the *'little linear clips'* located in apices[141] review area, citing the absence of a right breast with *'where's the breast shadow?'* and concluding the patient *'has had a mastectomy'.* Ahmed's comment 'oh, *yeah!* she hasn't got one!' suggests the student's vision has been aligned with the radiologist's - by tracing the right breast shadow with the cursor, the student's eyes track across the screen to the absence of a *left* 'breast shadow' - because there is no left breast to highlight.

This order was deployed to build intrigue and it supports the learning process of abduction, prominent in the work of radiological case studies (Saunders, 2008, 2009). Saunders introduces the notion of "abduction" (a form of reasoning, but distinct from deduction and induction) as something that can be applied to the diagnostic work of radiologists, but is rather a "kind of conjectural thinking", or "clever guessing", where observations point towards some form of hypothesis making some more probable than others in the diagnostic process. The language of radiologists, however, does not conceive the observation of surgical clips in the apices, the absence of breast tissue, or increased density over the left hemidiaphragm as observations, but as 'findings'.

Throughout his writings, Saunders uses the term "abduction" in the diagnostic interpretation of medical images; he talks, for instance, about marks, clues, and traces that must be distinguished from artefacts. Even if it is the normal radiograph that provides a scaffold for getting to know radiographic anatomy, findings such as surgical clips (categorised as 'metalwork' or 'foreign objects' by radiologists) are often used as findings that build intrigue and propagate certain assumptions. These 'findings' play a fundamental role in enabling

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[141] In his autopsis Dr. Delichon refers to this as the axilla (armpit) which in terms of 'review areas' is located in the apices.

medical students to see and work as ontological hooks that build their intrigue. Abduction and the observed presence of findings can thus be understood as a way of helping form a system of seeing in image interpretation. Such a standpoint speaks of "intrigue or abduction as theatre" and forefronts its social and cultural dimensions – of fleshy embodiment, comparison, and taxonomy – embedded in concern with training (Saunders, 2009: 155).

Whilst private abduction is no doubt possible, video recordings of professionals in-the-making, in academic settings, bring forth the nuances of interactional exchange and the pedagogical device of intrigue. In doing so, observational skills of seeing and interpreting abnormality are learned and practiced in performances of abductive craft, folded into the economy of intrigue. This finding is consistent with Saunders (2009), who resists the assimilation of 'abduction' to private cognition or mental affect in the enskilling of vision. However 'cognitively' oriented, the professionals' interactions with students and images (for example, highlighting the anatomy with a cursor) and the embodied demonstration of specific image making practices in original contexts contradict their connection to the cognitive sciences. Thus, in a significant contribution to the literature, these examples highlight how the 'social' constitutes a key step towards the assimilation of professionals' in-the-making very own abductive reasoning in medical image interpretation.

Such advice arguably extends the "bifocal vision" by realigning a focus on abnormal anatomy, as well as normal anatomy (Prasad, 2005). However, such advice is used here by professionals as a resource for seeing subtler abnormalities and overcoming fixation on one main area of interest (i.e. 'satisfaction of search'). The benefit of having a structure or system[142] for the inspection of the review areas performed by Dr. Delichon is reflected in his recognition during another class that *'you'll learn the bits that you always forgot to look at, all the things where you missed [review areas]'*, all the things referring to situations in which professionals categorise a finding as 'not obvious', 'hidden', 'obscured' or 'behind'. The following comment was taken from a typical radiography student CXR image interpretation lecture organised in the second week of semester one:

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[142] And insofar as there is a structure or system, it is not 'proper' abduction.

Mr. Hearken: As a rule of *thumb*, an adequately *exposed* [Gesture: both hands represent chest exposure] chest allows us to see lung markings through the heart [Highlighting 1: cursor highlights lung markings behind the heart]. So, can you see some branches or some vessels *behind* there? That's what we're looking for. We're not going to be able to see them as clearly as we do on the rest of the chest [Highlighting 1: RH hovers over left and right lungs], that's because there's a great big thing[143] filled with fluid sat in front of it. We're just wanting to see the outline, the structure, of those vessels [Highlighting 1: RIF[144] traces around some of the lung markings], as well as this big thing that runs down the middle [Highlighting 1: RH moves down the spine]. What's that?

Class: Spine

Mr. Hearken: The spine, yeah. So, to assess *exposure*, we're looking to be able to *see*, just through the heart, to see the lung markings, and to see the spine. So, if it's *under*-exposed you won't see that [Gesture: List construction], because there won't be enough *penetration* detected to get through the heart [Gesture: LH quickly emulates the movement of x-ray beams through the air]. If it's *over*-exposed, what do you think the flip side is? So, if we over-expose it, we might get a beautiful image *behind the heart*?

Chloe: You'd not get much of the stuff at the front of the chest?

Mr. Hearken: Well yeah, you would lose all this very, very fine detail [Highlighting 1: LH traces lung markings] so if you absolutely *blast* the patient, you're going to lose all this very, very fine detail. So it's a middle ground, with exposure, you want to be able to see detail behind the heart, but not so much that you obliterate all of this [Gesture: LH hovers over the lungs]

Such lectures frequently force students to *look at* anatomy and *through* anatomy and yet, although at one with the patient, the radiographer is part of the machine in which seeing is confirmed and produced. During this particular situation that is specific to CXRs, the professional endorses x-radiation exposure to enhance the visibility of the image to see through and behind the heart. This echoes radiologists' and radiographers' accounts when

[143] Refers to the heart.

[144] Right Index Finger

abnormalities are constructed as barn-door obvious because of the transparency of the images.

In her study on how physicians and technologists produce and interpret MR images, Kelly Joyce (2005) identifies how professionals take advantage of news media and popular culture rhetoric on the transparency of MR images. Joyce subsequently directs our attention towards the professionals' perception of the MR image as an 'actor' – one which conveys authoritative knowledge and detracts the image from politics and removes subjectivity in technical work and diagnostic interpretation. This point is extended in her later work, in which we subsequently learn that MR images that are imbued with authority[145] direct attention away from the professional and protect them, as evidenced, for example, by the prestige of MR technology over older imaging technology and phrases such as "cover your ass" (Joyce, 2008: 16), in which litigation has far more influence than it previously had in the United States. More on this later in the chapter.

Bridgestock radiologists and Woodfleet radiographers often persist in a similar support aimed at x-ray image interpretation by bringing x-ray images under a transparent agenda. These professionals also seem to align with Prasad's (2005: 301) suggestion that medical image interpretation also reveals "an unexpected trust in scientific imaging technologies to tell me the truth about my body". Such transparent framings correspond to other research and professionals' accounts of shoring up the authority of medical images during image interpretation, who recognise the importance of providing certainty and definitiveness towards a person's physical condition and not one that solely expresses concern and uncertainty (Joyce, 2005; 2008; Rystedt et al., 2011; Reed et al., 2016a; Reed et al., 2016b). However, inherent in much of this work is the management of ambiguity and uncertainty. Of particular importance for the training of students presented here is the systematic approach and scrutiny of the review areas by which students are encouraged to deploy to curb satisfaction of search. A closer exploration of the processes that lead to the prescription of this

[145] I return to the importance of images having 'authority' later in this chapter. For now, I want to stress that, like the professionals in Joyce (2008), students also take advantage of the authority of images to deflect attention away from themselves in the hot-seat. This deflection is exhibited by a lack of response and inactive movement as the students sit in Pause during moments of uncertainty absorbed by the white glow of the x-ray.

system suggests that professonals also imbue scepticism and curiosity towards x-ray images. In doing so professionals build a considerable momentum of intrigue through different types of recognised error that warn against 'disguise', the classifiably 'tricky' and the 'obviousness' of findings (Saunders, 2008); I tend to focus on what these processes accomplish, and highlight how such momentum sharpens a critical gaze. In effect this lays the course for the rest of this chapter as it becomes a balancing act between professionals' delivery of certainty and uncertainty. An early platform from which to begin to mount such a challenge comes in the form of objective elements – characteristically they are what the professional makes of recognised signs, representations and existing descriptions of disease in the organisation of interpretive work.

5.2 'Sign systems', eponyms, and diagnosis

So if radiologists and radiographers, as well as literature on radiological pedagogy, account for medical images in transparent terms, how is it further constituted in undergraduate education, that is, in training students to see and classify abnormality? Barley (1984: 235) claims radiologists were "tutored in sign systems" to interpret signs of disease and pathology. Måseide (2007) similarly argues that the demands of radiological work in medical problem-solving have a "symbolic character" in order to see and interpret pathology. Sandell (2010: 37) points out in ultrasound practices, how "markers" in scans can be attributed to "signs both of possible abnormalities and that one has obtained a good image". In analysing what shapes and constitutes the 'visual' in radiologists' interpretive practices, Burri (2012: 51) likewise suggests that "visual signs" and what is seen and recognised in medical images are a consequence of local sociotechnical practices of image production and interpretation, which are shaped by cultural meanings or institutional contexts.

Interestingly, in x-ray image interpretation training at BRMR and WURD, the abnormal (once 'seen') is often interpreted in an explicit classification through 'sign systems', 'eponyms' and 'description'. At most, x-ray image interpretation is bound up in 'sign systems' with further descriptive details. 'Signs' in musculoskeletal, abdominal and chest radiograph interpretation are a mixture of eponyms and real-world phenomena. For instance, 'Rigler's sign' is an eponym named after Leo George Rigler (the person who discovered it), whilst the 'sail sign' is named after a boat's sail because the abnormality resembles a sail. At WURD, professionals trained students to see the abnormality and take steps towards interpreting it. The following exchange between Mr. Hearken and Chloe is taken from a shoulder image interpretation class:

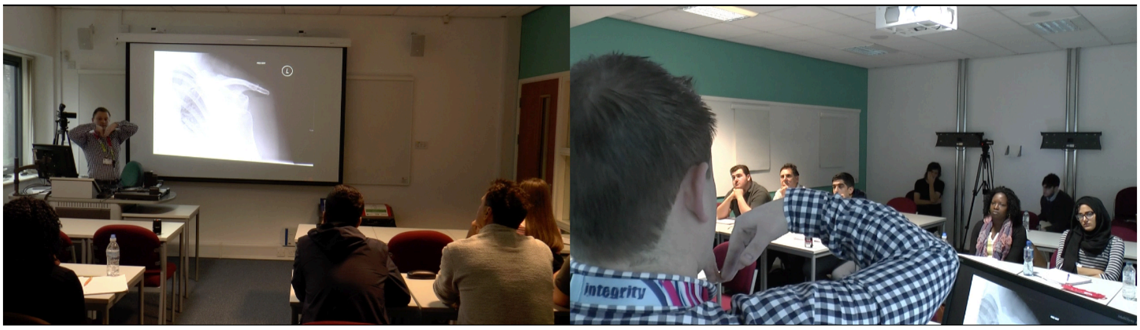

Figure 30 Mr. Hearken gestures a 'Hill-Sachs' fracture/'Hatchet sign'.

Mr. Hearken: This is another anterior dislocation. We've only got one view. What do you notice about the humeral head this time?

[*Silence: four seconds*]

Chloe: It looks like it's impacted?

Mr. Hearken: [Gesture: Points at Chloe as if agreeing or encouraging her to continue]

Chloe: Like it's overlaying it?

Mr. Hearken: Yeah as you can see this great big *divot* [Highlighting 1: lasers the 'divot' in the humeral head] out of it here so this is sort of a similar thing, the humeral head has come out of joint and the muscles have tried to pull it back into place and rather *knock* the greater tuberosity off this time it's kind of caved it all in [Gesture: both hands raised above the elbows, touching fingers to enact a 'divot' akin to a 'V' shape (Fig. 30] and this has got a specific name [Highlighting 1: uses laser to highlight the 'divot' in the humeral head] anyone know it? [*Pause*] Probably not come across it, it's either called the *Hill-Sachs* deformity or the *hatchet* deformity. So, Hill-Sachs were the people who first described it and *hatchet* apparently makes it look like that someone's taken an axe to it [Gesture: demonstrates a hatchet action] and caved it in. So, this is an absolute classic sign of an anterior dislocation. Sometimes what can happen is, sometimes you can dislocate your shoulder, but it can actually be pulled back

> into joint. But as it goes *back* into joint typically what happens is you get this deformity [Highlighting 1: lasers abnormality] so it will be sat in joint but you'll have this great big divot sat out of the humeral head [Highlighting 1: lasers abnormality] so it's a sign that it has been dislocated but it's spontaneously relocated itself.

Mr. Hearken begins the case presentation by identifying the radiograph as abnormal and interpreting it (*'this is another anterior dislocation'*), immediately drawing attention to the humeral head (*'what do you notice about the humeral head this time?'*). In response to Mr. Hearken's provocative suggestion, he helps Chloe see that there is something wrong with the humeral head (*'it looks like it's, like impacted?').* Mr. Hearken, encourages Chloe to continue with her description, demonstrating that he is in agreement that she has seen the abnormality and encourages further description (*like it's overlaying it?'*). A description practice then ensues, with Mr. Hearken talking about how the appearance of the abnormality can be described as a *'divot'* because it has *'caved in'* (Fig. 30). Mr. Hearken's use of hand gestures not only sculpts the divot as a 'V' shape, but also reveals the action of a *'hatchet'* to the ground, understanding how it happened and ultimately the mechanism of injury. Mr. Hearken interprets the abnormality as a '*Hill-Sachs* deformity' or the '*hatchet* deformity'. He attributes Hill-Sachs to *'the people who first described it'*, frames the hatchet deformity as if *'someone's taken an axe to it [Gesture: demonstrates a hatchet's action] and caved it in',* and later describes it as a *'sign that it has been dislocated but it's spontaneously relocated itself.'*

This multi-gestural practice, where interpretation is coordinated with familiar "manual actions" to make the abnormal socially meaningful, reflects a shift of perception between danger and awe, that is, the (clinical) information acquired around a radiographer's clinical practice and academic performance (Kendon, 2004: 10-15). This shift involves the bodily reenactment of dangerous MSK injuries that have harmful consequences for the body – that is performing how fractures, dislocations and subluxations happen, which, in their discourse, are referred to as the 'mechanism of injury'.

But what happens to x-ray image interpretation here? Whilst the abnormality is cited as an *'absolute classic sign of ... anterior dislocation'*, the details on it owe a lot to the metaphoric forms of the world where the abnormal is shaped as something Chloe 'knows'. Radiographers took advantage of this 'natural' affinity to identify trauma or fractures as everyday signs and built on these appearances by using descriptions. Interestingly, Mr. Hearken prioritises the descriptive capacity of interpretation over signs and names, particularly when it comes to the colloquial. Take, for instance, the boxer's fracture – *'what's this? And don't say 'boxer's fracture!' [Gesture: LH punches the table and makes a loud bang].* Prompted by class answers, Mr. Hearken warns students not to describe the abnormality using the colloquial *'boxer's fracture'* but rather to rely on a verbal description that prioritises a 'what', 'where' and 'how' system to organise and help describe their interpretation.

Mr. Hearken addresses the '*what*' as *'oblique fracture',* the *'where'* as *'of the distal metaphysis or neck of the fifth metacarpal',* and the *'how'* as *'and then what you might say, in conclusion, is boxer's fracture').* Despite Robert (radiography student) being told elsewhere[146] that this was a scrapper's fracture, Mr. Hearken describes the difference between a professional fighter and an amateur fighter as *'trained fighters, trained boxers, don't punch like this* [*Gesture: left arm swings aimlessly*]' and that *'it's a scrapper's fracture, it's your Friday night, swing like a, whatever, windmill; it's not a trained fighter's, so it's a bit of a misnomer.'* In both distinctions, the interpretation relies on the assumption that professional fighters use gloves or hand wraps to reduce the risk of injuries, as well as proper punching techniques, whereas the Friday night fighter is assumed to be drunk, emphasised by the aimless left arm swing above. Again, this is an inversion of Garfinkel's (1967) 'making the familiar strange' principle, where the abnormal is classified through analogies with familiar things (Lynch and de Ridder-Vignone, 2015: 104) and the metaphors underlying its conceptualisation are drawn from the imagery of boxing (Lakoff and Johnson, 1980). The following exchange between Mr. Hearken (WURD radiographer) and class members (radiography students) reveals the metaphoric process of learning to see and interpret a meniscus sign:

[146] It is clear to see that radiography students learn a great deal during clinical placement where they are privy to practices of seeing, interpreting, and diagnosis. Similar to Barley's (1986: 92) observation whereby "diagnostic knowledge always flowed from radiologist to the technologist", particularly when radiologists consulted with technicians "to give referring physicians immediate readings", Robert's comment implies that diagnostic information also flows from professionals to the students. Notably absent are questions of how students learn to see and interpret medical images in clinical settings. This merits investigation beyond this thesis.

Figure 31 Mr. Hearken presents a CXR of a pleural effusion in the right hemithorax and gestures the build up of pleural fluid. I have highlighted the meniscus sign.

Mr. Hearken:	Same sort of position on the other side [Highlighting 1: RH circles a curved up whiteness]. What we thinking? Too white, too black, missing, too big?
Lianne:	Too white
Mr. Hearken:	Too white [Pause] *and?*
Lianne:	Diaphragms are black
Mr. Hearken:	Diaphragms are black. The diaphragm's not normal, the costophrenic angle again is?
Zack:	Missing
Mr. Hearken:	*Missing*
Lianne:	Mm
Mr. Hearken:	What does this *look* like? [Highlighting 1: uses pen to trace over the meniscus[147] in the right hemithorax]
Nathan:	Fluid
Mr. Hearken:	Fluid level. If you pick up, imagine you pick up a bottle of water, or a cup of water, what happens to the fluid at the edge?
Jay:	Meniscus
Mr. Hearken:	Meniscus. You get a meniscus, that curving up [Gesture: Both hands enact the meniscus (Fig. 31)]
Lianne:	Mm

[147] A meniscus is what happens when you put a liquid into a container (e.g. beaker, test tube, bottle). The 'meniscus sign' is likely to be derived from radiology's scientific association where the 'meniscus symbol' is commonplace.

Mr. Hearken:	Alright? What do you think this might be then? [Highlighting 1: Uses pen to tap on the meniscus]
Zack:	The same thing
Mr. Hearken:	Fluid
Zack:	Fluid
Mr. Hearken:	Okay it's very *dense*, fluid, when you get a lot of fluid it's very dense so it appears very *opaque* so what's on the outside of your lung, what coats your lung?
Lianne:	Pleural cavity
Mr. Hearken:	*Pleura*

[*segment omitted*][148]

Mr. Hearken:	So that's pleural effusion. And again, the fluid might be [Gesture: list construction] blood, mucus, um water, we don't know, again it's the clinical history, which gives us the clue.

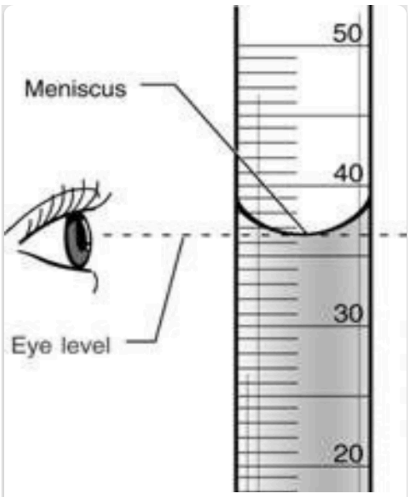

Figure 32 Meniscus symbol in science education

The case presentation begins with Mr. Hearken asking students to describe the anatomy at the bottom of the right hemithorax: Lianne sees that the area is *'too white'* and Zack sees that the

[148] I have decided to omit Mr. Hearken's description of surface tension. In short, surface tension holds up the lungs and allows movement.

costophrenic angle is *'missing'.* Following this, Mr. Hearken intentionally asks *'what does this look like? [Highlighting 1: uses pen to trace over the meniscus in the right hemithorax]'.* In response, Nathan sees that it looks like *'fluid'* presumably because of the way Mr. Hearken highlights the meniscus shape[149] with a movement that simultaneously enacts the curve of a liquid. Mr. Hearken then builds on this with the everyday or commonsense ontological assumption that *'if you pick up a bottle of water ... you get a meniscus',* where the water curves up at the edge, then links this *'curving up* [*Gesture: Both hands enact the meniscus (Fig. 31)*]*'* to the fluid in the *'pleura cavity'* on the radiograph. Such an ontology renders the *'pleura fluid'* to become meaningful, thus increasing certainty over a diagnosis of *'pleural effusion'*.

This constructs training as a gestural sign-making activity that situates students in a metaphorical and figurative landscape, arguably supporting a "cognitive-semiotic technique" of illness/signs designed to instruct interpretive practice (Müller, 2014: 140). This supports interpretive practice as an activity that makes the 'unfamiliar familiar' through visual comparison with everyday or mundane scientific phenomena. It also gives a whole new meaning to metaphors we might "live by" or "die by" (Nerlich & Jaspal, 2012). Although the use of metaphorical language has been explored before in the radiological discourse (Beaulieu, 2002; Joyce, 2005, 2006, 2008), there has been no attempt at studying how metaphors are imbued with meaning in those learning to see and interpret medical images – up until now. Notably, metaphors drawn from the world provide students an explanatory ability to target and interpret disease (Prentice, 2004; 2013). By framing the pleural effusion as *'blood, mucus, [...] water'* and allowing the use of a *'clinical history, which gives us the clue',* Mr. Hearken shapes radiography students as diagnosticians fashioning radiography's professional identity as medical. In contrast to previous studies of diagnostic imaging, radiographers are now able to interpret images and classify abnormality as well as being trained to produce images and recognise anatomy - a pattern of expertise that once "created a hierarchy of authority in which radiologists knew what technologists knew, but not the reverse" (Larkin, 1978; Barley, 1984, 1986: 87).

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[149] As another point of interest, the meniscus sign is akin to the 'dam' symbol cartographers use to depict hydrographic features, such as erosion and flood control, in the construction of topographic maps. In this instance, using the meniscus sign to represent mass fluid in the pleura and pleural spaces or *flooding* of the lung is highly appropriate.

Additionally, although Mr. Hearken highlights the meniscus, his claim that *'we don't know'* reveals the abductive inference and the prospect of misreading (Saunders, 2008). Nonetheless, my intention here is to recognise how x-ray image interpretation makes use of 'sign systems' during training and radiographers in-the-making are authorised to interpret the radiograph for pathology, as well as producing and technically evaluating radiographs. Here, radiography professionals state how they train students to enter the clinical workplace with an explicit imperative that reflects regulatory (SoR, 2013), National Health Service (NHS) and political (Government) policies that authorise participation in diagnostic x-ray image interpretation:

> We're training you to be professionals, medical professionals, and as such your terminology should reflect that. So, we want to start getting you to move away from the layman's terms and the non-technical terms. 'White' and 'black', no. Things like *opaque*, *density* rather than white and lucent or radiolucent if it's something that's too *black*. So, start training yourself or start trying to get used to doing that.
>
> **(Mr. Hearken, WURD radiographer)**

Likewise, radiologists trained medical students in sign systems, although teaching was more geared toward building upon prior clinical-radiological knowledge and traditions of radiological practice (Joyce, 2006). Radiologists worked to articulate a link between prior 'clinical-*medical* knowledge' and 'clinical-*radiological* knowledge', as well as demonstrate what the abnormality looked like *visually* in radiographs. Simply put, medical students are taught to see what they already know clinically. Often, it was the radiologist's role to draw upon prior radiological knowledge and bring it into vision with a sign. This alignment with a 'sail sign' emerges in the following exchange between Dr. Delichon (BHRD radiologist) and Amit (Year 5 medical student):

Dr. Delichon: Anything in the lungs?

Amit: *Leaning over the table* the lungs, umm

[*Pause: three seconds*]

Amit: Just tracing the pleura around and that looks okay, I think? **looks at Dr. Delichon for confirmation**

Dr. Delichon: *inhales* *shifts his seat away from Amit and moves back behind the workstation* *knocks down cursor* *So*

Amit: **recoils away from the table* *looks at Rehan and Riya for confirmation** did I miss something!? **Nervous laughter**

Rehan shakes his head and looks at Riya

Riya raises her left hand as if to point out the abnormality but withdraws her attempt

Dr. Delichon: *If* these are all vascular markings [Highlighting 1: cursor dabs right lung markings]

Amit: [Gesture: Le Penseur] Yeah

Dr. Delichon: Okay? So, these are vessels [Highlighting 1: cursor dabs right lung markings]

Amit: Uh-huh

Dr. Delichon: So, there's quite a lot of vessels here aren't there?

Amit: Yeaaaahhh

Rehan sits up straight from a slump position

Dr. Delichon: See? Now on this side [Highlighting 1: cursor dabs left lung markings] are there as many?

Amit: Nooo

Dr. Delichon: No. Which side do you think is abnormal?

Amit: The right

Riya's left hand points to the right lung but is quickly retracted

Dr. Delichon: You think the right side is abnormal? [Highlighting 1: places cursor in the right lung]

Riya: The left

Rehan looks at Riya

Amit: The left

Dr. Delichon: The left side, yeah, okay *nods head in agreement*. So there's not as many vascular markings when you're looking at the lungs [Highlighting 1: cursor dabs left lung markings]. There's no *focal* masses anywhere you can see, it just looks a bit, more *lucent*, [Gesture: LH raised to emphasise 'lucent'], doesn't project particularly well here. Now you said that the hemidiaphragm you can see?

Amit: Partially [Gesture: Le Penseur]

Dr. Delichon: So you can partially see it? [Highlighting 1: cursor traces part of the right hemidiaphragm]

Amit: Yeah

Dr. Delichon: And then you've got this weird straight line [Highlighting 1: cursor traces along the 'line' on the border of the opacity in the left lung] *looks expectantly towards Amit*

Amit: Mmmm, oh! Is that the ss-sail sign? *looks at Dr. Delichon*

Dr. Delichon: Yeah

Amit: Riiiggght

Dr. Delichon: If you ever see a straight line on a chest x-ray, It's probably not meant to be there, okay?

Riya tilts her head to the left

Amit: Okay

Dr. Delichon: So this is a straight line [Highlighting 1: traces cursor along the border of the sail sign] and you've lost part of the left hemidiaphragm [Highlighting 1: circles cursor around the left hemidiaphragm], so what do you think?

Amit: So, I think, lower lobe collapse, or? *Looks at Dr. Delichon*

Dr. Delichon: *nods head in agreement* yeah, left lower lobe collapse, good *LH scratches head*[150]

Amit: *looks at Rehan and Riya* it's obvious now! [Gesture: RH concedes]

Rehan breathes in and glances over at Riya

[150] There are a number of involuntary movements such as hair-scratchings, face-scratchings, manipulation of rings and chair adjustments.

Before Dr. Delichon has finished highlighting the collapsed lobe, Amit reveals that it is a 'sail sign' (*'Mmmm, oh! Is that the ss-sail sign?'*). The observation is then met with a larger demand that expects a diagnosis (*'so what do you think?'*) to which Amit responds '*lower lobe collapse*', albeit hesitantly. Importantly, Dr. Delichon exhibits frustration suggesting that he is disappointed that Amit did not see the abnormality: the short inhalation, coupled with the abrupt movement away from Amit to behind the workstation, knocking down the mouse, and the matter-of-fact '*So!*' suggest disappointment and that further efforts to reveal the abnormality are needed.

Dr. Delichon subsequently begins the abductive process of helping Amit see the abnormality with three stages of multimodal highlighting (Goodwin, 1994). First, the lack of vascular markings in the right lung (*'there's not as many vascular markings when you're looking at the lungs* [*Highlighting 1: cursor dabs left lung markings*])'; second, the obscured right hemidiaphragm (*'so you can partially see it?* [*Highlighting 1: cursor traces part of the right hemidiaphragm*]); and third the collapsed lobe 3) *'then you've got this weird straight line [Highlighting 1: cursor traces along the 'line' on the border of the opacity in the left lung]*)'. Bringing these actions together makes the abnormality salient and enforces a situation of "seeing as" (Vertesi, 2016). This way, Amit can see the abnormality and simultaneously interprets it (*'Mmmm, oh! Is that the ss-sail sign?'*). This suggests Amit knew about the abnormality prior to the seminar, possibly based on information from the radiology rotation or prior knowledge of lobar collapse learned elsewhere. Of particular importance for our understanding of practices of seeing, I show here that Amit is learning how and when it is appropriate to apply a sign to a particular presentation of anatomical findings in order to influence his (subjective) judgement – a process in which outcome information (i.e. the diagnosis) is organised by a multimodal interaction with other elements of semiotic action (i.e. the sign).

Curiously, observing interactions between Dr. Delichon and the medical students reminds us of the problematic performances of a game of chess. Radiologists are the self-assured masters of knowing the next move, unlike the medical students, whose body movements and hand gestures appear awkward and improvisational: both movements get broken down during moments of uncertainty. These breakdowns – what Goffman (1971) calls "broken down situations" in the interaction order – are often constructed alongside hesitancy and uncertainty when students encounter problems in reading the image.

The radiologists in this study were masters at reading problematic performances, repairing broken-down observations of findings, and maintaining seeing in case presentations: both masters of reading images *and* reading students. In the exchange above, Dr. Delichon notices Amit's lengthy struggle to see the abnormality and begins the labour of fusing hints[151] – such as *'anything in the lungs?'* and *'now on this side, are there as many?'* – with selecting what to see until the sail sign becomes shared between master and apprentice. Additionally, Amit attempts to deflect the question ('*that looks okay, I think?')* and looks at others for confirmation, as if to tactfully invite someone else to take over the responsibility of answering. Such 'ways of looking'[152] (Goodwin, 1981) are essential to enlist the help of others.

Moreover, Amit's techniques of deflecting answers to questions is a management of his medical identity and 'being seen' as a medical professional, self-aware of his radiological deficiencies and limitations (Willerslev, 2009). This similarity to a game of chess – a space where the use of body, gesture, looking, and language are fused together in physical judgement – summons the notion that the humans are the players and the radiograph is the game. Suppose, however, that the image is both game and *player.* That is, the image commands authority because it encapsulates students' attention of the human radiologist, and a control that ultimately dictates their move. From this perspective, it can be said that the image has a choice between two actions. This argument resonates with other studies that

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[151] Previous to this Dr. Delichon supplied Amit with other hints, such as *'the metastases is coming around the knuckle and the aorta and it comes out into the carina'*. However, this hint was not comprehended or understood by Amit. For instance, in reply to this hint, Amit replied *'Um I can see the right heart border and the left heart border'* failing to appreciate Dr. Delichon's hint that looking in this area will allow him to see that the anatomy is problematic. Also, Amit's observation about the heart suggests he is 'making it up' as the collapsed lobe is actually obscuring the heart. An experienced individual would also know that metastases in this area can cause collapsed lobes.

[152] There are many 'ways of looking', gesture, and embodied actions that merit further exploration. Whilst I captured many 'ways of looking' within the interactional space, I missed out on frontal perspectives of looking, including gesture and bodily actions in the establishment of attention and student responses to questions. This limitation was a consequence of video camera positioning (see chapter 3: Methods).

position imaging technology and images as 'actors' (Joyce, 2005, 2008), a designation that exemplifies the 'agency' of materials and objects or *nonhuman actants* in actor-network theory (Latour, 2005).

I suggest x-ray image interpretation training is a 'sign-alignment' activity and that its immutability contributes towards it as a critical practice. As an "immutable mobile" (Latour, 1986), it functions as a pedagogical resource between communities, so it enhances the analysis and classification of phenomena, such as abnormalities to newcomers and novices. This can explain radiography's empowerment in the interpretation of normal patterns/abnormal signs and a natural fit into the radiological workforce (CfWI, 2012) disrupting the traditional medically dominated interpretive hierarchy (Larkin, 1978; Barley, 1984; Saunders, 2008).

But what about situations in training where a diagnosis has been accomplished but the image can also be interpreted or diagnosed in different ways? Oftentimes, within such practice, pathology is given much attention because of its wide range of diagnostic appearances. Radiologists, in particular, were adept at building the medical students' attention towards alternative theories for the image: the work of differential diagnosis. Consider the following exchange taken from a CXR seminar in BRMR, between Dr. Saury (BHRD radiologist) and Alexander (medical student) after a collapsed lung had been interpreted as a 'sail sign':[153]

Figure 33 Dr. Saury has highlighted a 'Left Lower Lobe collapse ('sail sign'). It should be noticed that the LLL is highlighted and graphically represented (as a sail) at the same time.

[153] The collapse of different lung lobes is equated with different signs. For instance, a lower lobe collapse is classified as a 'sail' sign, whereas a 'luftsickel' sign is left upper lobe collapse.

Dr. Saury: [Fig. 33] So, what are the causes of collapse?

Alexander: Um [Pause] pneumothoraxss?

Dr. Saury: Yeah, so people often get pneumothorax[154] and collapse *mixed* up[155], they are different. Obviously, you're saying they are different things, but pneumothorax can do a big one

Alexander: Mhm

Dr. Saury: lots of gas in the um pleural space *can* cause the lung to collapse but you can have a pneumothorax without collapse

Alexander: Okay

Dr. Saury: okay? Yeah anything else? *drinks water bottle*

Alexander: *tuts* umm, m-massive in-infection or somethi-?

Dr. Saury: Yeahh, infections *scratches head*

Alexander: I'm trying to think, actually, I'm not

Dr. Saury: So?

Alexander: Uh, obst- uh

Dr. Saury: Go on [Gesture: points finger towards Alexander in encouragement]

Dr. Saury asks Alexander what the causes of a collapsed lung are, Alexander answers that a pneumothorax can cause a collapsed lung ('*Um [Pause] pneumothoraxss?*'). In response, Dr. Saury explains that a pneumothorax and a collapsed lung are often *'mixed up'* and that you *'can have a pneumothorax without collapse'*. This raises awareness that a pneumothorax can be associated with a collapsed lung as well as an inflated lung, which problematises interpretation. In answer to Dr. Saury's original question, Alexander then delivers two other different causes – an unfolding of answers that are as fitting as each other but are slow, thoughtful and staccato, emphasised by pauses in the description of the diagnoses, including gestures of frustration: '**tuts* umm, m-massive in-infection or somethin-?'* and *'Uh, obst- uh'.*

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[154] The presence of gas or air in the pleural space around the lungs which may or may not collapse the lung.

[155] There is a critical irony here. In my analysis of this passage I fell prey to this exact interpretive problem. Initially, I assumed a collapsed lower lobe was a consequence of pneumothorax. However, it turned out that a collapsed lobe and a pneumothorax are totally different pathologies with different causes. For clarity, I emailed Dr. Saury who explained to me that *'they both occur in isolation but a pneumothorax can also cause lung collapse.* It is for this reason why email correspondence became crucial during video and transcript analysis.

Alexander's answers are akin to guesswork,[156] arguably indicating that he is struggling. Afterwards *'Uh, obst- uh'* turns to *'obstruction of the bronchus?'* after some encouragement (*'go on')*. Dr. Saury accepts this as another cause of the collapse where other causes that underpin a collapsed lung soon follow:

Alexander: Obstruction of the bronchus?

Dr. Saury: Yeah, absolutely [Gesture: the 'A-OK' sign] that's really important, so you *can* get stuff pushing [Gesture: pushes the space between his two hands] from the outside, so *big* pneumothorax [Gesture: places left hand across the top of his right lung] or a *big* pleural effusion [Gesture: opens a space and pushes the space between his two hands] would cause *passive* collapse of the lung, it *pushes* the lung down okay? [Gesture: hands represent pleural effusion pushing the lung] But much *more* common than that is, is, in an *adult* is a fairly sinister sign, particularly if they're an adult smoker: bronchogenic tumours

Alexander: Mm

Dr. Saury: Or big lymphadenopathy of the hilum *blocks* off [Gesture: LH pinches the air] one of the bronchi you no longer aerate that bit of lung [Gesture: RH moves from the pinched point of the air downwards], the lung, the gas that's sat there [Gesture: opens a space between his two hands] is stagnant, it gradually gets reabsorbed and you lose volume [Gesture: closes the space between his two hands and gently claps hands]. It all just crunches down and there's no longer any gas in it. So the other thing is mucus plug in, so things that block the airways, so tumours you worry about, but if they've got bronchial sepsis or if they're on ITU[157] and lots of sputum production, then mucus plugs can do it as well, particularly if it flits about [Gesture: LH and RH touch the air] one lobe collapsed, you get a bit of physio, it comes back up, another lung collapses, a bit of physio it comes back up, it's not gonna be a tumour it's gonna be a mucus plug-in. In *kids* [Gesture: LH 'A-OK' sign] what's the cause in kids, almost-always?

Alexander: Foreign body?

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[156] This echoes radiology trainees' engagement with puzzling cases whose diagnostic efforts "have the status of a hazarded guess – informed, but not certain" (Saunders, 2009: 157).

[157] Intensive Treatment Unit

Dr. Saury: Yeah, so unless they have tumours, obviously kids do get tumours but yeah, usually it's inhaled foreign body. Sometimes with *kids* they don't have that, so the way the reabsorption happens, it happens between different bits [Gesture: RH strokes fingers of the LH] of lung and you need these particular connections [Gesture: RH pinches air] which actually develop later on, not all kids have them, so often actually if you *block* off uh the bronchus [Gesture: LH rests over his bronchus] then you'll get hyper expansion [Gesture: opens a space between his two hands], so gas manages

Alexander: Mm

Dr. Saury: To get in [Gesture: Right finger prods downwards] when they breathe in, they gradually inflate [Gesture: forces open a space between his two hands which become opposed, restricting his movement] but can't quite get out, it's like a ball valve sort of thing when they try to breathe out so huh-huh-huh-huh [Gesture: emulates imagined patient's breathing difficulty by inhaling and exhaling in a shallow manner enacting this as a restricted movement with his hands] it gradually pumps up and up and up and actually it's *lucency* [Gesture: opens up a space between his two hands] rather than collapsing down, okay? And the final thing is on ITU is ET tube down one of the main bronchi blocking off the other one, that's another common cause of collapse, okay?

Intimating that he was struggling with his diagnostic efforts, Dr. Saury – who is able to gauge the signs of struggle – takes over the responsibility of providing further causes for lung collapse, which in effect, acts as a way of disciplining Alexander about alternative diagnoses. Dr. Saury provides a detailed overview of other alternative possibilities that include *'a big pleural effusion', 'bronchogenic tumours'*, *'big lymphadenopathy'* and a *'mucus plug-in'*. This is reinforced by Dr. Saury suggesting that an '*ET tube down one of the main bronchi blocking off the other one'* can also cause a collapsed lung, presumably regarding its misplacement. It later transpires that the misplacement of tubes as well as lines also challenges seeing and undermines the interpretation (see later in this chapter).

An important observation here involves Dr. Saury's inception of the process of differential diagnosis for a collapsed lung using the same radiograph. He also suggests that an *'inhaled foreign body'* will implicate the appearance of lung anatomy and that a collapsed lung can also be caused by the professionals' misplacement of an Endotracheal Tube (ETT) in Intensive Treatment Unit (ITU). Whilst Dr. Saury uses these examples to demonstrate the difference in appearance between a collapsed lung and an overinflated lung (when a lung collapses it appears opaque as opposed to being *'lucency'*), it also points towards the significance of materialities and agency in the interpretation of images. At this point, differential information on the causes of a collapsed lung is given (*'lots of gas in the pleural space can cause the lung to collapse'*); in contrast with radiography, further dimensions of pathology are revealed. In radiology, attention is more focused on the multiple diagnostic possibilities of the pathological, the interpretive distinctions between pathological appearances, and the treatment of the condition (*'you get a bit of physio'*).

In such teaching practice, x-ray image interpretation training is to a large extent an inversion of the 'black box' metaphor (Latour, 1999: 304), a problem that describes "the way scientific and technical work is made invisible by its own success". In an analysis of the work applied to scientific practice, Latour (1999) suggests how the inputs and outputs of objects in a closed system are never questioned unless there is a problem; the internal complexity of an image or artifact will become redundant as long as people can continue to use it in the midst of their mundane activities and daily practices. The inner workings of the black box are never questioned, since it runs efficiently and continues to settle or replicate facts. Its output, therefore, is unlikely to be criticised because it produces a visual sense of truth, justification, and objectivity. However, I suggest that, within training practices, x-ray image interpretation is a matter of unpacking and problematising the black box, a seemingly ambiguous entity that needs to be opened and critiqued to provide professionals in-the-making with comprehensive information about image content. As such I turn my focus to professionals' discursive practice of unpacking x-ray images in traditional 'hot-seat' case presentations, exploring when this happens, and arguably what this result accomplishes in interpretive practice.

5.3 The misplacement and movement of lines and tubes

What are the factors that are particularly difficult for students during x-ray image interpretation training? Four reasons are offered: 1) the misplacement and movement of lines and tubes; 2) the surgical reorganisation of anatomy; 3) normal variants that mimic pathology; 4) technical inadequacy and aesthetically unappealing images. As alluded to earlier in the exchange between Dr. Saury and Alexander, lines and tubes are CXR taken-for-granted features, recognisable for seasoned medical students approaching the fifth year of their degree who will know about the risks of inserting NG tubes,[158] particularly in emergency situations when tubes can be misplaced or moved out of the stomach after movement. However, the taken-for-granted appearance of lines and tubes becomes compromised when there is something wrong with the patient, with professionals suggesting the *'AP-slump 'o gram'* as the cause of most uncertainty. Toward the end of a teaching case with three medical students, Dr. Maxwell (BHRD radiologist) explains:

> I've been labouring nasogastric tubes for your education because you guys will be involved. We have a policy of trying to report nasogastric tube chest x-rays within a couple of hours um uh to let you guys know you could always give us a ring and radiology if you want something checking uh some patients are impossible to place clinically on the ward because they have hiatus hernias and changes due to surgery.
>
> **(Dr. Maxwell, BHRD radiologist)**

Dr. Maxwell stresses the precise interpretation of NGT placement in CXRs, precisely because insertion becomes compromised when patients have a hiatus hernia[159] and have had *'changes due to surgery'*. Radiology professionals felt that doctors in-the-making lacked training in identifying the key features of lines and tubes, a trend reported elsewhere (Lee and Mason, 2013) and which undermined pre and post-surgery CXR image interpretation. Dr. Maxwell suggests that, despite awareness of lines and tubes among seasoned medical students, there is still unfamiliarity *('I've been labouring nasogastric tubes for your education 'cause you guys will be involved')*. Similarly, Mr. Hearken (WURD radiographer) authorises radiographers in-the-making to look for lines and tubes by stating they are *'iatrogenic'* – what he refers to as *'anything man-made or that we do to someone, medically induced, so it might be pacemakers, tubes, lines for feeding or for drugs, staples, [...] scissors.'* Mr. Hearken and Dr. Maxwell among others, import awareness of the iatrogenic to the systematic approach – students are thus reminded that iatrogenic artefacts are as important as the anatomy, while at the same time it

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[158] 'Naso' or 'orogastric' tubes

[159] It is commonly known that a hiatus hernia often obstructs the NGT insertion from entering the stomach.

assures a closer inspection of non-anatomical content in the radiograph. As such, CXR case presentations often begin with radiologists – Dr. Delichon in this instance – asking medical students to inspect for iatrogenesis (*'Any lines there?'*), with casual reminders if neglected (*'again, always check for lines, then go onto talk about the lungs'*). The following hot-seat exchange between Dr. Maxwell (BHRD radiologist) and three medical students (Sarah, Richard, Millie) illustrates the difficulties of distinguishing iatrogenic information from a portable[160] CXR:

Dr. Maxwell: Right, what about this one, Sarah? [*Presents a CXR on the LCD* (Fig. 34)]

Sarah: *tuts* Um, so portable in theatre again

Dr. Maxwell: Mhm

Sarah: It looks like we have a [Pause] is that a *pacemaker*?

Dr. Maxwell: Mhm

Sarah: Just under the skin

Dr. Maxwell: Mhm

Sarah: And there's also a nasogastric tube

Dr. Maxwell: Mhm

Sarah: Which *leaning forward over the table* *might* be in the right place, but I'm not entirely sure what I'm looking at

Dr. Maxwell: Okay

Sarah: Is it like an enlarged heart a megalocardiapathy [sic]

Dr. Maxwell: It's certain cardiomegaly, yeah

Sarah: Yeah, um

[*segment omitted*]

Dr. Maxwell: *tuts* so anyway the nurse wants to know if you can feed the patient [Gesture: RH punches into palm of LH], well *she* wants to feed the patient

Richard: *tuts*

Dr. Maxwell: '*C'mon doctor!'* *sits down on the seat behind the computer and faces Sarah*

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160 Portable x-ray machines are used in surgical theatre, in corridors, or on the ward for immediate imaging of sick patients. Surprisingly, sociological research has not called attention to the practices of portable x-ray production given its long history in the healthcare of humans and animals.

Richard:	*Places lips together and blows out between them expressing a sign of exasperation*
Dr. Maxwell:	'*Feed the patient*!'
Sarah:	Mm
Dr. Maxwell:	'It took me ages to put this nasogastric tube in, c'mon, c'mon make a decision!'
Sarah:	I don't *laughs nervously* I don't *knoww*, I'd want like a better view
Dr. Maxwell:	Would you? 'Oh! The radiographers have left the ward now'
Sarah:	**shifts uncomfortably in her seat moving sideways towards Millie** *exhales in frustration* umm *tuts*
Dr. Maxwell:	'The relatives are really anxious, the patient's not been fed for ages!'
Richard:	Can't you blow air down them and listen?
Dr. Maxwell:	You can
Sarah:	Aspirate?
Dr. Maxwell:	But that's not recommended, it's not a recommended test anymore.

[*segment omitted*]

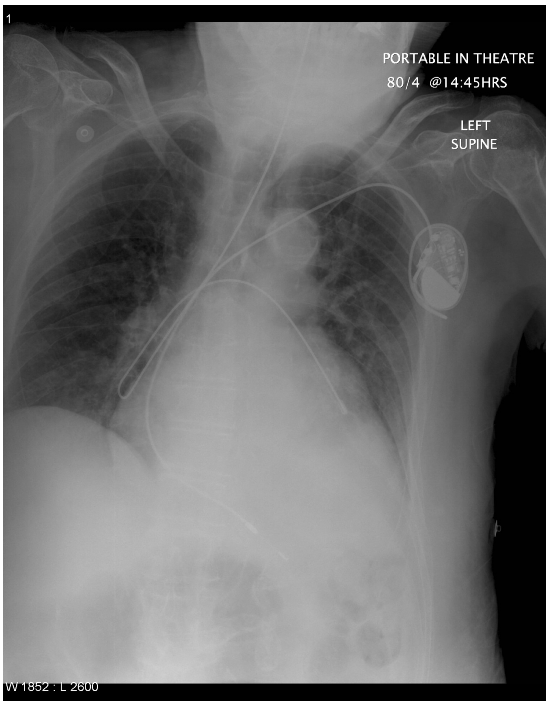

Figure 34 Portable CXR with a pacemaker line and a Nasal Gastric Tube (NGT). From this image it is impossible to distinguish between the pacemaker line and the NGT. Although it is possible to see the pacemaker (oval), it is difficult to discern its line.

Sarah doubts the NGT's placement, a response that is greeted vigilantly by the radiologist's *'okay'*. Without elaborating on her comment about the NGT, Sarah's eyes quickly transition to the heart describing it as *'enlarged'*, a claim that suggests the large heart size has distracted her from the NGT. After a brief pedagogical exchange[161] about heart size, where Dr. Maxwell draws on research evidence or 'stats'[162] to support Sarah's claim about an *'enlarged heart'* and the use of *'cardiomegaly'* as a corrective for *'megalocardiapathy',*[163] he directs her attention away from the heart back to the NGT. This quick shift implies the exchange about the heart size has gone on for too long. The consultant illustrates this concern about time by taking on the role of an anxious and restless staff nurse who seeks an immediate response from Sarah about whether to feed the patient.

This effort is better known as 'role-playing', whereby teachers interact with the students to illustrate their experiences and offer a change of perspective (Westrup and Planander, 2013). This distribution of experience stimulates the medical students to understand a particular issue – in this case the feeding of an extremely ill patient – from the perspective of the nurse who seeks immediate expert confirmation to feed the patient. The nurse's role, in turn, extends to the family because of their insistence that the patient needs to be fed. A discussion about techniques to assess whether the NGT has been positioned correctly in the stomach then ensues.[164] After Richard suggests blowing air down the NGT and listening for bubbling sounds[165] – a comment met with good-humoured dismissal *'that's not uh recommended! It's not a recommended test anymore'* – Millie takes a turn and suggests the aspiration of *'stomach gastric acid'* as a strong indicator for NGT placement. Once the consultant jovially confirms

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161 I have purposefully omitted this verbal exchange from the transcript as it moves away from the analysis of uncertainty.

162 This type of statistical information that equates Sarah's claim about the heart size with a numerical value ('if the heart's over 50% of the cardiothoracic ratio on a PA frontal chest radiograph that's abnormal') is typical of teaching interactions aimed at developing detail in detection and diagnosing. For instance, attaching a numerical boundary to heart size helps to distinguish normal from abnormal in AP projections. Nevertheless, the inclusion of 'stats' is noteworthy because it provides information about the types of 'facts' used in radiological teaching and reinforces numerical value over the visual.

163 Although this is not a proper medical term, it illustrates the jumbling of words by the novice and their attempts to 'catch a language'. Sociological research has so far neglected the challenges novices face acclimatising to visual-orientated language. In addition, this moment is one of many corrective practices in learning radiological terminology.

164 I have purposefully omitted this verbal exchange from the transcript due to its length.

165 Otherwise known as the "whoosh test".

Millie's guess of aspirating the patient using litmus paper to test for the stomach's pH he swiftly suggests this technique would not have the desired outcome for this patient:

Dr. Maxwell: Okay, but you can't aspirate anything from this. Occasionally you can't because the tip [Gesture: RH pushes index finger into a hole created by the left hand enacting the NGT tip going up against the mucosa in the tracheal wall] of the nasal gastric tube is up against the mucosa and you have the same problem with pushing air down [Gesture: RH fist knocks down against the fist of LH], you can push air down and listen to it, listen for it with the stethoscope over the stomach [Gesture: RH pinches the air in front of him to imagine the placement of a stethoscope on a patient's stomach] *fiddles with his hands* and try and hear the 'whoosh' sound, the 'whoosh' test, but occasionally the air can go submucosally if you've got the tip of the nasogastric tube against the nasal gastric wall which is quite common and again it's for the same reason why you don't always get an aspirator.

[*Silence: six seconds*]

Dr. Maxwell: I'm still waiting

Sarah: Oh, I'm sorry

Dr. Maxwell: What are you gonna do now?

Sarah: So we need to reposis-reposition the tube?

Dr. Maxwell: *Do we*? Okay fine. So I've not bullied you into

Sarah: **laughs nervously**

Dr. Maxwell: Saying we can feed the patient then?

Sarah: No **laughing nervously**

Dr. Maxwell: Okay, I'll have to work on my act

Sarah: **laughs**

[Dr. Maxwell presses a button on the keyboard highlighting the NGT in red. However, the NGT is positioned incorrectly above the stomach and not inside the Stomach (Fig. 35)]

Dr. Maxwell: Well *that's* the nasogastric tube

Sarah: Oh! Is *it*!?

[*Dr. Maxwell presses a button on the keyboard removing the highlighted NGT*]

Dr. Maxwell: So, it's a good job you're

Sarah: *So*

Dr. Maxwell: Not one to be pushed around by staff nurses!

Millie: What's the other thing then?

Sarah: Is that the pacemaker? [Highlighting 1: RH points]

Richard: Pacemaker

Sarah: Okay

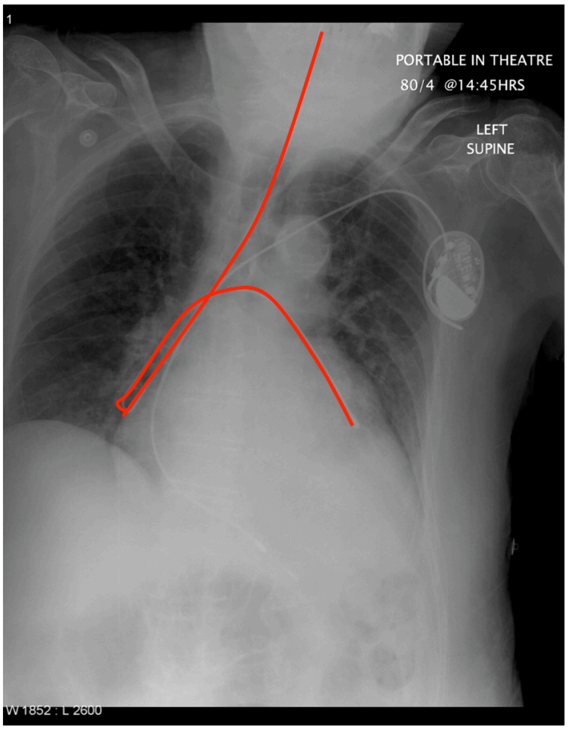

Figure 35 The NGT has been highlighted in red. Highlighting the NG tube alerts the students to its incorrect placement.

Sarah exhibits difficulties in distinguishing between the NGT and the pacing line, which inhibit her interpretation of the radiograph. This is best accentuated when Dr. Maxwell comments (*'well that's the nasogastric tube'*) and highlights the misplacement of the NGT bringing about considerable surprise from Sarah ('Oh, is *it!?*'). This leaves the idea that Sarah had not distinguished the NGT from the pacing line. Dr. Maxwell's comment that the patient could not be aspirated with litmus paper (*'you can't aspirate anything from this'*) and a description about the pitfalls of 'tip' movement[166] implied that the NGT was positioned incorrectly. Despite the pressures of the staff nurse and the demands of the family imaginatively played out by Dr. Maxwell, Sarah did not fall prey to the pressure of feeding the patient – she *knew* that the image was ambiguous and not to be trusted. However, this does not mean she could *see* the NGT and distinguish it from the pacing line. This leaves the idea that Sarah had not distinguished the NGT from the pacing line, but correctly guessed it was misplaced once implied by the consultant. Up until this moment, it is difficult from observational data to ascertain whether Sarah interpreted the radiolucent end or 'tip' in the stomach to be that of the NGT. However, Sarah's reaction to the highlight suggests that she did. Sarah did not consider the consequence of the patient's slump, earlier referred to as a *'slump 'o gram'*, altering or deviating the placement of the NGT tube. One implication is that what Sarah sees, knows or understands does not always reside in particular social settings and activity systems but may be learnt elsewhere within previous teaching practices and reflection on textbook cases of fundamental principles (Prentice, 2013), that is, cognitive assumptions that she brings to the table.

During fieldwork, my own observations of the teaching practice revealed that professionals deliberately chose CXRs with conspicuous and inconspicuous lines and tubes. Both sets of images are suffused with ambiguity and professionals often work *with* the image to amplify uncertainty, in order to increase the medical students' vigilance in the identification of lines/tubes and to convince them that pre-op and post-op images are highly misleading. Considering that the placement of the lines/tubes is compromised when the patient moves, as Sarah (medical student) demonstrates, and that professionals warn students about misplacement upon insertion, why is it reiterated and emphasised?

One reason for this is the 'critical' nature of x-ray image interpretation training; ensuring that the information of x-ray images is communicated under signs or conditions of uncertainty (Gunderman, 2005). A second reason is to enhance their knowledge/skills in x-ray image interpretation as part of a learning outcome in the undergraduate radiology curriculum (RCR,

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[166] The litmus test is not used to determine the position of the NGT anymore for this reason.

2017). The third reason is to safeguard against the misinterpretation of lines and tubes which is a clinical concern because *'you can potentially kill someone'*.[167] A number of news reports about patients dying from the complications of misplaced NGT placement (Blunden and Hinton, 2011) and its role in medico-legal case studies (Williams and McDavid, 2012) are well known across the UK medical community. Concerned in part by his group's difficulty in disambiguating the lines and tubes across three case presentations, Dr. Maxwell (BHRD radiologist) claims that misinterpreting a misplaced NGT '*is a "never event" and will likely end your career'* [168] in medicine:

> Every year there'll be a junior doctor in the press you know up before the GMC or whatever um in trouble for saying 'yes, you can feed the patient' and the nasogastric tube was in the wrong place, so it's one of those 'never events' that we have and you're all aware of never events. I've done this teaching for several years and we used to talk about never events before you even knew what they were. The last count was twenty-five that I'm aware of, of never events, events that should never happen if all the agreed protocols and safety checks are put in place so those are significant targets for trusts not to get never events.

Whilst Dr. Maxwell contends that junior doctors *'up before the GMC'* relates to the feeding of patients when the NGT is misplaced, his concern is appropriate regarding how x-ray image interpretation is constituted in teaching practice. The need to educate healthcare professionals about the misplacement of NGTs has been an important item on the NHS agenda since its classification as a 'never event' in the Department of Health's *High Quality Care for All* report (2008). Mr. Hearken (WURD radiographer) reinforced a similar message by suggesting that the correct placement of the markers is a *'legal requirement'.* The following exchange about marker placement was taken from a CXR image interpretation lecture two weeks into the diagnostic radiography course:

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[167] Dr. Saury

[168] Dr. Maxwell drew medical students into reading this as text on a PowerPoint slide that concluded a series of CXR case presentations with lines/tubes. The full text read: '*feeding a patient through a misplaced nasogastric tube is a 'never event' and will likely end your career'* and *'Do not take the risk. Ask for advice'.*

Mr. Hearken: In the case of the chest x-ray, is it the right bit of the body? Does it come across the right way? Has he got a marker? Is it correct? This one, is it right?

Geoff: Yeah

Mr. Hearken: Is it correct?

Anna: Mhm

Mr. Hearken: *Yes?* How do you know?

Anna: Well, I don't know their name or date of birth is right, but I know in terms of the right way [laughs]

Mr. Hearken: Okay so how do you know it's the *correct* way?

Anna: Cause their arms are at their side

Mr. Hearken: Yeah

Anna: And their chest is put up to the cassette and that's back to front

Mr. Hearken: Yep so how do we know? What structure lies on what side, do we know?

Anna: The heart

Geoff: heart

Mr. Hearken: The heart lies on the?

Anna: Left

Mr. Hearken: Left side. *Normally.* Some people have it the other way around. Alright if you ever get a chest x-ray and when you look at it and the marker's there and the chest is the wrong side, you're always gonna question it, 'cause it's not normal. Okay. But yeah, left's normal, but yeah his heart's normally on the left, okay? There are cases of litigation um where people have been *sued* for having the wrong marker on, or not putting the marker on so that's one of the most important things, so whenever an image goes up even if it's for teaching, the *first* thing you think about is [Gesture: List construction] 'name-date-maker'.

Mr. Hearken creates some ambiguity or doubt as to whether radiographers in-the-making can be sure that the marker is positioned *'in the correct way'*, namely because it may not indicate the *'right bit of body'*. Mr. Hearken suspects the students know which side the *'heart lies on'*, but casts doubt on this because *'some people have it the other way around'* and so advises them that radiographers can misplace markers which gets them '*sued for having the wrong marker*' as well as for *'not putting the marker on'* during image production.

Unsurprisingly, Mr. Hearken explains that correct marker positioning is *'one of the most important things'* and that it's *'the first thing you think about'.* In her study on x-ray volumetric imaging in radiotherapy,[169] Wood (2012) describes the discursive ordering of materials which stabilises the radiographers' objectivity in 'seeing' or 'doing' in the image-making process. Professionals avoided uncertainty using radio-opaque 'fiducial markers' implanted in the prostate to verify patient position thereby acting as a guarantor of accuracy. At Bridgestock and Woodfleet, radiograph image interpretation training is likewise subjected to claims of 'objectivity' or 'neutrality' (Wood, 2012) regarding the placement of lines/tubes and x-ray markers as a means of stabilising what should be seen or interpreted. Within the teaching practice, however, the imagined death caused by misinterpretation generates vigilance (rather than certainty) from medical and radiography students. Through awareness of misplacement and movement students are trained to vigilantly attend to the agency of human and material actors during interpretation. The radiograph allures certainty and uncertainty with multiple disguises; it is a double agent in academic teaching settings.

The radiograph echoes Joyce's (2005, 2008) description of images as 'agents', a phrase that captures the way in which humans position MR images as actors. In her analysis of the narratives used to discuss MRI, Joyce (2005: 443) suggests such personification is brought about by how the MR image is ascribed agency; the image is talked about as the provider of unmediated access to the body and the generator of authoritative knowledge. 'Transparent', 'objective' and 'neutral', this agency becomes a powerful rhetoric for 'trust'. Notably, Joyce focuses primarily on MR images and professional's revelations of patient conditions. During observations of teaching practice, transparency was not removed but saddled with uncertainty. Although the teaching practice of image interpretation by professionals occurred in the 'back-stage' area to clinical contexts (Goffman, 1959), certainty and uncertainty were closely fused together. The radiograph and the content of the image become uncertain because it was separated from the patient, the staff, the apparatus, and technology. The radiograph is subjected to intense and effortful 'role playing', where professionals become surrogates for bodies, machines, and materials, since students have not yet had the opportunity to become part of the 'network'.

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[169] X-ray image guided radiotherapy

5.4 The surgical reorganisation of gross anatomy

A second reason for uncertainty in x-ray image interpretation training corresponds to the surgical reorganisation of anatomy in post-operative radiographs. When Dr. Maxwell (BHRD radiologist) begins another case by testing medical students' knowledge of a post-operative radiograph [Fig. 36], asking *'what's CABG?'* (pronounced 'cabbage'), Sarah (medical student) rote-knowingly answers:

Sarah:	Coronary artery bypass surgery
Dr. Maxwell:	Good, what do you see?
Sarah:	I see sternotomy clips, is that what they're called?
Dr. Maxwell:	Sternotomy *wires*, yeah
Sarah:	Wires, wires
Dr. Maxwell:	Yeah
Sarah:	Um there's some metalwork in the clavicle on the patient's left [Gesture: RH swivels]
Dr. Maxwell:	N-uh yeah, that's just the left side marker, actually
Sarah:	Oh is it? *laughs*
Dr. Maxwell:	It's a very old fashioned film
Sarah:	Oh okay
Dr. Maxwell:	They used to put them on, yeah used to physically put the marker on the film [Gesture: RH places imaginary anatomic side marker on imaginary radiograph] to get it on so don't worry about that
Sarah:	Okay. Um *exhales* I don't know what else I'm looking at really. The diaphragm
Dr. Maxwell:	*Yeah*
Sarah:	Is *flat*
Dr. Maxwell:	Okay
Sarah:	On both sides but I don't know if that's ab-normal?
Dr. Maxwell:	So we've got the basic approach to the film. So, it's fairly well centred, it is adequately penetrated; if anything, it's slightly *over*-penetrated *tuts*, um it's not particularly rotated and you've pointed out some obvious things *looks at Sarah* like sternotomy wires, yeah?

[*segment omitted*]

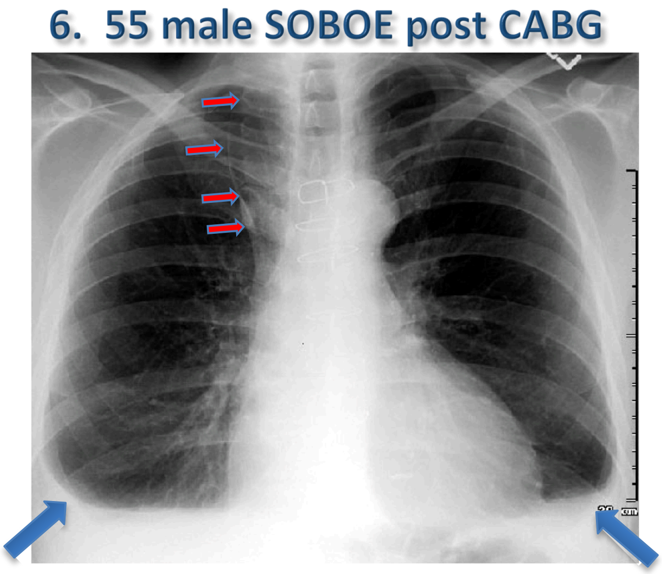

Figure 36 PowerPoint slide of abnormal CXR Case 6: '55 male SOBOE post CABG. A concave surface (meniscus sign) either side of the diaphragm (blue arrows) and azygos fissure (red arrows).

In the exchange above, Sarah sees that the '*diaphragm [...] is flat [...] on both sides*'. This emphasis on *'flat'* carries a suspicion of abnormality because diaphragms tend to be dome-shaped structures. It is worth noting that Sarah, at this stage in her training, will know that a normal diaphragm will be dome-shaped. Although, suspicious of the diaphragm, Sarah is unsure whether this is normal or abnormal (*'I don't know if that's ab-normal?'*), suggesting that she is unfamiliar with how the diaphragm is supposed to look after cardiothoracic surgery. Dr. Maxwell reflects on Sarah's uncertainty about the diaphragm with a delicate *'okay'* followed by a brief pause. This term in the context of teaching case presentations suggests Dr. Maxwell is not in agreement or satisfied with how Sarah has seen the (whole) diaphragm. At this point, an examined sequence begins, based on Sarah's *'the diaphragm is flat'* comment through the proposition of a question:

Dr. Maxwell: *Costophrenic angles*. What do you think of his costophrenic angles? You mentioned that his diaphragms were flattened? [Gesture: opens his arms out and brings them back to his chest, the palms of his hands gently clapping one another]

Sarah: *tuts* yeah

Dr. Maxwell: But we've actually *lost* the costophrenic angles, they've kind of reversed haven't they, really? What do you think about the cause of that? **looks at Sarah**

[*Silence: five seconds*]

Sarah: *exhales* I don't know *looks away* *nervous laugh*

Dr. Maxwell's question implies that Sarah has not seen the costophrenic angles at either side of the diaphragm. This question is combined with a publically available opening and closing of arms, and hands gently clapping one another. This flurry of "small behaviours" (Goffman, 1967: 1) is a physical extension of his question - a physicality that works to both emphasise his question and suggest that Sarah has not seen the costophrenic angles. Dr. Maxwell's fusion of talk and gestures allows Sarah to grasp that there may be a margin for error in her description: her response is to *tut* followed by a despondent 'yeah'. While it is clear that Sarah has described the diaphragm as flat, it is not clear whether she has seen the curved costophrenic angles on both left and right sides. At this stage in their training, the fourth-year medical student should recognise that the meaning of a costophrenic angle appearing convex or 'face down' is normal.

However, in this case, the costophrenic angles have a concave surface and are facing *upwards*. It is possible Sarah has still not seen the curves due to the absence of answer or lack of alignment. As well as talk, Sarah's bodily orientation away from the radiologist including utterances of exhalation, exasperation and nervous laughter express discomfort about not seeing. The consultant attempts to align Sarah's sight with the patient's costophrenic angles by producing a gesture depicting the curling up or 'layering up' of each angle in three-instalments: bringing his hands together at the midline of his chest, moving the hands apart in a horizontal line curved at either end, and repeating this movement back and forth (Fig. 37). In other words, the consultant represents the curved costophrenic angles by a gesturing schematic act of the hands (Streeck, 2009). Doing so helps Sarah *see* the curved costophrenic angles – communicated by the verbal *'oh yeah, there it is!'* – and understand how the accumulation of fluid in the pleural space above the hemidiaphragm causes the costophrenic angles to curve upwards, a concave appearance referred to as the 'meniscus sign':

Dr. Maxwell: It's fluid again. Fluid again in the pleural spaces and that is the *menisci*, meniscus sign. If you get fluid in the body it tends to [Gesture: Dr. Maxwell creates a horizontal curved line between his hands to enact the reversal of the flat costophrenic angles: (Fig. 37)]

Sarah: Oh yeah, there it is!

Dr. Maxwell: Layer up a little bit [Gesture: Dr. Maxwell creates a horizontal curved line between his hands to enact the reversal of the flat costophrenic angles]

Sarah: Yeah

Dr. Maxwell: At the edges, but that's normal post coronary artery bypass grafting.

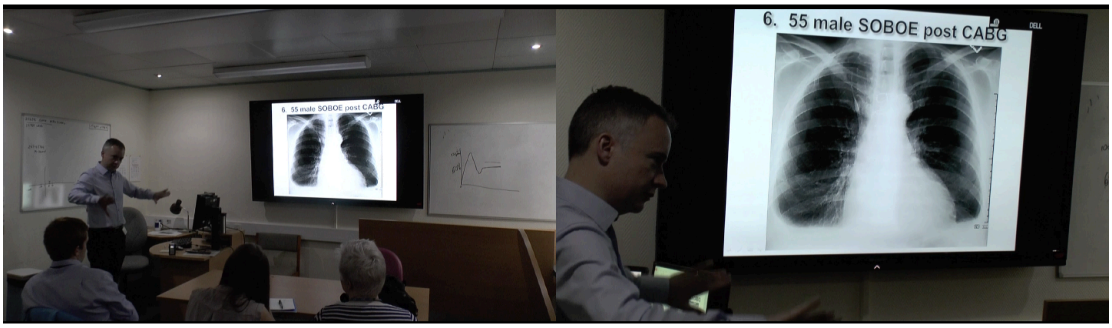

Figure 37 Dr. Maxwell gestures a horizontal line that curves upwards at either end to enact a reversal of the normally convex costophrenic angles, otherwise known as a concave 'meniscus sign'.

Dr. Maxwell places Sarah's uncertainty with the diaphragm down to her unfamiliarity with anatomy in post-operative radiographs. As mentioned earlier, a *'meniscus sign'* evokes an underlying abnormality of the pleural effusion. However, this curved appearance is *normal* for a patient after cardiac surgery.[170] In their attempt to recover the patient's health or physiology, surgeons often reorganise the anatomy inside the body. Surgical procedures become entangled with interpretive practice when post-op radiographs are requested. This spatial *in situ* reorganisation complicates the scrutinisation of the CXR review areas through the arrangement of a new 'normal': deviating what was previously pathological into a new normal. This operative manipulation is significant with a line of thought on how social actors

[170] The post-op effusions would usually be expected to resolve with time (i.e. the menisci will usually disappear).

(in this case surgeons) are the final arbiters in determining what constitutes normal (Canguilhem, 1991 [1966]).

So far the focus has been on the radiologist inviting an embodied and tacit alternative to the invasive incisions of cutting into the physical patient and 'seeing inside'. Attention to such alternatives is unsurprising in the communication, description and displaying of the interior of the body. The diverse and creative aspects of embodied conduct in radiology and the communicative actions by which radiologists gesturally let each other and their trainees know which relevant context they are in are absent within medical education and radiology literature. Although radiological communication has received some attention in the sociological literature, where there has been some discussion on the deployment of gesture as a type of practice that operates alongside technological devices (i.e. cursor) in seeing or not seeing abnormality, it is mainly limited to a few studies (Saunders, 2008; Ivarsson, 2017; Gegenfurtner et al., 2019). Whilst there is an emerging critique of embodied conduct and learning within the sociology of medical education, it has mainly concerned surgery education (Hirschauer, 1991; Prentice, 2013, 2014), and dental education (Hindmarsh and Pilnick, 2002) with 'sensorality' as a relatively recent arrival, particularly around auditory (e.g. pitch) and tactile information (e.g. vibration) in clinical examinations (Harris, 2016).

Yet radiology and its subspecialties have received little attention. Allied health professionals have almost no presence in sociological literature, so it comes as no surprise that a critique of radiography education and interpretive practice at the undergraduate level has been entirely omitted. In the absence of a social matrix of radiological education, we must move our attention to sociological work in and around surgery education to deepen our understanding of the relation between non-verbal communications and seeing in undergraduate radiology.

Prentice (2014: 89) argued that surgeons are good interlocutors of the human body, and that "surgical sight" is an embodied consequence of the exploration of the patient's body using their hands, eyes, and tools. However, her analysis of trainees portrays surgical learning or *doing surgery* in a clinical setting within a team where embodiment is always mediated by visualising technologies. Prentice (2013: 168) demonstrates that the presence of such technologies helps surgical trainees practice *control*: technologically mediated techniques for "controlling one's body and limiting harm". Such technology assumes surgeons are in control of the patient's body and are aware of the affordances it gives them to manipulate and reconstitute the body while operating, the latter serving as a virtual practice beyond the material world. As can be seen in Dr. Maxwell's gesture of the 'meniscus sign', technology and technical procedures are not always needed to see inside the body.

Sociologically, then, we can begin to appreciate the surgeon's temporal control over the re-arrangement of the patient's body, as he knowingly alters the physiological appearance in *real-time*. Those outside the operating room are not privy to such temporal anatomical changes where what happens *in between* pre-operative images and post-operative images is a vantage reserved for the surgeon. Radiologists and radiographers are pre-surgery and post-surgery people: surgical changes are observed before and after the image has been taken, but not *in between*. Removed from the praxis of the operating theatre, the role of both professionals is to train students to see newly arranged anatomy and a new *kind* of normal.

However, anatomical shifts can be misleading and place new demands on teaching interpretive skills as learning to see what changes have occurred inside (and outside) the body is not straightforward. Learning to see the "meniscus sign" – the concave curving of the costophrenic angles – was an accomplishment of seeing the physiological change, however, it was only one part of the "diagnostic jigsaw" (Reed et al., 2016a: 7). Although the radiologist had not intended for the meniscus sign to be the main clinical feature of the image, it still served a useful purpose of teaching the student the puzzling dimensions of image interpretation. It is one aspect of the consultant's "what do you see?" demands. The purpose of Case 6 was to highlight the linear shape of the azygos fissure as a normal variant (red arrows) where it is often posited pathologically by the uninitiated:

Dr. Maxwell:	Anyone spotted this line up here? [Highlighting 1: LH points to a linear shape below the apex of the right lung]
Richard:	Yeah
Dr. Maxwell:	What do you think that is?
Richard:	[*laughing*] I don't know, I was gonna ask you
Dr. Maxwell:	He's got a pneumothorax? Put another chest drain in? You like your chest drains don't you? Get some practice!
Richard:	That's not pneumothorax!

Dr. Maxwell:	Good. Why is it not pneumothorax?
Richard:	'Cause I can see [Gesture: RH pinches the air as if to focus] lung markings
Dr. Maxwell:	Good
Richard:	Outside
Dr. Maxwell:	Yeah you've got lung markings both sides of the line. The line isn't parallel to the chest wall [Highlighting 1: LH is placed sideways on the chest wall of the right lung] is where air normally accumulates in the pleural space [*Pause*], anyone? No, it's an azygos fissure. A-Z-Y-G-O-S it's just a normal variant in the azygos lung lobe so it's just that you recognise that it, you know, you do see that in about 6 percent of patients and you just recognise that it's *not* a pneumothorax on the edge of the lung.

In an attempt to guide Sarah's gaze to the main clinical feature of the image, the consultant takes it upon himself to depart from Sarah and share the same visual field with the group. Instead of engaging Sarah, he addresses the group and steers their attention by finger pointing, which highlights the detection of a curved linear shape in the apex of the right lung: *'anyone spotted this line up here?'*. Richard's answer to not knowing what the curvilinear shape is allows the consultant to jest whether the structure represents a pneumothorax (abnormal) and the treatment of a chest drain: *'he's got a pneumothorax? Put another chest drain in? You like your chest drains don't you? Get some practice!'.*

This exchange is made humorous by Dr. Maxwell because it is predicated on Richard's fatal guess of using a chest drain in the previous case as the main treatment to relieve the accumulation of blood in a small hemothorax. In the previous case, Richard's answer was immediately refuted by Dr. Maxwell who claimed chest drain insertion would cause a cardiac tamponade, a type of complication that causes the heart to compress due to the buildup of blood. Furthermore, much like "what do you see", the question "what do you think it is?" is supported by previous work on radiological learning (Saunders, 2008: 226), and common throughout general diagnostic training in the recognition of diseases. This moment of humour is indicative of radiological learning. Humour is a valuable feature in x-ray image interpretation training, and the timing when it is woven into teaching relates to the work of the comedian or presenter. For instance, joking works to remedy gaps in the student's radiological understanding through a retrospective recall of imprecise or inaccurate observations, descriptions. Jesting also works to temper indecisiveness, when Dr. Maxwell constructs a clinical emergency and shapes the context of a life and death situation.

5.5 Normal variants that mimic pathology

A third reason why there is uncertainty in x-ray image interpretation is the inclusion of normal variants wedged between abnormal images. It is a deliberate strategy, rather than a circumstance, to further enrich normal anatomical information by virtue of being interactionally uncertain. Like the medical students, normal variants also challenge observations from radiographers in-the-making when asked to interpret the image. At BHRD and WURD, normal variants – when present – often remain undiscovered in the radiograph, whilst professionals in-the-making are invited to comment on some other anatomic structures/features. Their inclusion undoubtedly stems from past events, in which professionals in-the-making (as well as professionals) misinterpreted normal variants as abnormal. Drawing attention to Dr. Maxwell's (BHRD radiologist) interaction above (*'he's got a pneumothorax? Put another chest drain in? You like your chest drains don't you? Get some practice!'),* as a reminder of the mediated character of uncertainty, Mr. Hearken (WURD radiographer) sends out similar invitations:

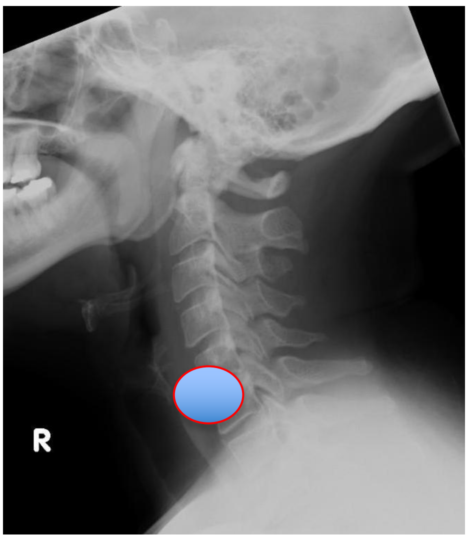

Figure 38 A normal variant of the C6 vertebra, bearing similarity to a fracture (highlighted).

Mr. Hearken:	Anyone notice anything on here? [Fig. 38]
Jim:	C6 superior top.
Mr. Hearken:	Superior top.
Jim:	Well, superior edge there's a-
Martin:	Is that a spur?
Mr. Hearken:	So, it could be a spur. So does it look attached?'
Sophie:	No.
Ellie:	No.
Mr. Hearken:	No, it looks like it's detached. So it could be a spur that's detached, you're absolutely right. The rest of the spine looks *pristine*. So I don't think it's that. What features are there on it? What does it look like?
Jim:	Teardrop
Mr. Hearken:	Like a teardrop. Say teardrops in a spine and everyone immediately goes, ugh! [Gesture: enacts the concerns of other professionals by contorting his face, straightening his body and pulling his left arm towards his chest to express alarm at the suggestion of a 'teardrop'] because they're bad news usually. All right?
Jim:	It looks like an ossification centre?
Mr. Hearken:	So why do you think that?
Theo:	Because it's *smooth*
Mr. Hearken:	Yeah. Does it look like a fracture? [Gesture: LH lies flat and trembles in the air as if to emulate the suspected abnormality.] Does it look *sharp*? [Gesture: LH grasps thin air as if to enact the suspect abnormality]. Does it *look* like someone's just pulled it off? [Gesture: LH enacts pull] Does it fit back on? [Gesture: LH enacts replacement] Those are all the kind of features of fractures [Gesture: LH pinches air] that look *sharp* [Gesture: LH lies flat in the air as if to emulate the suspect abnormality], it hasn't got cortical edge, alright? [Gesture: LH lies flat in the air as if to enact the suspect abnormality]. You could stick it back on and it would look normal. This one, I would suggest, does look a little bit smooth [Highlighting 1: rests cursor on C6], it's quite well corticated, if you stuck it back on the vertebral body probably would look normal, so that suggests to me it's likely to be a *normal* variant [Presentation gesture: rolls hands in air]
Sophie:	Mm! *surprised*

Mr. Hearken: These are quite common, especially in the C-Spine, we call them limbus vertebra, L-I-M-B-U-S [Gesture: LH expresses each letter with a finger as if drawing the word in thin air]. It can be associated with disc disease, and effectively what happens is the disc [1. Gesture: Both hands grab the imagined disc in the air (Fig. 39)], bulges [2. Gesture: Both hands roll over an imagined bulge in the air (Fig. 40)] and it pushes a bit of bone off [3. Gesture: LH sculpts the air enacting the pushing of the bone (Fig. 41)], but in a lot of people, particularly in the cervical spine, it's just a normal variant. *But* it is commonly associated, or commonly *mistaken* for these teardrop fractures, which are very, very bad news. But you can use the features to differentiate between normal and fracture.

Jim identifies the ambiguous anatomy as a *'spur'* and confirms its anatomical feature as *'detached'* for Mr. Hearken's benefit. Throughout much of the training, Mr. Hearken engages in what Saunders (2009: 152) defines as "artifice", namely selecting or 'marking' (Goffman, 1952) to convey a sense of interpretive risk or endangerment at misinterpreting the spur in the image (*'ugh!'/[Gesture: expresses the concerns of imagined professionals by contorting his face, stiffening his body, and then spasms his left arm towards his chest at the suggestion of the spur as a teardrop]).* Prior to revealing any information regarding the anatomic identity of the spur, Mr. Hearken supports abnormal observations of the image in reception to the *'teardrop'* he receives from his students. After a student (Jim) supposes that the spur looks like an osseous density or *'ossification centre'* of the cervical spine (neck), Mr. Hearken encourages Jim to continue with *'so why do you think that?'* Jim associates his observation of the spur to being an ossification centre, referring to the spur as actually '*smooth',* in the absence of knowledge on whether the C6 (6th cervical vertebra) anatomy was agreed upon as normal or abnormal.

Whilst momentarily agreeing that the anatomy looks smooth, Mr. Hearken playfully associates the spur with four explanations for problematic anatomic differentiation (*'does it look like a fracture'*, *'does it look sharp?'*, *'does it look like someone's just pulled it off?'*, *'does it fit back on?'*), before he confirms that it's *'likely to be a normal variant'*. This is what Goffman (1952: 458) terms "stalling", meaning the words and expressions used in the delay of allowing those a chance to become familiar with a new concept or that there is still a slight chance that the new concept has yet to occur. Mr. Hearken later suggests that the normal variant is a *'limbus vertebra'* and presents the embodied potential for learning language (Müller, 2014) by 'finger-spelling' the terminology in the air and plays some role in gestural representation as 'semiotic' (Kendon, 2004). This semiotic resource thus expresses a core professional concern among radiographers and is what participants in an interaction perceive and treat as important (*'L-I-M-B-U-S [Gesture: LH expresses each letter with a finger as if drawing the word in thin air]'*). Mr. Hearken attributes the normal variant to a common error of misinterpreting it as *'disc disease'* and to *'teardrop fractures'*, with him accrediting anatomic features (*'smooth'*) (*'sharp'*) in their pursuit of differentiating *'between normal and fracture'*.

Along with attributing abnormal characteristics to the anatomy (ascribing features that work towards the progressive revelation of attributing problems with anatomy, including anatomic limits, mechanisms of trauma, and unfavourable forms from everyday life standing proxy for trauma/pathology), professionals work alongside the image to increase critical engagement by capitalising on the similarities between normal variants and abnormality. Scope for disbelief capitalises on these similarities and the students' lack of knowledge for normal variants that are often discursively framed as interpretive risks. I interpret this as an attempt by professionals to replicate common radiological errors of the community in a safe space and give a performance of how disbelief can play out in the situation.

In one example, Mr. Hearken encourages students to *'seek one of these out *holds out Keats', Atlas of Roentgen normal Variants*'* when *'you come across something you're not sure about and not sure if it's abnormal or if it's normal'* because *'you can look to see, well, is it really abnormal or is it just part of the normal variants that we see in people.'* Whilst Mr. Hearken ascribes to the cognitivist dimension of learning to see radiographic anatomy, his body constructs a personal non-cognitive view of radiographic anatomy education. This is revealed when his "gesture phase" (Kendon, 2004) enacts the normal variant's pathological potential: *'it can be associated with disc disease, and effectively what happens is the disc [1. Gesture: Both hands grabs the imagined disc in the air (Fig. 39)*], *bulges* [*2. Gesture: Both hands roll over an imagined bulge in the air (Fig. 40)*] *and it pushes a bit of bone off* [*3. Gesture: LH sculpts the air enacting the pushing of the bone (Fig. 41)*]'. This kind of performative expectation not only ascribes normal anatomy (and a classification) to abnormality, but also enacts a potential misinterpretation by using his body as part of the performance.

		
Figure 39 'Gesture phase 1/3' in the re-enactment of a mechanism of injury (disc disease)	**Figure 40** 'Gesture phase 2/3' in the re-enactment of a mechanism of injury (disc disease)	**Figure 41** 'Gesture phase 3/3' in the re-enactment of a mechanism of injury (disc disease)

5.6 Technical inadequacy and aesthetically unappealing images

A fourth reason why there is uncertainty in x-ray image interpretation corresponds to technical inadequacy and aesthetically unappealing radiographs. This was of paramount importance at WURD, as radiographers were given a checklist to establish whether radiographs are technically adequate for interpretation. This included seven key principles that, in Mrs. Campbell's (WURD radiographer) words, form the acronym PACEMAN. PACEMAN's formulation as a seven-letter acronym bears resemblance to the practice of seeing as both a 'systematic' and 'cognitive' activity (Goodwin, 1994, 2000a, 2000b). These principles, displayed via PowerPoint, are:

Position: Correct position, any rotation, and relevant joint spaces seen?
Area: Is the area covered adequate?
Collimation: 4 way collimation seen?
Exposure: Factors, correct contrast and density?
Markers: Present and correct?

Aesthetics:	Centred correctly, 4-way collimation, aesthetically pleasing?
Name:	Correct patient name and date?

Mrs. Campbell suggests that in order to *'see if the technique we've used has produced an image that is diagnostic'*, student radiographers follow the principle of PACEMAN to make sure the radiograph is of adequate quality. Radiographers train students to abide by such stipulations, with Mrs. Campbell emphasising that abnormalities can be *'seen [more] clearly'* if students used PACEMAN to *'pick up on all of the points of evaluative criteria'.* According to her, the capacity to see any underlying pathology is enhanced by drawing on technical knowledge. This emphasis on technical knowledge also amplifies the patient's importance and the professional's role in seeing 'things' more clearly. The capacity to see 'better' is expressed by the relational emphasis between patient and radiographer.

However, it is always the radiographer who is involved in the image-making process. During a CXR image interpretation lecture, Mr. Hearken (WURD radiographer) exhibits how inadequate images compromise pathology observation and how missing pathology is a consequence of both patient and professional:

Mr. Hearken: If the image is not adequate, if it's *poor,* the ability or your confidence to detect pathology is much limited, much more limited. If I was reporting something and I had an image [Gesture: holds up imagined radiograph] which was *awful,* I would say so [pause] how am I supposed to report this confidentially if the image I've got isn't appropriate? [Pause] If someone came to try and sue me because I missed something, my defence is 'well I'm sorry but that image is not adequate'

Helen: Yeah which isn't the patient's fault

Mr. Hearken: *shakes head* No

Helen: So it's still your fault?

Mr. Hearken: It's still two person, well the *radiographer* should have either repeated it or documented *why* it wasn't adequate 'cause not all patients are gonna do what you want them to, they're not, not *all* images are gonna be perfect and there's often a reason for that but as long as it's documented, well that's the reason.

Mr. Hearken suggests that if the image is *'not adequate'*, meaning *'it's poor'*, it is likely to hinder seeing and compromise interpretation. Similarly, technical knowledge is expressed in radiology at the beginning of the seminars. Dr. Saury (BHRD radiologist) emphasises that *'technical accuracy: 'there are three things; inspiration, rotation, and penetration, I'll go through those, lines and tubes'*, citing that this is a *'really important thing'.* Dr. Saury explains that medical students have to assess these three principles since *'they cause loads of problems'* and suggests the assessment *'should come before you start looking at the rest of the chest x-ray'*, indicating that diagnostic confidence is enhanced by assessing whether the radiograph yields to the prescribed principles.

Likewise, Dr. Maxwell (BHRD radiologist) guided medical students through these *'technical aspects'* at the beginning of every seminar. Once again, these principles for assessing the technical adequacy of the images are another "immutable mobile" (Latour, 1986), a standard set of principles used between professions that accounts for technical and material observations in 'agential' terms. This becomes important in the production *and* interpretation of radiographs. The immutable mobile of technical principles, then, has strong policy consequences that ensure 'adequate' images are dutifully taken *during* and *after*[171] the image-making process, with the intention to produce a good standard or technically adequate radiograph for diagnostic interpretation. Having technically adequate or 'good' images can help reduce the number of radiographs being taken and limit patients' exposure to (further) radiation, leading students to participate in radiation protection practice outlined in the IR(ME)R 2000. It also represents a safeguard against the litigation mentioned earlier, by communicating the idea that adequate images enhance the visibility of pathology: *'if someone came to try and sue me because I missed something my defence is 'well I'm sorry but that image is not adequate'* (Mr. Hearken, WURD radiographer).

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[171] It is important to recognise that the PACEMAN system is routinely followed *after* image production. This is contextualised as a first stage critique to help determine whether a radiograph is 'technically' adequate *before* medical image interpretation. In addition, this led into a further discussion of a technically detailed '10 point checklist' that informed further technical principles of the image-making process *before* image interpretation. This information was provided as a material handout on a small laminated card. It is assumed that those radiographers who follow both sets of principles 'improve' or 'enhance' the radiograph and reduce uncertainty (for a full account of this practice, see chapter six).

Interestingly, this responsibility over whether the radiograph is adequate for diagnostic interpretation is shared between medical radiologists and allied health radiographers. The principles of technical adequacy are not exclusive to radiography. Although technical knowledge is the prerogative of WURD radiographers, the uncertainty of anatomy during teaching practice at BHRD means radiologists also provide medical students with information on technical principles. This preparation of technical information frames radiographic anatomy as problematising or, rather, as requiring critical analysis. Technical assessment is shaped by a politico-legal sphere and a 'litigation culture' which safeguards students against misinterpretation. These principles, thus, are felt to be necessary foregrounds that radiographs can be 'non-transparent' and not to be taken at face value. In a CXR image interpretation lecture, Mr. Hearken (WURD radiographer), who works part time in a hospital, reflects how inadequate patient positioning may hide or obscure the observation of pathology:

Mr. Hearken: So, on a chest x-ray how much of the lungs are actually *free* of superimposition and not *covered by* anything else? The heart, mediastinum, the ribs, the scapula. How much of the lungs do we actually *see*?

Emma: Thirty percent? Four-Oh no?

Mr. Hearken: Yeah, it's about a *third.* Sorry two thirds. It's the opposite way, about a *third* is *obscured* by heart, mediastinum and ribs. If you've got a tiny little lung tumour [Gesture: LH pinches air] *sat* in your chest [Gesture: LH transports pinch to the CXR], it's a good chance you won't see it because a lot of that chest is actually covered up. So, you want to make sure you're removing as much *superimposition* as you possibly can. *So* we try and move the scapula [Highlighting 1: LH points at the right scapula] for that reason, particularly important when we're looking at little pneumothoraxes [Highlighting 2: RH points towards the imagined pathology] or collapsed lungs which happen up here and if you've got the scapula in the way you won't see them.

Mr. Hearken reveals that a third of the lung anatomy is *'obscured by the heart, mediastinum and ribs'* and suggests the chances of seeing problematic anatomy are compromised because of overlying anatomy or *'superimposition'*. In the exchange about the CXR above, Mr. Hearken advises students to move as much of the scapula as they can from the lung field because superimposition prevents them from seeing pathology (*'if you've got the scapula in the way you won't see them'*). This assumes that the observation of the pathology is an effect of the relationship or 'coming together' of patient and professional and builds on Wood's (2016) notion of 'con-forming bodies'.

Despite careful positioning of detectors and asked to 'keep still' when x-ray radiation is fired, patients can rotate and adopt different positions. This alternation will make the composition different from the image intended for interpretative purposes. It is impossible to tell from the image whether the patient has rotated from the radiographer-managed position or whether the patient rotated by himself. Mrs. Campbell reveals the problem of patient 'rotation' during a lecture when discussing PACEMAN:

> It's very important when you do a chest x-ray that the patient's not rotated and there are ways we can tell, by looking at the anatomy, to tell if the patient is rotated or not [...] because by rotation we're projecting a different image than what we're expecting to see. So, if your patient's slightly oblique, then the heart might look smaller than it actually is. So, if the heart is enlarged but it's oblique, then it might look a bit smaller.

Mrs. Campbell suggests that it is the radiographer's job to make sure patient rotation does not occur because *'by rotation we're projecting a different image than what we're expecting to see'* which problematises anatomical observation (*'if your patient's slightly oblique then the heart might look smaller than it actually is'*). During a spine lecture, Mr. Hearken (WURD radiographer) further explains why patient rotation problematises anatomical appearance, this time by 'mimicking' the appearance of pathology:

> Like with all the other bits we mentioned about, when it comes to trauma we want the best picture we possibly can, the best image you possibly can; any rotation or lateral superimposition can mimic pathology, so trying to get the patient as straight as possible is absolutely key.

At BHRD, frequent comments on 'rotation' are always brought to the medical students' attention. In the exchange below, we can see how a rotated patient undermines any 'accurate' rendering of the aortic-pulmonary (AP) window[172] and problematises the observation of the anatomy:

Matilda: Can you just point out the AP window, please?

Dr. Saury: Yeah, it's a tough one. It's not a great x-ray to show you on this one just because they're slightly rotated.

In this instance Dr. Saury's comment suggests that a well-aligned patient in the image-making process can contribute towards aesthetic standards and interpretive accuracy. Moreover, the suggestion that techniques of patient positioning are used to validate and guarantee objectivity advances Hoel and Carusi's (2018) notion of "the measuring body". It is, instead, when we look at the patient's body, that standards of objectivity mobilised through measurements and quantitative apparatus, find a subjective and corporeal check. Just as with 'rotation', radiologists' frequent comments on 'collimation' are always brought to medical students' attention. Dr. Delichon has difficulty seeing the left costophrenic angle because of inadequate 'collimation' (i.e. 'chopped off')[173] as part of the production process:

> It's probably not an adequate film because not all the lungs are on, 'cause you're missing that little there, costophrenic angle.
>
> **(Dr. Delichon, BHRD radiologist)**

This comment is in response to a medical student who struggles to see one of the aforementioned review areas (costophrenic angles) due to inadequate 'collimation'. Having drawn his attention, Dr. Delichon identifies how the inclusion of the right costophrenic angle supports seeing the entirety of the right lung, whereas the left costophrenic angle is absent, making Dr. Delichon criticise the radiograph because it limits their perceptual field. Even when images are produced in the A&E department – a location that poses time restrictions

[172] A normal anatomic structure represented as a concave curve between the Aortic knuckle and the Left Pulmonary Artery.

[173] In email correspondence inadequate 'collimation' was explained to me as a body part that *'has been chopped off or missed off by not having the body part in the middle of the detector'* (Mr. Hearken, WURD).

between radiographers and the patient – high standards of technical adequacy are still expected. The comment below cautions the explanatory power of the radiograph is limited due to 'underpenetration', despite difficulties in patient positioning when managing seriously ill patients:

> Okay, now this guy's come in, he's come in from *A+E*, you can see it's a terrible x-ray isn't it? It's not very well penetrated.
>
> **(Dr. Maxwell, BHRD radiologist)**

Similarly, this comment is reflected in another CXR by another radiologist, again in response to a medical student who struggles to see the lungs and lung markings because it is 'underpenetrated':

> This is an under-penetrated radiograph. It's too white. You've not given enough x-rays to darken the film, so I can still see the lung markings but I can no longer see those vertebral bodies, it's all too white, I would not pick up a destroyed vertebral body there from a cancer because it's too white.
>
> **(Dr. Saury, BHRD radiologist)**

Such observations reflect how teaching x-ray image interpretation creates a bridge between two different professions "to the point of blurring allegiances" (Wenger, 1998: 115). Teaching practice is carried out by professionals who embody awareness of technically inadequate radiographs for the benefit of medical students' lack of technical knowledge; x-ray image interpretation training, without providing embodied experience of this phenomenon in action, thus opens up a greater space for uncertainty on behalf of those in the hot-seat. Such comments frequently label radiographs as problematic, and providing inadequate information regarding what can be 'seen' and 'interpreted'.

During teaching, professionals sometimes supplemented radiographs with CT images because they cut out patient rotation and movement. In other words, CT is said to improve stability and help see the anatomy more 'clearly'. Attention was also drawn to CT (and MR) imaging technology as excavating greater anatomical depth within which to see the abnormal in detail and reinforce or confirm the diagnosis. Although professionals provided substantive teaching content in the form of radiographs delivered in BRMR, in their eyes, CT was endorsed as the 'go-to' imaging technology to shore up the ambiguity of radiographs. Whilst radiologists often built up the importance of radiographic investigations (Dr. Delichon: *'you will be looking at loads of chest x-rays on the ward [as a junior doctor] ... just because there's so many of them*), CT was recognised as having professional and diagnostic value (Dr. Delichon: *'If you can say that this looks a bit funny ... and say let's get CT then you expedite the patient's care, okay?'*; Dr. Clyde: *'most people now progress to CT for abdo pain, surgeons don't tend to do anything without a CT scan'*). Radiologists often imbued CT with aesthetic judgements of providing depth, detail, and transparency: a 'better quality' image compared to the radiograph. The function of animation - made possible by the multiplanar reconstruction (MPR) technique - also seemed to underlie these aesthetic criteria. While comments about CT accentuated its prestige and played an active role in forming and shaping medical students' 'interest', they also contributed to the certainty of seeing. Radiologists, for instance, present CT to medical students as a technology that provides greater detail than the x-ray, and often compare radiographs with CT scans in case presentations 'to know for certain'.

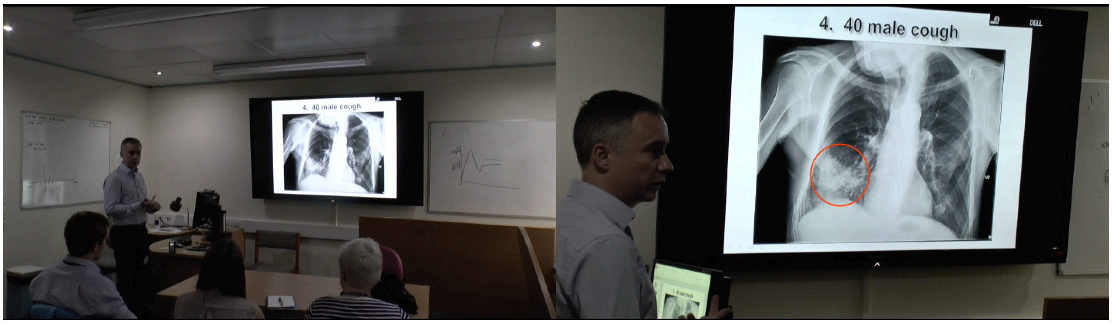

Figure 42 CXR case 4: '40 male cough'. I have highlighted what Dr. Maxwell describes as a 'major area of badness' in the RLL. This video still also shows a typical list-construction gesture: using fingers and hands to list whether the 'badness' is malignancy or infection.

The following extract shows the typical transition from radiograph to CT in a case presentation and the confirmatory ability of the CT to establish whether the abnormality is an infection or a malignancy:

Dr. Maxwell: [Fig. 42] We've got a major area of *badness* here [Gesture: LH 'C' gesture gripping the opacity], haven't we? [Gesture: LH swipes across the opacity above the right hemidiaphragm]

[*brief segment omitted*]

Dr. Maxwell: And we've got a fairly you know brighter [Highlighting 1: LH finger traces inside the opacity] white area peripherally and slightly more lucent centrally so the options really are infection or malignancy [Gesture: List construction]. Is it a mass? Is it you know a lung mass, or is it consolidation? *Looks at Millie* *LH gently slaps palm down into RH palm*

[*Silence: No answer*]

[*brief segment omitted*]

Dr. Maxwell: So the thing to do with this guy is [*Dr. Maxwell presses a button on the keyboard which transitions forward to the next slide which displays a CT scan of the patient six weeks from the previous x-ray* ([Fig. 43)] to get him a CT scan and try and work out whether this is a tumour or whether it's infection

Millie: Mm

Dr. Maxwell: And we can. There's a wedge-shaped area there [Gesture: LH 'C' gesture to enact pathology], and that's classically what you get with infection, there's no obvious underlying mass on his CT scan so um he was treated with antibiotics and he did turn up for his chest x-ray in six weeks' time and that was clear, so it was good news for him.

After Dr. Maxwell has established that the white appearance in the chest is a '*major*' and '*obvious*' abnormality, Millie is unwilling to respond to the question of whether it is some form of consolidation ('*infection*') or mass ('*malignancy*') and is subsequently told that the information provided by a CT scan will confirm this uncertainty. As Daston and Galison (1992) suggest in their discussion of 'mechanical representation', the consultant positions the CT as a technology that produces objectivity and authority. Although the CT is not a new imaging technology, I suggest it is considered an 'upgrade' to the radiograph. This reflects how both professionals often relegate radiographs (and consequently their students) as problematic, and providing inadequate information regarding what can be 'seen' and 'interpreted'.

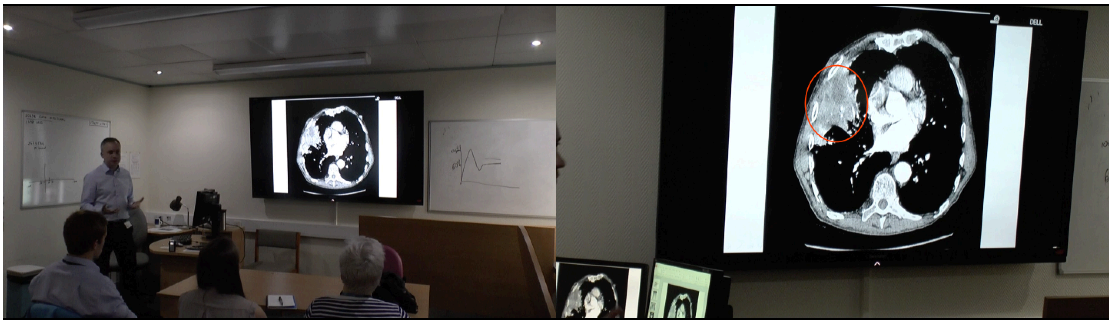

Figure 43 CT used as part of case 4: '40 male cough'. Dr. Maxwell transitions forward to the next slide which displays the patient's CT image. I have highlighted the 'wedge shaped area' he uses to describe the appearance of infection.

Interestingly, when teaching x-ray image interpretation at WURD, radiographers also endorsed the confirmatory ability of CT images over radiographs, as well as MR images. At times, CT is used to generate 'better' images and is associated with greater diagnostic certainty. The following extract between Mr. Hearken (WURD radiographer) and Mustafa (radiography student) about the use of CT to assess the extent of a Spinal Cord Injury (SCI) is taken from a spine image interpretation lecture (semester two):

Mr. Hearken: So x-ray can tell us that there is an injury there, a significant injury, we'd need something else to assess the spinal cord. Such as?

[*Silence: three seconds*]

Mustafa: CT?

Mr. Hearken: CT?

Mustafa: MRI?

Mr. Hearken: CT. Yeah, so to assess the spinal cord. Nowadays more and more the bony sides of things are being done by CT, because there are limitations in terms of plain film in an acute situation, about not being able to see anything; so a lot of the time if there's a suspected neck injury a patient will often go to CT anyway. So you would generally not come across these types of injury very commonly any more.

Mr. Hearken directs the attention to the limitations of the radiograph for imaging the spinal cord because it is made up of fibrous tissue embedded in the vertebrae. While the radiograph can help confirm the movement of bony anatomy (i.e. dislocation), CT is needed to assess if the spinal cord has been injured or as Mr. Hearken put it: *'snapped'.* Whilst CT is constructed as providing a greater level of anatomical detail and enhancing certainty, it is also endorsed as being beneficial for the critically ill by speeding up the diagnostic process and providing an immediate pathway to treatment. This echoes radiologists' accounts as Dr. Delichon pointed out earlier *'you expedite the patient's care'*. During a hip/pelvis image interpretation lecture in which a class of radiography students is told a patient needs immediate attention for acute trauma, Mr. Hearken (WURD radiographer) describes the detail of the CT over the radiograph:

Mr. Hearken: We're looking for bony injury, not because the bony injury itself is the pertinent bit, but it's an indicator that there is underlying soft-tissue injury and they need CT as soon as possible. As if by magic

[*Presses button on keyboard that transitions to the CT slide*]

Sally: Same person?

Mr. Hearken: Yeah, same person. So this demonstrates the extent. Now the thing with the pelvis x-ray is because you've got so much superimposition of structures it's very, very difficult to differentiate and identify the full extent of a fracture; so pelvis x-rays are very, very sensitive to picking up bony injury – like 96, 99 per cent – but you can't fully categorise it on one film alone; so they need CT to actually fully assess the bony extent before they actually go and fix it. So what the CT is really good for, especially looking around the acetabulum and the sacrum, is to look for the extent of the fractures, and the surgeons can use that to help plan what to do. And effectively what they do in cases like this is get two great big long screws and bolt the sacrum back together again. The pubic rami fracture is insignificant, they can plate them but it's not going to do much. The other thing about CT is you can also assess soft tissues as well, in the one scan. You do one scan and you change the settings, the algorithms, and you can assess both bone and soft tissues on the same set of data.

Here, Mr. Hearken describes how the patient needs *'CT as soon as possible'* when there is *'underlying soft tissue injury'* which is needed because the bony injury *'is not the pertinent bit'.* On this occasion, the bony injury is so severe that the patient needs CT *'before they [the surgeons] actually go and fix it.'* CT also prompts professionals to talk about how the use of algorithms can help manipulate the appearance of the image in different ways and excavate anatomical details from the mass of visual information.

On occasions where professionals comment on technical adequacy (rotation, collimation, penetration), as discussed earlier in the chapter, not only do radiologists and radiographers train their students about how *inadequate* images influence the anatomy, but they also transition to CT to 'clear things up' and make salient anatomical details that are otherwise uncertain with radiographs. The importance of technical knowledge in medical image interpretation is emphasised in other studies (Måseide, 2007; Dussauge, 2008; Rystedt et al., 2011; Wood, 2012), although this is explored in clinical settings and new imaging technologies. Nonetheless, at BHRD and WURD, radiographic anatomy – both normal and abnormal - is made uncertain in the early stages of learning diagnostic image interpretation.

5.7 Conclusion

This chapter identifies the wobbles, the uncertainties and the errors in the constitution of x-ray image interpretation training. Professionals often exibit x-ray images as transparent with references to the detection of abnormalities as 'barn-door obvious' and 'subtle'; these activities are also bolstered by the way professionals characterise abnormalities in order to say something about their classification or origin. However, this comes with a warning: they frequently warn about the problem of 'satisfaction of search', a perceptual error that occurs when the person is satisfied with the most obvious abnormality they've found and have missed detecting a subtle finding (whether pathognomic or incidental). Abnormal x-ray images are treated with critical engagement, or x-ray image interpretation generally, during hot-seat interactions. X-ray images are riddled with postures of uncertainty through the misplacement and movement of lines and tubes, the surgical reorganisation of the anatomy, normal variants that mimic pathology, and technically inadequate. Uncertain yet certain, x-ray image interpretation training is framed within the ambiguous contexts of 'missed abnormality', 'interpretive risk', and 'technical error' and further develops the idea that medical images cannot be taken at 'face value' (Coopmans, 2011).

Saunders (2008: 179) explains how radiologists as educators use exemplary images that have caused uncertainty in clinical contexts and how these images, classic or interesting as they may be, can also reflect a potential form of teaching value that is "deceptive, tricky, confounding". Here, I capture how professionals perform these images with undergraduate students in academic environments. In these moments of ambiguity and conjecture, I captured the organised uncertainties between what professionals wanted students to see or miss-see, in part influenced by common radiological errors and institutional mechanisms (e.g. 'never events'). I do not accuse professionals of purposely misleading the viewers into misinterpretation. Instead, I argue how this accounts as part of their professional vision of x-ray images – of what they purposefully do – to avoid radiological error on the shop floor. From this perspective professionals, embracing the indeterminate nature of the ambiguous image, bring about 'uncertainty', which has important implications for the contribution of being critical towards images (Gunderman, 2005). Moreover, the use of such uncertainty as an intentional product of controlling action intersects with professionals in-the-making hiding imprecise answers from the eyes of the professional that protects them from embarrassment (Goffman, 1961; Gunderman and Nyce, 2002).

Again, this reveals how x-ray image interpretation training is entangled in 'radiological vision' (Måseide, 2007; Dussauge, 2008). I express that it is this 'vision', embodied in professionals, particularly in allowing them to generate and reenact a system of problem-solving activities (Måseide, 2007), which accomplishes x-ray image interpretation training, in one instance, as an embodied experience which stresses the barn-door obvious since *'they will jump out and smack you in the face, they're easy, a six-year-old could pick those up'* (Mr. Hearken, WURD radiographer) yet associated with missed abnormality, interpretive risk, and technical error in another. Ambiguity is, at particular moments, enhanced as much as it is removed (Prasad, 2005; Saunders, 2008). In the academic setting, the subtle findings of x-ray image interpretation and the abnormality itself are communicated as opportunities to reduce ambiguity by interacting with the ability to zoom in and out on the computer display. However, the subtle abnormalities are said to carry a bigger threat to patients than the bigger and barn-door obvious abnormalities. This reproduces a correction of interpretation, where ‘subtle’ becomes the main interpretive risk in image interpretation and hence, the students are being corrected by the professional – *‘look at all parts or corners of the film, and not have this satisfaction of search’*, Mr. Hearken retorts: *‘all right, you spot one thing, keep going, make sure that when you’ve put that image down you’re happy that you’ve seen everything’*. Citing Berbaum et al.,’s (1990) classification, Delrue et al., (2011: 48) illuminate this issue of missing findings as an “under-reading error (false-negative responses)” which “occurs when lesions remain undetected after detection of an initial lesion”. It is through this correction, and the expansion of the novice gaze towards satisfaction of search as a radiological error, that a critical gaze is established. Although there are increasing corrections and expansions being made between the obvious and subtle, their commitments to x-ray interpretation training are frequently drawn towards the technical dimension of the image. Indeed, some professonals often talk about the technical quality of the image and to what extent it helps or hinders their visual confidence.

Not only do they recognise its centrality to interpretation, they claim it as a unique attribute of that interpretation. Despite there being some evidence that “radiologists sought an emphasis on their interpretive skills, and played down their role in technical production” (Larkin, 1980: 227), academic training with students illustrate how this specialized knowledge of the technical and procedural components of image production are brought out by professionals – the embodied aspect of interrogating behavior. The ambiguous world of x-ray images opened up by professionals are not only a focus on the abnormal. Due to ways that human actions and values influence the content of x-ray images, the ‘reality’ of these images is not limited to detection and perception between anatomies but extends to technical, cultural, and institutional practices in order to see the right thing (Joyce, 2005). Further, it extends to the process of building a ‘shared vision’ (van Baalen, 2019; van Baalen and Carusi, 2019) and the utilisation of radiographers and junior doctors to meet the increasing demand for x-ray imaging examinations and shortage of radiologists (Price, 2001; RCR, 2012).

In order to see (and say) the right thing, professionals correct and expand the radiological gaze by constructing ‘difference’ around the ‘adequate’ and ‘inadequate’. Here, the ‘inadequate’ image (with poor visibility of the image content and deviation from what is known to constitute the docile body), in contrast with the ‘adequate’ image (with good visibility of the image content and alignment towards what is known to constitute the docile body), is constructed as problematising interpretation. Thus, this reproduces an ideal type of what constitutes ‘adequate’ images/normal anatomy and simultaneously generates an unprecedented effect of order and certainty.[174] There is a common practice of correcting what is suspiciously abnormal to normal, which is conveyed through a gestural reenactment of the noticed misalignment of anatomy. These arguments are extended in chapter six by describing how x-ray image interpretation is entangled in cultural ideals of clarity, how professionals in-the-making are involved in this, and how the student’s ‘anatomic gaze’ can be ‘corrected’ and ‘expanded’ in academic settings.

[174] Especially in the interpretation of whether something is normal or abnormal.

6 Seeing clearly

In chapter five I revealed how x-ray images are registered with transparency in training practices and a relationship between professionals' making of certainty and uncertainty in academic settings. This analysis is extended in chapter six. I begin by exploring how x-ray image interpretation is disseminated through an ideology of clarity and obscurity. I reveal how these positions are reenacted and rendered at the beginning of interpetive enquiry in academic training practices (mostly primary-view secondary-view comparison) and via embodied engagement with cognitive artifacts (such as model anatomy and whiteboards). Such teaching practices and artifacts ready-to-hand[175] accomplish x-ray image interpretation as promoting normative expectations of clarity towards medical images and the idea that anatomic ambiguities can be reduced (Prasad, 2005; Måseide, 2007; Dussauge, 2008; Joyce, 2008; Burri, 2013).

In following this, I provide a description of how this emphasis on seeing clearly imbues professionals in-the-making with confidence towards anatomic intelligibility in their x-ray image. Both radiographers and doctors in-the-making are primarily accountable for knowing whether the radiograph is technically adequate for interpretive-diagnostic decisions (see chapter five). Endlessly reminded about the quest for 'technically adequate' images, professionals in-the-making (but mainly radiographers in-the-making) are disciplined into considering technically inadequate images as obscuring anatomic visibility and, potentially, training for the 'qualities' of the technical work as a means through which they ensure an 'adequate' interpretation/diagnosis. Finally, I identify how constitutions of x-ray image interpretation and cultural ideals of seeing clearly are reenacted in academic environments by discursive strategies from the anatomic gaze (anatomo-clinical gaze, medical gaze, and so on) to 'techno-scientific gaze'.

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[175] This concept of 'ready-to-hand' is often referred to in the literature on interaction with technology (e.g. Suchman, 1987: 53).

Whilst technically inadequate images (i.e. distorted or magnified anatomies) often give rise to normal radiographic anatomy *appearing* as abnormality, this misunderstanding can be corrected by 'correcting' the gaze to a technical sense that draws on clinical experiencs from image production. This correction not only means professionals deploy embodied and machine-relations for the visual problem at hand but also reveals the plasticity of vision whilst translating problematic images – including adequate images – with 'seeing as' (Vertesi, 2016). In chapter six, I do not engage in divisive arguments around visual (embodied) competency and whether the training offered to student radiographers puts them in a better position to identify common technical issues such as size distortion/magnification. Rather, I explore the imaging conditions under which a common misinterpretation occurs (i.e. due to size distortion/magnification) and how it problematises the distinction between normal/abnormal. Like Saunders (2008), I recognise how professional radiological vision is interconnected with image production and more complex than simplistic cognitivist logics of 'looking'/'pattern recognition' or 'mental' vs. 'body' debates.[176]

6.1 Reenacting clarity

As we have seen in the previous chapter, I described how discursive contexts (missed abnormalities, interpretive risks, technical errors) are positioned in a way that trains professionals in-the-making to not take images at 'face value' (Coopmans, 2011). Professionals presume some diagnostic uncertainty and project the image with theatrics of intrigue (*'could be'*, *'might be'*) and suspicion (*'you can probably see little markings'*, *'I think this is a breast shadow'*) to sustain critical analyses of x-ray images. Howwever, professionals often attempt to counter-balance such abductive reasoning by acts of transparency during teaching or through entwined terms such as *'adequate'* and *'clear'*. What constitutes adequacy and clarity exhibits again the importance of embodied (practical) knowledge and language, particularly gestures around how the image is made and how professionals procedurally produce that which is thought to be the 'right' body (Joyce, 2008; Wood, 2016). The dualism of 'adequate' and 'inadequate'' is often distinguished at the beginning of a new case presentation,

[176] The head vs. the body as a whole

during which students are trained to assess for the diagnostic quality of the radiographs so as to recognise, in the words of BHRD, a *'terrible x-ray'*.

However, as discussed earlier, a technical issue of the x-ray image is not so obvious to the uninitiated viewer due to a lack or absence of insight into how x-ray images are produced and optimised. This is further complicated by a lack of specifics in current UK radiation legislation about the referral criteria for radiation exposure, which are decided at a local or departmental level (DoH, 2012: 5). Whilst a regulatory definition of what constitutes a *'terrible x-ray'* is a grey area, recognising it is also difficult. Indeed, the whole situation of whether the image is clinically viewed as 'adequate' or 'inadequate' is accomplished as part of image evaluation[177] before abnormality is identified or classified as part of image interpretation/PCE. In the following exchange, taken at the 'Introduction to Image Interpretation 1' lecture as part of the 'Musculoskeletal Imaging 1' module,[178] Mrs. Campbell (WURD radiographer) describes to a large class of radiographers in-the-making how the procedural knowledge and actual production of the x-ray image may affect its interpretation:

Mrs. Campbell: So if you think about it, all different parts of the body, we have to examine them in different ways so that we can see clearly what the abnormalities might be, or the fractures might be or um the problems might be, okay? So then we also look at the image production and optimisation, so what exposure[179] factors do we use? Have you spoken to John about exposure factors this morning?

[*Pause: two seconds of silence*]

Mrs. Campbell: Not yet, not yet, okay. You'll be moving on to that [Gesture: Right arm abducts to her right as if pushing something aside]. But that just determines

[177] 'Image evaluation': A systematic approach that assesses the image for technical adequacy.

[178] Before this newcomers attended the 'welcome and introduction' lecture the first week into the course, in which I introduced myself and began the participant recruitment outlined earlier in 'Chapter three: Elucidating Methods'.

[179] Radiographic exposure factors control the radiation dose to the patient.

when you're talking about how much energy and *power* [Gesture: both hands push forward to emulate the direction of the radiation beam] you give the x-ray beam [Gesture: opens a space between her hands as if to articulate, position and capture the beam in space] to get through certain parts of the body [Gesture: both hands touch both shoulders as if orientating the beam towards the body and through the shoulder]. Would you think we use the same exposure factors [Gesture: moves the captured beam to her right side] for a hand [Gesture: RH palm faces student] as you would a pelvis? [Gesture: both hands rest on her pelvis]

[*Class: three out of forty five students say 'no'*]

Mrs. Campbell: No. Why not?

Clayton: Because you got a much larger, much larger depth of body to go through on the hip rather than the hand?

Mrs. Campbell: That's right, so you use smaller exposure factors for the hands [Gesture: rotates the hand as if controlling a dialer], so you need to understand *why* and how to use those.

After Mrs. Campbell accounts that different parts of the body require different examination techniques, she suggests that these differences in radiographic examinations are practices of image production and optimisation that guide her to *'see clearly what the abnormalities might be, or the fractures might be'*, and *'the problems might be'*. Mrs. Campbell supports her contentions by referring to x-ray image production and optimisation as the use of *'exposure factors'*. She then constructs features of exposure as *'how much how energy and power [Gesture: both hands push forward to emulate the direction of the x-radiation beam] you give the x-ray beam*', questioning why different exposure settings are required for x-raying the hand and pelvis, despite the class not yet having produced a radiographic image. Clayton (WURD student radiographer) responds by answering that there is *a 'much larger depth of body to go through on the hip rather than the hand'*. Whilst Mrs. Campbell acknowledges that *'you use smaller exposure factors for the hands'*, the perceived presence of exposure factors for seeing parts of the body and any 'problems' means the anatomy can be seen *'clearly'*.

Since radiography students are trained to adjust exposure factors for different body parts (because of differences in bone densities and tissue depth) rather than using a federated standard, they rely on the provisional presence of the corporeal patient as an indicator for successful seeing. Much like in BHRD, anatomic seeing, here, is based on the exposure power of the x-ray beam alongside other actors (the patient and the radiographer) to *'see clearly what the abnormalities might be'*. X-ray radiation, thus, represents qualities of the material apparatus of the x-ray technology through which the ambiguous image content is classified as normal/abnormal and seen as clear/not clear.

The standards of 'adequacy', endorsed by and governing medical imaging and the open 'window' into health and illness, continues to reinforce the idea that medical images render the body transparent or at least perfect and malleable bodies (Joyce, 2008: 50). STS scholars have sustained critique of medical imaging technologies in continuing expectations that produce 'clear' images - 'clear-cut' images for a 'clear' navigation of anatomical structures (Joyce, 2008; Burri and Dumit, 2008; Burri, 2008; Wood, 2016; Reed et al., 2016a, Reed et al., 2016b). But if imaging technology is perceived as giving professionals a "clear new window" into the body (Joyce, 2008: 50) so that anatomy can be "seen with outstanding clarity" (Good, 1994: 72) and ensures normal or abnormal (Reed et al., 2016b), we must question what this standard of clarity involves. Joyce (2008: 70) suggests visual clarity or transparency, despite its promise of objectivity and distance, is "etched together by local decisions and priorities, technology, and aspects of the physical body", with professionals being evaluated on aesthetic appearances (Burri, 2008) and the composition of visual signs (Burri, 2012) to the best imaging 'technique' (Wood, 2012). Although Prasad (2005) and Strudwick (2014) identify the quest for clarity as optimal or good quality images, such an expedition is not confined to the clinical workplace.

At Bridgestock and Woodfleet, the quest for seeing clearly is accomplished in teaching practices, particularly by the primary-view secondary-view comparison. Since radiographers in-the-making often struggle to establish the anatomic structures of the radiographic image during observation of primary images, the professional – as 'patient' or 'as-a-body' – strategically performs and transitions from a primary image to a secondary image and radiographers in-the-making into imagined technicians or 'medical auxiliaries' (Larkin, 1983; Barley, 1984, 1986). During the presentation of a standard PA wrist image, Mrs. Campbell

(WURD radiographer) imprecisely points out the supposed location of the scaphoid bone displayed on a large projector screen to a large classroom of radiography students:

Figure 44 PA wrist (Standard view)

Figure 45 Gesture that depicts standard view (superimposition of bones)

[*PowerPoint slide displays a PA wrist radiograph: Fig. 44*]

Can you remember we were talking about a PA wrist? This is about right. We've centred over the carpal bones [Highlighting 1: lasers the carpal bones], we've got the metacarpals here [Highlighting 1: lasers the metacarpal bones] and all the way down to the – **self interrupts**

[*brief segment omitted*] [180]

And as I said before, this is the scaphoid [Highlighting 1: lasers the scaphoid on PA wrist]. You know we were talking about the anatomical snuffbox? [Gesture: left hand lies flat in the air and

[180] I have decided to omit Mrs. Campbell's self-interruption that seeks to secure the spatial domains and anatomic relations of the imaged body part (the patient's arm) from the class. Once Mrs. Campbell has extrapolated the right answer from a class member that she repeats with emphasis (*'the distal third of my radius ulna'*) she continues her gestural annotation of the PA wrist.

the index finger of the right hand points to the location of the anatomic snuffbox]. Well, this is the scaphoid that sits here [Highlighting 1: lasers scaphoid], and it's *superimposed* [Gesture: Left hand and right hand enable a sequence of visible narrative action that superimposes the hands one on top of the other (Fig. 45)] so the bones are overlaid on each other [Gesture: left hand and right hand superimpose]. They fracture quite often [Gesture: RH index finger rests across the space or 'waist' between the fourth finger and thumb of the right hand] and they fracture across the waist of the scaphoid [Highlighting: lasers scaphoid on the image] [Gesture: Left index finger points to her waist]. But it's quite difficult to see it there? [Gesture: Le Penseur]. You can't really see it clearly [Gesture: both hands move quickly and chaotically in the air] So

[*Presses keyboard button to reveal a 'Zitter's view/banana view of scaphoid* (Fig. 46)]

Figure 46 Zitter's view/Banana view (secondary view)

Figure 47 Gesture that depicts secondary view ('elongation' of bones)

We do something called a Zitter's view or a Banana view, and we *purposefully* [Gesture: both hands open small space] *elongate* the bone [Gesture: both hands widen the space (Fig. 47)] so we can get a better picture of it. So, as you can see [Highlighting 1: lasers PA image], the hand is in a different position [Highlighting 1: lasers Zitter's image]. So, this time, with this one, the patient's hand is *straight* [Gesture: enacts the patient's PA hand image with the left arm angled 90° and left hand flat]. With this one the patient has what we call *ulna* deviation [Gesture: enacts the Zitter's view with the left arm angled 90° with the movement of bending her wrist to the little finger or the ulnar bone, side[181]] where the hand is deviated towards the ulna so it opens up this space at the start [Gesture: RH index finger rubs the shaft of the thumb on the LH], and then when we take the x-ray the wrist is PA [Gesture: LH performs the Zitter's imaging technique position and the RH performs the 45° angle of the x-ray beam down to the Zitter's patient position] and we angle the tube at 45 degrees so we *elongate* the bone even more [Gesture: both hands open wide space], and that's so we can see if there's any fractures more clearly. So we've talked about superimposition of structures where we can see where the carpal bones are superimposed on top of each other [Gesture: both hands move quickly and chaotically in the air]

Firstly, Mrs. Campbell ensures that the radiography students cannot distinguish the obscured anatomic structure (scaphoid) on the straight wrist PA image. She describes the primary image as *'quite difficult to see?'* with *'you can't really see it clearly [Gesture: both hands move quickly and chaotically in the air]'* which, according to Mrs. Campbell, is a consequence of it being '*superimposed [Gesture: Left hand and right hand enable a sequence of visible narrative action that superimposes the hands one on top of the other (Fig. 45)]'.* Secondly, having identified the difficulty in seeing the scaphoid, Mrs. Campbell points toward a secondary image that purposefully elongates the size of the bones within the wrist (snuffbox). Following the demonstration of a second PA wrist image, we can see how comparison is at play here (Pasveer, 1989; Dussauge, 2008); the (*'you can't really see it clearly')* comment is exchanged for a secondary or alternative view for a deeper assessment of the anatomy (*'we do something called a Zitter's view or a banana view, and we purposefully [Gesture: both hands open small space] elongate the bone [Gesture: both hands widen the space (Fig.47)]*]).

Nonetheless, a clear anatomic structure corresponds to a better view of the patient's anatomic body. The combining gesture and speech of *'the patient has what we call ulna deviation [Gesture: enacts the Zitter's view with the left arm angled 90° with the movement of bending her wrist to the little finger or the ulnar bone, side*]' and *'we angle the tube at 45 degrees so we elongate the bone even more [Gesture: both hands open wide space]*' entangle to shape expectations of clarity and *'so we can see if there's any fractures more clearly'*, with Mrs.

[181] For a technical glossary of wrist movements, see: http://www.ergovancouver.net/wrist_movements.htm

Campbell playfully expressing the anatomy *[Gesture: both hands move quickly and chaotically in the air],* since the superimposed anatomy of a straight hand obscures the quality of the image. Radiographs of secondary images provide opportunities for expectations of alternative patient positioning and become ideal for training clarity. This is particularly true in Mrs. Campbell's case, who accounts for her reason for presenting a second image for image interpretation (*'so we can get a better picture of it'*). She supports her choice by shaping her understanding of the secondary image as creating space with reference to both patient positioning ('*the hand is deviated towards the ulna so it opens up this space at the start [Gesture: RH index finger rubs the shaft of the thumb on the LH]*)' and imaging technique of the x-ray beam (*'we angle the tube at 45 degrees so we elongate the bone even more'*).

During the primary-view secondary-view comparison, reenacting clarity emerges not only with confident utterances of *'adequate'* and *'clear',* but also through the professional engaging in a process of 'coordinated gesture and speech' which becomes crucial to making the anatomy in the secondary view convincing and socially meaningful (Kendon, 2004). Here, both the physical body and the anatomical features attributed to the obscured anatomy work in tandem as mediating markers for clarity. The production of additional and different perspectives creates a visual opportunity for participants to be able to distinguish the anatomy as a transparent entity, together with providing another way of seeing in front and behind the anatomy, seeing through the anatomy and good imaging performance, constructing sociotechnical relations, and a deeper gaze at the 'clear' anatomy (Joyce, 2005; 2008; Burri, 2007; Burri, 2012).

Video recordings reveal that the clarity of the anatomy, a local embodied conduct, possesses desirable transparent traits accomplished by talk and action situated in multimodal semiotic interactions such as *'we actually can see nicely here' [Gesture: RH points at the proximal ends of the ribs]*, *'we've got a lovely view of the joint space' [Highlighting 1: lasers joint space]*, *'lovely view of the greater tuberosity [Highlighting 1: lasers the prominent area of bone at the top of the humerus]'*, *'If you get a decent axial view, beautiful, the anatomy is very clear'*, '*look at the clavicle, lovely and straight'* among others. In addition, anatomic structures "perform" (Burri, 2012) when visual signs are composed in the image with the anatomy visibly attributed to being a *'snuffbox'*, *'trabecular pattern'*, *'tent-shaped'*, *'saucer-shaped'*, *'cup'*, and *'moon-shaped'*.

This contributes to sustaining aesthetic-commitments of both clarity and obscurity in the outcome of radiographic technique and image quality.

This locally embodied means of seeing clearly is further accomplished by the cultural materials and 'props' (Goffman, 1959) of the academic environment. This is particularly true at Woodfleet, since it is a technician-based university where there is more technical elaboration than at Bridgestock, to establish a sense of technical skills (Prentice, 2013) and pursue the objective of combining image interpretation with procedural knowledge through teaching materials, such as 3D anatomic models, laser pointers, and metal anatomic side markers. BRMR, in contrast, did not offer technical related materials, nor did it adorn its walls with posters of certain kinds of imaging techniques.[182] However, the meeting room still offers visual engagement and tactile understanding around discourses of seeing clearly via embodied and material aspects of communicative situations related to everyday radiographic practice, including whiteboards (improvised as a detector) and PowerPoint media animating procedural techniques for medical students.[183]

At Woodfleet and Bridgestock, the continuous flux of moving bodies and gestural flows using the materials in the room in innovative ways is symbolic in character to the quest of seeing clearly in 'real' radiographic practice. Often at Woodfleet, for instance, during the demonstration of radiographic positioning, the professionals' use of laser pointers allow for a comparison with the anatomic content of the radiographic image. Using such materials, alongside PowerPoint reconstructions of well-aligned patient positions and the professional's own embodied experience is one of the key moments in learning the radiographic procedure. Offering such props helps construct actions in situated learning (Lave and Wenger, 1991), but

[182] For example, classroom walls were adorned with student poster presentations (e.g. 'A comparison of CT and MRI') designed to promote the authority and validity of 'advanced' imaging technologies and by extension improving their position or "epistemic authority and identity" (Burri, 2008: 36) within radiology and the broader medical field.

[183] BHRD radiologists also used 'dimmer switches' to lower the brightness of the room's light(s) – a move that helped see the overexposed (i.e. whiteout of anatomy) images that was a marker for inadequate image quality. WURD radiographers also understood the importance of controlling light and lowered the brightness of the rooms by switching the lights off and closing the curtains, actions that recalled the importance of a "dark room" in the making and interpreting of radiographs (Pasveer, 1989: 364).

also explains how professionals accomplish ideas around the clear image. The following exchange, taken from around four months into the study (MSK 1 II: 'Shoulder'), documents the ways in which a WURD professional uses a prop to demonstrate the difference between the axial and the AP shoulder. In this exchange I draw attention directly to Mr. Hearken's use of the laser pointer and of his body. His first response is to draw the students' attention to an obscured joint space (glenohumeral) on a standard shoulder AP and, in doing so he 'illustrates' what is being said or shown (Knoblauch and Tuma, 2011):

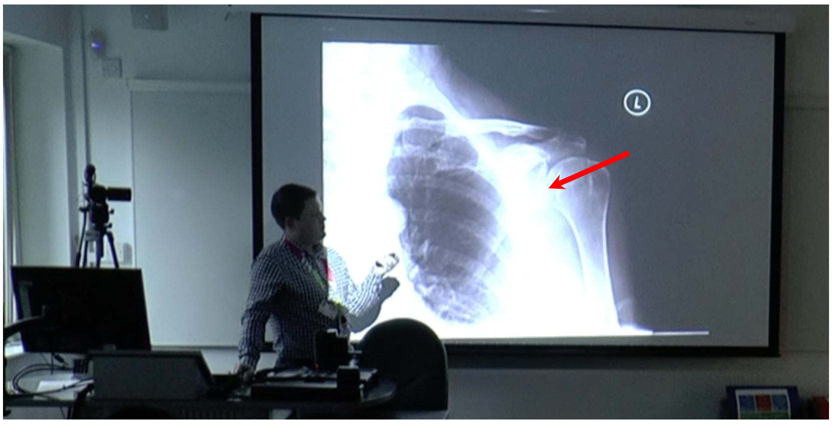

Figure 48 Mr. Hearken lasers the unclear joint space (Highlighted)

Figure 49 Mr. Hearken gestures to emulate the unclear joint space

Mr. Hearken:	Now on a standard AP do we get a nice decent glenohumeral joint space? [Fig.48]
Class together:	No?
Mr. Hearken:	No. Is that normal? [Highlighting 1: lasers obscured joint space]

Tammy: It's normal, but it's not clear through the space.

Mr. Hearken: Yeah, so it's a normal. We expect to *not* see – or sorry – we don't expect to see a nice clear joint space [Highlighting 1: lasers obscured joint space]. Why?

Tammy: Because they need to rotate to do that.

Mr. Hearken: If we stand in a normal AP position [Gesture: stands erect, faces directly forward, feet pointed forward and slightly apart, and arms hanging down at the sides with palms facing forward], why don't we see a nice clear joint space?

Tammy: Because it's going-

Mr. Hearken: Yeah. The glenoid [Highlighting 1: lasers the obscured joint space] doesn't run [Gesture: LA chops down straight through the air twice] in a sagittal plane, because it will run straight forward, it is at an angle [Gesture: LH angles outwards], so the humeral head *sits* in the front [Gesture: RH (as humeral head) superimposes and obscures the LH]; and you'll see that more clearly when we look at the axial in a minute. So on a normal standard AP view [Highlighting 1: lasers the obscured joint space], with the patient in an AP position [Gesture: stands erect, faces directly forward, feet pointed forward and slightly apart, and arms hanging down at the sides with palms facing forward (Fig. 49)], we will *not* see a nice clear joint space [Highlighting 1: lasers the obscured joint space on AP]. When is it important? When *do* we want to see a nice clean joint space? For what diseases? Do you know?

Tammy: Arthritis?

Mr. Hearken: Arthritis. Yeah. Osteoarthritis, or arthritis in general, when the hallmark of an arthritis is joint space narrowing. The AP shoulder is *not* a great view for looking at arthritis [Highlighting 1: lasers the obscured joint space on AP] okay? Because we can't see a clear joint space, so we use this.

[*Mr. Hearken presses a button that transitions to an AP Glenoid view/Grashey view*]

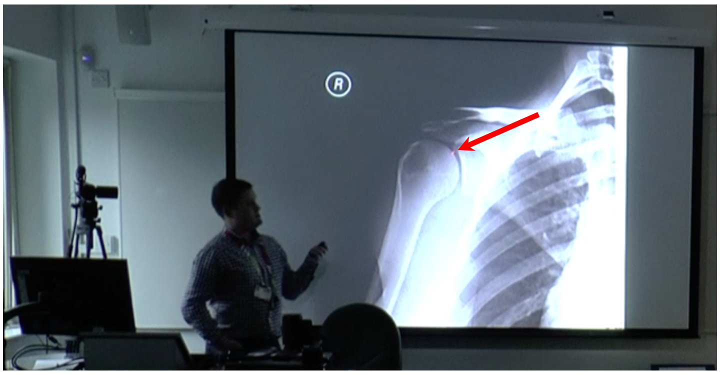

Figure 50 Mr. Hearken lasers the clear joint space (Highlighted)

Figure 51 Mr. Hearken turns his body as if turning the patient to create a clear joint space

Mr. Hearken:	Nice clear joint space now [Highlighting 1: lasers the open joint space (Fig. 50)]. How have we got from the previous, to that? Do you think?
Tammy:	Angle them
Mr. Hearken:	Think about your anatomy. Angled *what*?
Gemma:	Move the patient
Mr. Hearken:	The *patient*, not the tube [Gesture: LH emulates the tube position].
Gemma:	Yeah.
Mr. Hearken:	Yeah. Angle the patient. So which way, do you think?
Gemma:	Out [Gesture: both hands push her chest and rotates shoulder outwards]
Gemma:	Right next to the cassette
Mr. Hearken:	So if it's the right shoulder, you turn them towards the right. So if it's in this case, the glenoid [Gesture: 1. stands in front of the image; 2. RA is raised across his chest] is in that sort of orientation, and the humeral head is sat like that

	[Gesture: 1. LH and RH as fists meet together] so to get a nice clear joint space we turn them towards that side to get a nice clear joint space [Gesture: LH and RH turn to open space between them (Fig. 51)]. So, you turn them that bit further, between 15 and 30 degrees – everyone is slightly different – to get that nice clear joint space [Highlighting 1: lasers the open joint space]. So great for looking for arthritis. What do you now notice about the clavicle?
Tammy:	[Gesture: angles neck to her right]
Mr. Hearken:	Squished [Gesture: 1 Both hands open a wide space; 2 Both hands close the space]
Tammy:	Yeah.
Mr. Hearken:	*Foreshortened* might be a better way of putting it. So, we don't get a great view of the clavicle. The scapula is similar in this, it's actually partially obscured by the spine, don't see the coracoid as clearly. What happens to the greater tuberosity?
Melissa:	Disappeared.
Mr. Hearken:	Disappeared. It's gone around the back, so we can't see the greater tuberosity. Greater tuberosity is very important because it's a common place for avulsion fractures, and it's also a common place for other types of pathology, which, if we can't see it, we won't diagnose it.

With PowerPoint media embedded with clear/unclear images (e.g. AP shoulder vs. AP Glenoid fossa radiographs) and his use of multimodal embodied actions with talk and props to demonstrate clear images (e.g. *'nice clear joint space now [Highlighting 1: lasers the open joint space]'*) and unclear images (e.g. *'The glenoid [Highlighting 1: lasers the obscured joint space] doesn't run [Gesture: LA chops down straight through the air twice] in a sagittal plane'*), Mr. Hearken demonstrates ideals not only around the clear normal anatomy, but also around the 'adequate' workplace image.[184] The combination of embodied orientations and various material things and comparative strategies in reenacting a sense of anatomic clarity is

[184] This series of laser pointer movements is often considered a form of highlighting work (Goodwin, 1994), as work that is performed in addition to radiography in order to understand there is a planned trajectory of the x-ray beam from the machine to the anatomy without exposing students to radiation (as shown by Mr. Hearken in the final example).

accentuated in the distribution of 3D anatomic models (relevant to the imaged body part) to radiographers in-the-making which allows them to practice radiographic technique. At WURD, this is endorsed as helping radiography students 'measure' the radiographic anatomy, influencing the collimation of the x-ray beam which reduces scatter thus improving contrast, and as directing the radiation source towards an area of interest for diagnosis (Wood, 2012). The following exchange is taken from the same MSK shoulder image interpretation lecture, involving Mrs. Campbell (WURD, radiographer) distributing[185] three 3D model bones (humerus, scapula, and clavicle) to a large class of radiography students in view of a shoulder AP slide and essentially organising 'what they need to look at':

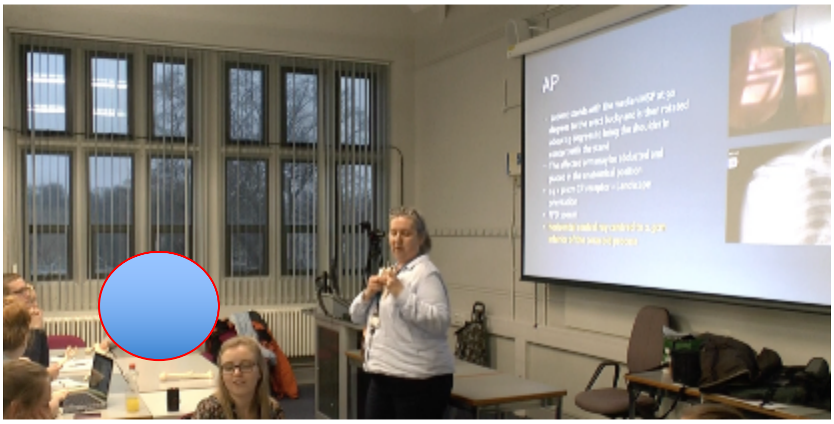

Figure 52 Mrs. Campbell measures the model scapula with her own body's scapula. Also, notice how Chloe (highlighted) emulates Mrs. Campbell by feeling and rubbing the coracoid process on her own body.

Figure 53 Two female students feel and rub their coracoid process, emulating Mrs. Campbell (highlighted)

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185 From a shopping bag full of shoulder bones and aptly titled 'bag for life'.

Mrs. Campbell: [*Presents 'AP' PowerPoint slide*]. We'll just start with an AP. *So*, as normal, the patient stands erect and you put the receptor in the upright bucky. Portrait or landscape?

Jim: Landscape

Mrs. Campbell: Landscape *nods* [Gesture: LH and RH touch both their coracoid processes] because what do we need to include?

[*Some members of the class respond with mixed answers*]

Jim: Clavicuh-uh med-uh-uh-clav-

Mrs. Campbell: *Nods in encouragement*

Jim: Both clavicle joints at both ends?

Mrs. Campbell: Yeah

Jim: And the proximal third?

Mrs. Campbell: Yeah, so you need to make sure you've got the skin border [Gesture: LH hovers over her right shoulder], but you also need to make sure you've got the medial end of the clavicle [Gesture: LH taps her left clavicle] as well, okay? So the patient stands with their back towards the receptor [Gesture: Mrs. Campbell demonstrates with the use of a whiteboard (as a detector) how to position a patient for a PA shoulder] okay and we, before the "do's and don'ts," we ask them if possible if they can hold their arm in an anatomical position so they can rotate their arm, okay? Then you would turn the patient slightly, fifteen degrees, okay? And then in that position then the patient will just stand. If you stand with the patient's feet apart, it's the same, it's the same with chest x-rays, if they're stood with their feet *together* then there's more opportunity of wobbling. If they're standing apart and they're *leaning* against the receptor anyway, okay? And then we send a horizontal beam *Reads from PowerPoint* 2.5 centimeters inferior to the coracoid process. So, show me where the coracoid process is on your scapula?

[*Students with scapula feel for the coracoid process, whilst those without feel their body*]

Chloe: [Gesture: Feeling above her left breast, rubbing her body's coracoid process (Fig. 52)] It's up here

Mrs. Campbell: *looking at Leanne and Megan* Yep, where's your coracoid process?

[*Leanne and Megan respond to Mrs. Campbell by rubbing their coracoid process* (Fig. 53)]

Mrs. Campbell: **Picks up a model scapula** Yep, so we're looking at these [Gesture: taps the coracoid process on the model scapula] underneath, so the coracoid process here [Gesture: measures the model scapula with her own body's scapula] so two point five, which I think is quite far in, two point five centimeters below and then you collimate. You collimate to make sure you include the medial end [Gesture: RH taps the middle of her clavicle] of the clavicle and soft tissue so you can see here [Highlighting 1: lasers the AP radiograph on the slide]. So, you've got the medial end of the clavicle there [Highlighting 1: laser highlights the medial end of the clavicle on the radiograph] and the soft tissue border here [Highlighting 1: lasers the soft tissue of the shoulder] and you make sure that you have the *whole* of the clavicle on [Highlighting 1: lasers the clavicle on the slide] and the proximal third of the humerus.

After Mrs. Campbell distributes three 3D model bones (humerus, scapula and clavicle) to groups of three students in the class and after each student has been assigned a 3D model in their group, she provides a demonstration of shoulder positioning. After demonstrating how the patient stands under the principles of AP positioning technique and consent in the anatomical position, she provides them with a numerical measurement of where the coracoid process should be imaged with reference to the source of the x-ray beam. Although Mrs. Campbell shows the students how the patient should stand, she asks them *'which is the coracoid process?'.* Students subsequently feel it on the scapula model and those without the model feel their own body's coracoid process. This dynamic practice of learning how to see, feel and position patients through their multimodal embodied interactions shows how both their hands and eyes are in play. Beginning to take hold here is a development of the tacit skills and craft knowledge required to image patients and 'think intelligently about positioning'. This reflects an interest in how professionals in-the-making learn to see by building an intense form of embodied relationship with 3D anatomical models (Myers, 2007, 2008; Prentice, 2013).

Mrs. Campbell claims that the x-ray beam should be centred to 2.5cm inferior of the coracoid process before making this measurement meaningful for the students by resting the 3D scapula model upon her own and then tapping it when 2.5cms is mentioned, as if to convey depth *'so the coracoid process here [Gesture: rests the model scapula against her body's scapula] so two point five which I think is quite far in, two point five centimeters below (the clavicle)'*. Whilst this observation recalls Carusi and Hoel's (2014: 203) notion of the measuring body: the idea that that body is the "measurant of ... things", it also highlights the students initial formation of a 'mechanical objectivity' that explicitly entwines human-technological agency in their practice of bringing anatomic areas of interest into view. In this sense, radiographers in-the-making can make explicit the contributions of their own personal knowledge and craft-work to image production. This tension between tacitness and explicitness about the impact of their own body and the patients on the image making process reminds us again of the student crystallographers in the work of Myers (2008: 186). Like the crystallographers, the radiographers "value the intuitions and embodied knowledge they contribute to their work: they deem the craft nature of their practice a virtue that raises the epistemological status of their data". The term 'critical epistemology of visualisation', coined by Myers (2008: 186), is thus an attempt to analytically grasp how human relations (and other objects) contribute to the formation of the image and become careful about qualifying the technical status of not only their own visual production, but that of others.

In other props used by Woodfleet, radiographers in-the-making are given metal anatomic side markers to help others know whether the body part is left or right, which is a basic radiographic requirement outlined by SoR (2014) best practice policy[186] (*'so you'll be provided with two markers and these should be on your x-rays'*). They also benefit from the equipment in the classroom, such as whiteboards or doors to understand x-ray collimation[187] (*'so what we do is turn the patient [Gesture: Mrs. Campbell places the student's left arm in an anatomical position against the whiteboard]'*). Such props, in unison with embodied interactions of gesture and corporealised transference in the academic setting, deepen the expectant sensorium of radiographers in-the-making – who can experience the benefit of *'centering'*

[186] The SoR (2014: 1) policy document reads: "best practice is that anatomical side markers should be present in the primary beam for all images and SoR expects this to be the case unless there are exceptional circumstances".
[187] This often includes the needs and experiences of positioning patients in discomfort.

from the anatomy – and cultivate their body towards learning a future x-ray image as a technically competent product (e.g. using the 3D anatomical model and their body to influence precise positioning of shoulder and tacitly estimating the angulation of x-rays for collimation).

So how does this relate to x-ray image interpretation? The use of the 3D anatomic model blurs the boundary between their body and technical skills and drives a disposition towards the embodied knowledge that radiographers have of making clear and compelling images. This construction of the clear image contributes towards a normative expectation commonly found in communities of practice (Goodwin, 1994; Lave and Wenger, 1991; Myers, 2007; Prentice, 2013). I argue that any deviations in the selection, measurement, and positioning of body parts (dedicated to 'cleaning up' and 'correcting' levels of action) in order to relate to patients are viewed as diagnostically unwarranted and can become grounds for misinterpretation. And this is why, when technically inadequate images are presented in case presentations, professionals in-the-making learn not to take these images at face value. They must learn via three comparative strategies: comparison of their own body with 3D model anatomy; observing other students doing the same task and correcting accordingly, and observing the body-work of professionals (e.g. mimicking the location of gestures and 3D models on the professional's body, and the way the patient was positioned in the image). A sense of technical skill plays a key role in membership to a community of practice, embodied perception, situated learning, and establishing a register of technical-anatomic standards in medical images that mitigate its ambiguity (Saunders, 2008). As factual measures and equivalences, props – alongside the subtle coordination between talk and body – contribute to the clarification of meaning and the representational standards of the body in order to stabilise the interpretation of the x-ray images. The technical skill acquired from the recursive relationship between 3D anatomic models and the body in action, thus becomes part of the procedural knowledge or "production procedures" in which certain images can be criticised and cautioned, particularly technically inadequate images not aligned with cultural idealisations of clarity (Ivarsson, 2017: 24). When discussing the pursuit of radiographic clarity during a didactic lecture, Mrs. Campbell (WURD radiographer) claims:

Mrs. Campbell: 'Aesthetics' [*Reads from the PowerPoint slide*]. I'm quite proud of my images. I like them to look good, and make sure that things are centred

	properly, that they can see the collimation, which is what we said here [Highlighting 1: Lasers the inadequately collimated radiograph]. Is this one aesthetically pleasing?
Class together:	No.
Mrs. Campbell:	No. It's not centred. We've missed some of the anatomy on there, so that's not good.

Mrs. Campbell states that the objective of radiographers in-the-making is *'to make sure that things are centred properly'* so that they prepare an image of diagnostic quality for interpretation in which professionals *'can see the collimation'*. She highlights how any radiographic anatomy that is *'not centred'*, regardless of whether it is normal/abnormal, makes the image problematic, as it has *'missed some of the anatomy'* since the image desired by professionals must be *'centred properly'*. Dr. Maxwell (BHRD radiologist) similarly claims during a CXR interpretation class that when radiographers receive *'supine chest x-rays'* this means it is likely to be *'rubbish because when we lay them flat [Gesture: RH rotates flat] any fluid that is there will dissipate [Gesture: RH and arm quickly raises upwards] and we won't see it'*. At BRMR, Dr. Maxwell warns about the potential pitfalls of technical issues, such as undesirable patient movement in the process for emergency imaging:

> If you get a portable x-ray [Highlighting 1: LH points at text 'AITU Portable Supine 76KVP 3.2MAS@ 14.55] it's never going to be as good as a departmental x-ray. You know, the patient is flat out [Gesture: LH slides through the air as if sliding an imagined detector plate underneath the patient], so they shove the x-ray plate in under their back, so the x-ray equipment won't be at necessarily the right height, and the patient might be breathing throughout it, you know, assisted ventilation [Gesture: LH points at the tracheal tube that is inserted into the trachea for providing oxygen], but they won't be able to hold their breath for the film; so there's movement, artefact, and poor imaging conditions, and a chaotic intensive-care unit; so those are all the reasons why you've got, you know, this is real life, the x-rays you will have to deal with on the sick patients will be bad for those reasons [Highlighting 1: presses button on keyboard that highlights the second (double lumen) endotracheal tube], they won't be technically as good as the ones you see in the books.

Dr. Maxwell warns against the dangers of patients who are *'flat out [Gesture: LH slides through the air as if sliding an imagined detector plate underneath the patient]'*, referring to a supine patient, rather than someone who can stand, and presents x-ray image interpretation as confounding, when revealing the presence of a hidden endotracheal tube *'[Highlighting 1: presses button on keyboard that highlights the second (double lumen) endotracheal tube]'*. For Dr. Maxwell, it is problematic when there are obscured and hidden realities, for these images *'won't be technically as good as the ones you see in the books'* because of the way '*there's movement, artefact, and poor imaging conditions'*, meant to reflect the imaging of seriously ill patients in a hospital's "profilmic reality" (Ostherr, 2013: 2010). The moving patient body and aesthetically 'bad' image are often mutually constructed as a tactic during training, in a way that teaches students to connect ad hoc imaging conditions with constraints on anatomic visibility and undermining the finality of the diagnosis. Here I reveal what constitutes the clarity and distinctness of the image content as being founded in the embodied demonstrations and interactions with the visual media of PowerPoint images in BRMR and WURD.

Earlier, I highlighted the professionals' view that x-ray image interpretation is made familiar to radiographers in-the-making because of the image's 'visual performance' (Burri, 2012), that is, the purposeful composition of anatomic signs in an image as a result of the contingent and situational nature of image production. This does well enough to suggest why x-ray image interpretation is seen to value the reenactment of future image making to "realist codes" for which professionals' bodies become the primary instruments (Saunders, 2008: 26). During a video recording of Mr. Hearken during a shoulder x-ray image interpretation class, he endorses the production of secondary views in addition to standard views because *'you can't tell on one image whether something is sat or where it is sat [Gesture: LH and RH fingers overlap, tuck in, and move forward as if to obscure and hide the anatomy]'*. After he attributes this to an *'overlap between the glenoid and the humeral head, the articular surface of the humeral head'*, Mr. Hearken suggests a *'standard image'* of the anatomic structures is not enough for professionals; shoulder dislocations and subluxations are not immediately clear and so he concludes, *'the axial is one way in which we can provide that third dimension to identify whether the humeral head is sat where it's supposed to'*. Here, the 'visual performance' of unclear x-ray images and uncertain x-ray image interpretation become synonymous, coming together, enacted as an embodied demonstration for 'matter out of place' (Douglas, 1966), and, in turn, for not taking images at face value (Coopmans, 2011).

In chapter five, I described how aesthetic expressions such as *'you can see it's a terrible x-ray isn't it? It's not very well penetrated'*, *'to be honest the lungs are a bit scruffy', 'looks a bit crappy doesn't it *face expresses grimace* for want of a better word so they're probably aspirated'*[188] are used by professionals when exhibiting the initial reactions to their uncertain observations of image content. This often corresponds to professionals' initially perceiving of the radiograph and its interpretation as 'ambiguous', a patient's anatomic body outside the desired biomedical norm; "bodies have to be customised to a specific physical norm, that is, refractory bodies have to be disciplined by forcing them to conform to the image of a 'normal,' average body which is both physically intact and not too large in weight or size" (Burri, 2007). X-ray images are constructed as ambiguous in four ways: comparatively, particularly the focus on clear and unclear images analysed together;[189] gesturally, in the process of using hand gestures to enact superimposed anatomy obscured from the x-ray beams; figuratively, in which unfavourable familiar features of the world are projected onto the image being depicted, and literally, via the technical terms of poorly composed images.

For professionals, the embodied actions and props used to help see radiographic anatomy characterise back-stage performances as being more 'truthful', whereby enactments of image production can knowingly contradict the formal and the clinical presentation (Goffman, 1959; Hafferty and Castellani, 2009). We can see how back-stage work in academic settings such as these reveals how professionals, who demonstrate before their audience, engage in interactional and organisational work with image-making and interpretation. Furthermore, the selection of "puzzling cases as theatrical props", as illustrated by the frequency of what one might call 'technically inadequate' and 'unaesthetically appealing' images, is used for the "artifice or obfuscation that is often ingredient in them" (Saunders, 2009: 157). These images come to confuse a naive observer, particularly in the disruption of normal/abnormal

[188] Breathe something out: an aspiration of breath.

[189] The latter generated in part by situatedness and emergency (that problematise the comprehension of key anatomy).

expectations. I suspect the inadequate 'visual performance' of the x-ray images represents an out-of-place deviation in the embodied composition of clarity.

Since training is founded and maintained by the idea that diagnostic imaging prevents missed abnormalities or difficult interpretations (van Dijck, 2005; Joyce, 2008; Saunders, 2008) and with newer technologies sustaining and enhancing "cultural ideals such as perfectibility and malleability" (Joyce, 2008: 50), the out-of-place anatomy represents a diagnostically undesirable outcome. Thus, x-ray images with unordered and unconventional anatomy are likely to confuse or contradict a system of categories (Douglas, 1966). The same can be said for the fracture or pathology in the image (often described in unpleasant terms as a consequence of violent damage or unfriendly harm, an embodied account of demonstrating the mechanism of injury). Whereas the previous two chapters highlighted abnormality as matter out of place (for example, in Mr. Hearken's Hill-Sachs fracture/'Hatchet sign' classification *'the people who first described it'* and enacted by his body *'hatchet apparently makes it look like that someone's taken an axe to it [Gesture: demonstrates a hatchet's action] and caved it in'*), here I want to follow up on what happens to the anatomy in image production in order to make these images diagnostically useful. For both, their principal medium is and *must* be normal radiographic anatomical knowledge, because only a comprehensive absorption of radiographic anatomic taxonomy offers the possibility of interpreting the image 'precisely' (Dussauge, 2008).

6.2 Seeing clearly and technical evaluation: 'forget the pathology, we assess quality first'

So how do these images of clarity or obscurity involve medical and radiography students? In chapter five, I suggested training practices implicate professionals in-the-making, though doctors in-the-making more than radiographers in-the-making, in relation to interpretive-diagnostic decisions. Similarly, professionals in-the-making and especially radiography students are further involved in the cultural narratives of seeing clearly during a technical evaluation of radiographs (which is the precursor of looking for pathology). A closer proximity to image production, translated to radiographers in-the-making, increases their involvement in malpractice litigation if the ambiguous image may lead to uncertainty and radiological errors. Nol et al., (2006) and Perez et al., (2015) have produced data specifying radiographers' technical errors, based on the inadequate creation of radiographs, independent of image interpretation/diagnosis. Both studies suggest that technical errors are largely associated with junior radiographers and a lack of imaging experience and training (i.e. lacking adequate technical skills in the performance of imaging procedures).

Whilst radiographers are in place to reduce technical errors during image production, it goes without saying that any technical errors in the image can lead to decreased confidence in image interpretation and visual perception errors occurring in the translation of radiographic content (Buckle et al., 2013). The discourse of 'technical adequacy' (interchangeable with 'diagnostic quality' and 'optimal images'), reinforced through the embodied demonstration of these error factors, ensures radiographers in-the-making systematically evaluate technical competence to inform diagnostic certainty (Perez et al., 2015) and help prevent litigation (Burri, 2013). Video footage taken during an MSK image interpretation summary and OSCE revision training between Mr. Hearken (WURD radiographer) and a large classroom of radiography students illustrates this:

> Whilst you can diagnose things or rule things out on an x-ray, the *quality* of that image is very, very important to how confident and certain we can be about that. And there may be times when we're not able to get the optimum images, which is fine, that's the way it goes; but we can identify that and indicate that when we are giving our interpretations for people in whatever form that might be. You'll notice if you ever read reports, if there was a problem with image quality or the image is suboptimal it will say so, more so than anything else to cover the reporter's *backside* if something goes wrong.

Radiography students' inclusion into legal practice (i.e. patient litigation) when there is *'a problem with image quality or the image is suboptimal'* is raised regarding the reading of the diagnostic report. Mr. Hearken alleviates this concern by advising the description of suboptimal images should be included in the written report and by stating that adequate images are not always attainable (*'there may be times when we're not able to get the optimum images, which is fine, that's the way it goes'*). Professionals at Bridgestock and Woodfleet demonstrate a vast knowledge of the sources of litigation, but particularly radiographers, who have a rather substantial awareness of radiographers in-the-making being more susceptible because of their role in image production. For instance, Mrs. Campbell (WURD radiographer) justifies the decision to train the production of secondary images rather than rely on a standard image (the former concentrates on the area of interest in a forensic-fashion and extends the limits of visual experience) by suggesting '*they do so many different ones, 'cause they do outlet views as well where you can see the acromion more clearly*'. In this way, the litigation discourse is a social accounting method that chimes with risk-related issues (Horlick-Jones, 2005). At the beginning of a CXR image interpretation class, Mr. Hearken (WURD radiographer) explains why radiographers in-the-making must systematically evaluate the image for technical adequacy before sending it to PACS and, hence, the image deemed to be clinically adequate with which to interpret and diagnose:

> The first thing you need to do is you need to assess the adequacy [Gesture: hand claps]. If you've got an *awful* image it's going to reduce the ability to identify pathology and it's going to reduce your *confidence* [Gesture: list construction] to categorically say, 'yes, there is something there'. If I'm reporting and I've got an image which is absolute *tripe* [Gesture: both hands hold up imagined image] I'm going to say so because when it comes back, when someone comes to sue me for missing something I'm going to say, 'well, that's not my fault this image is awful' [Gesture: RH shakes the imagined inadequate image]. So you've got to assess the quality first. Patients might not let you get perfect images [Gesture: both hands open space to reenact a patient position], patients are difficult [Gesture: both hands frustratingly shake imagined problematic patient] that's *fine*, but when you come to assess the pathology [Gesture: both hands rotate to form a ball to enact imagined pathology], an abnormal, your confidence in that image is tempered by the fact that you haven't got a brilliant image. So that's why image quality is so important and you forget the pathology, we assess quality *first* [Gesture: both hands emphasise an imagined adequate image], *then* we go through the systematic review [Gesture: RH touches the text 'systematic review' on the PowerPoint slide] and this applies to chest, abdo, MSK, ultrasound, CT, MR, the lot.

Mr. Hearken claims radiographers in-the-making are more likely to experience someone coming to *'sue'* them, since professionals often account for their interpretive/radiological errors with reference to the technical inadequacy of the image (*'well, that's not my fault this image is awful [Gesture: RH shakes the imagined inadequate image']*). By matter-of-factly stating *'forget the pathology, we assess quality first'*, suggesting that radiographers first and foremost assess the technical quality before looking for abnormality, Mr. Hearken highlights how inadequate images can *'reduce the ability to identify pathology and ... reduce your confidence [Gesture: list construction] to categorically say, 'yes, there is something there'*. Thus, the vulnerability of radiographers in-the-making in NHS's particularly legalistic and adversarial political culture and their being part of a diagnostic culture in which litigation has far more influence than it had before (de Bere and Petersen, 2009) seem to exercise some form of systematic attention in undergraduate x-ray image interpretation. Armed with this litigation knowledge, radiographers in-the-making may construct their professional practice as erasing cognitive and perceptual uncertainties in x-ray image interpretation.

Joyce (2008) suggests radiologists and technicians take steps to avoid possible lawsuits and that the "spectre of litigation" exists in a stable and alienable form; litigation encourages the production of more images (creating lucrative and growing imaging economies) and calls on professionals to become more certain in their diagnosis. In the context of x-ray image interpretation training, this reply often encourages producing a more detailed image, i.e. patients having a Zitter's view image in addition to a PA wrist. Professionals having the effect of endorsing additional imaging by citing technical errors in the production of radiographs arguably points towards the practice as one with more control over their procedures of clarity alongside other technical choices (adequate patient positioning,[190] appropriate x-ray exposure, appropriate use of collimation, and so on). Such procedures are demonstrated to ensure they have, as Dr. Maxwell (BHRD radiologist) claims, *'a well-centred, adequate, well-penetrated film, so it's a fairly high-quality diagnostic x-ray.'* Other research has recognised, indeed, that medical imaging professionals participating in x-ray image interpretation evaluate the technical aspects as part of their capacity to see clearly, that is, as a means of reassurance and a sense of security that their anatomic image is a clear window into the patient's body and free of technical errors (Pasveer, 1989; Prasad, 2005; Joyce, 2005, 2008; Saunders, 2008; Wood, 2012, 2016).

Radiologists can similarly contribute to figuring medical students (perceived as junior doctors) as being at risk of litigation should something go wrong with the interpretation/diagnosis. This observation pointed to the presence of two major technical

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[190] Such as lines and tubes.

issues. Video recordings revealed that medical students were at risk of misinterpreting two technical errors inherent to the creation of radiographs involving seriously sick patients in danger of incorrect line positioning, and that patients who have a history of surgery are more likely to encourage medical students to miss-see varieties of iatrogenics. Neither of these issues will be passed over silently, but will be dissolved by litigation. In this case a short sharp admonition was made at the beginning of each case presentation, in that it stopped the bad behaviour of assessing the image for pathology (as their principle object of interest) and reminded medical students that looking for lines and tubes was a priority (Dr. Saury: '*the first thing you should look for when you analyse a radiograph is lines and tubes or any evidence of previous surgery*'; Dr. Delichon: '*tell me about the lines and tubes first*'). A video recording taken of a CXR image interpretation seminar between Dr. Maxwell (BHRD radiologist) and two medical students (Ravi and Muhammad) highlights this further:

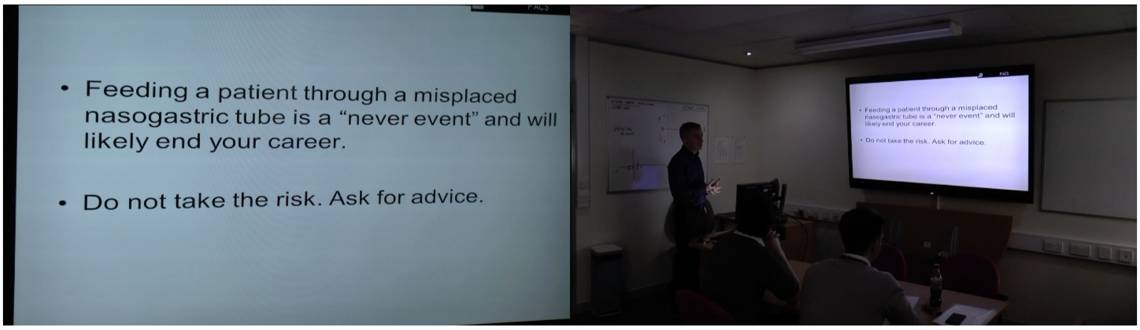


Figure 54 Dr. Maxwell presents a slide about misplaced NGTs as 'never events'

Dr. Maxwell: So this is the pacing wire [Highlighting 1: LH index finger traces the moved position of the pacemaker wire in the stomach] it's a single pacing wire which comes round, and then obviously it's been placed in theatre and since the patient has not been able to provide a gag or a cough reflex it's gone down the right main bronchus, back up and down the left main bronchus [Highlighting 1: LH index finger traces the pacemaker wire]. The fact that this pacing wire is so low down on the film is the patient is slumped over [Gesture: Both hands open space and turn to enact patient rotation], which you correctly identified. And they've got significant cardiomegaly [Gesture: LH index finger circles the large bulge of the cardiothoracic ratio], because the cardiac apex is down here [Highlighting 1: LH index finger traces the cardiac apex]

Ravi: Right. Okay

Dr. Maxwell: So the whole diaphragm is being pushed down [Gesture: 1. Both hands open space, 2. Body slopes downward, 3. Hands push down as if pushing down the diaphragm] by this enlarged heart. So it's a conspiracy of little things that kind of lead people up the garden path.

Muhammad: Yeah, so don't go, don't be-

Dr. Maxwell: But that, you know, you won't be fooled like that in real life, it's just there to kind of make you think it's not always that straightforward.

[*Dr. Maxwell presses a button on the keyboard which transitions forward to a text-only slide warning students about misplaced NGTs as 'never events'*] [Fig. 54]

Dr. Maxwell: And that's just to labour the point, really. I mean in years gone by there was always at least once a year there'd be a junior doctor up before the GMC or something, accused of killing a patient by having them being fed through a misplaced nasogastric tube. And now you have to have an x-ray, and it has to be reported, in this trust, I don't know, there may be some trusts where you won't get the report through still, and you'll be having to have a look at it yourselves and make those decisions; so don't take what happens in Bridgestock for granted elsewhere. Although things are improving nationwide so you should really ideally have a report, and if the radiologist isn't happy they can always put some contrast down themselves and reposition it in the department.

Ravi: Yeah.

Dr. Maxwell: So speak to your *seniors* and speak to the radiologist if you're not sure. There's never events, the last I heard there were twenty-five never events and these lists that might continue to grow.

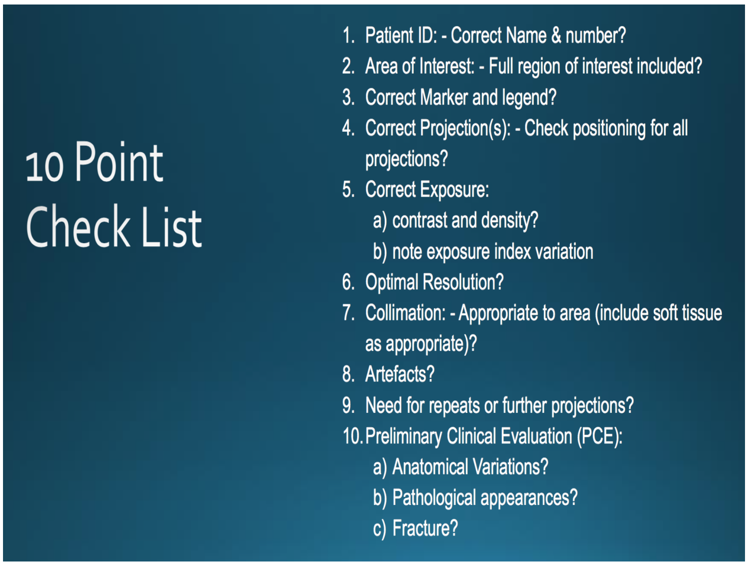
After Dr. Maxwell confirms the location of the pacemaker wire position change to the class, he accounts for this knowledge because of its gravity and gestures how the lateral movement of the patient has led to its displacement down the stomach. Importantly, Dr. Maxwell reassures Ravi and Muhammad to '*speak to your seniors and speak to the radiologist if you're not sure*', supplementing the treatment and contrast information with professional-expert help from radiologists intended to remedy the (now) evident pacemaker lead displacement. Dr. Maxwell also identifies those seriously ill patients lying on their backs and a variety of lines/tubes as a *'conspiracy of little things that kind of lead people up the garden path'*, that is, as further complicating the observation and critique of the image. Here, the doctor in-the-making figured in relation to never event scenarios is associated with the fear of litigation, an accountable figure who may be subjected to poor interpretive practice via incompliant patients.

In her work on the production of Cone Beam Computed Tomography (CBCT) images in radiotherapy practice, Wood (2012, 2016) claims that the projected anatomy displayed in CBCT images is "co-produced", extending to implicate both professionals and patients. At Bridgestock and Woodfleet, professionals in-the-making, patient, and radiographic image are, often, seen as having a recursive and entangled relationship. In this homologous move, professionals in-the-making are assured that at some point being at risk of technical inadequacy is inevitable (Mr. Hearken: *'there may be times when we're not able to get the optimum images, which is fine, that's the way it goes').* Ponder the ensuing quotes taken from radiologists and radiographers during their interactions with medical and radiography students: *'not all patients are gonna do what you want them to, not all images are gonna be perfect* (Mr. Hearken); *'it's probably not an adequate film because not all the lungs are on'* (Dr. Delichon); '*we talked ... about the need to elongate the neck, to internally rotate the leg, so we can see the femoral neck at its longest, we can see these trabeculae as clearly as possible'* (Mr. Hearken); *'obviously sick patients often aren't able to comply, you don't get the same quality images from them'* (Dr. Maxwell).

Similarly, Mr. Hearken (WURD radiographer) suggests radiographers in-the-making in particular *'always go through the adequacy first, name, date, marker, area of interest, exposure, position, artefacts, before you look at any pathology whatsoever [its] technical quality.'* Professionals in-the-making are thus at risk of litigation and professionals' inadvertent misinterpretation/diagnosis. Consequently, professionals in-the-making receive litigation-aversion information; they are the ones first in line to evaluate the technical errors in preparation for image interpretation, thereby enhancing the (epistemic) certainty of what professionals want when writing reports/clinical evaluation.

As noted in some of the extracts above, uncertainties often appear at the beginning of interpretive practice with a professional in-the-making potentially being first in line to see the image (*'you guys as presumably as junior doctors might be the first and only people to look at the film for quite a while until the radiologist gets round to reporting it'*), the potential for dealing with technically inadequate images (e.g. '*there may be times when we're not able to get the optimum images)*, and how professionals interpret the quality of the written reports on inadequate images (*'importantly this is a PA radiograph, they don't always write PA on a PA radiograph, they should always write AP on an AP radiograph'*). Nonetheless, with x-ray image interpretation training governed by a discourse of litigation and both the radiographer and radiographic image becoming mutually entangled, radiographers in-the-making may feel responsible and self-critical if they are to produce a poor quality diagnostic image and/or misinterpretation resulting in an incorrect diagnosis. This depiction has been reported on in an article in the *Guardian* documenting the prevailing victimisation, stress and fear of radiographers in-the-making about patient positioning in imaging departments, afforded limited time to 'get the best possible image' (Morgan, 2015). It is illuminated further in Woodfleet by giving radiographers in-the-making a '10-point checklist', a process which, according to Mrs. Campbell, ensures *'you follow a systematic review'*.

Mrs. Campbell advises students, and specifically those *'looking at images'*, to *'know the routine you have to go to'* by following step-by-step instructions *'so that when you start writing comments you know you're going to follow a systematic review'* which '*when you get to the end of it you've answered all of the appropriate questions".* The card reads:



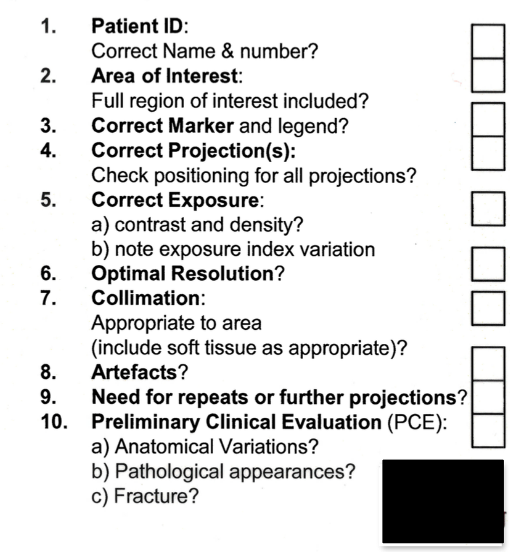


Figure 55 '10-point checklist': (TOP) Laminated card that elaborates articulations of PACEMAN to engender a systematic search for the 'qualities' of technical work and for abnormal detection (PCE). (BELOW) PowerPoint slide that presented the same information.

This card provides a systematic method for the identification of technical criteria that would evaluate diagnostic quality and further elaborates the PACEMAN principle (chapter five) as part of a more critical analysis for the radiography students. The card also draws on instructions made by BHRD radiologists who urge medical students to *'develop a strategy now for how you want to look at x-rays'* providing details via *'a bit of a handout that goes through the things you should look at'* since *'you will be looking at loads of chest x-rays on the ward, [and] don't get reported particularly quickly by radiologists just because there's so many of them'*. The advice and disciplining of medical students to utilise a (simpler) similar systematic for the organisation of technical seeing is exemplified by the PowerPoint slides accompanying the talk and the handout, specifically comparative CXR examples of inspiration, rotation, penetration, and foreign objects (lines/tubes).[191] These presentations also ask medical students to think about other technical details of images, such as personal identification ('PID') and demographics (Gender, age) – specifics echoed by radiographers (*'name-date-maker'*).

[191] Appendix 15

In time, we shall come to see that the systematic approach to technical adequacy *'becomes natural'* (Mr. Hearken, WURD radiographer) and *'second nature'* (Dr. Delichon, BHRD radiologist) or done *'without thinking about it'* (Mrs. Campbell, WURD radiographer), and comprises another algorithm/script (Linaker, 2012) in bringing about critical observations, expertly deployed as a precursor to the systematic approach for pathology (see, for example, Rystedt et al., 2011). This emphasises the expert's role in image interpretation as, faced with the complexity of technical-identifying information that she/he is facing, they will eventually resort to their own subjective form of this knowledge and "individual idiosyncrasy" (Carusi, 2009: 38) refined by experience and repetition of activities.[192] Indeed, Dr. Delichon encapsulates this point eloquently when he states*: 'so you don't have to use that one, but it's a good starting place and then you can adapt things as you want to from that, okay?'.* This technical appreciation of radiographic anatomy - its movement, position, and orientation - resonates with the interpretive process towards artwork (Steier et al., 2015).

The teaching methods (e.g. primary-secondary images) and cultural materials (e.g. 10-point checklist) grounded in the canny bodies of Bridgestock and Woodfleet professionals accomplish the categorisation of radiographic 'error' made by radiographers, who, at the stage of evaluating the image for 'technical adequacy', become accountable for raising the technical issues of interpretive concern. Whilst the educational literature advises individualistic looking at and pattern recognition of radiographic anatomy, these text-level discourses become problematic alongside the technical issues inherent in the creation of the radiographic image, such as patients' rotation and movement (Wood, 2016). This highlights the dominant and embedded ideologies of clarity prevailing in a litigation culture where students, and particularly radiography students, are positioned in a broader technical world and where patients become extensions of embodied perception. Joyce (2008: 16) claims that in an era shaped by the "spectre of litigation", healthcare professionals must prevent and identify every 'technical error' of their anatomic image irrespective of the (spiraling) cost to the patient. With radiologists expressing concern toward anatomic misinterpretation of radiographs, systematic approaches discipline professionals in-the-making into identifying

[192] In which one does not do in isolation but takes on meaning in relation to strong social shapers (e.g. imaging technology, patients).

errors as measurable and identifiable, encouraging them to be reflexively critical towards the patient's body during image production in preparation for image interpretation and diagnosis.

As a physical reminder, in the many classrooms of WURD, images and props are used in a fluid way for sense-making and to develop a generative relation that hinges together professional, patient and machine. Recognising this relationship with frequent reminders of *'the better you know your radiographic knowledge and your general anatomy the better'*, these embodied demonstrations inform professionals in-the-making about concerns such as visual bias, imponderable anatomy, and inadequate radiographic technique. This depicts the development of a professional vision as something that needs to be organised and disciplined into, a distributed pedagogic accomplishment containing (embodied) know-how as the means of ensuring professionals in-the-making conduct the best interpretation as possible. The explicit disciplining of professionals in-the-making into varieties of systematic self-conduct in the interpretation of radiographic knowledge serves as a form of coding practice (Goodwin, 1994) "employed to avoid ambiguities" (Rystedt et al., 2011: 878), whereby any missed or misunderstood deviations in images disrupt their visual conduct in ways that put them at risk of misinterpretation and misdiagnosis.

In the context of academic x-ray image interpretation training, the practice can be seen as the educated attention and managed observation for those assessing 'technical adequacy'; to engage in some sort of risk-observing conduct, as Brady et al., (2012: 8) maintains, is to "outline a graduated approach to the management of perceived or identified errors or discrepancies in radiological practice". The management of observation implies the acquisition of all technical, scientific, and anatomical information about the quality of the radiographic anatomy (Gunderman, 2013), entangling sight with technical and anatomic information as potentially promising a transparent image (Wood, 2012). This can explain why some radiographers in-the-making, responsible for ensuring whether the radiograph produced is adequate enough to interpret, can become harassed, bullyied, and blamed if optimal images are not achieved on clinical placement (SoR, 2010; Morgan, 2015).

A number of such feelings are also expressed on occasions in WURD, inevitably when radiographers have anecdotes to tell about the time they or one of their peers experienced incompetence over the production of inadequate images. Take Mrs. Campbell's story of not removing *'a nice pendant'*[193] during a chest examination to which she made the radiologist '*to not be very happy': 'I can remember when I was a student having to go to a radiologist and thinking 'oh, he's going to rip my head off', and he did'* and to some extent reflects social practices of distinction between the professions (Burri, 2008).

Emphasising the clarity and 'visibility' of the radiographic anatomy, and the embodied conduct of professionals in-the-making in ensuring this by adhering to technical standards, is influenced by the idea that the radiographic image is not simply transparent nor non-transparent but, rather, is "manipulated and perfected" (Joyce, 2008: 50). In other words, the attributes of the radiographic image are framed as the product of rule-abiding radiographers, as well as emerging from a patient's able bodiedness of individual responsibility and conforming (Wood, 2016). Committed to producing 'finer' images, radiographers in-the-making are thus burdened by the increased sophistication of image processing tasks and are disciplined into enhancing aspects of professional confidence at stake during the interpretation/writing of formal reports (Saunders, 2008). This includes understanding technical issues during x-ray image interpretation training.

Discursive devices such as interpretive risk and clarity (through imaging technique and optimisation) accomplish training as a critical engagement with radiographs and their relation to embodied perception. This nature of critical inquiry and its relation to the body develops the embodied conduct of students, and certainly of the radiographer in-the-making, who must ensure the clarity of the images. It is a regime that creates visibility and becomes embodied at the interplay of user and material form of the images (Lynch, 1985b; Friedrich, 2010). As throughout this thesis, embodied conduct is woven amongst an array of systematic coding systems (e.g. 10-point checklist), and various ways of gesture and highlighting – practices used to accomplish professional vision (Goodwin, 1994). Moreover, the positions taken up by professionals of the imaging community with regard to quality not pathology, 'never events', and 'spectre of litigation' might be viewed as retrospective-prospective

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[193] I make a distinction between artifacts (extraneous objects) and *artefacts* (a consequence of a technical error in the production and processing of images). Regardless of the distinction, both are said to interfere and problematise visual perception (Joyce, 2005; Friedrich, 2010).

orientations to practice (Garfinkel, 1967: 93-94). Indeed, my interpretation of this is that they are rules that have a strong explanatory or descriptive power (or resource) that is considered meaningful because "of what has been said previously" (Koschmann et al., 2011: 539). Furthermore, it is imperative to show how the interactions of students are organised in such a way by being offered 'a rule of thumb' or *rule-like* features as a means of "guaranteeing you are safe" (2011: 529).

6.3 Correcting and expanding the anatomic gaze

In this chapter I have revealed how x-ray image interpretation training intersects with cultural demands for clarity and how this involves (particularly radiographers in-the-making) professionals in-the-making. In the last section of chapter six, I show how size distortion (magnification)[194] in x-ray image production is discussed within x-ray image interpretation training predominantly taking place in BHRD. Size distortion/magnification is an important teaching point in x-ray image interpretation; it is meant to show that the observer must be able to understand how inadequate positioning of bodies can lead to the anatomy becoming distorted or magnified. This was a major concern for those who lacked experience in image production and was a common source of misinterpretation in this study. I start by citing the example of Dr. Saury (BHRD radiologist) who plays an active role in this process by demonstrating how x-ray images are produced. In doing so, he also draws closer attention to the consequences of patient positioning for producing clear image content, and considers the possibilities of magnification:[195]

[194] Size distortion usually refers to magnification. The two terms are used interchangeably.

[195] In the 'Introduction to Radiology' lecture with a large cohort of medical students (Year 4).

Figure 56 Gesture phase 1/3 in the demonstration of image production (magnification)

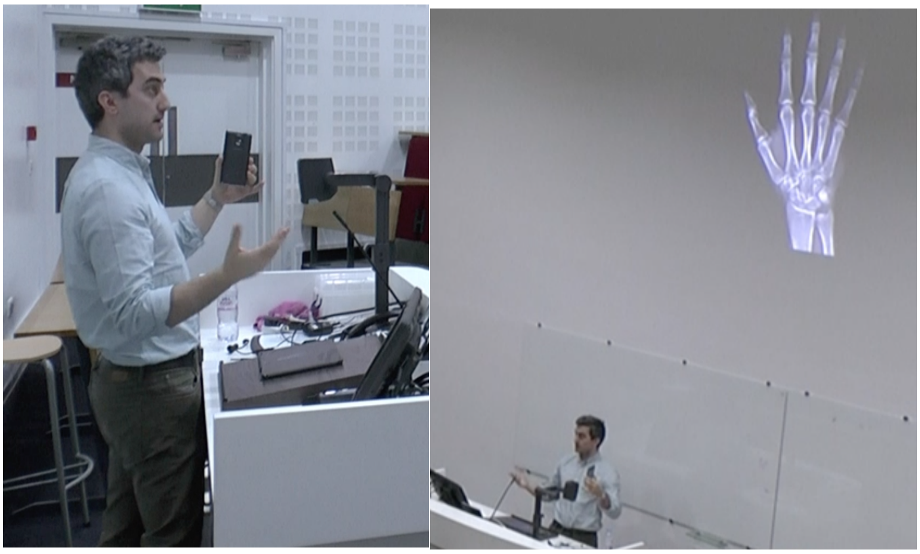

Figure 57 Gesture phase 2/3 in the demonstration of image production (magnification)

[*Dr. Saury presents a radiograph of a hand* (Fig. 56)] The other thing to know about the physics, the one other important thing about the geometry is that you want whatever you are imaging to be as close to the detector as possible [Gesture: RH lies flat on the phone being held by LH (Fig.56)]. As soon as you pull it away [Gesture: RH pulls away from the mobile phone] because it's a fan beam you're gonna start to get magnification and blurring [Gesture: RH opens a large space between his RH hand and his LH holding the mobile phone (Fig. 57)]...

Figure 58 Gesture phase 3/3 in the demonstration of image production (magnification)

[*Dr. Saury presents a slide of the same hand but magnified.* (Fig. 57)] ... in the same way as if you put your hand on the table [Gesture: RH hovers and lies flat on the workstation (Fig. 58)], like with the shadow you produce. And we want as crisp [Gesture: RH pinches air] an image as possible, and *that* is important for the chest x-ray, and I'll explain why.

[*Dr. Saury presents a slide: 'How is the CXR taken? Ideally like this'* (Fig. 59)]

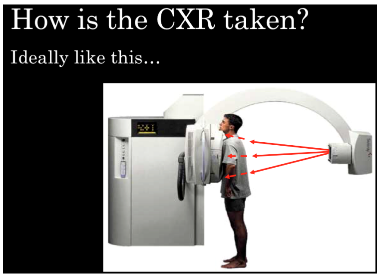

Figure 59 PowerPoint slide for 'ideal' patient position (PA) for a CXR

So *ideally* we take a chest x-ray like this and the patient stands facing the detector – this is the detector here, this is the x-ray tube – then you put the current across it, x-rays come out, they *enter* the patient's back, the posterior surface of the patient, exit the patient anteriorly. So the chest x-ray you produce with the patient this way round is a *PA* [Gesture: RH emphasises word with Smartpen] chest x-ray, posterior-anterior chest x-ray. And we like that because the heart is an anterior mediastinal structure...

[*Dr. Saury presents a slide displaying a PA positioning* (Fig. 60)]

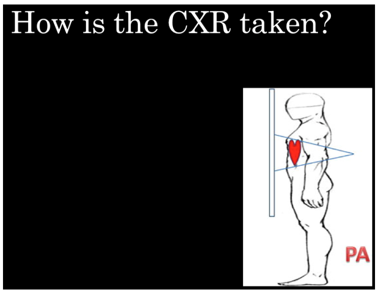

Figure 60 PowerPoint slide for (PA) CXR

... it sits right behind the chest wall [Gesture: RH lies flat across the front of the chest], cause one of the things you're looking at is the heart size, one of the things you're interested in is the heart size, you want it to be as close [Gesture: RH lies flat across the front of the chest] to the detector as possible so you don't get much magnification or blurring.

[*Dr. Saury presents a slide which displays both AP and PA positioning* (Fig. 61)]

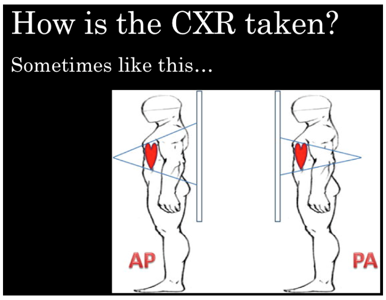

Figure 61 PowerPoint slide for AP and PA CXR

If we do it the other way round – and, basically, PAs we do, when the patient is fit enough to stand up and lift their arms up [Gesture: Lifts the right arm up], do various things that are required to do it. An *AP* is when the patient is not so mobile and might need to sit down, certainly any portable x-rays done on the ward you slide [Gesture: RH slides behind back as if sliding the AP detector behind the supine patient] the detector in behind the patient who is slumped in their bed and fire the x-rays from the other end; so you get an AP radiograph. *Clearly* the heart is now much further away from the detector so you get *much more* magnification or blurring, so your examiners and people will expect you to know that on an AP radiograph 'you-cannot-interpret-the heart-size' [Gesture: opens both hands to emphasise magnification and heart size]. The other problem is the upper mediastinal structures [Gesture: RH index finger points to the anatomy on his body], they can look very *weird* [Gesture: both hands open to represent magnification] on an AP radiograph because they do get magnified

> quite a lot. So if you're looking for kind of aortic dissection – you should probably be doing a CT actually nowadays – but one of the signs of an aortic dissection is a *widened* mediastinum [Gesture: both hands open], the mediastinum *often* looks wide on an AP radiograph, so that you have to bear in mind which way round the radiograph has been done.

This didactic presentation exhibits many points that I have identified throughout the thesis: professionals in-the-making having a categorised awareness of technical issues in image production (*'as soon as you pull it away [Gesture: RH pulls away from the mobile phone] because it's a fan beam you're gonna start to get magnification and blurring'*, the significance of technically adequate images (*'and we want as crisp [Gesture: RH pinches air] an image as possible, and that is important for the chest x-ray'*), the expectant signs of abnormal anatomy (*'but one of the signs of an aortic dissection is a widened mediastinum [Gesture: both hands open to represent a deviated mediastinum']*), the notion of looking at/pattern recognition of x-ray images being a mangle of talk and gesture inextricably lodged between the relevant graphic representations (x-ray of the hand) and materials (mobile phone) of the environment that organises work-relevant perception ('*the heart is an anterior mediastinal structure [Dr. Saury displays a PA positioning diagram]. It sits right behind the chest wall [Gesture: RH lies flat across the front of the chest]*).

For my intentions here, I highlight Dr. Saury's consideration of *'magnification'*. However, what we find here can be regarded as embodying an activity system that encompasses more than talk (Goodwin, 1994, 2000a; Måseide, 2007): whilst talking about magnification, Dr. Saury locates a relevant point on the diagram and, through gesture, adapts his body accordingly to the patient position. Both his bodily movement through space and his use of materials such as the mobile phone are visible events. Prior to training students in image interpretation, Dr. Saury cites 'magnification' on four occasions, using this to highlight the importance of technical issues on interpretive judgement and how neglecting this results in poor diagnostic judgement and radiological errors. In addition, the option of interpreting the heart or mediastina is not allowed in this case because standard and secondary views cannot be taken;

instead, only an impromptu and emergency AP is taken which magnifies chest anatomy (particularly heart and mediastina anatomy).[196]

I video recorded similar actions in other training classes including when professionals in-the-making were at risk of radiological error because they were unfamiliar with how the appearance of anatomy could change depending on its distance from the detector. Dr. Saury's inherently practical and domain-specific (Livingston, 2006) radiological reasoning, through a "situated activity system" (Goodwin, 1994) encompassing semantic categories and multiple semiotic fields (such as the field of the PowerPoint slide and the one inhabited by his body and the materials) not only allows professionals to imaginatively situate themselves in the workday routines of image production, but also provides "scaffolding" (Vygotsky, 1978) for the medical student's observation of the limitations associated with imaging techniques. This observation echoes one of the curriculum objectives of the RCR (2017), identified as a common learning outcome for UK radiology teaching (Jacob et al., 2016). As the GMC and MSC (2015) have said, the potential risks for the healthcare professionals are raised in academic learning environments where the practice of teaching technical procedures (and even harmful outcomes) can be done in a safe manner without any harm to the patients.

To refresh, before the interpretation/diagnosis of x-ray images is practised during training at WURD or BHRD, professionals in-the-making are advised to assess its technical adequacy. If this is completed, they can move on to image interpretation and systematically search for abnormality. To help establish awareness of size distortion/magnification, the affected anatomy is elaborated and demonstrated upon by the professional for the benefit of the novice (cf. Goodwin, 2000a) who is thrust into an "imagined world" (Sellberg, 2017: 2317) of radiographic practice. During one CXR image interpretation seminar, Dr. Saury (BHRD radiologist) entertains some concerns regarding anatomic observation due to bodily distance from the detector:

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[196] This is because the technical effects of an AP view magnify chest anatomy. Now the heart and mediastina anatomy become problematic because they are distant from the detector.

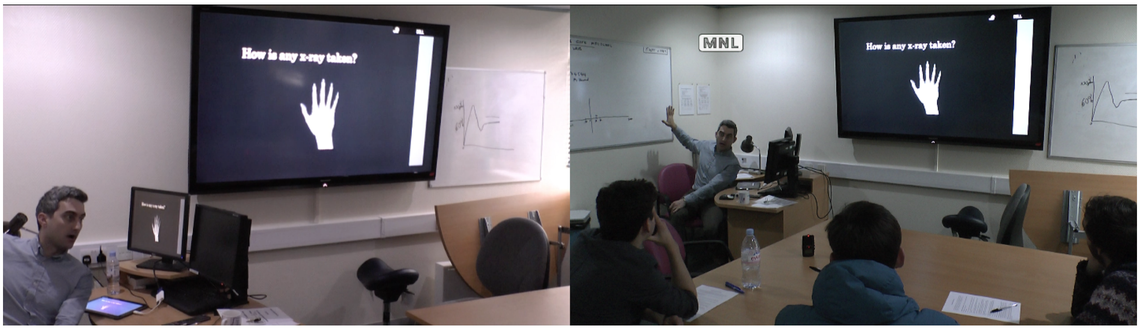

Figure 62 Dr. Saury's embodied multimodal performance for x-ray image production

Dr. Saury: So there's my hand [*talking about the hand on the slide* (Fig. 62)], so the areas, I think we mentioned yesterday and again, the cortical bones are very dense, there's bits of cortical bone [Highlighting 1: hovers the cursor over the cortical bone on the hand diagram] here so they absorb lots of x-rays, it's white behind there. The soft tissues much less denser, it looks grey it absorbs few x-rays and so slightly *more* x-rays hit the detector behind this dense bit of bone so you get grey here [Highlighting 1: hovers the cursor over the soft tissues on the hand diagram]. In between the fingers it's just air [Gesture: LH and RH open space]. Air absorbs very little, it's low density. You get lots of x-rays hitting and you get blackening of the image in that area. So that's the *basics* of it, that's all the radiophysics I'm gonna do. Other than to say: what happens if I pull my hand away? What's going to happen to the image if I pull my hand away? [Gesture: RH is placed flat on the whiteboard and then removed]

Jim: It'll get larger

Dr. Saury: Yeah, so it's gonna get *magnified*

[*Dr. Saury displays a magnified version of the previous hand diagram*]

Dr. Saury: And it's gonna get a bit more blurry and that's important for the chest x-ray because- so you understand why, because it's a fanning out beam and you get the magnification if you're further away from the detector.

Dr. Saury acknowledges how medical students must understand the relationship between radiophysics and anatomy through a PowerPoint presentation of a hand radiograph and, by criticising the aesthetic quality, he demonstrates the ambiguous image as a consequence of the hand's anatomic distance from the detector in techno-scientific practice *'what's going to happen to the image if I pull my hand away? [Gesture: RH is placed flat on the whiteboard and then removed]'*. The following exchange between Dr. Maxwell and Muhammad in another video recording uses similar discursive communication:

[*Dr. Maxwell presents a diagram of a PA CXR*]

Dr. Maxwell: So, in terms of heart size – that's a PA chest X-ray – posterior anterior. So, this is the x-ray emitter [Gesture: RH points at the emitter], and this is the screen [Gesture: RH points at the screen/detector] that's detecting the x-rays. He's got his back to the emitter [Gesture: RH points at the patient's back] so it's a posterior film. The heart is at the front of the chest [Gesture: RH points at the heart in front of the detector], so there's very little magnification when the x-rays travel from the heart to the screen. Yeah? So that's why the heart is less than 50 per cent on a PA film.

[*Dr. Maxwell presents an AP case presentation titled: '3.75 male SOB'*]

Dr. Maxwell: Now you're allowed up to 60 per cent, or possibly even up to two thirds on an AP film. This guy has probably had an AP film, and that's because the heart is magnified.

[*Dr. Maxwell transitions backwards to the previous slide that presented a PA CXR*]

Dr. Maxwell: If you think about that guy the other way round, if he was stood the other way round, then there would be magnification between the x-rays hitting the heart here [Gesture: RH rubs the patient's back] and finally hitting the screen [Gesture: RH points at the detector]. So that's why you're allowed a greater heart size relative to the lungs.

[*Dr. Maxwell presses button to reveal an AP case presentation titled: '3.75 male SOB'*]

Muhammad: Is that like your gold standard, then?

Dr. Maxwell: The PA? Yeah, the PA is this gold standard. That's the one that if your GP sends you in with a cough and you're otherwise fit and well, you'll have a PA chest x-ray in the department. And all the rest are, you know, like this [Gesture: RH points at the image] this is a *terrible* film in terms of adequacy, penetration, but this is what you're going to see on a guy who is tachycardic, tachypnic,[197] not staying still, he's sat bolt upright struggling for breath on the ward, he's scoring highly on the severity score, the nurses are in a panic, they ask you to come and have a look at him.

Dr. Maxwell points out ambiguity in anatomic seeing when exclusively projected toward *'an AP film',* where the patient is *'not staying still, he's sat bolt upright struggling for breath on the ward'* and *'there would be magnification',* rather than a *'PA film'* where *'the heart is at the front of the chest [Gesture: RH points at the heart in front of the detector] so there's very little magnification when the x-rays travel from the heart to the screen'* and is the *'gold standard'.* Dr. Maxwell's embodied demonstration of the '*AP film'* reveals a distinction between the size of the heart *'at the front of the chest [Gesture: RH points at the heart in front of the detector] so there's very little magnification'* and the size of the heart when *'stood the other way round'.* In a back-stage environment, where professionals in-the-making are prepared for *'real life'* and can labour over medical images of seriously ill patients (*'it's artificial really, isn't it, you can wait a few more minutes and have a bit more of a think about things'*), Dr. Maxwell opts for a techno-scientific gaze over an anatomic gaze[198] when discussing anatomic distance from the detector and/or magnification. This character of technical applicability is also embedded in the discursive space once potential patient rotation/discrepancies in patient positioning are misinterpreted by students and a magnification of anatomy is provided as a reason.

It also perfectly illustrates the point made by Amann and Knorr Cetina (1988: 159) that ambiguity is eliminated by embedding people in the procedure by reference to its "procedural history and to the experience of other participants". In BHRD, once a magnification of

[197] Tachycardia (abnormally rapid heart rate > 100 beats per minute); Tachypnea (very rapid respiration > 30 beats per minute)

[198] Or "anatomo-clinical gaze", more precisely (Foucault, 1973)

anatomy – for any body part – is considered to disrupt the anatomic translation, a discursive space opens, correcting the 'anatomic gaze' to the 'techno-scientific gaze'. In contrast, during training where the sociotechnical anatomy is seen as 'subtle' or 'barn-door obvious', the 'techno-scientific gaze' is commonly assumed.[199] Thus, it is here where the anatomic gaze can be corrected and expanded to remedy the ambiguity about the production of radiographic anatomy.

The malleability and calibration of the gaze are exemplified by an exchange between Mr. Hearken (WURD radiographer) and a large class of radiography students before transitioning to a secondary view/CT image. When Mrs. Campbell asks her class of radiography students *'what's the disadvantage of an axial?'*, a class member responds with *'magnification'* to which Mrs. Campbell replies *'yeah magnification, 'cause it's long, what's the first thing?'*. Mrs. Campbell confirms the ambiguity of the radiographic anatomy of the shoulder, which is causing misinterpretation, is a consequence of difficult patient positioning for an axial (*'it's a hard position to get people into':* radiography student). The interaction in the classroom follows this enactment quite closely: *'when they come in, what are you asking them to do for this? [Gesture 1: LH points to the axial slide] can you do that? [Gesture: elevates her right arm whilst maintaining the angle] *laughs nervously under her breath* uh-uh-uh [Gesture: body enacts the patient's discomfort] so people can [struggle]'*). This echoes with the first part of this chapter, and with Wood's analysis of cone-beam imaging and unwanted patient movement, known as "intra-fraction movement" (Wood, 2016: 772). This ambiguous anatomic image is afforded a technical explanation for its problematic appearance. The following transcription is taken from a seminar involving Dr. Saury (BHRD radiologist) and Jacob (medical student) of a patient 'rotation', an undesirable patient movement causing magnification which can confuse anatomic understanding:

[199] This assumption that technically effected anatomy will be known to the uninitiated observer finds its parallel in a cognitivist notion of 'looking' at x-ray images that takes radiographic observation to be a taken-for-granted facilitator for seeing.

Figure 63 Dr. Saury's embodied conduct of patient rotation. This makes salient the consequences of magnification on mediastina anatomy and helps Jacob to see that the ascending aorta (highlighted with a cut red line using a SmartPen) has, in fact, not deviated.

Dr. Saury: If you wanna have a crack at this one [Gesture: RH points SmartPen at Jacob]

Jacob: Okay, so there's shadowing in the [Pause] upper and mid zones on the right

Dr. Saury: Yeah, absolutely. Um and [Gesture: rotates body to his left as if remembering the teaching point] what do you think about- *interrupts himself*, so I've said look for volume loss. If you think, it could be collapse, it could be consolidation, it could be various things, it could be tumour, I guess. Do you think there's any volume loss there?

Jacob: It does look like the mediastinum has shifted?

Dr. Saury: So, I haven't actually gone into *assessing* rotation, but this patient's *slightly* rotated

Jacob: Okay?

Dr. Saury: I'll tell you how to do this on there, and they're *leaning* [Gesture: leans slightly to his left] slightly towards on one side, so actually I think *that* accounts *partly* for it. *More* than that: it's an AP radiograph, okay? So for that reason [Gesture: points at the whiteboard] we were saying with the magnification [Gesture: both hands extend and open a large space]: anterior of the heart gets magnified [Gesture: opens both hands but brings them closer to the anterior or front of his chest] so do the other anterior, so this is [Highlighting 1: Highlights the ascending aorta which is hidden behind the opacity with an intermittent or 'cut' red line] actually gonna be the ascending aorta coming up here

Jacob: Oh, r-ight

Dr. Saury: And it just looks magnified [Gesture: Both hands open medium space] cause they're a little bit rotated [Gesture: Subtly rotates the body to his left (Fig. 63)] as it's AP. So, actually, I think there probably isn't any volume loss.

Dr. Saury and Jacob reflect on potential *'volume loss'* in the chest image, with Dr. Saury eventually revealing to Jacob that he is seeing magnification of mediastina anatomy because *'this patient's slightly rotated'* but *'more than that: it's an AP radiograph'*. These actions mean *'it just looks magnified [Gesture: Both hands open medium space]'* and *'there probably isn't any volume loss'*. Once again, the appearance of the 'right' anatomy is made visible and shaped through a discursive practice (making salient the consequence of rotation and magnification on mediastina anatomy by highlighting the ascending aorta with a cut red line using a SmartPen which has, in fact, not deviated) being deployed in a situated activity system for the needs of locally situated learners (Goodwin, 1994). The embodied conduct exhibited in BRMR reveal the aggregable nature and malleability of 'seeing as', correcting to a technoscientific gaze – within Dr. Saury's discursive practice – from a clinical anatomic gaze, once misinterpretation is suspected and back to a clinical anatomic gaze once more for interpretation/diagnosis.

This could be read as part of the disciplinary organisation of seeing (e.g. that seeing x-ray image content is a technical task for the medical students, just as much as the composition of the image is the job of the radiographers). According to Alač (2008: 505), a distorted anatomic image has a dynamic quality which allows professionals to give account, via multiple semiotic resources, of 'how the distortion came about' for those learning to see, like the resource of digital images and the one inhabited by gestural bodies in action. "Important elements of the production of visibility involve integrations between multiple semiotic fields generated through the use of gesture, digital images, and body orientation as features of the practical problem solving". However, whilst Alač claims a demonstration of technical effects are not necessarily a shift from the 'anatomic' to the 'technoscientific' gaze of the imaging production/technique, the embodied talk and situated action (Suchman, 1987) in BHRM indicates this can occur once radiographic anatomy is unsuccessfully seen and their observation of technically effected anatomy is not aligned with the professional's.

Concerned at the prospect of misunderstanding patient rotation since '*it does look like the mediastinum has shifted?',* Dr. Saury invites Jacob into the pitfalls of the positioning technique, since *'it just looks magnified [Gesture: Both hands open medium space] cause they're a little bit rotated [Gesture: subtly rotates the body to his left (Fig. 63)] as it's AP'*. When discussing this image, Dr. Saury is pressed into demonstrating an aspect of technical work with the medical work being relegated to the embodied enactment of a physical rotation. Indeed, the technical effect is referred to as the consequence of patient 'rotation' which emphasises a technoscientific gaze over the anatomic gaze. This discursive deployment of technical work helps reveal the methods deployed by professionals to deepen understanding of anatomic ambiguity, both for themselves and for professionals in-the-making. Consider the following pedagogic exchange between Dr. Maxwell (BHRD radiologist) and two medical students (Sarah and Richard) regarding an AP CXR (which is considered to have an abnormal heart size):

Dr. Maxwell:	What's normal and abnormal in terms of heart size?
Sarah:	About 55% of the-
Dr. Maxwell:	Okay well if the heart's over 50% [Gesture: opens large space between RH and LH] of the cardiothoracic ratio on a PA frontal chest radiograph that's abnormal.
Sarah:	Mhm
Dr. Maxwell:	But obviously an AP film [Gesture: LH introduces the AP image] we've got relative magnification of the heart size
Sarah:	Oh, yeah
Dr. Maxwell:	So you're allowed up to 60% [Gesture: opens small space between RH and LH]. But this is clearly above 60%. Clearly an enlarged heart
Richard:	Does it matter that it's rotated?
Dr. Maxwell:	It does a little bit, yeah**.** You got measures in there, you got people who just eyeball it and report it but you can see the left hemidiaphragm's actually [Gesture: RH curves through the air] *extended gaze at the image* lower than the right isn't it? But the patient is slumped over [Gesture: opens large space between RH and LH in a sloping manner] that way
Richard:	Yeah

Confirming Sarah's suggestion of an enlarged heart, Dr. Maxwell claims her observational work could be further determined by knowing *'what's normal and abnormal in terms of heart size?'*, a question he swiftly answers by supporting numerical information in observational work: *'if the heart's over 50% [Gesture: opens large space between RH and LH] of the cardiothoracic ratio on a PA frontal chest radiograph that's abnormal'*.[200] Dr. Maxwell implies that knowing this numerical measurement of the heart size/cardiac size and position of the heart anatomy to the image detector (AP/PA) ceases ambiguity around the magnified anatomy. Richard concludes the exchange by acknowledging the issue of patient rotation (*'does it matter that it's rotated?'*) to which Dr. Maxwell responds with a further numerical solution (*'you got measures in there, you got people who just eyeball it and report'*) although presumably this other evaluative trait is directed towards the radiographer (more about this later).

According to Roepstorff (2009: 191), this process recalls an education of attention, which, through socially organised perception, "allows one to 'see' the image as part of a larger narrative" and a key process that establishes the "borders" of a community of practice. The example presented here also recalls the professional boundaries of radiology where radiologists deploy 'boundary work' and 'distinction practices' to improve both the prestige of radiology and the actor's individual status within the hospital community (Burri, 2008). This is a pedagogic concern particularly for radiologists teaching radiographs – as suggested in these reflections of one specialty trainee and senior radiologist: '*I'm not interested in the technical aspects; I'm more concerned about the pathology', 'to be honest the lungs are a bit scruffy but I'm not going to go into that with you, that's not what I'm interested in'* (Dr. Saury), and *'I think it can be difficult to say something PA or AP and you can get around that by saying it's a frontal chest radiograph so you're not committing yourself, but it's not something I'd be worrying about'* (Dr. Maxwell). I extend this insight, showing how professionals bring out the social construction of 'boundary work' (Gieryn, 1999) in forceful and explicit ways in the delivery of image interpretation education.

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[200] A WURD radiographer echoed this statement: *'the heart should never be more than the width of the chest, so a third is average, so a half or more is abnormal, but that assumes we've got a PA x-ray'*. When Mr. Hearken asks Gemma *'what happens with an AP?'*, she responds *'heart becomes magnified'*. To this question Gemma answers correctly (*'it becomes magnified, right!'*), yet additional attention to the heart as a measurable quantity or magnitude for meaning making is elaborated upon in a performative idiom stabilising the sociotechnical premises of PA and AP images: *'if the patient becomes rotated it changes shape and size, if the patient hasn't taken a decent inspiration it changes shape and size, so you can only measure it accurately on a perfect PA chest x-ray which you never do more than a half.'*

I would like to suggest that the efforts to demarcate the boundaries of radiology also serve as a necessary background for seeing or, to put it slightly different, seeing that may be connected to prioritised forms of seeing or action. Up until now, the interrelation between technical knowledge and medical knowledge may appear prominent in the training setting, where technical information explicitly appears as a necessary prerequisite for 'seeing the right thing', as in *'the heart is less than 50 per cent on a PA film. Now you're allowed up to 60 per cent, or possibly even up to two thirds on an AP film'* (Dr. Maxwell). In contrast, the medical-radiology x-ray image interpretation scenario could suggest a more medical mode of seeing. In addition, Dr. Maxwell's "transmutation of the visual into the numerical" (Carusi and Hoel, 2014: 208) recalls Mrs. Campbell's earlier instruction to radiographers in-the-making to invoke prior observational work on technically-laden observational assessment: *'so the coracoid process here [Gesture: measures the model scapula with her own body's scapula] so two point five, which I think is quite far in, two point five centimeters below and then you collimate.'* In a teaching environment in which time is afforded *'to labour the point'* (Dr. Maxwell, BHRD radiologist), professionals adopt numerical methods to manage this observational work.

This analysis allows me to suggest that demonstrating anatomy in technical terms - strategically creating a hybrid between the 'medical gaze' and 'technical gaze' - can help manage perception. In her ethnography of how a Mars Exploration Rover team crafted digital images to contribute to mission planning and scientific interpretation, Vertesi (2016) argued how team members could see the same Martian features differently to achieve different purposes and that these seeing as experiences were not 'found' experiences but purposefully crafted ones. For Vertesi (2016), this allows Mars scientists to approach ambiguous images of Martian objects and terrain with coherence, recognisability, and meaning, to develop a 'seeing as' experience, enabling them to both acquire different possibilities produced by the technology and make it visible to team members as well as an imagined "audience of amateurs" who may be watching the Mars exploration (2016: 221). Similarly, in BHRD, one method of demonstrating objective and technical observation of technical issues at hand, or, rather to train 'seeing as' (Vertesi, 2016), is by discursively shifting the anatomic gaze to a technoscientific gaze attributed to the work of radiographic practice (reinforced by its object to image distance). Put simply, professionals are playing an active mediating role in establishing a 'seeing as' practice of technical issues with their body and not reliant on the image-processing techniques used by the Mars Rover team.

6.4 'Seeing as' in x-ray image interpretation

So how does x-ray image interpretation figure into this? In the previous pedagogical exchange demonstrating the size distortion/magnification, Mr. Hearken (WURD radiographer) refers to the technified heart, not the gross anatomic structures of the heart, during x-ray image interpretation. This technical and anatomic shift is in contrast to the confident accounts professionals sometimes provided in chapter four and five, mainly to x-ray image interpretation as being a matter of 'looking at/pattern recognition' and promising the 'barn-door obvious' (although I identified how such professional vision was undermined during training by interpretation troubles such as technical inadequacy and missed abnormalities). The following didactic presentation is taken from an embodied multimodal interaction between Dr. Saury and a PowerPoint slide in front of many medical students in a large lecture theatre:

> [*Dr. Saury presents image 1: normal CXR and **straight patient***]
>
> You want the patient to be facing straight towards you [Gesture: both hands straighten the imagined patient] because the mediastinum is the column in the middle of the chest [Gesture: pulls imagined patient towards chest and rests both hands on mediastinum] and you want to see the lungs on either side. As soon as they're slightly looking to one side [Gesture: turns his body left] the mediastinum is oblique [Gesture: both hands angle the imagined mediastinum] and it's covering bits of both lungs [Gesture: both hands overlap each other] so it becomes harder to interpret. The way you'd tell whether someone is rotated about this axis [Gesture: RIF points onto his head], if you need something in the midline at the back of the patient [Gesture: RH reaches behind and taps the right shoulder], so the spinous processes which stick off the back of the vertebral bodies, and these blobs uh there and there you can see the shape of them [Highlighting 1: draws a downward line over the spinous processes]. So that's the midline at the back [Gesture: RH reaches behind and taps the right shoulder] those are the spinous processes, and then you *compare* them with where the clavicles [Gesture: both hands touch the medial sides of the clavicles], the medial ends of both clavicles are at the front, because that's telling you where the midline is at the front. So, we've got clavicle here [Highlighting 1 / Graphic Representation 1: draws over the left and right clavicles] say this is both sides, this patient is nice and straight.
>
> [*Dr. Saury presents image 2: normal CXR but **patient is rotated** for comparison*]

> This patient is *not* nice and straight, so here's a spinous process, there's a spinous process [Highlighting 1: Draws over the spinous processes], and *this* is the median end of that clavicle [Highlighting 1: Draws over the median end of the clavicle], this is the median end of that clavicle [Highlighting 1: Draws over the median end of the clavicle]. Again, this is sometimes hard for people when they're starting to see, even when they've got the x-ray unpacked in front of them; so *practise* working out where the clavicles are, picking them out, and working out the rotation. This patient has looked to their left because the left [inaudible] gap has opened up [Highlighting 1: Colours in the gap]. If the patient looks to their left [Graphic representation 1: draws an arrow from the neck to indicate direction] the [Gesture: both hands touch the clavicles and turns to his left] clavicles move over to the left and the left one dangles out over the apex, the spinous processes move to the right [Gesture: RH motions a right movement of the spinous process]; and you can tell which way they've looked. This is the left because the left side is wider. So again rotation – this isn't the same patient, so probably they've got a bit of an ecstatic aorta anyway because they're quite old, but *part* of this is rotation, and *that* is aorta coming all the way out here [Highlighting 1: Draws over the widened aorta on image 2], on this side that is aorta coming down there [Highlighting 1: Draws over the straight aorta on Image 1]. And you've got a bit more soft tissue sticking out here [Highlighting 1: Draws over the right aorta on image 2], and you can see it does change the appearance [Gesture: opens wide space between hands], and it can look quite wild, particular the aorta, so you need to be aware of it.

Dr. Saury enacts his technoscientific gaze to demonstrate a patient who has not been straightened and where specific anatomy is out of place, suggesting the *'patient has looked to their left'* because of the widening of the left side. However, Dr. Saury's critically examining gaze suspects that the patient has also *'got a bit of an ecstatic aorta'*, a finding often associated with the normal aorta when *'the patient is quite old'.* Finally, Dr. Saury informs the medical students that the actual appearance of the convoluted structure is a consequence of magnification, since *'part of this is rotation, and that is aorta coming all the way out here'* and *'it can look quite wild'*. It is clear, Dr. Saury, an experienced radiologist, is the only one in the theatre who can realistically ascertain if the enlarged aorta in the image is a consequence of patient rotation and whether the enlarged aorta has influenced the appearance (intensity) of the anatomy in the image rather than a possible underlying abnormality (for instance malignant tumours are often concealed by an enlarged aorta).

Although radiologists are often highly critical of image quality and radiographic practice because image interpretation can fall whim to the 'barn-door obvious', they have little or no teaching opportunities in academic settings about what routine situations constitute uncertainty about the obvious since their responsibilities are directly connected to diagnosis when training image interpretation.

At BRMR, it is not always possible for radiologists to explicitly inform medical students on matters of size distortion/magnification and limitations of image production during training for two reasons. Firstly, radiologists had a limited amount of time required to conduct teaching due to low staffing levels and a challenging workload in the department, which required regular re-negotiations of 'cover'. Such is the dominance of clinical demands (i.e. 'on the ward') and meeting workload targets, that teaching in the meeting room was not immune to time constraints and the demands of the surrounding clinical environment. The very large role of work duties carried into the meeting room accelerated the pace of introduction rituals, teaching (for example, hurried students in question-answer sequences: *'any quick abnormalities you can see?*; '*this one, again, spot diagnosis'*; *'sorry it was a bit whistle stop'* (Dr. Delichon, BHRD radiologist), and left case presentations unfinished: *'we've only got fifteen minutes [left] [and] we've still got quite a few cases to go through, so we'll kind of pick out the important bits'*: Dr. Delichon, BHRD Radiologist. A lack of time entailed not just limited exposure to normal radiographic anatomy, but also a limited time spent on learning about radiographic practice. This often resulted in the radiologist encouraging medical students to seek out radiographic practice and learn aspects of image production from the radiographers (*'if you've been down to B floor and actually seen some in practice [how x-ray's are taken] which is really good actually cause it helps you visualise what's happening when you look in an x-ray'*: Dr. Delichon, BHRD radiologist). Despite radiologists being critical of radiographs and purposefully selecting problematic images for image interpretation (Dr. Maxwell: *'I think it's important for you to see those kinds of images really, because most of you are not going to go into radiology'*), the time constraints for teaching meant less time was spent on building a critical relation to normal radiographic anatomy and the image making process (including any sociotechnical issues of image production/interpretation).

Secondly, x-ray image interpretation for medical students is focused on the search for abnormality, prioritising the signs of disease and/or fractures, its clinical diagnosis, and treatment options over the more technical considerations of images. For example, as Dr. Saury claims *'to be honest the lungs are a bit scruffy but I'm not going to go into that with you, that's not what I'm interested in'* in answer to a particular question from a medical student (*'uh I think I can see sort of, generally there appears to be increased opacity across all of the lung fields'*). This shows how professionals must often decide whether teaching students about magnification of anatomic structures is appropriate or not with reference to the image being presented. However, since the radiographs selected for image interpretation by radiologosts predominantly contained abnormalities, the focus for medical students was learning to see and interpret signs of disease and trauma in order to accomplish a clinical diagnosis. This is in comparison to radiography students whose priority is to produce and technically evaluate the image in order to help medically trained personel to accomplish a succesfull, confident and accurate diagnosis. Although this thesis does highlight a boundary-crossover by radiographers (i.e. radiography students learning a systematic approach to see and interpret signs of pathology), clinical diagnosis of the x-ray image still remained the preserve of medicine.

Here, the impetus of interpretive training in medical contexts is based on using 'abnormal' images and attempting to reassure students that structures are 'normal'. However, as we have seen in Dr. Saury's account above comments on the consequences of size distortion/magnification occasionally creep in during interpretive practice. This is because CXRs mislead normal anatomic understanding on a greater scale and distinctions become problematic due to what Dr. Maxwell states as '*a wide spectrum of normality*'. The problem of this wide spectrum of normal anatomy is further complicated by technical errors of inadequate patient positioning and risks of patient movement (rotation and breathing). During a CXR image interpretation class, for example, Mr. Hearken (WURD radiographer) claims:

Mr. Hearken: One of the things we want to look for is accurate measurements and to look for normal anatomy. If you twist [Gesture: Mr. Hearken holds an imaginary patient and then twists the patient to his left side] someone and turn someone off centre [Gesture: Both hands continue to hold the imaginary patient and continue to twist the imaginary patient side-to-side] what happens to their normal anatomy?

Gareth: Bigger or [Pause]

Mr. Hearken: Yeah, magnif-

Gareth: Smaller?

Mr. Hearken: Yeah, it becomes distorted or bigger or smaller. So if you've got someone who's not *straight* [Gesture: Both hands continue to hold imaginary rotated patient] all of the measurements and the orientation and the angulation we want to look for and start to interpret are *lost*, so the patient has to be straight. So how do we assess for rotation? [Gesture: Le Penseur][201] *On the image* [Gesture: both hands hold imagined image] how do we assess the patient for rotation? [Gesture: prayer][202]

[*Silence: two seconds*]

Julie: If it, um foreshortening, or?

Mr. Hearken: Foreshortening? Yeah?

Julie: Like when one side of the ribs [Pause] looks [Pause] like

Mr. Hearken: Yeah that's, that's the first one. How many *lungs* have we got?

[*Exhange omitted*][203]

Mr. Hearken: *So,* if we've got two of something [Gesture: continues holding both hands up palms facing outwards to enact the two lungs] what can we do?

Julie: [quietly] spread 'em?

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[201] Exchange omitted: a teaching gaffe is corrected where a student is confused whether the radiographer means assessing the 'patient' or the 'image' for rotation.

[202] Prayer gestures are an extension of teaching practice so that questions are asked in the 'hope' that they will be answered. The silence following the prayer gesture is fundamental to thinking about students having divine inspiration. For a fascinating account on image interpretation as a holy practice, see Saunders's ethnography of a CT suite (2008, 2009), where radiological diagnosis is associated with "divination" (2008: 130) and radiologists are seen as "hunters and *priests*" (2009: 145 [emphasis added]).

[203] Exchange omitted: three students question if it is a trick question. In addition, and unrepresented here is another teaching gaffe. Mr. Hearken's hand placements at *"two sets"* are translated by the students as 'two breasts.'

Mr. Hearken: If they're two of the things that are actually identical in terms of anatomy

Stacey: Compare them?

Mr. Hearken: *Compare* them. So, look at *symmetry*. So, look at one side of the chest [Highlighting 1: RH touches the left lung zone] compared to the other [Highlighting 1: RH touches the right lung zone]. Do the lungs look the same size? Do the ribs have the same orientation? [Highlighting 1: RH points at the image]. Okay so that's what we can assess [Gesture: opens space between hands as if holding imaginary patient], but generally that will only be distorted if the patient is actually really rotated [Gesture: Mr. Hearken twists and turns his body side-to-side]**.** If they're only *slightly* off [Gesture: Both hands pinch the air to enact small rotation] there's *another* way we can assess that it that's a bit more accurate [Gesture: prayer], what's that one? [Gesture: prayer]

[*Silence: five seconds*]

Julie: Spine?

Mr. Hearken: The spine, yess [Gesture: prayer]

Julie: Clavicles?

Mr. Hearken: And the clavicles [pause] okay so what we can do, there's a couple of measurements we can take. *So, this is* [Highlighting 1: cursor traces over the medial end of the right clavicle] the medial end of your clavicle. What does medial mean?

Class: Middle

Mr. Hearken: What's the opposite?

Gareth: Lateral

Mr. Hearken: This is the medial end of your right clavicle; this is the medial end of your left clavicle [Highlighting 1: cursor traces over the medial end of the left clavicle]. What sits in the middle of those two? [Highlighting 1: cursor traces the spinous processes]

Julie: [Quietly] Spine?

Mr. Hearken: *Spine* and specifically these little circle things are called spinous processes. They look like little teardrops. So if we take a measurement or eyeball, you don't have to take a- you don't have to get a ruler out [Gesture: opens space between hands enacting the imaginary ruler] you can eyeball it

Julie: The space?

Mr. Hearken: The measurement, the gap or the space between that clavicle and that spinous process and the spinous process and that clavicle [Highlighting 1: cursor hovers from the medial end of the right clavicle to the spinous processes, then hovers from the spinous processes to the medial end of the left clavicle], if the patient's *straight* [Gesture: opens space between hands to enact imaginary straight patient] it should be the same distance [Gesture: LH and RH pinch the air to enact the distance between the clavicles]. If you've got one that's bigger than the other [Gesture: LH pinch widens] the patient is rotated, alright?

Mr. Hearken suggests radiographers in-the-making, upon receiving a CXR for image interpretation, assess for patient rotation as part of technical adequacy. The ability to demonstrate the patient rotation (*'if you twist [Gesture: Mr. Hearken holds an imaginary patient and then twists the patient to his left side.] someone and turn someone off centre [Gesture: Both hands continue to hold the imaginary patient and continue to twist the imaginary patient side-to-side]*), is, for Mr. Hearken, an important pedagogical moment for radiographers in-the-making learning to see size distortion/magnification. Alongside this reenactment of size distortion, another specific 'shape distortion' is mentioned, which occurs when the beam alignment of the central x-ray is not aligned with the anatomy.[204] Mr. Hearken intensifies this point by identifying how uncertainty surrounds the normal anatomy (*'what happens to their normal anatomy?'*) when the patient is moved away from the detector (*'it becomes distorted or bigger or smaller'*), later suggesting the compromised image may mislead image interpretation (*'the angulation we want to look for and start to interpret are lost'*). He concludes by suggesting there are two ways to *'assess for rotation*'. First, comparing the lungs (*'so look at symmetry. So look at one side of the chest [Highlighting 1: RH touches the left lung zone] compared to the other [Highlighting 1: RH touches the right lung zone]'*) and second, the gap or space between the clavicles and the spinous processes which lends itself to measurement and quantification (*'the measurement, the gap or the space between that clavicle and that spinous process and the spinous process and that clavicle [Highlighting 1: cursor hovers from the medial end of the right*

[204] This may be because the centering of the central x-ray has not aligned precisely with the anatomic part being imaged or because the anatomy prohibits alignment.

clavicle to the spinous processes, then hovers from the spinous processes to the medial end of the left clavicle]').

Mr. Hearken suggests that patient rotation is a reason why professionals in-the-making may misinterpret size distortion/magnification and explains why the practice of looking at radiographic anatomy (especially chest anatomy) is inherently problematic for those learning to see in WURD. Its ambiguity, supplemented with the embodied ability to objectively see and measure being tacitly demonstrated to radiographers in-the-making, ensures why x-ray image interpretation trains a relation between film and flesh and dwells in a betwixt and between space. It defies categorisation as a purely cognitive practice which is not strictly a (mental) image-centered activity: rather it is a "bodily form of cognition" (Myers, 2015: 75). A solution designed to help them see this with greater degree of certainty is supplementing a reenactment of the ambiguous anatomy (often to provide imaginary patients and machinery) with a technoscientific method of assessment. This discursive practice is often utilised in WURD to identify exaggerated technified anatomic appearances that may mislead those unfamiliar with image production.

This point resonates with Dussauge's (2008) ontologically inflected analysis of traditional radiological methods for radiologists working with MR images (such as 'subtraction' and 'contrast agents') who increase the contrast of the images, and "therefore enhance the visual separation or isolation of bodily structures". While agreeing with Dussauge's (2008: 91) stance that these technological methods have influenced the gaze, my study extends this discussion by providing examples of how such methods are embodied and mimicked in order to understand image content. Such a standpoint drives the portrayal of x-ray image interpretation educators as having subjective-objective bodies (Latour, 2004) and collapses the boundary between person and machine (Wood, 2016) for easing professionals in-the-making into imaging practice with a questioning critical capacity about the image. As a way of discussing the transfer of experience and the correction of the gaze, my thesis reveals how the extension of professional bodies - and ultimately their gaze – embodies such properties.

Through an unpacking of the "visual performance" (Burri, 2012: 53) in which people attempt to reenact images in a way in which the realities represented are thus inherently social, the narrative events and embodied activities of out-of-place anatomy are accomplished. Rystedt et al., (2011: 871), through ethnographic studies of uncovering the practical work in radiology, describes how classification work of anatomical knowledge in a new imaging technology (tomosynthesis) involves learning whether the "phenomena under scrutiny are to be judged as adequately represented or as merely occasioned by the technology itself". Since people "come to embody the properties of anatomical pictures", the radiographic image becomes a "functional extension" of the professional's body into the patient's body, since its anatomic status (as an instance about whether the structure is abnormal or not) is incomprehensible without assistance from 'normal anatomy' as a reference guide (Hirschauer, 1991: 290). Hirschauer's analysis of surgical operations and how they index a reciprocal exchange of anatomic knowing between patient and professional is a valuable asset here.

For Hirschauer, physicians who construct the operative site from the indistinct flesh of the patient's body acquire two bodies: there is an "abstract body", learnt from anatomy textbooks and anatomical models, and a body that is *acquired* as it participates in the practice of skilled work. Thus, what I want to press is how the "*abstract* anatomical model in the physician's mind and the *material* patient's body mutually inform each other" (Prentice, 2004: 162; emphasis added). Idealised anatomical representations, as part of medical imaging matters, are easily subjected to adjustment; it builds a relation between experience and representation and simultaneously brings in many different aspects of the patient via technoscientific mediations, in which knowledge and embodied conduct develop together combining "the anatomical *knowing that* of the visible, and the anatomical *knowing how* of making something visible" (310; emphasis in original).

Using Hirschauer's discussion of surgical operations as functional extensions and the interpretation of rules (on a symbolic level) of technical adequacy and inadequacy, we can see how embodied gestures of precise positioning, classifying, and unwanted patient movements emerge at WURD and BRMR. In the case of x-ray image interpretation, phenomena (e.g. body parts, anatomy, side markers) that are likely to confuse or contradict this system of classification work will be considered 'out of place' (Douglas, 1966). Seeing the radiographic anatomy, outside a set of ordered relations, thus requires seeing as; seeing as experiences are not 'found' but demonstrated, the result of embodied conduct and particular norms ensuring "the proper way to make knowledge using digital materials. Thus, talk about work with constraints is related to anxieties about the nature of digital knowledge production" and the "continued importance of community-shared values of self-conduct in the production of trustworthy scientific knowledge" (Vertesi, 2016: 193). Much like the way the Mars scientists use software packages to reify categories of Martian objects and terrain through interpretive practice, they present a seeing as experience to viewers consistent with the community's categorical distinctions (Vertesi, 2016). WURD and BRMR, as stated, deliver training that ensures normal radiographic anatomy is not seen as abnormal or that the subtle features can be seen as distorted/magnified. As such the anatomic gaze – or rather technoscientific gaze – within x-ray image interpretation, works to construct a "radiological description" (Måseide, 2007: 215) as an objective and professional product; it is "the radiologist's task to replace ambiguity with certainty and to generate a shared and objective radiological vision" (2007: 203).

By settling on an explanation of x-ray image interpretation as awareness of phenomena outside a set of ordered relations where professionals in-the-making can see a distinction between size distortion/magnification and abnormality, uncertainty is reduced. Correcting a (human) anatomic gaze towards the image into a (machinic) technified gaze means that a magnification is made visible in the image, ambiguities are clarified, and the dysfunctional components and the order of interpretive practice is restored through the demonstrable professionals' interactions (cf. Hutchins, 1995).

6.5 The breaks/fractures slide

My interest in analysing how the student gaze can be constructed and corrected can extend to visual media, particularly the 'types of breaks/fractures (#'s)' slide, a large PowerPoint slide embedded with diagrammatic representations and textual descriptions of common fractures in WURD. Radiographers encourage radiographers in-the-making to draw upon this visual information to help recognise the fracture pattern as a specific type of fracture and assist in writing a concise written description of the radiograph such as 'oblique fracture' as part of PCE.[205] The following pedagogical exchange is taken from a didactic lecture between Mrs.

[205] For an extended treatment of PCE, see chapter 1 in this thesis.

Campbell (WURD radiographer) and a large classroom of radiography students who are presented a PowerPoint slide with eight illustrated fracture types, with the accompanying text providing a term for each type:

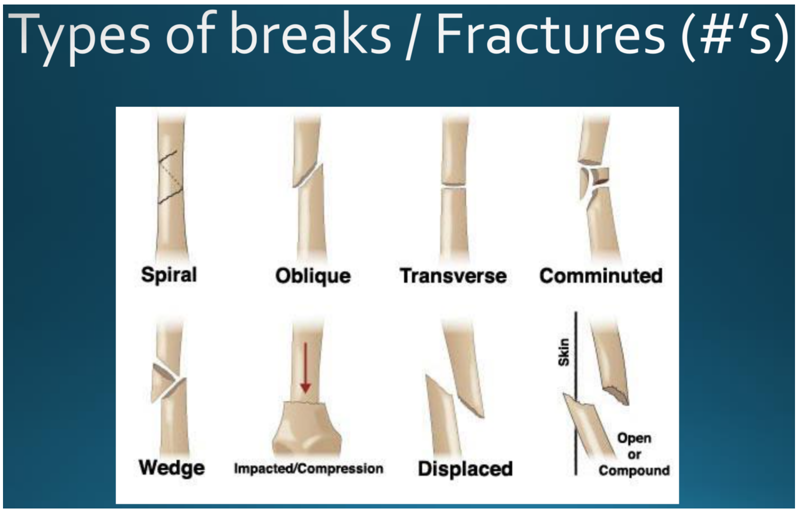

Figure 64 'Types of breaks/Fractures' slide (First week of the first year)

[*Mrs. Campbell presents a slide with the text 'types of breaks/fractures (#'s)' and eight types of fracture in illustrative form*].

Mrs. Campbell: So, there are different types of fractures, so when you're talking about scientific terminology, when you're writing it [Gesture: writes in the air], writing comments and things, you'll need to state what type of fractures they are, okay? When people say 'fractured' they think there's only one [Gesture: both hands open a large space as if to emphasise one fracture], but there are different ones, as you can see here

[*Presses button on keyboard to present a slide with the text 'oblique fracture' and its radiographic equivalent*]

Mrs. Campbell: This is an oblique fracture. Through which body part?

Class together: Tibia

Mrs. Campbell: 'Oblique fracture of tibia'. We'll go into more detail about that later because it's a bony ring [Gesture: RH index finger draws a large ring shape in the air four times], and normally within a bony ring if you have

	a polo [Gesture: both hands form to make a polo shape], if you have something circular [Gesture: both hands form to make a polo shape] can you *break* it in one place?
Class together	No.
Mrs. Campbell:	No. So normally if there's a bony ring involved, if it's broken in one place then it's more than likely broken [Gesture: both hands jerk in the air with RH fingers spread] or dislocated [Gesture: both hands jerk in the air with flat RH] in another. But that's one thing about x-rays, once you found something, if you saw that [Gesture: points at image] would you go 'oh, that's it!'?
Class together	No.
Mrs. Campbell:	No, you can't. You've got to go through the whole criteria [Gesture: RH enacts A, B, and C of 'basic image interpretation': Alignment, Bones, Cartilage (joint), Soft tissues] and *look at* the whole anatomy [Gesture: RH index finger draws a large circle in the air] to make sure that you're not missing anything off there, because sometimes obviously there's more than *one* abnormality.

Mrs. Campbell presents radiography students with the fracture slide because *'when you're writing it, writing comments and things, you'll need to state what type of fractures they are'* and in turn transitioning to the next slide draws attention to *'this is an oblique fracture'* because of a specialised comparative strategy connecting form to classification as well as specialised terminology (Rystedt et al., 2011). Mrs. Campbell's information is far from pattern recognition, potentially inciting uncertainty in the radiography students by drawing on gesture, physical demonstration within question and answer sequences or "this-is-that" discourse often found in anatomy training (Fountain, 2010: 62). Though these explicit exchanges of fracture types in the classroom will be taken for granted, their role will prove to be crucial, strengthening seeing of bony abnormalities with 'objectivity': this exercise in viewing comparatively and establishing correspondence, further exemplifying the use of "gold standards" in understanding the anatomy depicted in medical images (Prasad, 2005: 302).

Mrs. Campbell suggests that if a bony ring is involved '*then it's more than likely broken [Gesture: both hands jerk in the air with RH fingers spread] or dislocated [Gesture: both hands* *jerk in the air with flat RH] in another'.* Mrs. Campbell helps reinforce this by crafting a 'ring' hand shape to depict the circular ring of the tibia when claiming *'if you have something circular [Gesture: both hands form to make a polo shape] can you break it in one place?'.*

However, such discursive practice is arguably suggestive of ambiguity about the image. This is an ambiguity deliberately endorsed and performed by Mrs. Campbell, since '*that's one thing about x-rays, once you found something, if you saw that [Gesture: points at the image] would you go 'oh, that's it!'?'*. In addition, one could attribute Mrs. Campbell's plea to the radiography students' written description as a move towards role extension into commenting and one in which they are accountable for image interpretation and diagnosis in the event of litigation (Reeves, 1999). Nonetheless, I note Mrs. Campbell's preference for gross anatomical seeing over technoscientific seeing once the fracture is 'barn-door obvious' rather than 'subtle', that is, an anatomic structure/feature for which a size distortion/magnification of the anatomy has not occurred.

Mrs. Campbell also asks the radiography students – despite raising a fundamental ambiguity concerning circular and ring-shaped anatomy – when they turn their gaze to the anatomy to deploy a deliberate and systematic method of basic image interpretation so the specific type of fracture, a distinct pattern of abnormality, can be confronted with certainty. Mrs. Campbell sternly advises *'make sure that you're not missing anything off there, because sometimes obviously there's more than one abnormality'* before she transitions to the next slide, titled spiral fracture (*'so this is a spiral fracture'*). Securing the anatomic status of the radiographic image once ambiguity is suspected appears to be of utmost importance to WURD. It disciplines the learning of terminology with a 'visual memory' and fosters the schematic, idealised identification of seeing future abnormality (Friedrich, 2010). During an x-ray image interpretation summary and OSCE revision lecture, Mr. Hearken highlights its importance in identifying injuries:

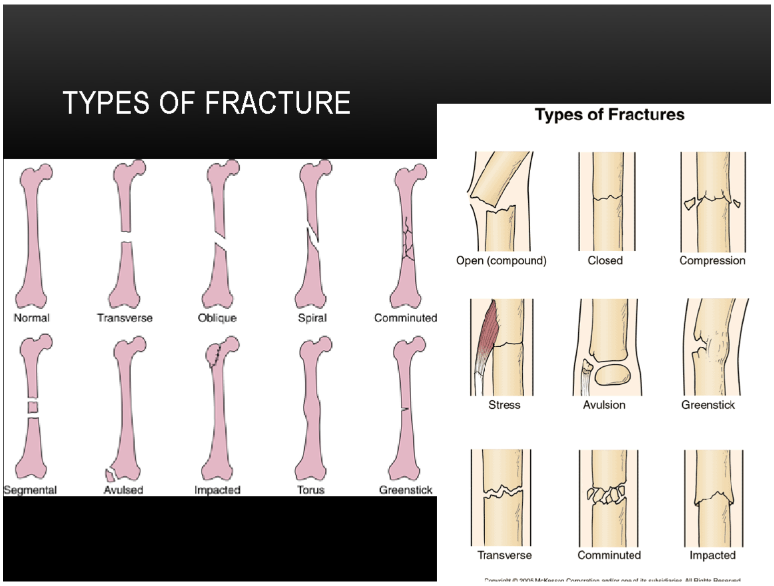

Figure 65 'Types of fracture slide' (Last week of the first year). The slide presents a greater world of fracture types following the initial group of eight fractures.

[*Slide titled: Identifying injuries' which reveals the text (1) 'Bones: cortical breaks; Lucent/sclerotic lines; Interruption of trabecular pattern'*]

Mr. Hearken: We're looking for injuries. What are we looking for? Well, sometimes they will jump out and smack you in the face. They're *easy*, a six-year-old could pick those up. What about the more subtle ones, what are we looking for? So we're looking for cortical breaks, so we want to follow each bone around the edge [Gesture: LH index finger traces the outline of the imaginary bone], we're looking at the cortex of each bone, looking for any interruptions or steps *reads text on PowerPoint slide*. But as well as looking around the outside of a bone make sure you look inside, look at its texture [Gesture: LH grabs the imaginary bone and shakes as if to force it open], does it *look* a normal homogenous texture? I.e. it's the same all the way through, or are there *disruptions* to the trabecular pattern? Are there areas of lucency or sclerosis? So certain types of fracture there will be *no* cortical break at all. Take for instance the hip fracture; a subtle hip fracture you will see no step, you will see no line, all you'll see is a *smudging* or a loss of that trabecular pattern. So force yourself to look inside the bone as well [Gesture: LH grabs the imaginary bone and shakes as if to force it open].

[*Mr. Hearken presses button on keyboard to present the text: (2) 'Soft tissues': Effusions;*

Fluid levels; Swelling; Soft tissue planes']

Mr. Hearken: Look at the soft tissues. They will give you clues. Most of the time they will *not* point out the site of the injury but they *increase* our suspicion. Look for the presence of an effusion. What's an effusion?

[*Pause: four seconds*]

Mr. Hearken: Effusion is fluid within a joint. What does it tell you?

Callum: Injury around the joint?

Mr. Hearken: It's fluid in the joint, there's a problem. There's *something*, but it doesn't say there is a fracture, it doesn't say there is arthritis, it doesn't say there's an infection; it's just saying 'there's fluid in that joint'. Now if the patient has had trauma then it's most likely to be *blood*, which indicates a soft-tissue injury; and if there's a soft-tissue injury and blood then there's a higher chance there's going to be a bony injury. But effusions in the joint don't *specifically* say there is a definite fracture, they're just highlighting or *increasing* our level of suspicion.

Mr. Hearken's account begins by identifying the cortical bone breaks/fracture slide as a standard for radiographers in-the-making *'looking for injuries, what are we looking for?'* Since professionals in-the-making have to look intently and discriminatingly for *'the more subtle ones',* the breaks/fractures slide becomes a stabilising resource when *'looking for cortical breaks'* by following the outside of the bone (*'the cortex of each bone, looking for any interruptions or steps'*) and the inside (*'are there disruptions to the trabecular pattern, are there areas of lucency or sclerosis'*). Similar stabilising resources include presenting abnormal radiographs with types of breaks that occur *inside* the bone[206] or fracture signs where the fracture is unlikely to be seen[207] while simultaneously translating these into hand gestures that depict the fracture but also emphasise the break based on the 'imitation of actions' (Bourdieu, 1977: 87) (these are only offered at WURD because radiographers are primarily

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[206] Interruption of bony trabecular pattern

[207] Soft tissue swelling; Joint effusion (i.e. 'sail sign')

trained in MSK trauma interpretation and commenting, where the focus is on broken bones and dislocation). Such cultural resources and embodied actions reveal the importance of (visual) 'abnormality', constituted or objectified as common standards of 'abnormality'. Interestingly, these illustrations of abnormality adorning the fracture slide maintain and promote radiological knowledge regarding patient characteristics and the type of injury. In a shoulder image interpretation class, three radiography students (Ellie, Martin, and Geoff) reflect on this together and show the slide's value alongside size distortion/magnification in practice:

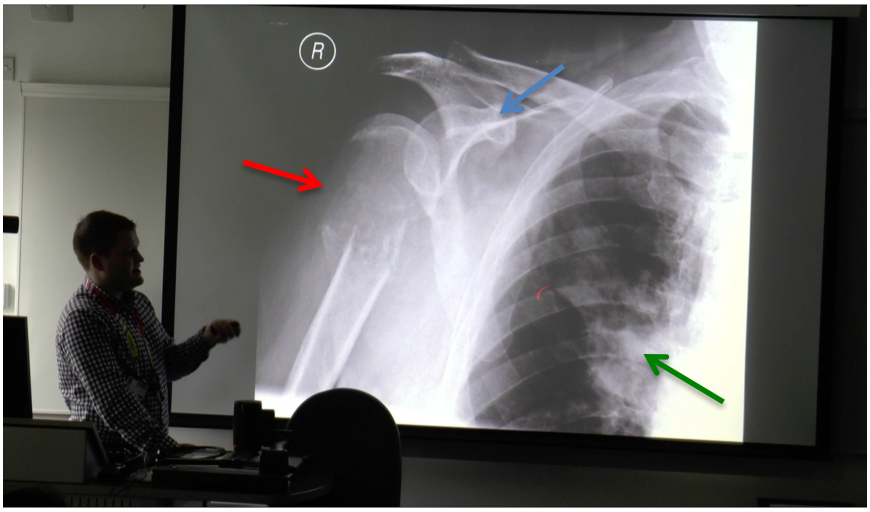

Figure 66 Mr. Hearken presents a PA shoulder with two abnormalities AND magnification. Metastasised cancer in arm (Red), Tumour in chest (Green), and Magnified coracoid process (Blue).

Mr. Hearken: What about this one?

Ellie: Surgical neck?

Mr. Hearken: So, surgical neck fracture. What else do you notice?

Ellie: Subluxation?

Mr. Hearken: It does look like it's subluxed; I think it's probably the projection, the patient looks [Gesture: steps away from the image as if having a further view away helps him to assess for rotation] doesn't look positioned right.

Martin: Is it the coracoid?

Mr. Hearken: Look at the fracture [Highlighting 1: lasers the abnormality]. What's going on with all this bone?

Geoff: Fragments?

Ellie: Is it arthritic?

Mr. Hearken: Not arthritic. Where has the bone *gone!?*

Ellie: Exactly! *laughs*

Mr. Hearken: Where has the bone gone?

Martin: It's *compressed*?

Mr. Hearken: So you've got a bit of the cortex there; where is the cortex…?

Ellie: Uh, oh right. There, like [Pause] yeah.

Mr. Hearken: No guesses as to what this might be?

Martin: Would you say it's an old patient?

Mr. Hearken: It *is* an old patient.

Martin: So could it be an osteopeadic bone?

Geoff: Is that avulsion?

Mr. Hearken: It *could be* osteopenia; if you look at the rest. Osteopenia tends normally to affect the whole skeleton. So you've got, if you look at the rest of the bones [Highlighting 1: sporadically lasers other bones] they all look *okay*, and the humeral head looks *okay* [Highlighting 1: lasers the humeral head]; so it's just this bit here [Highlighting 1: lasers the unknown abnormality]. What might *cause* a bit of bone to be effectively eaten away?

Martin: Osteoarthritis? Osteo*me*olitis?

Mr. Hearken: It could be osteomyelitis. What is osteo*my*elitis?[208]

Martin: So that's from diabetes?

Mr. Hearken: Yeah, typically osteomyelitis in the feet in diabetics. What *is* the myelitis caused by? [Gesture: both hands caress an imaginary ball in the air as if shaping the suspected abnormality]

Martin: Is it infection?

Mr. Hearken: *Infection*

Ellie: Oh!

Mr. Hearken: So it could be osteomyelitis, or bone infection [Gesture: both hands shape the suspected abnormality]. Absolutely. What's the other possibility? What else tends to eat things away?

[*Silence: 7 seconds*]

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[208] Here, Mr. Hearken corrects Martin's pronunciation of 'osteo-ME-olitis' to 'osteo-MY-elitis'. This is just one of the many important components of learning to see and say as part of wider description practices. This process is important for "intelligible speaking" and has very clear rhetorical insistence in more public pronouncements of observation (i.e. the workplace) (Robillard, 1999: 156).

Mr. Hearken: Or take the place of other tissue?

Martin: Canss-cancer?

Ellie: Oh yes.

Mr. Hearken: Malignancy [Gesture: both hands shape the suspected abnormality]. So it could be a myeloma potentially; it could be a metastasis, it could be a primary bone tumour [Highlighting 1: lasers the unknown abnormality]. Anything else you notice on this image?

Ellie: The coracoid seems really magnified!

Mr. Hearken: [Highlighting 1: lasers the coracoid]. I think, again it's the projection it's been taken in. The patient has kind of, I think, looks a little bit sort of leant back [Gesture: Leans back as the patient which suggests the side of the abnormality is further away from the detector (presumably because of the pain)]. What's going on here? [Highlighting 1: lasers the right lung]

Martin: Pneumothorax?

Mr. Hearken: It's not a pneumothorax. I know what you mean, but there's some sort of consolidation or something going on in the chest [Highlighting 1: lasers the right lung]. The patient referred for a shoulder x-ray, through a GP, with shoulder pain; x-rayed, reported as 'suspected malignancy in the shoulder, pathological fracture', sent for CT, picked up, primary tumour in the chest. So this is a case of a primary tumour in the chest [Highlighting 1: lasers the right lung (Fig. 66)] which has now spread or metastasised into the humerus [Highlighting 1: lasers the right humerus]. The thing about it was, when it was reported this wasn't picked up [Highlighting 1: lasers the right lung]

Ellie: Yeah, because they were focusing on the shoulder!

Mr. Hearken: They were looking at this. So, the important bit is *not* that [Highlighting 1: lasers the right humerus], it's actually where it's come from [Highlighting 1: lasers the right lung]. So, it was only picked up about three or four weeks later when they did the CT and identified it that it was a lung cancer that had spread, and not the other way around.

I argue that the pattern of a specific fracture type present on the slide and equipped with its comparative radiographic equivalent relates to the "seeing and believing in practices of scientific truth-making and perceptual convention" accomplished in routine academic training

(Burri and Dumit, 2008: 300). In undergraduate interpretive training, the future images for image interpretation will be subjected to specific and universalising types of abnormality, inherent in actual interpretive practice. This reflects a common universalising and systematising treatment towards familiar problems of interpretation (Douglas, 1975) such as 'missed abnormalities', 'interpretive risks', and 'technical errors'. The discursive correction to a 'technoscientific' gaze is used when discussing the possible size distortion/magnification of radiographic anatomy to distinguish abnormality from normality. Prentice (2013) argues that in such situations, professionals present the anatomical image as an object that physicians learn to manage with various technologies and organise instability. With the radiographic anatomy categorised as size distortion/magnification, a technoscientific gaze is enacted and the gross anatomical gaze is corrected. This, I argue, is useful when professionals need to provide objective proof and display confidence from the radiographic anatomy and it could additionally help professionals in-the-making do the same when possible appearances of size distortion/magnification are present. Such practices, in addition to the knowledge of enacting the visibility of the abnormality on the breaks/fractures slide, allow an effective seeing as of radiographic anatomy in academic training. X-ray image interpretation is a tentative and misleading practice, yet in academic settings, radiographs with entangled and ambiguous images are 'unpacked' (Rystedt et al., 2011) and, essentially, 'critically'engaged.

6.6 Conclusion

This chapter explored how x-ray image interpretation training can discipline ideas around human-machine clarity which, according to some authors, generates a narrative of transparency that shores up the authority of medical images as an objective source of knowledge (Joyce, 2005, 2008; Van Dijck, 2005). It seems procedural knowledge and technical standards around images and clarity shape the understanding of radiographic anatomy, particularly with respect to imaging practices, such as patient positioning and imaging technique (Wood, 2012, 2016). With x-ray images, seeing clearly is mainly aesthetic in character – particularly its discursive 'visual performance' as a driving force of anatomic reality (Burri, 2012). The potential x-ray image with ambiguous anatomy is thus constructed as a disruption to professional expectations of anatomy, threatening their capacity to see normal/abnormal, and a deviation in their personal/shared embodiment of 3D normal-anatomic expectation. In addition, I describe how 'technical adequacy', educated to professionals in-the-making as a systematic evaluative resource, influences cultural ideologies of clarity and how radiographers in-the-making, regularly undertaking first line x-ray image interpretation as one of the routines of reducing interpretive risk, subsequently become accountable to litigation, should there be radiological error (i.e. misinterpretation) or discrepancy in the written reports.

In addition, I suggest that the notion of clarity lies between the 'anatomic gaze' and the 'technoscientific gaze'. The radiographic anatomy during x-ray image interpretation is in a between and blurred state. One the one hand, it makes learning comparable to the 'looking at/pattern recognition' of textbook images, yet on the other it resists appealing to this as anatomic appearances or technically effected anatomy often needs discursive explanations to recognise the structure-in-question in a particular context of imaging technique (Joyce, 2005). For instance, the process of learning size distortion/magnification is largely generated in the social space of 'activity systems' (Goodwin, 1994) and involves integrations between multiple semiotic fields generated through the use of body orientation, digital images, and gesture as features of practical problem solving (Alač, 2008).

Since medical images need to be 'cleaned up' or 'calibrated' (Dussauge, 2008), the lack or absence of attention to particular forms of imaging technique can diminish or at least threaten interpretive certainty. As qualified practitioners in the production of x-ray images and x-ray physics (Dr. Saury: *'we have physics teaching throughout the first 6 months of training'*), BHRD professionals can subsequently transform the perception of 'anatomy' to a 'technified anatomy'; a type of 'seeing as', where professionals perform "the image into something meaningful, distinguish foreground from background or object from artifact, and highlighting key features while downplaying others" in the very demonstration of the image itself (Vertesi, 2014: 24). This shift of visual analysis refocuses sight, repairs problematic seeing, and accomplishes awareness of the sociotechnical effects and instabilities of x-ray image production on anatomic structures. Just as Foucault (1973) argues medical knowledge is caught up in an endless reciprocity, a truth to be deciphered via a perceptual configuration, it is in this reciprocity that the 'true' anatomy within radiographs is explicated.

All of these factors combined – such as the value placed on seeing clearly in image production, a vital importance for professionals in-the-making to minimise interpretive risks, the making and minimising of undesirable technical effects in radiographic anatomy, and interpretive training ultimately fostering the contention that the visibility of obscured radiographic anatomy can be enhanced and optimised – helps show, as built on in chapter five, a pragmatic reason why radiological error and litigation in UK are "uncomfortably common" (Brady, 2017: 171). In chapter seven I bring this thesis to a conclusion by focusing on how this one particular purpose of image interpretation training draws attention to important pedagogical goals for both radiology and radiography.

7 Discussion

Throughout three chapters I have sought to answer the research question: 'how do professionals in-the-making learn to see in x-ray image interpretation training and consequently build radiological vision in the academic setting?'. In between chapters, I discerned a relationship between coverage of the image and embodied performance. More specifically, having a more complete view of professionals and images, this thesis is an important contributor to embodied accounts of how medical image interpretation is performed in taken-for-granted teaching practice (Polanyi, 1958; Barley, 1984; Saunders, 2008; 2009; Engel, 2008; Friedrich, 2010; Prentice, 2013; van Baalen et al., 2016) and how values around medical images intersect with reflections on the 'transparency' of diagnostic imaging technologies (Pasveer, 1989; 2006; Van Dijck, 2005; Joyce, 2005; 2008; Dussauge, 2008; Saunders, 2008; Burri, 2012). In doing so, its specific contribution to extending the field may best be examined in four ways.

First, it draws on video ethnographic data that is missing in research on medical image interpretation training, simultaneously exhibiting the exchanges between people, images, and sense modalities and what happens in taken-for-granted academic teaching. This video ethnography of interpretive practices in institutions of education, advocates the use of video recordings and video-based observation for providing unprecedented opportunities in explaining the embodied skills and revealing the tacit activities of professional training practices (Goodwin, 1994; Lynch and Macbeth, 1998; Greiffenhagen, 2008). Second, it supports a growing talk to expose and reject mental models of learning labelling and incorrectly treating x-ray image interpretation training as simply a 'cognitivist' endeavor (Gegenfurtner et al., 2017). This labelling of 'cognitivism' discounts the complex cultivation and interpretation of medical images as a social practice (Joyce, 2005) and prevents a thorough insight into how human cognition is shaped socially. Thirdly, I identify a pluralism of sociological and ethnomethodological concepts to help analyse the taken-for-granted and qualitative dimension of a practice that reenacts a certain professional vision and socio-cultural norms of its community (acting as its 'backdrop'). Fourthly, I attend to the complex assemblage of professional vision, discursive practices, and embodied conduct in deconstructing, through its own professional practice, a highly taken-for-granted expertise.

This thesis has sought to show how learning to see and interpret x-ray images is accomplished in embodied and tacit forms in academic settings, clustered around a material and cognitive infrastructure that all mutually inform each other (Goodwin, 1994). More specifically, it highlights the ways in which training in x-ray image interpretation represents a 'critical practice' which has: transformed interpretive hierarchies, invigorated the allied health profession, shaped issues surrounding 'socio-legal' dynamics (Mulcahy, 2003), contributed to 'workforce flexibility' and alleviated increasing imaging workload (Brady, 2017). Importantly, I draw explicit attention to teaching practices and professional vision in which visibility is constructed, professional vision is (re)enacted, gestures are deployed, situated learning is accomplished, and radiological vision is essentially demonstrated in academic settings. By distinguishing the importance of training in x-ray image interpretation from the clinical workplace, I track the emergence of learning processes and specific practices of organising perception and cognition, which, as shown, raises important questions about embodied dimensions of visual expertise that easily obviates or subverts a pure cognitivist analysis (Ivarsson, 2017; Gegenfurtner et al. 2019).

Specifically, I show how x-ray images occupy a rather strange position in academic training. There is distributed, collaborative and agonistic problem solving – I borrow and employ the notion 'radiological vision' (Måseide, 2007) when I refer to this across the thesis. I interpret these radiological problem-solving activities as examples of how professionals situate students in activity systems to discursively organise interpretive work with themselves and with other students, but also in relation to cognitive artifacts, scripts/systems, technology, representations, and other patterns/signs (Måseide, 2007). Early in x-ray image interpretation training, for instance, professionals conduct their body in relation to patterns/signs, representations, and the patients' bodies since professionals in-the-making have yet to reach the bodied practices that construct and interrogate the image. In order to enhance the visibility of anatomy, this information is passed on through radiologists and radiographers "expert systems" (2007: 23). Such professionals, though radiographers particularly, however, are situated in the process of 'getting it' in terms of participating in the professionals' embodied and procedural knowledges that are at times hands-on 'craft-work' (Lave and Wenger, 1991). Under the guidance of the radiographer, they seek to craft presentations of technically adequate images. Thus, at Bridgestock and Woodfleet, training is often embodied conduct for distinguishing the presence of “matter out of place” whether it is abnormal anatomy or normal anatomy that has moved for some reason (Douglas, 1966: 35).

What is more, this radiological vision emerges in how radiographers (more than radiologists) claim the ability to learn normal is based on classic introductory (radiographic anatomic) textbooks, yet spend most of their time situating and grounding radiographers in-the-making in a cycle of embodied multimodal interactions, moving bodies and reenactments of x-ray images.[209] However, most importantly, professionals (including radiologists) assert that training has cognitivist tendencies and ensures that a highly detailed ‘picture in the mind’ accurately reflects reality in the world (Prentice, 2013), but also that the anatomy itself presupposes the learners’ ‘pattern recognition’. However, much of their teaching is about accomplishing a critical stance towards x-ray image interpretation; it is not without clinical bias (imaging request card), since clinical information can bias a specific mental model; it is not immune to optical illusions (e.g. mach band sign), which mimic abnormal anatomy on the grounds that two anatomic structures are geometrically congruent. Additionally, x-ray images have areas of interest and become cast as having a ‘common place’ for injuries and generating anatomic expectations of professionals which could have an adverse effect on interpretation or, rather, ‘seeing something that is not there’. Whilst professionals are critical of the radiograph on two-dimensional grounds, training for x-ray image interpretation is taken for granted and becomes part of the established embodied conduct of ‘seeing’, reasoning, and image-making (meaning-making).

Additionally, despite professionals’ directed critique of x-ray images and cautionary tales towards ‘satisfaction of search’, teaching practices in the academic environment can render problematic anatomies recognisable. Sign systems, eponyms, and the ‘realities of practice’ (Wood, 2012) with problematic anatomy (fractured, pathological, disorderly) are made visible in revealing the sources of the dynamics of discursive demonstration and patient illness. Merging problematic anatomy with recognisable signs, eponyms and the realities of imaging practice reenacts a perceptual order that characterises the relations with the symbolic or exemplary status that permits standardisation and authority (Burri, 2012).

[209] Where anatomic structures and features have been made notational and available to access online (via anatomy.tv or Google images).

Radiographs with problematic anatomy, or at least those considered at risk of radiological error, are given priority in the academic setting. With case presentations purposefully selected for their ambiguity, they are mobilised to make sure professionals in-the-making do not take the images at face value with specific discursive contexts of 'missed abnormality', 'interpretive risk', and 'technical error'. This unpacks x-ray image interpretation and uncovers the role of uncertainty in teaching and ambiguity of content variations of images in daily clinical practice. Such discursive forms remind us that "curiosity, imagination, judgement are best not thought of as innate faculties or private virtues that the worker brings to the workplace, but as faculties reproduced in social settings" (Saunders, 2009: 163). The notion that images with problematic anatomic content enroll observers in multiple perspectives of diseases is illuminated through differential diagnosis as well as the notion that irregular anatomies are usually shaped by metaphors of 'disturbance' and a dynamic interplay of discursive factors are important to the process of visibility (Joyce, 2008; Saunders, 2008; Burri et al., 2011). Radiographic anatomic seeing owes as much, or more, to the profound social processes of interaction and comparison with well-known forms, as it does to the cognitive formalised knowledge of anatomical conditions obtained by radiation.

These contributions reveal the dynamic and complex dimension of a teaching practice in which problematic anatomy (fractured, pathological, disorderly) itself is constructed as 'barn-door obvious' in one moment and as 'subtle' in another and a possible reason for misinterpreting an x-ray image. For the most part, however, x-ray image interpretation is imbued with a reluctance to take the image at face value and affords a view of radiographs as misleading, that is, something which can be fundamentally difficult for the novice to interpret and, if an image is inadequate, something which constitutes a reason for misinterpreting trauma/disease. Learning to distinguish normal from abnormal structures – and radiographic anatomy more generally – is uncertain and tentative. In radiology and radiography education, this is often the case. Agreeing with Saunders (2008) that the classification of radiographic anatomy (in this case problematic anatomy) and ideas around both diagnostic imaging and expectation/demonstration are constituted by discursive practices in undergraduate education, I reveal how training in x-ray image interpretation is a critical practice of the image and how the image, before normal/abnormal is fully established, is enacted and constituted as ambiguous. This process speaks of an interesting and ironic paradox of visual learning: a reasoning that increases the anatomic visibility and certainty of the image with abnormality also decreasing the chance of being certain towards the closure of abnormal images. Exactly what I mean by 'paradox' is the duality of x-ray image interpretation training, especially vis-a-vis presentation of abnormal images: professionals would conduct a privileged space for objectivity and transparency (e.g. signs, eponyms), but would also conduct a degree of uncertainty inherent to each image, as part of a unique problem solving model that generates a particular critical engagement.

At this point, I argue that visual training/learning opens up an analytical space for critical sensibility. There is a reluctance to take the medical image at 'face value' (Coopmans, 2011). I bring this up to highlight what I see as the main challenge in routine image interpretation training and indeed support the "processes of apprenticeship in putting a certain vision firmly in place within a community of practice" (Grasseni, 2009: 9). The aim, though, is not only to acknowledge the *processes* through which people are invited to exercise a critical analysis of images by learning to relate to specific materials, taxonomies, and bodies. It is also to appreciate the *wider social context* for specific practices of seeing, particularly the ways in which both professionals and professionals in-the-making are under pressure to make difficult diagnosis and reduce radiologic error against the backdrop of a dwindling workforce and increasing workload (Brady, 2017).

It is reasonably clear that in this case a key consideration in visual training/learning is the explicit attempt to combat professional uncertainty by apparently having explanations rooted in cognitive psychology. However, while professionals talk the cognitivist talk, they do not actually adhere to it in their practice. As the data shows, with the descriptions of how professionals teach cognitive scripts/systematic approaches in practice, there is much embodied knowledge at play in these practices, whether in the sharing of verbal knowledge or the tacit skill.[210] This cognitive model discounts the complexity of the lived nature of *in situ*

[210] Curiously, radiography professionals often go further in teaching with common reference to the term **'*habitus*'**; a notion that has phenomenological underpinnings for how bodily habits emerge from and shape social interactions (Bourdieu, 1977). For example: *'to abduct that far and it's quite difficult to get, so obviously dependent on the **habitus** of the patient [Gesture: RH touches her side, while the LH remains touching her shoulder]' (Mrs. Campbell)*; *'but sometimes the patient body **habitus** and the way someone is built can make it very, very difficult to get that C7-T1 junction'* (Mr. Hearken).

visual cognition, denies the importance of a sociotechnical system in conceptualising the mediating role of technology in visual expertise, maintains unhelpful distinctions (for example, cognitivism vs. social), and is potentially unsolvable, since the tag of mentalistic cognitivism opens up a complex paradigm of multiple scientific theories across medicine and psychology (Burri and Dumit, 2008; Gegenfurtner and Merriënboer, 2017).

It is tempting to label training as an exhibition that fluctuates between certainty or uncertainty, that is, between being reassuringly confident or unnervingly ambiguous. The reality, of course, is much more complicated. Indeed, training in x-ray image interpretation is different than training with other medical imaging modalities. This is mainly because x-ray images consist of a two-dimensional array of different structural densities of the interior of the body that is three-dimensional in nature. Arguably, this means that visual training is different to the likes of ultrasound, CT, and MRI and ultimately gives the impression that non-irradiated 3D imaging uncovers the 'true nature' of internal anatomy. It would be wrong, therefore, to indulge in a sweeping generalisation about all training across 3D imaging modalities and how medical and psychology research translates to an outdated cognitivism.

Rather, drawing on video footage, I reveal how professional vision - that is often taken for granted in accordance with conventional analyses - accomplish x-ray image interpretation training as a tacit component of image production/interpretation[211] and image content in critical terms. Here, I have a reason to suggest why professionals in-the-making may misinterpret the image if they do not understand image production. In her analysis of the narratives used to discuss MRI examinations in the USA, Joyce (2005, 2008) suggests there are different drivers for misinterpreting anatomic content, highlighting interpretation troubles of discrepancy aimed at whether image content represents stable anatomy, disease, or artifact. Similarly, Wood (2012: 11) goes for a deeper understanding of interpretive pitfalls in images produced by cone-beam imaging and argues that inadequate radiographic technique and unacceptable degrees of patient rotation produced magnification; "a manipulation that reduces visibility". I read x-ray image interpretation training as a 'critical

[211] This also shows the effort to acquire a 'unique adequate competence' for description and accurate representation of the person's point of view in regards to image making (Garfinkel, 2002). For a detailed documentation of the researcher's relation with complex phenomena, see 'chapter 3: methods'.

practice' and support Wood's argument that misinterpretation is not *exclusively* attributable to the radiographer's inadequate image making skills – it is also attributable to a lakc of knowledge about normal radiographic anatomy and its various guises.

Interpretation is inseparable from image production and technical-aesthetic judgements must be made with reference to professionals attempting to avoid patient suffering or sensing that a professional was finding it difficult to accurately position a severely ill patient. Interpretation appears to be based on patients conforming to the protocols of the professionals as much as it is with professionals conforming to the protocols of the department (Wood, 2012; 2016). For the learner here, "meaning does not arise from isolated perceptions, but from the stream of relations, associations and experiences which are variegated and yet intimately interconnected" (Belova, 2006: 104).

However, I do show *how* a common misinterpretation happens and how this can be exhibited through how clinical image production practices construct x-ray images as ambiguous and problematise visual engagement. Whilst I refrain from a cognitivist analysis of image interpretation training, I am equally aware of not portraying training as an arena free of enacting cognitivist tendencies. Since those interested in the evolution from novice to expert cannot consider training and visual expertise more generally apart from its cognitivist roots (Ivarsson, 2017), perhaps it is better to make an excision between 'cognitivism' (operating with a positivist approach at the level of the individual eye) and 'distributed cognitivism' (operating with a interpretivist approach at the level of collective eyes and interaction with people and objects) (Hutchins, 1995). Training in x-ray image interpretation, as shown in this thesis, is associated with both and especially the latter, where cognition is distributed across people.

However, I argue that training in academic settings goes *beyond* distributed cognition and includes the body's role in shaping cognition and problem solving: training is not merely thinking, but 'thinking with eyes and *hands*' (Latour, 1986, emphasis added), where people engage with images on a bodily level (Merleau-Ponty, 1962). The pursuit for accurate interpretations in the absence of imaging technology is made possible by the physicality of the body, and its *a priori* involvement with the diagnostic imaging world (shown by this study), serves to make a distinction on which anatomies can be interpreted and cannot be interpreted in the image. In this way, the main option is to raise awareness about some of the available misinterpretations, where training interactions focus on specific problematic areas and become exhibitive methods for the reenactment of uncertainty or error, an "opening for a 'slippage' of practice" (Wenger, 1998: 93).

This is amplified by the embodied conduct of x-ray image production; the professional needs "procedural knowledge about how to describe x-rays and how the actual production of an x-ray may affect the resulting image" (Måseide, 2007: 203). The range of diagnostic medical imaging examinations available for detecting potential abnormalities has increased in the NHS UK, yet the stock of sociotechnical knowledge supplementing the process of problem-solving is limited (Bhogal et al., 2012). Whilst this appears to shape radiographers in-the-making as embodied image-makers and, by simple extrapolation, 'button pushers' (Larkin, 1983), it seems medical students have little understanding about how imaging affects the anatomy. What has emerged is the groundwork of including questions about appropriate use of imaging techniques to solve the clinical question as a critical curriculum component in undergraduate radiology education (Kourdioukova et al., 2011a; RCR, 2017). Radiology must thus also take responsibility for ensuring a critical and technical viewing of radiographic practice, such as presenting imaging techniques rather than reinforcing medical diagnostic knowledge and professional boundaries (Burri, 2008).

Whilst professionals do play a role in teaching their students to be critical in x-ray image interpretation and how not to accept x-ray images at face value, their teaching practice is considered in the wider context of NHS diagnostic imaging services. Indeed, there is a variety of heterogeneous influences which have combined to accomplish x-ray image interpretation training as a thoroughly critical affair and particularly the image itself as not to be taken at face value. This includes a history of patients with cancer exposed to the risk of misdiagnosis by junior doctors (CQC, 2018), a recent record of medical student deficiencies in image interpretation (Eisen et al., 2006; Boutis et al., 2010), introducing practices of assessment (i.e. RadBench) for enhancing interpretive performance (Wright and Reeves, 2017), the fear and increase of litigation and malpractice lawsuits (Donovan and Manning, 2006), the fallibility of medical image interpretation as a psychological or cognitive practice (Custers et al., 1996), the technoscientific innovations that threaten the authority of older imaging technologies (Burri, 2008), a preoccupation with avoiding 'technical errors' (Nol et al., 2006; Perez et al., 2015) and credibility of reports in a diagnostic outcome (Burri, 2013), recommendations of visualisation and optimisation tools which position the anatomic image as perfectible through many layers of human and machine mediation (Joyce, 2008), and media coverage of doctors who have misdiagnosed patients on the basis of misinterpreted radiographs (Harrison, 2013). Thus, as I have outlined, lots of people and practices are involved in the discursive reenactment of not taking images at face value in order to reduce radiological error.

Data appears to suggest that the educational path to curb the misinterpretation of x-ray images involves methods of in-depth bodily demonstration in the 'back-stage region' (Goffman, 1959). Drawing on Scott (2015: 260), this allows "actors to relax out of role, rehearsing, reflecting on and sometimes contradicting the show that had been presented out front". This strategy acts as a crucial player in demonstrating the image production process to influence practical reasoning and as an incentive to voice (what would otherwise be discrete) problematic acts of interpretation because of the 'socio-legal' dynamics of medical mishaps (Mulcahy, 2003). Nonetheless, I reveal how this translation of x-ray images is brought to life in embodied and discursively pragmatic ways in academic settings. Although visibility being a crucial outcome for health care is part of the Western cultural utopia of the transparent body (Dussauge, 2008), there is a strong need for it in academic training contexts. This connects with the techno-science of anatomic visibility and the improving endeavor of diagnostic imaging which has "extended radiology's gaze deeper within the body and made radiology's utopic transparent body really transparent: visible from any spatial point of view" (Dussauge, 2008: 79). Whilst I have previously suggested professionals organise training and pick out images via a hierarchy of clinical relevance, diagnostic imaging is often never dormant or separate from the early stages of anatomy training; no sincere assertion of anatomic fact is essentially unaccompanied by insight into technical objectivity or a persuasive desire for the significant refigurations of human bodies. Its influence is felt in distinguishing between 'adequate' and 'inadequate' images (Saunders, 2008). Diagnostic imaging has introduced objectivity in distinguishing the 'adequate' from the 'inadequate' image in interpretive practice by gaining knowledge of 'problem' bodies, whilst equating the body with numerical and visual information.

Such practices of seeing adequate and inadequate images begin in the classroom because the practice of producing/interpreting images has thus *articulated* the professional's body with a specific 'seeing as' (Vertesi, 2016). As an integral part of Western biomedicine and of our social culture, such education animates and brings to life the perception around 'adequate' images. These strategies of construction and elaboration of the adequate image are more than a physical extension from hand to screen (a two-dimensional world of the imaged patient's self). It is one more extension of our society - which seemingly privileges medical images as reliable and correct, identifying mechanical objectivity as essential to anatomical vision. Thus, it seems diagnostic imaging has played a key role in embodying a distinct technological system – an assembly of the projected patient, scientific discourse, apparatus and image production practice – throughout modern x-ray image interpretation education.

The language of imaging professionals claims to be objective and neutral, yet in training, their embodied conduct reenacts a rich demonstration of different kinds of 'technical mediation' (Latour, 1994) between practitioner, machine, and the patient's internal self, via discursive degrees of adequate and inadequate images (Saunders, 2008); "images are not simply situated but inseparable from the conditions of their acquisition and interpretation" (Wood, 2016). According to Wood (2012), these two categories of visual information - of adequate and inadequate - are a mechanistic pursuit for objectivity, yet have been demonstrated and made 'true' through the context and content in order for the radiographer to see or not see the anatomy.

At Bridgestock and Woodfleet and in learning to see more generally, x-ray images are similarly involved in such 'discursive practices' (Goodwin, 1994) of missed abnormalities, interpretive risk, and technical errors. This demonstrates the ambiguous character of the x-ray image (i.e. its technological and social context) and changes how the anatomy should be seen, perceived, or how it affords a profound influence on the anatomy as normal/abnormal. These observations represent an ironic comparison between professionals and me: just like the work of feminist techno-science scholars, professionals also aim to unravel the contingencies, contradictions and complexities that surround the portrayal of images as 'objective' (Beaulieu, 2002) and 'transparent' (Joyce, 2008). Rather than being figured as "detached image" as Wood (2012: 197) describes it, the x-ray image is embedded into a heterogeneous assemblage of multiple actors into a material-discursive form through the demonstration of image content that serves as a tool for thinking and seeing with radiographic anatomy. This problematises the mental model of anatomical learning purportedly endorsed by professionals in medical image interpretation education:

> "By describing anatomical learning as the construction of a mental image of human anatomy, including a knowledge of three-dimensional structure and its identifying terms, he [the surgeon-as-teacher] creates a view of anatomy that leaves out the social, cultural, and material dimensions of anatomy" (Prentice, 2004: 108).

Whilst Prentice concentrates on the surgeon's learning to see the internal body, her work helps shore up my arguments put forward here. The prescribed rhetoric of 'mental image', for Prentice (2004: 108), "deemphasizes the role of the body – and the emotions – in anatomic learning and early physician training". As Prentice (2004) shows, the constant focus on sublimating learning or knowing under a cognitivist label, coupled with the promise of novel online image interpretation courses[212] framed as reducing anatomic ambiguity, shares much in common with the doctrine of a modernist project to 'disembody' or 'linguistically represent' the self (Prentice, 2013: 171). In this respect, my discussion of academic x-ray image interpretation with regard to learning and practice highlights some limits of x-ray image interpretation as a modernist project of disembodied gaze and thus tempers the study with a somewhat postmodern sort, where learning to see within x-ray images is a facilitation of 'technological' or even 'cyborg' bodies (de Bere and Petersen, 2009: 164).

The desire to 'see clearly' has become a common trope in popular narratives (including professionals' discourses), as includes the fear of missed abnormalities and malpractice suits caused by technologists' poor workmanship (Joyce, 2008; Saunders, 2008). X-ray image interpretation training, as exhibited in this study, intersects with wider sociotechnical and cultural expectations or knowledge of certain images. Discursive – as well as pragmatic – practices of seeing adequate and inadequate images reenacted via the embodied practising of image interpretation are widely demonstrated and objectified through sequences of image production that are elicited from bodily techniques. Coupled with a community increasingly driven by ideals of mechanical objectivity (Daston and Galison, 1992; Daston, 2008), the anatomical body, presented as being disobedient, becomes an undesirable artefact that

[212] Posted by instructors

disrupts accumulated expectations of anatomic visibility in the delivery of definitive diagnoses based on images alone (Saunders, 2008; Wood, 2012; Wood, 2016). Using Daston and Galison's (1992) concept of 'mechanical objectivity', Beaulieu (2002: 82) describes the ways in which practitioners' acts of vision or sensory interpretation are "considered to be problematic and might best be replaced by a quantitative, mechanical objective set of scan evaluation programs", this relating to the consideration of numerical data and the mathematical processes central and omnipresent in their practice. According to Beaulieu, then, images with little or no measurement disrupt, distract or discredit the practice of seeing, by both educators and their communities (i.e. radiography and radiology). This is particularly pertinent in learning to see x-ray images, where those images certified as adequate enough to interpret present alongside 'terrible' images, that is, poor images that obstruct the ability to see and say and safely make the diagnostic claims his/her colleague submits.

This type of activity challenges the already objectified status assigned to images by the community, an idea which closely parallels Alač's (2008) important remarks on how mathematical processes "are *indexed* by the PI's gestural enactments, tightly coordinated with the digital images and conceived as performances of practical actions" [emphasis added]. By making interpretive training and radiographic practice publically available through the embodied conduct between x-ray images and gesture, as shown in this research, one can argue this is problematising the idea of *learning*– specifically of forms of knowledge that cannot be written down and has (tacit) *skill* at its core (Grasseni, 2009).

My focus on the ongoing tentativeness of x-ray image interpretation training in academic environments importantly reveals the purposeful and overt dispositions towards purposefully selected images, but also confronts those who consider the clinical as the more 'superior' setting. X-ray image interpretation training and learning to see is a mixed or intermediated practice. It offers the confidence of seeing normal and abnormal radiographic anatomies prior to participation in clinical workplace settings and can shape a competent workforce, yet also induces great uncertainty in professionals in-the-making and provide a running narrative on what images professionals value. Interpretive training, thus, raises interesting and provocative questions, for educators in medical image interpretation and those-in-the-making alike, about the role of physical bodies for making content meaningful, of bodily technique, and when technique (or its absence) *becomes* a problem.

8 Conclusion

I hope that my ethnographic video-based arguments will spark further qualitative and reflexive dialogues – and thus communicate and reinforce the role of professional vision in organising learners' cognition and perception of x-ray images. We know professional vision as embodied and acquired through tacit practices (e.g. coding the shades of radiographic anatomy, reenacting radiographic practice). These create a specific perception of the x-ray image being scrutinised through discursive strategies that establish "rhythms of critical appraisal across the landscape of organs, and store up credit for one's serial attentions" (Saunders, 2008: 292).

Interpretive training shapes the way learners reason and act about radiographic information, particularly in the "capacity to learn from error" and doing a job that "involves critically inspecting our daily work and practice systems" (Gunderman, 2009: 159). Moving beyond the clinical and into non-clinical arenas, academic training is an overlooked practice for revealing the taken-for-granted methods in visual expertise and helps to explore how ideas around professional vision are developed and continuously reproduced according to distinct cultural systems (Goodwin, 1994). In sum, by taking the body as a site for knowledge seriously, I reveal how analysing the 'taken-for-granted body' one forgets what one relies on (Merleau-Ponty, 1962). The audience (you) will come to realise how important the body is in learning to see and will provide a refreshing counterpose to conventional norms of positivist and cognitively orientated analyses of image interpretation education. I anticipate that this will enrich the minds of the audience, highlighting the social dimensions of cognition and perception and how these practices of seeing are mediated through talk, gesture, and material artifacts.

However, because my study focused on pedagogic interactions in academic settings, it has left some important questions unanswered: what happens to the development of professional vision in the university-workplace transition? What visual expertise is gained or lost during this transition? If visual expertise is lost, what is gained in its place and why does this happen? How are the same features of student misinterpretation, such as patient rotation, enacted in the digital x-ray suite? How do students learn to see these instabilities themselves through inadequate patient positioning in the digital x-ray suite, but also generate understanding of how anatomy appears radiographically? These questions point to the need for: 1) research on the university-workplace transition and learning to see in the clinical environment more generally, and 2) research on the production aspects of learning to see and what is perceived of as error or anomaly in the image. It is undeniably important for professionals to understand how students learn to see in producing images and its implications for the future reduction of radiological error.

This specific study has a broader appeal for considering professional vision, situated learning, embodied conduct, and visual communication. It illustrates how x-ray image interpretation makes room for critical analysis in academic teaching practices and how learning to see x-ray images is given greater value via a close body-machine relation. Thus, I provide a sociological commentary on what types of images are valued and who/what is established as normal/abnormal during image interpretation. Overall, I show how an awareness of critical practice can enhance interpretive ability and for purposes of reducing radiological error. This has implications for enhancing patient safety, particularly in medical education where my findings provide evidence for why medical students need to understand how radiographs are produced, what they depict, and how they can lead to misinterpretation.

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Appendix

Appendix 1: Research Ethics Documentation: Radiology

Downloaded: 23/10/2016
Approved: 20/08/2015

Peter Winter
Registration number: 140150210
Sociological Studies
Programme: PhD in Sociology

Dear Peter

PROJECT TITLE: Medical students learning diagnostic X-ray interpretation
APPLICATION: Reference Number 004868

On behalf of the University ethics reviewers who reviewed your project, I am pleased to inform you that on 20/08/2015 the above-named project was **approved** on ethics grounds, on the basis that you will adhere to the following documentation that you submitted for ethics review:

- University research ethics application form 004868 (dated 08/07/2015).
- Participant information sheet 1011000 version 1 (03/07/2015).
- Participant consent form 1011002 version 1 (03/07/2015).

The following optional amendments were suggested:

Like the other reviewer I felt that the information sheet could be clearer.

If during the course of the project you need to deviate significantly from the above-approved documentation please inform me since written approval will be required.

Yours sincerely

Sally Midgley
Ethics Administrator
Sociological Studies

Appendix 2: Research Ethics Documentation: Radiography

The University Of Sheffield.

Downloaded: 23/10/2016
Approved: 26/06/2015

Peter Winter
Registration number: 140150210
Sociological Studies
Programme: PhD in Sociology

Dear Peter

PROJECT TITLE: A comparison of visual knowledges in diagnostic X-ray interpretation between medicine and radiography across the Higher Education Institution (HEI)
APPLICATION: Reference Number 003503

On behalf of the University ethics reviewers who reviewed your project, I am pleased to inform you that on 26/06/2015 the above-named project was **approved** on ethics grounds, on the basis that you will adhere to the following documentation that you submitted for ethics review:

- University research ethics application form 003503 (dated 04/05/2015).
- Participant information sheet 1006959 version 1 (03/04/2015).
- Participant consent form 1006961 version 1 (03/04/2015).
- Participant consent form 1006960 version 1 (03/04/2015).

The following optional amendments were suggested:

- that the application should be amended to reflect and justify the true level of confidentiality/ anonymity possible - that the information sheet/ consent forms be amended to address the concerns of clarity - that the researcher considers relocating the position of the Recording equipment to minimise accidental breaches of confidentiality

If during the course of the project you need to deviate significantly from the above-approved documentation please inform me since written approval will be required.

Yours sincerely

Sally Midgley
Ethics Administrator
Sociological Studies

Appendix 3: Participant recruitment email: Radiology

Volunteers for understanding the development of radiological vision in undergraduate training

Dear medical student,

You are invited to participate in an Economic Social Research (ESRC)-funded study that looks to understand *how* medical and radiography students learn to interpret medical images. The study will use video to help make visible the subtle and nuanced interactions of the learning process. This method will focus primarily on the techniques used by the radiology lecturer to make meaningful image interpretation for student understanding: the practice of distinguishing normal from abnormal in X-ray and CT interpretation.

The study will mainly focus on the academic and classroom component that is part of your radiology rotation organised by radiology lead Dr. Maxwell.

Attached to this email is: (1) an information sheet that describes the study in more detail, including information about volunteering and video recording, and (2) a consent form.

I would be very grateful if you would consider taking part in this study.

If you would like to take part in this study, please complete and sign the consent form and hand in to either Dr. Maxwell or myself. If you would like to know more, please don't hesitate to contact me via email or phone. The research has received ethical approval from the University of Sheffield's Research Ethics Committee (UREC).

Thank you for reading.

Best wishes,

Peter Winter

Appendix 4: Participant information sheet: radiology

Department of Sociological Studies University of Sheffield

Understanding the development of radiological vision in undergraduate training

INFORMATION SHEET FOR MEDICAL STUDENTS

Invitation
You are being invited to take part in a research study. Before deciding whether you would like to participate, it is important for you to understand why the research is being carried out and what it involves. This sheet outlines the purpose and implications of the study and provides more detailed information about its conduct. I am happy to answer questions and clarify anything that is unclear. Please take time to read the following information carefully and discuss it with others if you wish. You will be able to keep this sheet and if you take part you will be asked to sign a consent form which you will also keep. If you would like to participate, please sign up. Thank you for reading this.

What is the purpose of the study?
The learning of X-ray interpretation is not well understood. Despite X-ray being amongst the most routinized techniques in imaging practice, the lack of research into the processes and interactions of students learning to 'see' or 'read' radiological images raises significant questions about teaching, interpretive knowledge/skills and possibly patient safety.

I am *not* interested in measuring competence or performance. This study will consider ***how*** medical and radiography students learn to 'see' or 'read' X-rays as part of their undergraduate training. I am particularly interested in the techniques professionals use to help you interpret X-rays, including what you find useful or relevant in the learning processes.

Do I have to take part?
It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you are free to withdraw at any time and without giving a reason.

What will happen to me if I take part?
Video recording
I will video-record the image interpretation class (as part of your radiology rotation) at The Royal Hallamshire Hospital, Sheffield which runs between **14/01/16 – TBC.** Everyone in the class will be given a consent form to participate. If anyone decides they don't wish to be recorded there is an option on the video analysis software to blur or render you indistinct. Also, the cameras can be positioned so it doesn't include you.

What about confidentiality?
Information from individual interviews will be kept strictly confidential. The research location and identities of everyone taking part in the study will be anonymised. Any information which may identify you will be removed. Electronic or manual data collected (video recordings, audio recordings, transcripts) will be stored in a locker on University of Sheffield security-controlled premises (i.e. Department of Sociological Studies) and on an encrypted, password-protected MacBook Pro laptop, both of which will only be accessible by the researcher.

Are there any risks?

I recognise that some may feel uneasy at being recorded on video during lectures - please let me know and I will be sure to blur or render you indistinct using the video analysis software. For those who participate in interviews I guarantee to stop recording at any time if anyone feels uncomfortable and would like to stop. To make you feel at ease about video recording, video is now regarded as a highly valued resource for research in medical and allied health education, particularly in the analysis of teaching practices, consultations and clinical skills.

What are the potential benefits of taking part?
The opportunity to reflect on your own learning may be of benefit to your education and future practice. The overall findings of the study will aim to improve education, and may inform the redesign of UK radiology/radiography curricula. Findings may also inform future policy on effective workforce integration and facilitate collaboration in the workplace. Data will be disseminated in research papers, presentations and conferences.

Who is organising and funding the research?
Doctoral researcher Peter Winter, Department of Sociological Studies, University of Sheffield is organising the study. I am funded by the Economic Research Council (ESRC) and supervised by Dr. Kate Reed and Dr. Susan Molyneux-Hodgson.

Who has reviewed the study?
This project has been approved by the University's Research Ethics Committee (UREC) and judged not to require NHS REC approval. I will also be following the ethical guidelines of the Economic Social Research Council (ESRC) and the British Sociological Association (BSA).

What if I wish to complain?
Contact Dr. Kate Reed on k.reed@sheffield.ac.uk or Dr. Steven Kennish via steven.kennish@sth.nhs.uk

If you are willing to participate please read the information sheet and sign the consent form.
Thank you for reading.

Contact for Further Information
Peter Winter
University of Sheffield, Department of Sociological Studies
Elmfield, Northumberland Road, Sheffield S10 2TU
Email: Pdwinter1@sheffield.ac.uk
Website: http://www.sheffield.ac.uk/socstudies/postgraduate-research-students/pdwinter
Mobile: 07861371512

Appendix 5: Participant information sheet: Radiography

Department of Sociological Studies University of Sheffield

Understanding the development of visual knowledge in X-ray interpretation in the HEI

INFORMATION SHEET FOR STUDENT RADIOGRAPHERS

Invitation

You are being invited to take part in a research study. Before deciding whether you would like to participate, it is important for you to understand why the research is being carried out and what it involves. This sheet outlines the purpose and implications of the study and provides more detailed information about its conduct. I am happy to answer questions and clarify anything that is unclear. Please take time to read the following information carefully and discuss it with others if you wish. You will be able to keep this sheet and if you take part you will be asked to sign a consent form which you will also keep. If you would like to participate, please sign up. Thank you for reading this.

What is the purpose of the study?

The learning of X-ray interpretation is not well understood. Despite X-ray being amongst the most routinized techniques in imaging practice, the lack of research into learning and interaction in medical education raises significant questions about teaching, interpretive knowledge/skills and possibly patient safety.

<u>I am *not* interested in measuring competence or performance.</u> This study will consider how medicine and radiography disciplines distinguish between what is considered normal or abnormal during X-ray interpretation in the initial learning environment. I am particularly interested in the processes and strategies that students find useful or relevant when interpreting X-rays.

Do I have to take part?

It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you are free to withdraw at any time and without giving a reason.

What will happen to me if I take part?

I will video record your image interpretation lectures which run between **23/09/15 – 20/07/15.** Everyone in the class will be given a consent form to participate. If anyone decides they don't wish to be recorded there is an option on the video analysis software to blur or render you indistinct. However, bear in mind that the video recorder will be positioned at the back of the class where the back of your heads will be mainly seen.

What about confidentiality?

Information from individual interviews will be kept strictly confidential. The research location and identities of everyone taking part in the study will be anonymised. Any information which may identify you will be removed. Electronic or manual data collected (video recordings, audio recordings, transcripts) will be stored in a locker on University of Sheffield security-controlled premises (i.e. Department of Sociological Studies) and on an encrypted, password-protected MacBook Pro laptop, both of which will only be accessible by the researcher.

What do I have to do?

Attend your diagnostic image interpretation lectures throughout semester one and semester two of your first year of study (level 1). I will look to video-record your learning in classroom settings across Hallam University.

Are there any risks?

I recognise that some may feel uneasy at being recorded on video during lectures - please let me know and I will be sure to blur or render you indistinct using the video analysis software. For those who participate in interviews I guarantee to stop recording at any time if anyone feels uncomfortable and would like to stop. To make you feel at ease about video recording, video is now regarded as a highly valued resource for research in medical and allied health education, particularly in the analysis of teaching practices, consultations and clinical skills. Rest assured that your participation is an important contribution to an essential project that will greatly benefit teacher training and student understanding in medical and radiography education.

What are the potential benefits of taking part?

The opportunity to reflect on your own learning may be of benefit to your education and future practice. The overall findings of the study will aim to improve education, and may inform the redesign of UK radiology/radiography curricula. Findings will also help to inform future policy on effective workforce integration and facilitate collaboration in the workplace. Findings will also be delivered to professional bodies interested in the work (e.g. The Society College of Radiographers and The Royal College of Radiologists). Data will be disseminated in research papers, presentations and conferences. Additionally, I will set up a project web page to keep you updated.

Who is organising and funding the research?

Doctoral researcher Peter Winter, Department of Sociological Studies, University of Sheffield is organising the study. He is funded by the Economic Research Council (ESRC) and supervised by Dr. Kate Reed and Dr. Susan Molyneux-Hodgson.

Who has reviewed the study?

This project has been reviewed by University of Sheffield's Research Ethics Committee (UREC). I will also be following the ethical guidelines of Economic Social Research Council (ESRC) and the British Sociological Association (BSA).

Contact for Further Information

Peter Winter
University of Sheffield, Department of Sociological Studies
Elmfield, Northumberland Road
Sheffield S10 2TU
Email: Pdwinter1@sheffield.ac.uk
Website: http://www.sheffield.ac.uk/socstudies/postgraduate-research-students/pdwinter
Mobile: 07861371512

Appendix 6: Participant consent form: (Radiology and Radiography)

The University Of Sheffield.

E·S·R·C ECONOMIC & SOCIAL RESEARCH COUNCIL

White Rose Social Science DTC
Universities of Leeds, Sheffield & York

Study title: Understanding the development of radiological vision in undergraduate training

Name of Researcher: Peter Winter

1. I confirm that I have read and understand the information sheet dated __________ for the above study and have had the opportunity to consider the information, ask questions, and have had these answered satisfactorily. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason. ☐

3. I consent to events such as lectures, group discussions and interviews being audio/video-recorded and understand that these will be anonymised. For example, participants will be referred to by pseudonyms in any publications arising from the research. ☐

4. I acknowledge that my data (i.e. video footage, audio, learning diary, transcripts) may be used in the PhD thesis and presented at academic outlets including publications and conferences. ☐

5. I acknowledge that I can request a copy of the PhD thesis and access its findings, and copies of video footage and transcripts can be returned to participants for verification. ☐

6. I understand that participation or non-participation in the study will have no effect on grades or assessment. ☐

I agree / do not agree (delete as applicable) to take part in the above study.

______________________________	____________	______________________
Name of Participant	Date	Signature
______________________________	____________	______________________
Researcher	Date	Signature

When completed: 1 for participant; 1 for researcher

Appendix 7: Research ethics for retrospective email correspondence

Hi Pete

Your ethics amendment has been approved (please see email from Harrie, below).

Best wishes

Sally

---------- Forwarded message ---------
From: **Harriet A Churchill** <h.churchill@sheffield.ac.uk>
Date: 9 December 2018 at 09:47
Subject: Re: Ethics 003503 Peter D. Winter - minor amendments for approval
To: Sally E Midgley <s.midgley@sheffield.ac.uk>

Dear Sally,

I can approve this ethics amendment which is the use of an additional data collection method - email conversations data. I can confirm this is a minor amendment and no further review action is needed.

Best wishes.

Harrie

Appendix 8: Examples of email correspondence questions

- What do you consider to be 'technical effects' in radiography?
- Are foreshortening and elongation types of optical illusion or shape distortion? What's the best way to describe these?
- When a professional (radiographer/radiologist) says: 'I don't know how well it projects on here' - is this in reference to the gross 3D projection of the bony anatomy? Or is it in reference to how the x-ray beams project the anatomy in the 2D image?
- What does it mean when a radiograph as a 'high contrast' or a 'low contrast' and what does this mean in terms of visibility of anatomy? For example, if a radiograph of an anterior ankle has a high contrast would that cause a 'high blur'? Would application of a low contrast decrease the brightness of a radiograph?
- How are radiology rotations/clinical placements organised?
- When children have a pneumothorax does the lung collapse but actually appear lucent? Or is it that the child is diagnosed with pneumothorax but the lung hasn't collapsed? It seems like the pneumothorax/lung collapse is more visible (opaque/white/sail sign more defined) in adults, whereas in children this might not be the case?
- Is there a term or concept around misinterpreting the wrong pathology? For instance, if a medical student mixes up a collapsed lung with pneumothorax? I know there are terms for 'underdiagnosis' (false negatives) and 'overinterpretation' (false positives). However, this type of misinterpretation is different from these two?

Appendix 9: EASST 2016 abstract

Cultivating radiological vision through highlighting/graphic representation

Peter D. Winter
Department of Sociological Studies
University of Sheffield

Short abstract:
Using video footage, I explore highlighting/graphic representation practice in the early stages of x-ray image interpretation training in medical-radiology. My analysis contributes to discussion on the development of professional vision and embodied skill, while contributing insight to a regime of interpretive practice.

Long abstract:
STS has previously identified highlighting practices (Goodwin 1994) among radiological professionals in the production and interpretation of medical images (Joyce, 2008). However, as yet there appears to have been no attempt to study the ways in which this practice is learned. My focus then, is on the highlighting practices found in undergraduate medical students' training. I explore the teaching practices of radiologists in a meeting room that is 'back-stage' to the clinical and workplace setting. Drawing on Goodwin's notion of professional vision, the paper presents how highlighting work is imbued with meaning for those learning to 'see' and 'interpret' x-ray images and shows how highlighting helps to cultivate a professional vision of normal and abnormal anatomy. Using video footage and novel video analytical techniques, I will show how the highlighting of anatomy had two functions: to make salient anatomy that is present in the image; and to make expectable anatomy that is absent in the image. I will also show how the activity of making anatomy salient/expectant is an ambiguous practice in that they are both highlighted and graphically represented *at the same time*. Graphic representation can take multiple forms such as: hydrographic (specifically the symbolic language of erosion and flood control); and geometric, including shapes such as ellipses, arrows, zig-zags, dots, and 'blobs'. This paper contributes to an understanding of the diverse practices that are used to build professional or radiological vision. Doing so will tease out some of the creative techniques that allows the professional to speak authoritatively on what they see, while imbuing students themselves with a radiological vision in apprenticeship.

Appendix 10: Radiography cohort 2015/2016: dates and consent

Radiography students

Woodfleet University	Number of participants	Gender split
Consented	42	13 male 29 female
Non-consented	6	2 male* 4 female

* The second male student emailed me on 12/10/15 asking to be removed from the video

Appendix 11: Radiology rotations 2015/2016: dates and consent

Medical students

Rotation/room/date	Number of participants	Gender split	Phase group
Radiology rotation 4 *BRMR* (5/10/15 - 28/11/15)	12	6 male 5 female	Phase 3b
Introductory lectures: Intro to radiology lecture* *Large lecture theatre, medical school* (13/01/16)	6	5 male 1 female	Phase 3b
Radiology rotation 1** *BRMR* (18/01/16 – 04/03/16)	7	5 male 2 female	Phase 3b
Neurology* rotation** *Neurology meeting room* (02/03/16)	10	5 male 5 female	Phase 3a

* The 'Introductory lectures' was a day of hour-long lectures introducing the whole year cohort to their forthcoming clinical rotations.
** I decided to miss Dr. Saury's teaching on 01/03/16 as it clashed with AXR image interpretation class. To make up for this, Dr. Saury offered me the opportunity to record CT image interpretation training
***This teaching occurred as part of a neurology rotation in the neurology department and used CT images (of the head) instead of radiographs

Appendix 12: List of video recordings

Semester 1 Profession	Module	Location/class type	Professional	Date	Video	Audio	Duration	Number of students	Gender split F	Gender split M
Radiography *- Split into two lectures*	MSK 1/Introduction	- Large classroom (Old building) - Lecture	Mrs. Campbell	28/09/15	X2	X2	Part 1. 51mins 13secs	?	?	
	MSK 1/Introduction to Image Interpretation	- Large classroom (Old building) - Lecture			X2	X2	Part 2. 45mins			
Radiography *- Intro 'what are x-ray images?' Inc. radiophysics* *- Small room* *- Using anatomical models*	Application of Imaging 1/ Labelling exercise	- Small classroom. (New building) -Seminar/Round robin	Mr. Richards	01/10/15	X2	X2	4 hrs. (Approx.)	Group 1: 11 Group 2: 11 Group 3: 11 Group 4: 9? **Total: 42**	7 8 8? 7?	4 3 3? 2?
Radiology *- Some AXR cases*	CXR/AXR Interpretation	Meeting room Radiology	Dr. Maxwell	06/10/15	X2	X2	1hr 11mins	3	2	1

		department.								
Radiography - *Interruption (Mobile phone)*	Application of Imaging 1 CXR	- Average Classroom. (New building) - Lecture/Round robin	Mr. Hearken	08/10/15	X2	X2	59mins 14secs 51mins 5secs 56mins 43secs 52mins 56secs	Group 1: 12 Group 2: 12 Group 3: 12 Group 4: 9 **Total: 45**	8 8 8 6	4 4 4 3
Radiology - *Same group*	CXR Interpretation	Meeting room Radiology department.	Dr. Saury Dr. Maxwell	20/10/15	X2	X1	1hr 16mins 1hr 2mins	3	-	3
Radiology - *Same group* - *Uses CT* - *No AXR*	CXR/AXR Interpretation	Meeting room. Radiology department.	Dr. Delichon Dr. Maxwell	03/11/15	X2	X1	1. 57mins 7secs 2. 42mins 4secs	3	1	2
Radiology - *Uses CT*	CXR/AXR Interpretation	Meeting room. Radiology department.	Dr. Delichon (CXR) Dr. Maxwell (CXR/AXR)	17/11/15	X2	X1	55mins 41secs 1hr 8mins	2	2	-

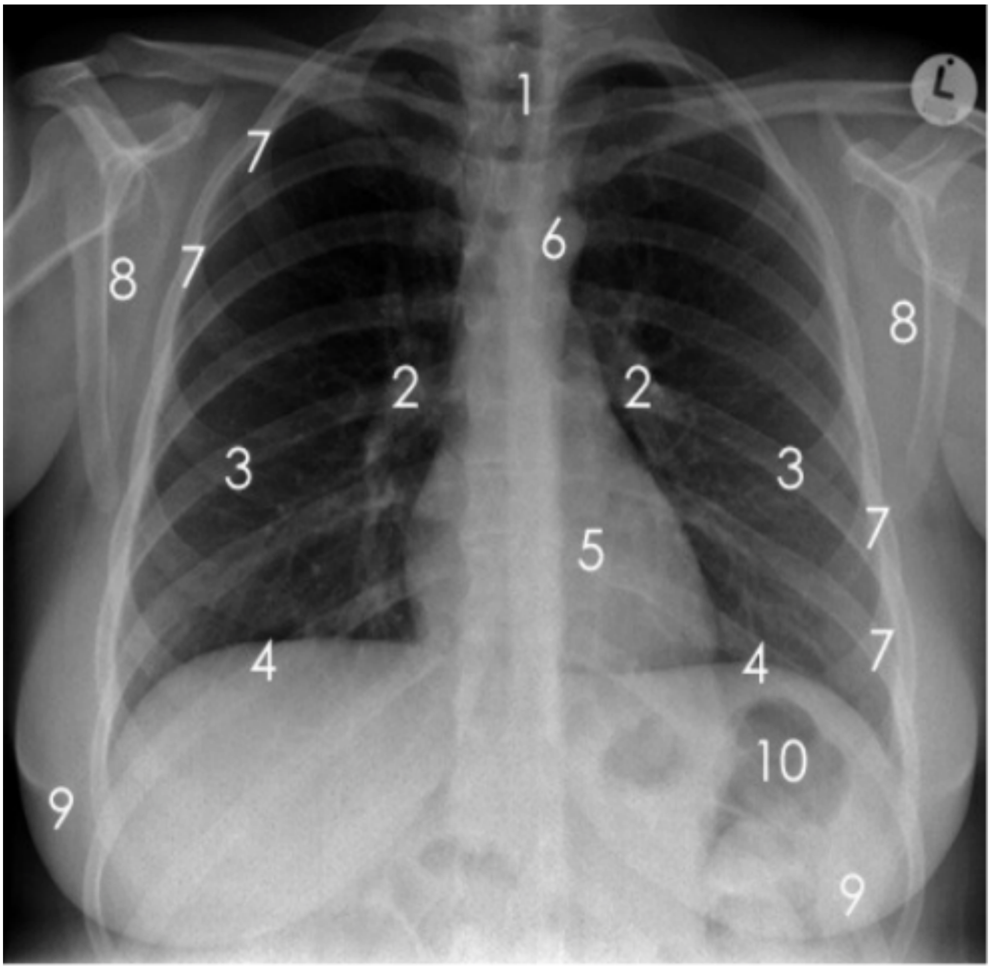
Semester 2 Profession	Module/Lecture	Location	Professional	Date	Video	Audio	Video Duration	Number of students	Gender split	
									F	**M**
Radiography	MSK 1/Shoulder II	Large classroom. Old building - Lecture	Mrs. Campbell	04/01/16	X2	X3	1. 53mins 51secs 2. 36mins 48secs	**Total: 38**	26	12
Radiography Other info: - *Help from RA* - *Female participant moves audio recorder elsewhere*	MSK 1/ Shoulder II	- Average classroom. New building - Lecture/round robin	Mr. Hearken	07/01/15	X2	X2	57mins 35secs 1hr 1hr 8mins 1hr 1mins	Group 1: 8 Group 2: 13 Group 3: 8 Group 4: 7 **Total: 36**	5 9 5 5	3 4 3 2
Radiology - Ethics discussion with female student - Fire alarm + Evacuation	CXR interpretation	- Large lecture Theatre 2. Medical school. - Lecture	Dr. Saury	13/01/16	X2	X3	47mins 33secs	**Total: 58?** (Approx.)		
Radiology - Joined by FYD	AXR interpretation	Meeting room. Radiology	Dr. Clyde	18/01/16	X2	X2	43mins 49secs	4	2	2

looking to specialise in radiology		department.								
Radiology - Joined by FYD looking to specialise in radiology		Meeting room. Radiology department.	Dr. Maxwell	19/01/16	X2	X2	54mins 45secs	4	2	2
Radiography *- Asked to write a placement learning diary* *- Participated in lecture by 'playing with bones'*	MSK 1/ Pelvis II	Classroom. New building - Lecture/round robin	Mr. Hearken	21/01/15	X2	X3	1hr 32mins 1hr 15mins	Group 1: 17 Group 2: 11 **Total: 28**	F: 12, M: 5 F: M: 3	
Radiology	CXR interpretation	Meeting room. Radiology department.	Dr. Maxwell	02/02/16	X2	X2	1hr 5mins	2	-	2
Radiology *- No time for AXR*	CXR/AXR interpretation	Meeting room. Radiology department.	Dr. Maxwell	16/02/16	X2	X2	50mins 14secs	3	1	2
Radiography	MSK 1/ Spine II	- Small classroom. New	Mr. Hearken	25/02/16	X2	X3	1hr 42mins 1hr 32mins	Group 1: 17 Group 2: 14	F: 13, M: 5 F: 10, M: 4	

		building - Lecture/round robin						**Total: 31**		
Radiography *- Help from RA* *- Small group presentations* *- Split into small group work.*	AoI 1/AXR II	- Large classroom. Old building. -Lecture	Mr. Richards	01/03/16	X2	X3	1hr 58mins	14 15 **Total: 29**	F: 10, M: 4 F: 10, M: 5	
Radiology *- Phase 3a on neurology attachment*	CT head	Neurology meeting room Neurology department	Dr. Saury	02/03/16	X2	X3	59mins 46secs	Total: 12	5	6
Radiography *- At end of class a female participant asks: 'how can I stop recording this thing?'* *- Some students stayed at the end but were out of shot. Camera turned off after the above student commented.*	MSK 1 II summary and OSCE revision	Large classroom. Old building. Lecture	Mr. Hearken	14/03/16	X2	X3	1hr 34mins	 **Total: 31?**	F: 24? M: 7	

Radiography - Round robin - In group 3, video camera is imagined as the source of x-ray/detector (19mins) - Uses model skeleton	FINAL MSK 1 II	- Small classroom. - New building. Seminar/round robin	Mr. Hearken	17/03/16	X2	X3	57mins 50secs 57mins 53secs 56mins 24secs 52mins 41secs	Group 1: 8 Group 2: 9 Group 3: 9 Group 4: 7 **Total: 33**	F: 6 F: 7, M: 2 F: 7, M: 2 F: 6, M: 1

Appendix 14: Normal CXR anatomy with 'visible' anatomical structures 1-10



Visible structures

- **1** - Trachea
- **2** - Hila
- **3** - Lungs
- **4** - Diaphragm
- **5** - Heart
- **6** - Aortic knuckle
- **7** - Ribs
- **8** - Scapulae
- **9** - Breasts
- **10** - Bowel gas

Appendix 15: Systematic approach for CXR (radiology)

i) diaphragm ii) heart iii) hila iv) Apices

How to Review the Chest Radiograph

The following is a logical way to review a CXR as the order lends itself to presenting the findings as you go along but any order is fine so long as it covers everything and you stick to it. If presenting, don't present every single negative finding as you'll find that it gets boring. Aspects can be summarised eg. "technically adequate", "lungs clear", "normal heart and mediastinum" etc.

Patient identifiers and demographics: Name, hospital number, date of birth/age, ethnicity, gender

Technique: PA/AP, erect/supine, portable

Technical adequacy:

Inspiration- This depends on the patient but ≥6 anterior ribs above the diaphragm is a good guide.

Rotation- The medial ends of the clavicles should be equidistant from the spinous processes of the vertebral bodies.

Penetration- The vertebral bodies should be perceptible through the heart but the lungs shouldn't be too black (ie. you should be able to see the vessels).

Field of view- The whole of the thorax should be included on the image.

Lines, tubes, foreign material: Describe what's there eg. sternotomy wires, metallic mitral valve replacement, surgical clips in the axilla, right internal jugular line, NG tube, ET tube etc. In the case of lines and tubes, state whether they are in satisfactory positions.

Heart and mediastinum: Normal contours, size, borders, density, lines (paravertebral, azygo-oesophageal, junctional)? Don't worry if you are not familiar with all of these- some are radiology minutiae!

Lungs: Opacity (consolidation, reticular, nodular, mass), lucency: hyper-expansion, bullae, pneumothorax, volume loss (mediastinal shift/tracheal deviation/hilar displacement **towards** the lesion, diaphragmatic elevation), mass effect (mediastinal/tracheal/hilar shift **away** from the lesion).

Pleura: Thickening, effusion, calcification, nodularity.

Bones: Lucency, density, fractures.

Soft tissues: Surgical emphysema, calcification, nodules, mastectomy.

Review areas (areas where it is easy to miss stuff- so look again!): "Beneath" the diaphragm (ie. the upper abdomen and the basal segments of the lower lobes- parts of which lie behind, and are therefore superimposed on top of, the diaphragm on the chest x-ray), "behind" the heart (easy to miss things as it's already pretty white here), the hila (lots going on here (vessels, bronchi etc.) and a common place for malignancy and lymphadenopathy to hide), the apices (again, worth a review as there is lots going on with ribs, clavicles etc. getting in the way).

Summarise: If presenting, don't forget to summarise. Try to keep it succinct with only the main positives and important negatives mentioned. Finally, come up with the diagnosis (hopefully) or a list of differentials (lean on your surgical sieve if all else fails) and explain your next steps eg. referral to the lung cancer MDT.

Appendix 16: Systematic approach for CXR (radiography)