# Towards Invisible Style of Computer-Mediated Activity: Transparency and Continuity

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# Abstract

Whether use is for learning and training, entertainment, information gathering, communication or commerce, an encounter with three-dimensional interactive mediated environments (e.g. virtual reality, virtual environments and computer /digital games) can be considered an experience. Implied in the associated terms engagement, involvement, agency, immersion and presence is that experience presupposes users' focus of attention is directed towards mediated content. While a proliferation of work identifies the experiential potential of products, technology and interactive media, tools and techniques from human-computer interaction are however, unable to fully account for this shift towards an experiential perspective.

This thesis proposes an invisible style through the unity of transparency of equipment and continuity of mediated content to allow users to continuously experience a mediated environment and encourage users in "staying there". This works towards providing ways to reason about mediated environments that enhance natural human abilities to work, play, learn, shop, communicate, create and be entertained. To this end, concepts from activity theory are extended and fused with those from human-computer interaction and film, leading to the development of the hierarchical activity-based scenario approach and a framework of experience to reason about human practice and experience of performing work and non work-related activities within contextual environments depicted virtually. This activity-based approach informs analysis and in turn design of scenarios/narrative for experience through an invisible style to maintain a continuous illusion of interacting in mediated content so encouraging users in "staying there".

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*To mum and dad*

# Chapter One Introduction

Interactive mediated environment is the term used to encapsulate similarities in, and the merging of, computer-based media such as the Internet, virtual environments and reality, and computer/digital games. In contrast to the standard two-dimensional graphical user interface (GUI) windowing environment, the display is the window into illusions of real, imaginary or abstractions of three-dimensional environments or space. Through either a first or third-person perspective, space is the context of use providing opportunities for user activities in scenarios with objects and actors. The egocentric nature of performing activities and the environments' real-time response induce feelings of acting vicariously (i.e. experienced imaginatively through another person, being or object) within a mediated environment. Acting vicariously has the potential to induce experience in users.

The motivation for this thesis is an attempt to find ways to reason about the concepts described above. To this end, it describes work towards the formation of a conceptual framework in which to reason about experience of use with, and guide analysis of interactive mediated environments. The emphasis of this thesis is on evaluation. While the motivation for conducting HCI research is commonly cited as "design is where the action is" (Newell and Card 1995), design, use and evaluation are however, all intertwined and overlapping practices so investigation of one without consideration of the others is problematic (e.g. Bannon 1993, 1994; Rogers, Sharp and Preece 2002). That is, considered from an engineering perspective, to assess whether design meets requirements, it is necessary to evaluate design in the context of use and any subsequent shortcomings are then used to inform redesign and so on, in an iterative manner. Designing consistently well requires knowledge about what makes good design, informed from principles, guidelines or criteria. So how do we know what is good design and how can we evaluate to meet design requirements?

What are the evaluation criteria by which to assess design in use? Furthermore, how do we inform design and evaluation to keep in-step with rapid technological and innovative developments in interactive mediated environments? Although design, use and evaluation are intertwined processes, it must be emphasised that design is not the main focus of this thesis, but to find appropriate ways to evaluate IMEs; that is, the evaluation of design in use. Therefore, the work in this thesis concentrates primarily on evaluation.

While previous work has made significant contributions further informing our knowledge of evaluation and design, they generally remain isolated and disparately performed research activities. This fragmented approach makes difficult the effectiveness and ease in which to interweave research activities that may benefit from a unified or shared analysis and design agenda. Aside from human factors related issues such as, physiological (e.g. pupil response, EEG), psychophysical (e.g. relate stimulus magnitude to subjective rating) and system performance characteristics (e.g. frame rate, field-of-view, resolution), the thrust of previous work can be identified as coming from two distinct areas. The first builds upon human-computer interaction (HCI) focusing on interaction (e.g. Bowman, Johnson and Hodges 2001; Poupyrev, Weghorst, Billinghurst and Ichikawa 1998) and usability (e.g. Kaur, Maiden, and Sutcliffe 1999; Hix, Swan, Gabbard, McGee, Durbin and King 1999; Steed and Tromp 1998). However, it is argued that the unique concepts introduced by performing activities vicariously within mediated environments, as outlined above, are insufficiently supported by traditional HCI design and evaluation methodologies developed for the standard two-dimensional GUI. So attempting to extend these methodologies to account for such complexities in human-interactions may prove limiting and problematic. Indeed, there has been concern for some time that HCI informed from cognitive science is too restrictive a paradigm and a turn towards other theoretical approaches has been proposed (Bannon and Bødker 1991; Kaptelinin 1992; Kuutti 1996; Nardi 1996b; Norman 1991; Rogers, Bannon, and Button 1994). These concerns stem from the need to consider context, artefacts and the social (as opposed to individual) in relation to work-related tasks and technology as witnessed for example in the interest shown in Computer Supported Cooperative Work (CSCW). The second area of research comes from an experiential perspective. Much experiential research has focused on user feelings of "being in" or "being there" (Heeter 1992) within a mediated environment and similar terms used to describe the concept of "presence". While much work in presence has been carried out with some even identifying it as an important goal of virtual environments (e.g. Slater and Wilber 1997; Bystrom, Barfield and Hendrix 1999), presence restricts discussions to experience that occurs "instant by instant" (Lombard 2000; Lombard and Ditton 1997). Hence, it could be argued that experiential research on a sense of presence has perhaps overshadowed or even overlooked other experiential work of interactive mediated environments, and in particular, in virtual reality. So rather than restricting discussions within the constrained boundaries of a sense of presence, it is argued that a shift towards a wider arena in which all experiences occurring in unfolding events, episodes, the "big picture" of a scenario and the after-effects/affects/consequences that are, or have been, witnessed or evoked in users of interactive mediated environments is more useful. The limiting factors in HCI and experiential analysis and design, as outlined above, and the continuation of these disparately performed research activities could potentially fail to identify and locate significant issues that may inform design further and propel this technology into more useful and exciting areas in the workplace, at home, at leisure, in education and on the move.

Lombard and Ditton (1997) have attempted to shift the concept of presence further defining it as the "perceptual illusion of non-mediation". Thus, drawing attention to the importance of perceptual and continued feelings of a non-technologically mediated illusion and focus of attention staying in the illusion. Continuous uninterrupted interactive mediated environment use helps maintain the illusion for the user (e.g. Usoh, Arthur, Whitton, Bastos, Steed, Slater and Brooks 1999) and continue the potential for the inducement of experience. Disruptions break the illusion and consequently, break experience. Accepting this argument we can say that one of the goals of interactive mediated environment use is to remain or stay focused in "flow" (see below and chapter two for further discussion) of interacting in the illusion. Concurring with this, it is argued that focus be directed towards informing mediated design that helps users to maintain or stay focused in activities in the illusion. That is, rather than talking about "being there" this thesis focuses on concepts that are better described as *staying there*. While captured well in the "perceptual illusion of non-mediation", staying there however, shifts the focus of research from presence to a wider arena in which to reason about all experience that is induced in, or witnessed by users. Staying there is a similar concept to that used to capture audience and spectators' attention in theatre and film. Most notably are Laurel's (1986; 1993) visionary ideas laying the foundations for informing user-interface design from theatre. In order to inform methods for analysis and design of interactive mediated environments for staying there, this thesis borrows from concepts and techniques used by another mediated environment to grab and hold spectators' attention - film. In particular, it extends the ideas of the "invisible style" of Hollywood filmmaking (e.g. Messaris 1994 pp. 150-154). While previous work demonstrates the enthusiasm for informing design of user-interface (e.g. McKendree and Mateer 1991; May and Barnard 1995) and virtual environments (e.g. Laurel, Strickland, and Tow 1994; Pausch, Snoddy, Taylor, Watson and Haseltine 1996; Persson 1998) from film, this work is largely confined to comparison, commenting and suggesting, and there is very little in the way of clearly drawn out paths from film or filmmaking to analysis and design.

Users interact with mediated environments for a number of reasons, for example, work-related, education, commerce, leisure and entertainment. It is argued that any encounter with technology can be considered an experience. Our intentions drive our use. Whether motives are as Malone (1981) puts it, intrinsic (i.e. internal) or extrinsic (i.e. external), if the outcome of interactive mediated environment use does not match-up to, deliver on, is not interesting or informing, etc., it will not have been successful in providing outcomes that motivated users to use mediated environments. This has the potential to lose or break users' attention. However, even if our motives have not been matched, users may find something else interesting that captures their attention. In which case new motives are created that stimulates users' interactions, encouraging them to stay there, keeping them in "flow" of their activities and so continues the potential for the inducement of experience.

While usability traditionally informed analysis and design of computer-based applications that supported work-related tasks, there is however, a need to account for the shift in computer use to a more experiential perspective. Indicators of this shift can be seen in the increased use of the term *user experience.* While the term has gained increased currency to encapsulate emotional, affective and consumer use of computer-based systems and products it has not however, found widespread acceptance and its precise meaning remains unclear. One reason for this is that irrespective of the amount by which user's intentions are to shop, "learn, explore, noodle around, play, and entertain ourselves" (Laurel 1993 p. 134), aspects of usability (e.g. useful and usable) are still of great importance. In addition, while there is no disputing the need to consider experiential use, users still however, perform work-related activities with computers. Therefore, it is argued that usability and user experience should be considered as complementary and harmonious. In short, they are different sides of the same coin and this is captured well in the call for "expanded concept of usability" (Hassenzahl, Platz, Burmester and Lehner 2000; Logan 1994).

In what can be considered as a reply to this call, this thesis will argue for the fusion of two concepts from HCI and film. First, is the concept of *transparency* of enabling, supporting or mediating technologies and interactive devices that has received much attention in HCI (see further explanation below). Discussions on transparency are continued in chapter four. Second, the context of use or content of a mediated environment and objects, virtual actors and things within it (constructed from anything from cartoon-like to photo-realistic) and their real-time behaviours needs to maintain a convincing, coherent and continuous flow of narrative, held together rationally within the scene, settings and circumstances of what is best described as the social and cultural framework depicted virtually. In short, to use a filmic term, it is argued that interacting within mediated environments must have *continuity* - a term that will be elaborated and so deserves further explanation. Aristotle maintained that for things to have continuity "quantities – lines, surfaces, solids, motions, and in general time and space – must be continuous, not discrete" (Lovejoy 1974 pp. 55-56). The Oxford English Dictionary (1989) defines continuity as: 1. "the state or quality of being uninterrupted; having no ...breaks; uninterrupted connexion of parts; un-brokenness"; 2a. "...uninterrupted in sequence or succession"; 4a. "continuous or connected whole; a continuous or unbroken course or series". Continuity is increasingly used to emphasise moves in computer use and design. For example, to model and reason about the continuous nature of emerging and novel human-computer interactions (e.g. Doherty and Massink 1999; Doherty, Faconti, Massink and Wilson 2002; Faconti and Massink 2000; Smith, Duke and Massink 1999), to refer to the "smoothly integrated" virtual and real environments in augmented reality (Nigay, Dubois and Troccaz 2001), to inform design of a "smooth animation" "to maintain an illusion of a perceptually consistent [virtual] world" and provide continuity of experience for users (Hubbold, Murta, West and Howard 1995; see also: Slater, Steed and Chrysanthou 2001), and similarly relating continuity to experience, in a field geology study contributing to a "continuity theory of presence" that informs virtual planetary explorations (McGreevy 1992; 1994). This is no less relevant than some of the most important arguments and goals of traditional *time-based* media (e.g. radio, TV, film) to maintain a continuous and coherent flow of content or narrative, to engage humans and as an antidote to disruption. In broadcast media for example, continuity is defined as: 6b. "a series of linking announcements, interpolations, or the like in a radio programme or broadcast; the maintenance of a continuous sequence in broadcasting"; and in cinema continuity is defined as: 6a. "a detailed scenario for a film; also, the maintenance of consistency or a continuous flow of action in successive shots or scenes of a cinema or television film" (Oxford English Dictionary 1989). Referring specifically to the Hollywood filmmaking process, Bordwell, Staiger and Thompson (1988 pp. 194-213) refer to this as "continuity system". Indeed, May and Barnard (1995) talk about informing interface design from cinematography by "preserving thematic continuity". Chapter five discusses further continuity in film as encapsulated in the term "invisible style". In this thesis, continuity will refer to the continuous and coherent flow of content of computer-based media or mediated environments in response to human interactions. It is argued that the alternative to continuity is: an interrupted whole, discontinuous, discontinuity, in other words, breakdown. In addition, this thesis will work towards the development of arguments that allow society and culture within mediated environments to be considered by the way they have continuity. To encapsulate *transparency* and *continuity*, the term *invisible style* of computer-mediated activity will be used. Invisible style aims to promote design that will encourage users to hold their focus of attention in the content (i.e. staying there) and as a consequence, users receive experience that is intended by designers.

To this end, what is required is a conceptual framework in which to consider an invisible style and formulate a basis to reason about human practice and experience of performing activities in scenarios in the context of use (i.e. social and cultural environment depicted virtually) within mediated environments. Furthermore, this theoretical approach must provide a means of incorporating/transforming the physical interactive device into a virtual tool (i.e. linking the physical with the virtual) in the context of use and so provide the illusion of acting directly within a mediated environment rather than with an "intermediary". Such a conceptual basis is found in concepts provided by activity theory originating from Soviet psychology (Leont'ev

1974, 1978, 1981) and formulated from "sociocultural" psychology (e.g. Cole 1996; Engeström 1987; Vygotsky 1978; Wertsch, Del RíO and Alvarez, 1995). The adoption of activity theory has been seen by many as an alternative and expansion of cognitive science to inform HCI (e.g. Bannon and Bødker 1991; Nardi 1996a). Furthermore, Mantovani and Riva (1999) have proposed a sociocultural approach as an alternative concept for considering presence. Activity theory provides a hierarchical framework and theoretical basis in which to view human practice (i.e. individual and social) in contexts, mediated by artefacts (i.e. mental and physical), through the unity of consciousness and activity. Extending concepts of activity theory and fusing it with those from HCI and filmmaking, this thesis provides an arena in which to model and reason about human practice and experience of low-level device operations through goal directed actions/tasks to a holistic activity perspective, rather than task/goal-based interface (i.e. tool) use in isolation (i.e. traditional HCI). Furthermore, this provides the basis for the analysis and design of scenario or narrative in interactive mediated environments.

Finally, this thesis advocates moves towards a craft-based approach in the design of narrative and mediated environments. Related discussions concerning "soft" or "hard" approaches have continually surfaced in the HCI community (e.g. Long and Dowell 1989). This thesis is not arguing against engineering or scientific methodologies, but emphasises the artistic and creative aspects of design of interactive mediated environments within permissible constraints of the media or platform. As mentioned, the work contained in this thesis is informed from filmmaking. The craft-based nature of filmmaking is described well in the words of Boorstin (1995 p. 5): "How does a surgeon attack a tumor, a lawyer a murder case, or an architect a concert hall? When you learn a craft, or a profession, or an art (and film is all of these), you have to master a way of thinking as well as a set of skills. A way of approaching the problem that make techniques your tool." This thesis works towards the development of concepts, models and tools to inform the analysis of interactive mediated environments. This in turn is able to inform design of IMEs; however as mentioned, design is not the focus of this thesis, rather the emphasis is on finding appropriate ways to evaluate IME design in use. The ways in which the approaches developed in this thesis can inform design of IMEs are discussed in future work in chapter nine (9.4).

## 1.1 Thesis Outline

The work herein is best described as multidisciplinary. This means that much of the research carried out into normally disparate subject areas from both art and science are interwoven and generally inform one another. The chapters are compartmentalised into main subject or research areas, referring between chapters and presenting literature reviews where appropriate.

To start, chapter two presents a review of experiential research of computer-based systems. Next, the merging of usable and experiential computer use as encapsulated in Hassenzahl, Platz, Burmester and Lehner's (2000) and Logan's (1994) call for an expanded concept of usability is reviewed. Finally, a literature review of usability, evaluation and previous usability evaluation studies of virtual reality and their limitations is presented.

While the widely used "think-aloud" verbal protocol technique is singled out as being potentially appropriate for use with virtual reality (e.g. Kaur, Maiden, and Sutcliffe 1999), chapter three describes empirical studies that demonstrate limitations with this method when applied to desktop and head-mounted display (HMD) based virtual reality (VR) systems. In particular, it is ineffective when used in isolation and as later chapters show inappropriate for experiential evaluation. Furthermore, the unavailability of effective and standardised criteria to guide evaluation is problematic because reliance is placed on the evaluator's knowledge. If the reader requires little or no convincing of the limitations of traditional usability techniques when applied to VR then they are advised to skip to chapter four that marks the beginning of work towards the development of ways to inform evaluation of interactive mediated environments (IME) in this thesis.

Chapter four proposes the use of transparency in an attempt to inform evaluation of VR systems. The term transparency as used in this thesis is described well in the words of Nardi (1996b p. 11) "to describe a good user interface...one that is supportive and unobtrusive, but which the user need pay little, if any, attention to". In adopted concepts from activity theory, it is found that notions similar to transparency are encapsulated in concepts of functional organs. A model of interaction in VR and guidelines that are intended to be a shorthand way to interpret concepts from activity theory to help identify disruptions to transparent interaction are formulated and tested against usability problems captured in the empirical study of HMD based VR. While this was shown to be effective, limitations were identified relating to the border between the user and the mediated environment, the problematic identification of context of use and consideration of artefact in context of use (i.e. socio-cultural environment depicted virtually). Proceeding chapters work towards the identification of the context of use of interactive mediated environments.

Chapter five looks to another artificial but highly successful visual medium, film. It is argued that techniques of filmmaking can inform developments in interactive VR. In particular, concepts of context, invisible style, mediation, cinematic conventions (i.e. idioms), breakdown in illusion and framework of experience (i.e. voyeuristic, vicarious and visceral). To draw similarities with film while at the same time highlighting its potential interactivity and similarities with other emerging computer-based media, VR is referred to, from this chapter forward as interactive mediated environments (IME).

Chapter six formulates a model of context of use in mediated environments incorporating functional organs and users' objective. It is argued that by maintaining the situation depicted in this model, the mediated environment, objects contained in it and interactive artefacts can be considered through the concept of functional organs. That is, to enhance natural human abilities: to work, to play, to learn, to create and to explore and as a consequence, induce experience in users. Informed from this and chapter five, guidelines from chapter four are extended to include breakdown in illusion. While these were successful in categorizing usability problems as breakdown in interaction, illusion or both, limitations in thinking-aloud techniques and task-based approaches are highlighted. To overcome limitations it is argued that a turn towards an activity and holistic perspective is necessary to provide an arena to reason about both usability and user experience. Drawing on HCI and filmmaking, an activity-based scenario approach is argued for. Furthermore, activities are identified as being characterized by the coincidence of objective outcome and motive to form "activity proper" (Leont'ev 1981 pp. 399-400), the meaningful unit of analysis in activity theory. Extending the analogy with filmmaking, it is argued that activities (and recursively to actions and operations) can be considered as a "cut up" or splicing of storylines like edits in film. Consequently, this forms the basis for a language to plan, model and describe non-linear scenario/narrative that is characteristic of new and emerging media.

Chapter seven identifies what is meant by experience in interactive mediated environments by drawing on work in experiential design and evaluation of computer-based systems and other media. Adopting a framework of experiences induced in spectators of film: voyeuristic, vicarious and visceral (introduced in chapter five), these are extended to interactive mediated environments.

Chapter eight develops a questionnaire (see: Appendix IV and V) to capture these experiences and this is applied to two studies. Using results from the questionnaire and expanded concepts of activity theory (i.e. the hierarchical activity-based scenario approach: HABS) provides an arena in which to reason about human practice and experience of performing activities and scenarios with interactive mediated environments. The studies attempted to answer the following research questions:

1. to what extent is experience within the broad categorisations of the developed framework evoked in users, and overall how effective is the questionnaire at capturing user experience in interactive mediated environments?
2. what assumptions can be drawn about the extent to which inaccurate or deficient experience potentially breaks or shifts users' focus of attention from the mediated to the real world?
3. do users' self-reported disruptions correspond with: those observed by the evaluator, the experience data from the questionnaire, or suggest breaks or shifts in users' focus of attention from the mediated to the real world?
4. what conclusions can be drawn about the effectiveness of the matrices to capture user's vicarious experience?
5. are there any correlations between components/items of the three Vs questionnaire?
6. did the hierarchical model of interaction and the extension of the notion of functional organs provide an appropriate and effective arena in which to reason about the design of interactive mediated environments and their potential to provide experience?

Chapter nine provides a synthesis of work contained in this thesis to find ways to evaluate three-dimensional interactive mediated environments (e.g. virtual reality, virtual environments and computer games) for usability and user experience. It discusses the concepts of invisible style (transparency of equipment and continuity of content) that are informed from film to encourage users in staying there experiencing the mediated environment, shows how studies carried out throughout this thesis relate to each other, the main themes of the thesis (i.e. staying there through an invisible style) and to the HABS approach and how they provide ways to reason about disruptions to an invisible style; it highlights limitations of existing usability evaluation methods and approaches as identified in previous research, through argument and in studies carried out throughout the thesis and makes recommendations to overcome these limitations; it discusses the hierarchical activity-based scenario approach and framework of experience which address the limitations of traditional usability methods and provides a structure in which to reason about scenarios, experience, context, concepts of staying there and the invisible style in a single framework. The research questions raised in chapter eight are reconsidered in chapter nine and finally, limitations are discussed and recommendations for future research directions and challenges are presented.

Finally, chapter ten summarizes the contributions of the thesis and in particular, outlines a methodology (concepts, methods and tools) to operationalise an invisible style to capture breakdowns and user experience to evaluate IMEs for both usability and user experience. This is achieved principally through the hierarchical activity-based scenario (HABS) approach together with the three Vs framework of experience (voyeuristic, visceral and vicarious). In addition, guidelines to aid in user's comprehension of space and guidelines to identify and categorize usability problems through breakdown are discussed. A future work section concludes by discussing potential extensions of the work contained herein. In particular, extensions to HABS and concepts from activity theory to inform analysis and design, to integrate more closely HABS and the three Vs framework in order to inform design of IME content and scenarios to induce or evoke appropriate and/or stimulating three Vs experience in users and encourage them in staying there, and extending an invisible style of IMEs through the development of guidelines or techniques to manipulate on-screen space and time in IMEs to provide a way to shape character, story and enhance user's experience.

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# Chapter Two User experience, usability and evaluation

This chapter presents reviews of evaluation, usability and experiential work of computer-based systems highlighting the disparately performed nature of this research. It forms one of the main arguments for the thesis that usability and user experience are interwoven concepts and should both be considered in analysis and design of interactive mediated environments. While much is learnt from an isolated approach, and indeed, is necessary for the analysis of certain features especially in the early stages of design or when highly specific evaluations are of interest, to be able to consider the experiential aspects of design, it is argued that computer-based system use needs to be considered as a whole. Furthermore, this holistic approach is necessary to assess the success of artefact use that is only made clear when observed in its intended mediated environment setting.

## 2.1 Experiential design of computer-based systems

Interaction with computer-based systems has long been identified as having the potential to induce experience in users. "The quality of the user's experience" has been described as "the ultimate criterion of User Centered System Design" (Norman and Draper 1986 p. 63). Experiential design is appearing rapidly. In most part, this is due to technological developments in computer-based and ubiquitous systems and devices, and merging of media (e.g. audio, graphics, photography, animation, moving images, etc.), and shifts the traditional view of computers as machines for work towards one that is not only for work but also for play, entertainment, education, training, communication, knowledge gathering and commerce. Examples of experiential computer use (categorized for clarity) are in: digital/multi-media (e.g. Laurel 1993; Mallon and Webb 2000; McLellan 2000; Murray 1997; Picard 1997), interactive mediated environments and VR (e.g. Heeter 1995, 2000; Robertson 2000; Pierce, Pausch, Sturgill and Christianen 1999) and the Internet (e.g. Höök, Persson and Sjölinder 2000; Wright, Belt and Lickorish 1998). Specific experiences have been identified as being induced in users through empathy and catharsis (Laurel 1993), emotional and affective (Picard 1997), curiosity, interest, entertaining and aesthetic (Höök, Persson and Sjölinder 2000) and fun and enjoyment (Hassenzahl, Platz, Burmester and Lehner 2000). Furthermore, a common feature in much of this work and argued in chapter five is the introduction and development of characterisation, story, scenario and narrative. For example, in digital media (Laurel 1993; Murray 1997; Picard 1997), interactive mediated environments and VR (Robertson 2000; Pierce, Pausch, Sturgill and Christiansen 1999) and the Internet (Höök, Persson and Sjölinder 2000; Wright, Belt and Lickorish 1998). Hayes-Roth (1998) concurs with developments in this direction suggesting "we will achieve the desired experimental qualities (joy, rapture, enlightenment) by building story systems...around interactive characters". The common driver in experiential research is well described as an attempt to provide a pleasurable interaction for users.

The terms "engagement" (Laurel 1986 p. 69) and "agency" (Laurel 1993 p. 117) are widely used to describe the situation in which the inducement of experience occurs in users. They imply that the inducement of experience presupposes that users are absorbed in the illusion of interacting with a computer-based visual environment. Disruptions to users' interaction may potentially break the illusion and consequently break the experience. The concept of *transparency* and *invisibility* of computer use has long been argued for in HCI (e.g. Bødker 1991; Holtzblatt, Jones and Good 1988; Nardi 1996b; Norman 1998; Rutkowski 1982; Shneiderman 1987; Weiser 1991; Winograd and Flores 1986) as an antidote to disruption or breakdown. Much of this and similar work in HCI can be identified as being informed from philosophical and psychological works of Dewey (1925, 1934), Heidegger (1962), Leont'ev (1974, 1978, 1981) and Gibson (1979). For summaries and comparisons between some of these see for example, Dreyfus 1991; Koschmann, Kuutti and Hickman 1998; Heeter 1991. The use of the term transparency in computer-based systems is described well in the words of Nardi (1996b p. 11) as an interface is deemed successful when it is "supportive and unobtrusive" and "the user need pay little, if any, attention to" it when performing tasks. Put another way, the "experience of transparency" (that is, transparency in use) of an interface enables users to "remain in the flow of their work" and as a consequence, users "focus on the accomplishment of their tasks, and feel satisfied with how their work is moving along" (Holtzblatt, Jones and Good

1988). While this is very similar to Laurel's (1993) concept of agency (i.e. "the power to take action" p. 117), the consequence of transparency as described above in examples from HCI, is to keep users in "flow" of their work-related activities and not on the resulting experience. The idea of transparency in regard to work-related activities is probably best described as "transparency of equipment" (Dreyfus 1991 p. 64) or an antidote to "equipmental breakdown" (Koschmann, Kuutti and Hickman 1998). The different perspectives can be illuminated through similar arguments by Carroll and Thomas (1988) and picked-up by Hassenzahl, Platz, Burmester and Lehner (2000) (see below), as traditional HCI is concerned with usability concepts such as, *easy to use*, while Laurel's (1986, 1993) concern is experiential, or as they put it, "fun to use".

That is, Laurel's (1986, 1993) interest is not in the transparent "equipment" or "intermediary" (e.g. Laurel 1986 pp. 74-76) that is *easy to use* and keeps users in "flow" of work-related activities per se, but in the resulting experience it provides users. In her attempt to inform interface design from theatre and drama theory, Laurel (1986, 1993) links ideas of transparency to engagement (i.e. emotional and rational) through the notion of "mimetic illusion" (Laurel 1993 p. 116) borrowed from Aristotle. Mimetic illusion comes from a deliberate representation of a medium. For example, a "doll" to represent a person, a "painting" to represent a real or imaginary landscape, a "play" to represent real or imaginary events and new and emerging media to represent objects and environments, that can be either "real" or "virtual" (Laurel 1986 p. 70). She argues that "engagement means that a person can experience a mimetic world directly, without mediation or distraction" (Laurel 1993 p. 116). Distraction or awareness of the artificiality of the means of mediation would "explode the mimetic illusion" (Laurel 1993 p. 116). To avoid this she "insists" upon "direct agency" or "participation" "in the mimetic context" because of the experience it provides for users (Laurel 1986 p. 75). She refers to forms of mimesis as "pleasurable engagement" (Laurel 1986 p. 71).

Mallon and Webb (1997; 2000) build on the work of Laurel (1993) and argue that while transparency of interaction helps to create engagement, aids learning and enhances user experience, there is little in the way of criteria and methods for informing design and evaluation of engagement in "multi-media" systems (e.g. Jacques, Preece and Carey 1995; Webster and Ho 1997). Chapter four develops the concept of transparency through the transformation of interactive devices into functional organs. Subsequent chapters extend this idea to the context of use within interactive mediated environments. Thus, providing a means of considering users' engagement in activities performed directly within a mediated environment rather than with an intermediary. Moreover, this provides a theoretic basis to explore further user experience from interacting within mediated environments and a way of informing design and evaluation.

A similar idea to Holtzblatt, Jones and Good's (1988) "flow" is Csikszentmihalyi's (1975, 1990; Csikszentmihalyi and Rathunde 1993) construct of "flow". However, his work is more akin to Laurel's ideas of transparency as "engagement" or "direct agency" and a resulting participant experience. Csikszentmihalyi's "flow" construct is where involvement or engagement in an activity is so intense that a participant such as rock climber, surgeon or chess player consequently feels: a loss of time, lack of self-consciousness and intrinsically rewarding experiences, etc. It arises when skill and challenge are optimally matched. That is, between the skill of the participant and the challenge of the opponent whether it is: a sheer mountain face, fighting to keep a patient alive or an intellectually matched chess rival, respectively. While his research may usefully inform our knowledge on applications that demand a degree of challenge and skill in operation, for example in computer games (e.g. Ghani and Deshpande 1994), it is argued however, that Csikszentmihalyi's "flow" construct is inappropriate where neither skill or challenge are necessary qualities for the successful interaction with an application.

Similar to Laurel's (1986, 1993) ideas of "mimetic" illusion is that of the illusion of "presence". Presence is one of the most intensive and continued areas of research in experiential design of computer-based systems. Although no consensus definition of this concept yet exists, it is commonly described as user feelings of "being in" or "being there" (Heeter 1995) in the illusion created by a mediated environment. [Reeves (1991) provides one of the earliest uses of the term "being there" which he borrowed from the title of the novel by Jerzy Kozinski (1976) and the film directed by Hal Ashby (1979), to describe how viewers experience the environment they encounter on television. See: Lombard and Ditton (1997).] Presence is seen as a primary driver for mediated environment design and evaluation and consequently, has prompted much research in an attempt to elucidate its underlying determinants and find measures for their assessment. For summaries see: IJsselsteijn, de Ridder, Freeman and Avons (2000).

More recently there has been a shift in research in presence away from its original highly specialised focus of user feelings of "being there" towards a wider arena that allows us to describe the experience witnessed or evoked in users of mediated environments. This is well captured by Lombard and Ditton (1997) who suggest an alternative to the views that originate in most part from research in "telepresence" (see: Sheridan 1992; Steuer 1995). They define presence as the "perceptual illusion of non-mediation". That is, the perceptual or continued feelings of a non-technologically mediated illusion induce a sense of presence. This widens the scope of presence to include various traditional and emerging electronic visual media and technologies, both interactive and non-interactive, including: television, cinema, IMAX, the Internet, computer games, simulation rides and VR. Central to their definition is that the inducement of presence from these media is dependent on the invisibility or transparency of enabling or mediating technologies. This is very similar to that advocated by many in the HCI community in the design of traditional user interfaces as described above. Although, like "agency" and "engagement", the "perceptual illusion of non-mediation" is concerned with the experience it provides users. Discussions on presence and ideas for other kinds of experience users may get from interacting within mediated environments are developed in chapter seven.

Until recently, presence research has been carried out in relative isolation from much of the experiential work in HCI and has at best been sidelined, or at worst ignored by that community. The reasons for this could be they regard presence as highly specialised, ill defined and better left in the realms of fantasy and science fiction. However, shifts in research from both presence and HCI to wider experiential perspectives in which to set user activities with computer-based systems may identify similar research goals between these traditionally disparate communities. This may potentially orchestrate moves towards the development or merging of a related or shared design agenda. Indeed, with increasing moves from work-related towards experiential computer use, there is a growing interest to consider concepts like that of presence as demonstrated in recent shifts in HCI related workshops, conferences and panel sessions. Likewise, there is growing interest in the VR community that is accustomed to experiential research to consider HCI concepts such as those of usability and performance.

As mentioned, central to Laurel's (1986, 1993) ideas of mimetic illusion is the concept of transparency. Transparency is central to the success of another illusion and experience generating medium, film. The main difference between film and theatre is that film is a mediated environment unlike theatre or drama. All mediated environments undergo some form of processing before they are presented to the spectator/user. The techniques of filmmaking and film's mediation may inform techniques for design and evaluation of interactive mediated environments. Therefore, this thesis looks to the successful visual medium of film, in particular, the "invisible style" of Hollywood filmmaking (e.g. Messaris 1994 pp. 150-154). The "invisible style" of film, like that advocated by the "mimetic illusion" or the "perceptual illusion of non-mediation", owes much of its success to its ability to keep spectators' awareness from the mediating or enabling technologies and thus, maintain their illusion of non-mediation. Hence, regardless of the complexity of the underlying mediating technologies, spectators are able to focus on the content of film and engage themselves in uninterrupted levels and varieties of experience intended by filmmakers. This is the overriding motivation of filmmakers, that is, "shaping experience" (Boorstin 1995 p. 199). Although the term "invisible style" is attributable to Hollywood filmmaking, all styles of film, to one degree or another, makes use of the "invisible style". For example, in hiding of the artificiality of the means to capture and project film. Disruptions break the illusion of film and so break experience for spectators. Borrowing from film, this thesis argues for "invisible style" of interaction in mediated environments. For the purposes of evaluation, it argued that like film, disruptions or breaks to invisible interaction or content may disrupt or break the illusion and consequently disrupt user experience, pointing to potential problems in design. The main advantage for evaluation is that user experience of interacting within the VR content may be considered independently from the technology that supports it. This may support the evolving nature of the enabling technologies of VR as well as other new and emerging media technologies. In terms of design, the main advantage is that anticipation of breakdown informs design (Winograd and Flores 1986). Discussions and reviews on film, breaks to the illusion of film, the experience spectators get from film and how developments in filmmaking can inform the evaluation and design of interactive mediated environments are continued in chapter five.

The above outlines the shift in computer use towards an experiential perspective. The question now is: How can we find methods to analyse and design for experience? While many are working towards an experiential turn, at the time of writing, there is little in the way of evaluation and design guidelines as identified by Mallon and Webb (2000). One approach suggested by Hassenzahl, Platz, Burmester and Lehner (2000) is a call for "expanded concept of usability" from guidelines such as those found in ISO's 9241 (1997) (i.e. effectiveness, efficiency and user satisfaction).

### 2.1.1 HCI turn to the experiential

In an attempt to account for the shifts towards a more experiential design focus Hassenzahl, Platz, Burmester and Lehner (2000) suggest a turning away from traditional HCI performance-based and work-related design and evaluation criteria (e.g. as captured in: effectiveness, efficiency and user satisfaction: ISO 1997) towards one that encompasses both a work and a non-work-related emphasis. That is, from research, models and theories of work and work-related activities with computers that is central to most work in HCI (e.g. Bødker 1989; Norman 1991), to one that encompasses activities with the intention to "learn, explore, noodle around, play, and entertain ourselves" (Laurel 1993 p. 134). To account for this shift in focus, Hassenzahl, Platz, Burmester and Lehner (2000) build on the work of Logan (1994) and call for an "expanded concept of usability", one that promotes users' "fun and satisfaction" and is additional to traditional task and work-related design and evaluation criteria. They cite earlier work that makes similar observations arguing that the "narrow focus" of traditional usability doesn't extend well to consumer or home products (e.g. Adams and Sanders 1995; Kim and Moon 1998; Logan, Augaitis and Renk 1994). In an effort to find design principles to promote fun and enjoyment of a software system they suggest analysing "what makes computer games fun". In particular, Malone (1984) in his work on intrinsic motivation identifies three broad design categories: "challenge", "fantasy" and "curiosity" and each consists of "recommendations for designing an appealing computer game". However, while these categories may well be appropriate to earlier computer games (circa 1980's) it is questionable whether they transfer well to the enormous increases in complexity and evolving genres of today's computer games. Furthermore, it is difficult to see how they would transfer effectively to a wider assortment of developments in emerging applications of interactive mediated environments other than computer games, hence, prompting the need for more appropriate criteria.

In a footnote, Hassenzahl, Platz, Burmester and Lehner (2000) acknowledge the similarity between the International Organization for Standardization's (ISO 1997) third broad category "user satisfaction" and their proposed expansion to the concept of usability to incorporate fun and satisfaction. The awkwardness of this footnote points to the tension between ISO's user satisfaction and their call for a new or expanded concept of usability. They describe the difference as ISO's "user satisfaction" "is conceived as a consequence of user experienced effectiveness and efficiency rather than a design goal in itself". They go on to suggest this "implies that assuring efficiency and effectiveness alone guarantees user satisfaction". That is, suggesting ISO's emphasis is towards work and work-related computer use. To ease this tension perhaps it is reasonable to suggest that user satisfaction be considered as a design goal in itself and expanded to encapsulate components such as, fun, enjoyment, emotional, affective, hedonic, challenge, fantasy, curiosity and aesthetic. Moves in this direction could perhaps lead to the formation of a standard incorporating both usability and user experience and is appropriate for the design and evaluation of computer-based systems involving both work and non work-related activities.

## 2.2 Criteria for the evaluation of virtual reality

The GUI WIMP-based environment made the desktop metaphor standard for user-computer interaction. Tasks with GUIs are carried out using input interactive devices: keyboard and mouse, interacting with two-dimensional graphical objects, such as, menus, widgets and icons, performed in a windowing environment using "direct manipulation" (Shneiderman 1982; 1983; 1987). Tromp (1997) suggests that the decisive factors that need to be considered when evaluating an application running on a GUI are:

i. the performance and behaviour of the computer-based system
ii. human performance and behaviour with the application

In contrast, VR systems come in many guises for which there is no dominant paradigm. The central component of all VR systems is the three-dimensional computer generated visual models (e.g. cartoon-like to photo-realistic) of real, imaginary or abstractions of objects and environments. This third dimension creates a space or environment where all activities are performed. Tromp (1997) describes this as, tasks are not only performed *with* the VR application, but also, *within or inside* the virtual environment (VE). This is the main difference between the evaluation of tasks with GUIs and VR systems. Therefore, in addition to the evaluation criteria for conventional GUI applications as outlined in (i) and (ii) above, Tromp (1997) suggests that the evaluation of tasks performed with VR applications is also concerned with human performance and behaviour *within* the VE. This sets VR and three-dimensional virtual interfaces apart from GUIs. That is, the added third dimension has created an environment or space within which all tasks are performed. Furthermore, it is commonly believed that interacting within the environment has the potential to induce experience in users, as discussed above. To encapsulate this while at the same time emphasising the focus of this thesis (i.e. usability and user experience), a criteria of 'human practice and experience *within* a virtual environment' is used. Furthermore, (ii) above is likewise amended to emphasise an experiential shift. To provide a short hand way to show the interest of this thesis in users interacting with, as well as within a virtual environment these are incorporated as shown in (2) below:

1. performance and behaviour of the computer-based system
2. human practice and experience *with* and *within* a virtual environment

So, in answer to the question: What is the difference between the three-dimensional virtual interface and the two-dimensional graphical user interface? It is that the additional third-dimension creates a virtual environment or a space in which all activities (e.g. navigation and exploration, and object manipulation) are performed. Furthermore, performing activities has the potential to induce experience in users. This thesis attempts to find ways to evaluate these criteria. Chapter six develops a model to illustrate the criteria captured in (2) and identify mediated environments of interest to this thesis. This model relies on the explanation of a number of concepts that are tackled in subsequent chapters and so is not presented here.

## 2.3 Usability

The next chapter tests the effectiveness of traditional usability evaluation applied to virtual reality systems. To find appropriate methods for these studies, an investigation of usability and usability evaluation methods was carried out. Usability has long been applied to many systems, tools, electronic devices, everyday appliances and computer-based products. Rubin (1994) states that there is no consensus definition of the term usability that would be acceptable to all professionals in the usability community. He cites Booth's (1989) operational definition of usability that would include one or more of the following four factors: usefulness, effectiveness (ease-of-use), learnability (easy-to-learn) and attitude (likeability). This is similar to the International Standards Organisation DIS 9241-11, as introduced above, that defines usability as the ability of users to carry out work-related tasks with video display terminals (VDT): effectively, efficiently and with satisfaction (ISO 1997). Put another way, the more successful people are in accomplishing their tasks and the more satisfied they feel in carrying out their tasks, the more usable a user interface is judged to be.

The alternative to considering usability is poor quality and extra costs incurred during design and development (Gould and Lewis 1985). Unusable interfaces are frustrating to users (Carroll and Campbell 1989; Preece, Rogers, Sharp, Benyon, Holland and Carey 1994). According to Rubin (1994 pp. 3-23) designing usable interfaces will avoid "hard-to-use" products and systems, increase user acceptance and may therefore increase profits. He adds to this, usability is not simply "the ability to generate numbers about usage and satisfaction" (p. 19). Numbers may indicate whether a product works or not, but he warns that "there is a distinctive qualitative element to usability as well, which is hard to capture with numbers and difficult to pin down" (p. 19). Rubin (1994) suggests that it has to do with how one interprets usability data and recommend an appropriate course of action. He gives 5 reasons why hard-to-use products and systems are designed:

*1)* Emphasis of product development has concentrated on the system and not on the end-user.

*2)* Original users and developers of computer-based products once had similar levels of technical expertise. So systems were designed that required a certain level of technical know-how. However, today's computer-based systems users are not necessarily technical experts.

*3)* Many organisations treat the design of usable systems as if it were "just common sense". Therefore, there is a great need for usability education of designers, developers and management.

*4)* Non-integration of development teams each will add to create a product that is unusable. Therefore, more integration and communication between individuals and teams involved in developing computer-based systems is required.

*5)* In the past, designers of computer-based systems were hired for their technical expertise and their goal was simply getting the product to work. Now though, the focus has shifted from simply getting the product to work, to the end-user and how the product communicates. However, Rubin (1994 p. 9) warns that "many organisations still value the technical implementer's (machine) skills over the designer's (people) skills". To overcome some of these difficulties many advocate a "user-centred design" approach (e.g. Norman and Draper 1986).

**2.3.1 Usability problems in virtual environments**

Many researchers have identified significant usability problems with user interaction in VR systems (Rushton and Wann 1993; Kaur 1997). Whilst usability of conventional graphical user interfaces has received considerable attention over the past decade, it is still a relatively recent topic to virtual environments. According to Macredie (1995) and Kalawsky (1998) the main problem seems to be matching the VE system with the user by incorporating a robust human factors based programme into the design, development and evaluation process. The context of these comments refers to the complex technologies and the belief that an engineering/scientific approach is necessary for analysis and design of VR. On the other hand, Rushton and Wann (1993) suggests that "virtual reality builders need to take a user-centred approach and the development of hardware and software techniques should be driven primarily by consideration of the human to be placed in the system and what the user needs to perform tasks" (e.g. Wann and Mon-Williams 1996).

**2.3.2 Evaluation of usability: choosing an appropriate method**

To test usability, generally goals and objectives are specified which are typically defined in measurable terms. These terms essentially test one or more of the aforementioned attributes (e.g. Booth 1989; ISO 1997). Usability goals are measured using evaluation methods and techniques. Evaluation involves gathering and processing feedback on specific issues that are being studied to demonstrate the worth or validity of a design. This is in order to improve features of an interface or assess a completed interface. Furthermore, evaluation methods help identify undesirable features and failings with interface design. Rubin (1994 p. 3) states simply that evaluation is undertaken as an "antidote to this problem of hard-to-use products".

There is an abundance of evaluation methods in HCI. For the newcomer to evaluation, gaining a general understanding and choosing an appropriate method and deciding how and when to apply it can be a daunting undertaking. There are no hard and fast rules for choosing the best evaluation method for the job. Each method has its own particular strengths and weaknesses. Many researchers have developed methods, categorisations or taxonomies to help in this process. From standard HCI texts for example, Dix, Finlay, Abowd and Beale (1998) identify eight factors to consider in the selection of appropriate methods: the stage of development, user environment, qualitative measures and quantitative measures, subjectivity or objectivity of techniques, immediacy of response, intrusiveness, resources and information provided. While factors of this kind are useful, their use still requires a thorough understanding of a range of evaluation methods.

A complementary or alternative approach to classify evaluation methods is taxonomies. This provides a way in which to categorise and compare evaluation methods to help understand and choose between them. For example, Howard and Murray (1987) provide a taxonomy separating evaluation techniques into just three categories: expert-based, theory-based, and subject-based. In contrast, Preece et al. (1994) provide five categories: Analytical, Expert, Observational, Survey, Experimental. More formal is McGrath's (1994) taxonomy as illustrated in figure 2.1. It consists of a framework of evaluation methods categorized into similar groups and arranged along adjective paired dimensions (e.g. abstract/concrete, obtrusive/unobtrusive). Furthermore, three "desirable features or criteria", generalizability (i.e. to other populations), precision (i.e. of measurement and control over superfluous factors not being studied) and realism (i.e. "naturalness" of context of use) are identified. While the evaluator is "always trying to maximise...all three criteria" their position in the framework emphasises the trade-offs that have to be made between them. That is, increasing the importance of one criterion will reduce that of one or both of the others. While McGrath's (1994) framework may at first sight seem quite elaborate, it provides a useful and comprehensive framework in which to understand and contrast HCI evaluation methods.

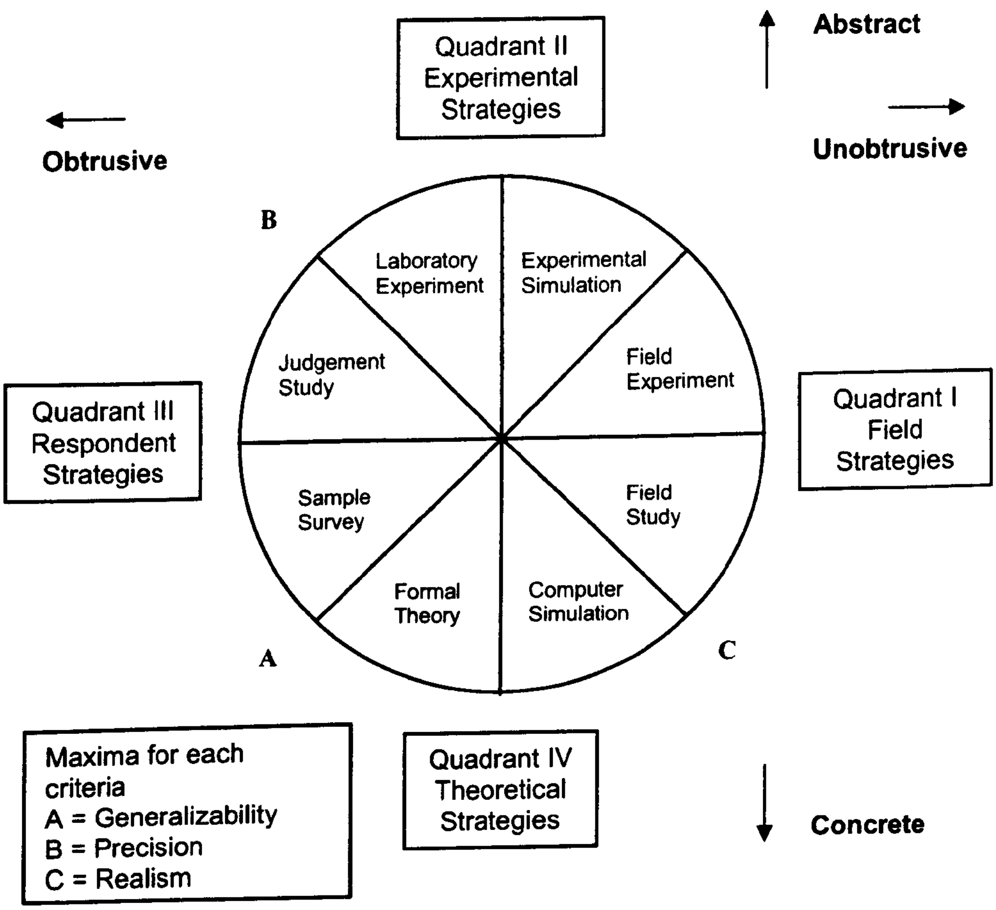



**Figure 2.1 McGrath's taxonomy of evaluation methods**

The taxonomy consists of four main strategies: *field, experimental, respondent, and theoretical*, and each of these identifies two sub-groups of evaluation method types:

***field strategies:*** study of systems in use with real tasks in real work settings.

*field studies*: observe technology or process in situ, disturbing as little as possible, e.g. ethnography (e.g. Suchman 1987), contextual inquiry (e.g. Holtzblatt and Jones 1993) and contextual design (Holtzblatt and Beyer 1996; Beyer and Holtzblatt 1998).

*field experiments*: where the impact of changing one aspect of the work environment is observed, e.g. beta testing of products and technological change

***experimental strategies:*** are usually associated with laboratory-based studies.

*experimental simulation:* where a real system is created in the laboratory for experimental purposes by typical end users, e.g. usability testing (e.g. verbal protocols: Ericsson and Simon 1984; Lewis 1982) and usability engineering (e.g. Tyldesley 1988; Whiteside, Bennett and Holtzblatt 1988).

*laboratory experiments*: to gauge the impact of an interface feature, such as, positioning and naming of menus, and design and layout of icons, e.g. controlled experiments.

***respondent strategies***: as their name suggests, obtain responses from respondents.

*judgment studies*: responses are obtained from a small set of "judges", typically providing information about the stimuli under study (e.g. an interface), e.g. usability inspection methods - heuristic evaluation (e.g. Nielsen and Molich 1990; Nielsen and Mack 1994) and cognitive walkthroughs (Polson, Lewis, Rieman and Wharton 1992).

*sample surveys*: responses from a broader set of respondents, typically designed to provide information about the respondents, e.g. questionnaires and interviews.

***theoretical strategies***: refer to evaluations with respect to human-computer interaction theory.

*formal theory*: to provide insights into interface suitability typically used qualitatively, e.g. Norman's 7 stages (Norman 1988).

*computer simulations*: models of, say, interfaces are developed (from knowledge of human information processing) and run on computers to derive predictions of user performance, e.g. GOMS (Goals, Operators, Methods, and Selection) (Card, Moran and Newell 1983; Kieras 1988).

Although the framework is by no means all-encompassing it is useful because it provides an effective way to help compare and contrast the many evaluation methods and identify where usability and experiential evaluation approaches of interactive mediated environments are best placed. Some of these methods in this taxonomy are more popular in HCI than others and so it is questionable whether researchers conducting evaluation will attempt, or will even have to consider them all when deciding on an appropriate method. That is, in the HCI literature usability evaluation methods are commonly categorized into two groups: usability inspection or analytic and empirical (e.g. Gray and Salzman 1998). Many studies have made attempts to analyse the cost-benefit (or "discount" Nielsen 1989) of these most popular methods with varying results. For example, Nielsen and Landauer (1993) suggest that for "medium-to-large" scale evaluation projects the highest benefit to costs is achieved with 4 heuristic evaluators and 3 test users. Jeffries, Miller, Wharton and Uyeda

(1991) comparing cognitive walkthroughs, heuristic evaluation, usability testing, and interface guidelines found heuristic evaluation and usability testing fared better than cognitive walkthrough or the use of guidelines. Also, they found usability testing to be more expensive, but heuristic evaluation required more expert evaluators. Karat, Campbell, and Fiegel (1992) compared empirical usability testing and walkthroughs with individuals and pairs of evaluators to two user interfaces and found that usability testing identified most usability problems. Baecker, Grudin, Buxton and Greenberg (1995) state that these studies are preliminary, and should be viewed as an ongoing series of attempts to compare evaluation methods. They conclude that the best approaches appear to be heuristic evaluation and empirical usability testing. Indeed, this coincides with their popularity of use judging by their appearance in the HCI literature as mentioned. However, as shown in earlier studies, each evaluation method has its "strengths and weaknesses" identifying different usability problems (Desurvire, Kondziela and Atwood 1992) and so perhaps should be viewed as complementary methods. Finally, these discussions would not be complete without mention to Gray and Salzman's (1998) paper challenging the validity of published comparative studies of usability evaluation methods like those mentioned above. The paper, reviews and provoking responses are probably one of the most enlightening discussions on the application of experimental design to usability evaluation to appear in the HCI literature. The future use of experimental design in usability evaluation remains to be seen and is not the subject of this thesis, although to quote from two responses: Monk (1998) suggests that "there is a value for carefully constructed experiments", however, "experiments should be employed to answer small questions" "not to answer grand questions such as those considered by Gray and Salzman"; Oviatt (1998) suggests that "perhaps the most important point made by Gray and Salzman is that studies comparing UEMs *'must be conducted that delineate the trade-offs – the advantages and disadvantages – of each method'* that is, they are capable of telling us different things about usability" [italics added to emphasise Gray and Salzman's (1998) quote].

As a starting point an initial investigation was carried out to find the appropriateness of heuristic evaluation (Nielson and Molich 1990; Nielsen and Mack 1994) and evaluation methods that employ users using a think-aloud verbal protocol (Lewis 1982; Ericsson and Simon 1984). Heuristic evaluation is a technique performed by usability specialists or experts who judge the usability of an interface against a set of guidelines or heuristics. Evaluators use their experience and intuition to identify whether a guideline makes sense in a particular context and how to apply it. Nielsen and Mack (1994) proposed a set of ten guidelines from an analysis that suggests which guidelines provide the best coverage from a factor analysis of published usability problems. Close examination of each of the ten usability guidelines or heuristics revealed that some heuristics do make sense in the context of VR. For example, *Visibility of System Status:* whereby, the system should always keep users informed about what is going on, through appropriate feedback within reasonable time and, recognition rather than recall; *Make Objects, Actions, and Options Visible:* these could clearly be made applicable or mapped to three-dimensional computer generated graphical environments and objects. Whereas, some of the ten heuristics were seen to be inappropriate for use with VR, that is, some guidelines did not make sense in the context of VR. For example, *Flexibility and Efficiency of Use:* support accelerators or fast paths for both experienced and inexperienced users; *Help Users Recognize, Diagnose, and Recover from Errors:* to express error messages in plain language. That is, it is difficult to see quite how fast paths and help systems would be supported in the context of VR.

An interesting line of research is to investigate the effectiveness of the ten heuristics that are considered appropriate or make sense in the context of VR. However, considering that Nielsen and Mack's (1994) guidelines were obtained from extensive studies of eleven published projects, and the resulting set of ten usability guidelines were obtained from an analysis of 249 guidelines, it would seem inappropriate, and possibly a little naive, to tweak or tinker with the guidelines in the hope of making them appropriate for the evaluation of VR systems. Steed and Tromp (1998) provide results of an evaluation study of a collaborative VE highlighting limitations of this method. In particular, they suggest that while heuristic evaluation is applicable to two-dimensional GUI environments it needs to be extended to account for interactive capabilities in three-dimensional virtual environments. That is, while heuristic evaluation picked-up a number of usability problems, without guidelines being appropriate for use with three-dimensional virtual environment they were perhaps relying on personal heuristics developed from their own experience and initiative to capture usability problems. Gabbard, Hix and Swan (1999) report similar limitations of heuristic evaluation applied to VR, see below. Therefore, a further in-depth investigation of heuristic evaluation is necessary to determine the appropriateness of extending this technique to VR. Within the scope of the thesis this is not possible. However, what is learnt from the research in this thesis may be used to inform heuristics or guidelines for the evaluation of interactive mediated environments.

In contrast, empirical evaluation can take the form of interviews, questionnaires or observation. An effective way to obtain direct feedback is to observe users while performing a think-aloud verbal protocol. One of its earliest proponents in HCI was Clayton Lewis (1982). Deriving from "protocol analysis" (Newell and Simon 1972) psychological research methodologies for investigations of puzzle solving, games playing and the like, the think-aloud verbal protocol is a technique in which subjects say out loud what they are thinking and doing during a problem session. Its purpose is to provide an insight into subjects' thoughts and thus presents "an opportunity to trace cognitive processes" (Russo, Johnson and Stephens 1989). In HCI it is used either concurrently whilst performing a task (i.e. a kind of running commentary) or retrospectively on completion of a task (i.e. from memory, by viewing a video or listening to an audio recording). It has been used in studies of virtual environments. For example, in the virtual environment design and evaluation work of Kaur (1998). However, little has been carried out to test the appropriateness and effectiveness of this technique to evaluate virtual environments. Therefore, in an attempt to find out its potential use with VR an investigation of the think-aloud technique is carried out.

#### 2.3.2.1 Investigation of think-aloud verbal protocol

The wide adoption and use of think-aloud verbal protocols prompted many studies aimed to determine its validity. For example, Russo, Johnson and Stephens (1989) conducted four studies to test the validity of both concurrent and retrospective think-aloud verbal protocols. They found that retrospective protocols are reliant on users' memory and hence, may produce problems of forgetting, and even worse, inventing things. Ericsson and Simon (1984) concur with this and warn against using all retrospectively collected protocols. In contrast, one of the main problems levelled against concurrently thinking-aloud is that the user is however, effectively required to do two things at the same time: perform the task itself and secondly, talk about their actions or what they are thinking whilst performing a task. This may place an added strain on the user and therefore, the validity of a concurrent think-aloud verbal protocol has been questioned. Ericsson and Simon (1984) suggest avoiding concurrent think-aloud protocols where instructions invite subjects to self theorize or explain their thoughts, "instead subjects should be asked to report their thoughts". The results of studies by Russo et al. (1989) indicate that generating a concurrent think-aloud verbal protocol can prolong the response time of a task and more importantly, may alter the accuracy of some tasks. However, they conclude that concurrent verbal protocols are not invalid and so should not be avoided. Additionally, they add further support by stating that "nothing can match the processing insights" provided by a concurrent verbal protocol. For an in-depth discussion see: Russo et al. (1989) and Ericsson and Simon (1984).

Whilst the literature suggests the validity of a concurrent think-aloud verbal protocol, Hackman and Biers (1992) identify two main drawbacks involving studies with single users. The first is with regard to the low "quantity" of verbalizations where subjects have to be constantly prompted to verbalize out loud and secondly, the low "quality" of verbalizations that is likely to be of low value or use to an interface designer. They suggest that the commonly used practice of conducting evaluation studies with unaccompanied single users in laboratories and monitoring their behaviour with computer-based applications through a two-way mirror, may be responsible for this. That is, the "unnaturalness of the situation"; this may make users feel uncomfortable, embarrassed, self-conscious, or they may just be too shy to talk aloud in isolation. In an attempt to overcome these difficulties researchers have produced a range of techniques that are variations on the think-aloud verbal protocol to make the user feel more comfortable during evaluation studies. These range from having a passive observer acknowledge single users' verbalizations with "OK" and "uh huh" (Kato 1986), to constructive interaction (Miyake 1982; O'Malley et al. 1984) and a very similar technique, co-discovery learning (Kennedy 1989) whereby two users work on a task as a "team" – "their communications are used as information for possible system redesign". The results of a study by Hackman and Biers (1992) to compare the effectiveness of studies with single users in isolation, single user studies with an observer present, and with a "team" of users, showed that "team" studies produced a higher "quantity" of verbalizations and that these were of higher "quality" to designers of software interfaces. This is most likely due to the fact that evaluations using a "team" of users may overcome the "unnaturalness" of single user studies. Despite the fact that their results show that "team" studies produce higher "quantity" and "quality" of think-aloud verbalizations, and that they describe "team" methods as "efficient", the main drawback however, is that two users are employed in each evaluation session. To all intents and purposes this is effectively using double the manpower to that of single user studies.

An alternative and "low cost" approach that can be considered to lie somewhere between single user and team methods is the co-operative evaluation technique (Monk, Wright, Haber, and Davenport 1993 p. ix). Introduced by Wright and Monk (1989), this technique encourages dialogue between a single user and evaluator in the form of questions - pertaining to the study's application or task under evaluation. The co-operative nature of this approach is designed to make single users feel a part of an evaluation, as a co-evaluator and not a subject under evaluation. Hence, this attempts to overcome the "unnaturalness" of single user studies whilst at the same time building in a means to coax further verbalizations from the user – prompting for further verbalizations where necessary - and thus provides the opportunity to probe further lines of inquiry relating to concerns of usability (Monk, Wright, Haber, and Davenport 1993). To test the effectiveness and appropriateness of the think-aloud technique to evaluate the usability of VR, chapter three describes studies of desktop and HMD VR applications.

### 2.3.3 Usability evaluation of virtual reality

Limitations in using traditional usability evaluation and design methods and approaches have been echoed by many in the VR community (e.g. Kaur 1998; Kalawsky 1998; Gabbard, Hix and Swan 1999; Hix, Swan, Gabbard, McGee, Durbin and King 1999; Steed and Tromp 1998). The main reason identified is that methods are ineffective to account for the additional third-dimension. For example, Kalawsky calls for a range of methods to account for the high interaction capabilities, spatial awareness and presence introduced by the third-dimension. Gabbard, Hix and Swan (1999) suggest that "incompatibilities between GUIs and VEs may render" "proven" and "well-tested" usability design and evaluation methods "inapplicable" to VEs. They suggest that while "heuristics are considered the defacto standard for GUIs, we have found them too general, ambiguous, and high-level for effective and practical heuristic evaluation of VEs". Likewise, Steed and Tromp (1998) suggest that heuristic evaluation and cognitive walkthrough need to be extended to account for interactive capabilities in three-dimensional virtual environments. Finally, Kaur (1998) states that guidelines borrowed from standard user interface design, such as, ISO 9241 (ISO 1997) are "likely to prove inadequate because they do not address the range of interactive behaviour afforded to by VEs". However, while all of the above may acknowledge the experiential capabilities of VEs, they focus primarily on usability design and evaluation. To overcome limitations in usability methods, Kaur develops a model of interaction and behaviour and employs a traditional think-aloud technique in studies to evaluate desktop VR (Kaur, Maiden, and Sutcliffe 1999). She maintains her model is an elaboration of Norman's (1988) seven stage model of action. It incorporates three cycles (i.e. task/action, explore/navigate, system initiative) consisting of 21 interlinked stages of activity in an attempt to predict general interaction behaviour in VE's. Further to that, forty-six design properties were drawn up in an attempt to support the user during each cycle. Kaur suggests that the advantages of this approach are that the model of interaction provides support for tasks in VEs and provides a way to mediate between requirements, design and evaluation. Her model attempts to achieve this by identifying usability problems and suggesting an appropriate design solution that increased the usability of their desktop VR test application.

General remarks about the limitations of Kaur's (1998) approach are that while the model supports a sequential nature of interaction designed to support desktop VR used in her studies, it may not however, generalise to other VR configurations. For example, head responsive VEs using a head mounted display, where a user can interact with a virtual object while at the same time plan to navigate or simply look around the virtual environment. Interaction of this kind is concurrent in nature and is not supported in Kaur's model of interaction. Furthermore, it is difficult to tell just how effective and applicable the design properties will be to other desktop virtual environments and moreover, other VR configurations other than those used in her studies. That is, can the design properties generalise to other virtual environment applications running on a range of VR configurations, whilst at the same time be specific enough about the usability design problem that will inform VE developers. In addition, Kaur's use of single-users employing a traditional think-aloud verbal protocol may incur problematic use associated with the low "quality" and "quantity" of user's think-aloud verbalisations, as highlighted by Hackman and Biers (1992) and previously discussed in section 2.3.2.1. As argued in section 2.3.2.1, in an attempt to overcome these limitations the co-operative evaluation technique will be employed in studies of HMD and desktop VR (see: chapter three).

More specific limitations are that while Kaur et al. (1999) conclude from empirical studies that there is support for the three stages of her model, however, she identifies problems found in the mapping of the flow of users' interaction onto the model of interaction, backtracking to other cycles and skipping stages within cycles. Considering that Kaur (1997) states that the model must be accurate and representative of actual interactive behaviour in VEs and this will lead to useful usability principles in VEs, by her own assertion she identifies the model's problematic use. Hence, it may be difficult to identify certain usability problems or it may even hide their existence altogether and the subsequent application of design guidance can only be as successful as the accuracy of the model used to predict user actions. Kaur's model of interaction may be viewed as an "ideal model of what users should do, not what they actually do" (Bannon and Bødker 1991 p. 235). In a similar vein, Tromp and Fraser (1998) highlight the relative unpredictability and "freedom of navigation and interaction in VEs" in comparison to user actions with GUIs. That is, in VEs "it is difficult to predict what actions users will take and in what order they will perform their actions". They suggest that standard HCI techniques or others such as using specified colours and flashing features "are not elegant solutions in a VE" for guiding user attention to the next action. Borrowing from Suchman's (1987 p. 49-50) ideas on "situated action" they suggest that "rather than attempting to abstract the action away from its circumstances" and "build a theory of action out of a theory of plans" a more appropriate approach to inform user interaction in VEs is to study user action that is dependant upon "material and social circumstances".

Kalawsky (1998) states that traditional human computer interaction evaluation techniques are ineffective at dealing with virtual interfaces, because "the problem with conventional or empirical human factors evaluation techniques is that they tend to investigate particular features of a VR system in isolation and ignore the context with respect to the overall system". That is, "even though useful results are obtained in this way it is difficult or impossible to begin to understand where real design improvements can be made" by looking at specific features in isolation rather than considering a VR system as a whole. Furthermore, it is difficult to see how the results obtained from an isolated and generally ad-hoc approach can generalise to other VR applications and configurations. Moreover, by not taking a holistic approach and ignoring the context of use of VR makes it difficult to consider human practice and experience within a mediated environment.

Similar arguments against taking an isolated evaluation approach have been raised for some time within the HCI community (e.g. Winograd and Flores 1986). With conventional computer-based systems the context of use includes the environment in which it sits. For example, Bannon and Bødker (1991 p. 231) draw attention to this, saying that there is concern for a more integrated, holistic approach to human thought and action. This concern arises from limitations in cognitive science to inform models of human computer use from task-based work achieved by a closed loop "information-processing loop" (Kaptelinin 1996b p. 112). These concerns stem from the need to consider context, artefacts and the social (as opposed to individual) in relation to work-related tasks and technology as witnessed for example in the interest in Computer Supported Cooperative Work (CSCW). Bannon and Bødker (1991 p. 231) suggest that this "has led some people to search for a different theoretical framework as the basis for our experimental and observational studies" and this is in most part driven by a need to account for contextual use. As Kaptelinin, Nardi and Macaulay (1999) put it, "such understanding directly affects design and evaluation by revealing what users are up to and how they might most effectively use a technology". To this end, many alternative activity-based theoretical frameworks have been proposed. As mentioned previously, activity theory is adopted in this thesis. Deriving from Soviet psychology (Leont'ev 1974, 1978, 1981) and inspired by Marx and Engels' philosophy emphasising praxis it is one possible alternative that may provide "a richer depiction of the HCI field" (Bannon and Bødker 1991 p. 228). Activity theory encapsulates holistic activity (i.e. both internal and external activity) emphasizing context, motive, social and cultural aspects, artefact mediation, etc. and these are identified throughout the thesis in a piecemeal fashion to be appropriate and extendable to interactive mediated environments. These discussions begin in chapter four. Similar concepts in activity theory are found in the GOMS model of Card, Moran and Newell (1983) (see: chapter four), models of Rasmussen (1986, 1992) and the work of Reason (1990), distributed cognition (Hutchins 1994) and situated action (Suchman 1987; see also, Lave 1988) deriving from ethnography (Garfinkel 1967). The purpose of this thesis is not to compare and contrast these various approaches to find out their appropriateness to interactive mediated environments; that would require a long, sustained research effort. For examples of comparisons of these frameworks and related discussions see: Draper (1993), Kuutti (1996), McCarthy, Monk, Watts and Wright (1998), Nardi (1992a; 1996c).

# Chapter Three Traditional evaluation applied to VR

As reported in chapter two, the general approach to evaluating virtual reality (VR) systems is to conduct ad-hoc or one-off studies, specific to the application or system for which it was devised. Consequently very little knowledge learnt from these studies can be effectively generalised across a range of virtual reality systems and applications. Furthermore, previous studies commonly employ off-the-shelf evaluation methods (devised for use with 2D WIMP computer-based systems) and judge the success of design features, applications, interfaces, computer systems, etc. by their ability to support frequently performed tasks against broad criteria, such as, effectiveness, efficiency and satisfaction (ISO 97). Although these methods and criteria appear effective, there has been very little attempt to question their scope and limitations. This chapter is an attempt to identify the salient qualities and characteristics of virtual reality and to find methods by which these can be captured. It describes empirical evaluation studies of desktop VR and stereoscopic head mounted display (HMD)-based VR. The central aim of the studies is to test the effectiveness and appropriateness of traditional methods when applied to VR systems. In addition, this works towards the development of methods that aim to generalise across a range of VR systems and applications.

As a starting point, the co-operative evaluation technique is employed as argued in chapter two. Co-operative evaluation is a variation on a think-aloud verbal protocol, whereby, in addition to concurrently "thinking-aloud", users are encouraged to ask any questions about an evaluation, relating to the computer-based system, the application, or the tasks that they are required to perform during the evaluation. As well as this, the evaluator may ask questions of the user at any time during the evaluation. Furthermore, the additional probing technique enables evaluators to enquire into users' difficulties with an interface and potentially may open up the opportunity to elicit further usability problems that may not have otherwise been exteriorised by the user. The co-operative nature of this technique aims to incorporate the user in the evaluation process as a kind of co-evaluator. Although designed "to improve a user interface specification by detecting possible usability problems in an early prototype or partial simulation" so that it meets the requirements for usability (Monk, Wright, Haber, and Davenport 1993 p. ix) the co-operative evaluation technique can be used at any stage of the design process (Faulkner 1998). Hence, co-operative evaluation seemed an appropriate technique for use in the studies. Additionally, a method is developed which attempts to turn round the qualitative think-aloud type data into quantitative data. This provides a way of evaluating empirical "think-aloud" evaluation methods and will be useful for comparing their effectiveness to evaluate 3D VR systems.

## 3.1 Evaluation of desktop VR

A summative usability evaluation[1] (i.e. "that take place after the product [application] has been developed" Preece, Rogers, Sharp, Benyon, Holland and Carey 1994 p. 603) of a desktop VR system was developed and a preliminary study then conducted, as reported in Marsh and Wright 1999. The purpose of the study was twofold. Firstly, to test whether the evaluation technique, co-operative evaluation, is effective in the evaluation of desktop VR systems. Secondly, to provide a way of assessing the purpose of the desktop VR system, attempts were made to capture a user's awareness of the spatial layout of virtual environment (VE) and the objects and their positions within the VE.

### 3.1.1 Study

Four users were employed in a summative evaluation[1] of a desktop VR system. The following are the research questions that the study attempts to answer:

i. is co-operative evaluation an appropriate technique for evaluating the usability of desktop VR and if so, how effective is it?

[1] A summative usability evaluation is carried out to test whether a completed product or application meets design requirements. While the study described in section 3.1 was carried out on a completed (off the shelf) desktop VR application and one of the purposes of the study was to capture, reason about and inform the evaluator of one of the important requirements of the desktop VR system's design (i.e. transfer of spatial knowledge to users), another important purpose of the study was to provide the evaluator with a test of evaluation methods, that is, an evaluation of evaluation methods.

ii. can users' awareness of the spatial layout of the 3D virtual environment be captured?

The four users volunteered to participate in the study. They consisted of two males and two females. All used computers in their daily work and two users had home computers. Their daily computer usage ranged from approximately 1 hour to 9 hours per day. Only one user had experience of VR for entertainment purposes.

#### 3.1.1.1 Desktop virtual environment

The test environment for the study was a desktop VR system called the Virtual Production Planner (VPP 1997). VPP is a desktop VR based training system. End users are intended to be student and professional television camera operators, producers, set designers and directors. Its purpose is to provide a teaching and development environment for a range of studio television production techniques from, storyboarding, camera operation and planning, development and creation of virtual productions, to set design and layout, and directing virtual productions. The sets provided are 3D computer generated graphical representations of two British Broadcasting Corporation (BBC) television programmes, the soap opera "EastEnders" and the news and current affairs programme, "Newsnight". The range of features and functions that can be performed in the "Newsnight" set are representative of that provided in the VPP system and therefore, this was used in the evaluation study.

#### 3.1.1.2 Method

Three standard tasks were devised to test the usability, functionality and effectiveness of the VPP:

***Task 1. Identify / Operate Cameras:*** Users are asked to identify the five cameras in the studio. Four conventional studio cameras that move around the floor of the studio, and one free or flying camera, and perform the following: Select cameras, Move cameras, Control the camera views.

***Task 2. Orientation / Familiarization:*** The second task consisted of three phases. Firstly, by viewing through camera "1", navigate around the "Newsnight" studio, and draw a plan view of the studio. Secondly, using the flying / free camera navigate around "Newsnight" studio and again draw a plan view of the studio. Finally, users were shown how to obtain the plan view mode of the studio and asked to move the cameras around the studio from the plan view.

***Task 3. Set-Up / Line-up Cameras:*** Without using the plan view, subjects were asked to position camera "1" to show a close-up of the presenter, and position camera "2" to show a shot of the presenter over the guest's left shoulder. Using the plan view, subjects were asked to position camera "3" to show a straight-on shot of the desk, with the presenter and guest seated at opposite sides and the monitor over the desk, and finally, position camera "4" to show a close-up of the guest with the studio monitor displaying the BBC logo to the left of the screen. Following task three, subjects were asked to complete a questionnaire and a debriefing session was then carried out.

To obtain information about how well VPP supports the tasks, users were asked to adopt a concurrent think-aloud verbal protocol. Additionally, users were encouraged to ask the evaluator any questions about the desktop VR system and the tasks that they were required to perform, and they were informed that the evaluator may ask questions of the user at any time during the evaluation. This method of evaluation is co-operative evaluation, as previously described. To provide a way to assess the co-operative evaluation technique, a method is developed which attempts to turn round the qualitative think-aloud type data into quantitative data. Based on a similar technique proposed by Hackman and Biers (1992), empirical evaluations are assessed according to the *quantity* and *quality* of the users' think-aloud verbalizations. The quantity is attained by counting all verbalizations; scoring a single utterance, statement, or sentence, or group of these relating to the same issue, as one. The quality of each of these is then judged as low or high, by two evaluators: the study evaluator and an independent evaluator. The criteria by which this will be judged is as follows:

> *Low quality* usability problems are judged to be of low importance or low quality to designers of virtual environments, are more than likely to be user errors in operation, and with more usage and time will have little problem overcoming. Generally, errors of this type point to a user's inexperience (i.e. novice user or unfamiliarity) rather than problems of interface, application or computer system's design. Although, consistently occurring problems could

also be the outcome of a problematic interface/design feature that is difficult to learn or use.

*High quality* usability problems are judged to be of high importance or high quality to designers of virtual environments and most likely will not be overcome with more usage and time. Generally, errors of this type point to problems of a design feature, interface, application or computer system's design.

The general idea behind the criteria is to determine that either the usability problems (UP) are as a result of an inexperienced user that can be overcome with increased time using the system or highlight potential problems with design. Additionally, it provides a method to compare and contrast evaluation studies through quantity (e.g. occurrence) and quality (e.g. low or high) and is essentially a way to evaluate the evaluation technique. Furthermore, from a practical point of view it enables the tabulation of usability problems (by occurrence and severity) and thus, presents the opportunity to assess concerns of usability and to make informed judgments about their causes and suggest potential solutions. Finally, because awareness of the spatial layout of a television studio is of paramount importance for camera operators, directors and set designers, etc. in their everyday successful routine work, user's were asked to draw plan views (i.e. bird's-eye view) of the studio and the positions of objects within the studio on grid paper in an attempt to capture the accuracy of transfer of spatial information from VE to user. Two plan drawings were made whilst navigating around the studio: one using the conventional studio floor camera (moving along the floor of the studio) and the other using the flying camera (flying through the space of the studio).

#### 3.1.1.3 Results

In reference to table 3.1, users' times to complete the study ranged from 15 to 43 minutes (26.5 minutes mean). The evaluation produced a total of 130 verbalizations. Of these, 30 were usability-related verbalizations and 10 (33%) were exteriorised following evaluator questions to the user. A full list of usability-related verbalizations exteriorised during the evaluation study is given in the Appendix II.

The usability problems were judged to be of low or high quality to designers of VEs by the two evaluators (see: table 3.3 and related text below). A confusion matrix to show the level of confidence and not chance judgements of low or high quality usability problems is shown below in table 3.2. From the confusion matrix, we have a coding schedule of 2 different categories (low, high) and there are 30 occasions when coding has taken place. With two observers, an agreement takes place when they both use the same code for the occasion. If they use different codes then that is in disagreement. The pattern of agreements and disagreements is shown in the 2 dimensional matrix in table 3.2.

**Table 3.1 Think-aloud verbalizations from evaluation of a desktop VR system**

| User: | *1* | *2* | *3* | *4* | *Total* |
|---|---|---|---|---|---|
| Think-aloud verbalizations (in-total)<br>(average time for each verbalization in seconds) | 14<br>(184) | 66<br>(28) | 31<br>(36) | 19<br>(47) | 130 |
| Usability-related verbalizations (quantity in total)<br>(percentage of total verbalizations) | 9<br>(64%) | 12<br>(18%) | 3<br>(9%) | 6<br>(32%) | 30 |
| Evaluator questions to user | 24 | 14 | 6 | 3 | 47 |
| Prompting usability-related verbalizations<br>(Percentage of usability-related verbalizations) | 5<br>(55%) | 3<br>(25%) | 1<br>(33%) | 1<br>(17%) | 10 |
| User questions to evaluator | 8 | 2 | 3 | 5 | 18 |
| Reminded to talk-aloud | 7 | 0 | 0 | 1 | 8 |
| Study time (minutes) | 43 | 31 | 19 | 15 | |

The diagonal from top left to bottom right, indicate agreement between the two observers; scores off this diagonal indicate their disagreement. The evaluators were in agreement 25 times, and of these, 15 of the usability problems were judged to be high quality and 10 low quality. The remaining 5 were judged to be both high and low. Using Cohen's Kappa (K), the results of the confusion matrix provide a significance rating of 83%, which according to Fliess (1981) gives an "excellent" degree of confidence for the result (for example, see: Robson 1995). Therefore, of the 30 usability-related problems, 15 were judged in agreement to be of high quality and, of these, 7 (~50%) were exteriorised following a question from the evaluator to the user.

**Table 3.2 Confusion matrix: desktop VR verbalised usability problems**

| | | *Evaluator 1:* | | *Total* |
|---|---|---|---|---|
| | | low | high | |
| *Evaluator 2:* | low | 10 | 5 | 15 |
| | high | 0 | 15 | 15 |
| | ***Total*** | 10 | 20 | 30 |

On analysis, the users' 30 usability-related verbalisations were reduced to 11 related, similar or duplicate usability problems. In reference to table 3.3 overleaf, down the left hand column are the 11 overall usability problems by users, along the top row. Indicated in each segment is the number of times each usability problem was verbalised by each user, and whether this was judged to be of low (L) or high (H) value to designers of desktop VR virtual environments. Entries with just one letter, either "L" or "H", indicate that each evaluator was in agreement. Two entries, "L" and "H", indicate that the evaluators were in disagreement, and "E" indicates that the usability problem was exteriorised following a question from the evaluator to the user.

Finally, an attempt to capture the users' awareness of the layout of the studio and objects was made. Essentially, the plan views drawn by all users, for both the conventional and the flying camera were very similar. The greatest difference between them was in the increased level of detail including, the layout of the studio and the number of objects in the studio that were contained in the flying camera's plan view. Refer to table 3.4. The percentage of the total number of objects and their correct location that were drawn in the plan view using the free or flying camera to navigate around the studio, was 92.5%. This is in contrast to 72.5% of the total number of objects and correct locations drawn in the plan view using the conventional floor camera "1". However, the plan view using the flying camera was drawn after the users had already navigated around the studio using camera "1", drawing a plan view as they went, and therefore, a cumulative effect may well have had an influence on these results.

**Table 3.3 Reduction of think-aloud usability verbalizations to similar usability problems (L = Low quality; H = High quality; E = exteriorised following evaluator's question)**

| Usability Problem | User 1 | User 2 | User 3 | User 4 | No. of Times Usability Problem Verbalised | No. of Users Verbalising Usability Problem |
|---|---|---|---|---|---|---|
| Collision with objects within studio | HE HE | LHE LH LH | LH | LH | 7 (2 HE, 4 LH, 1 LHE) | 4 |
| Initial interaction with on-screen cameras | H | H | H | H | 4H | 4 |
| Moving through objects - Disorientation | HE | HE | | H | 3H (2HE) | 3 |
| Confusion with camera control on-screen icons | | L | HE | HE | 3 (2HE, 1L) | 3 |
| Confusion with other on-screen icons | LE L | LE | | L | 4L (2L, 2LE) | 3 |
| No representation of free/flying camera | | H H | | | 2 H | 1 |
| System should show where user is, and what's happening | HE | | | | 1 HE | 1 |
| Confusion with main and mini views | L | L | | | 2L | 2 |
| Confusion about camera movements | | L L | | | 2L | 1 |
| Feedback selecting camera in plan view | H | | | | 1H | 1 |
| Problems with specialised terminology | | | | L | 1L | 1 |
| Total | 9 | 12 | 3 | 6 | 30 | |

**Table 3.4 Studio objects drawn on the plan views: using camera 1 and the free camera. "X" represents correctly identified and positioned objects.**

| | Camera 1: Plan View | | | | Free Camera: Plan View | | | |
|---|---|---|---|---|---|---|---|---|
| **User:** | *1* | *2* | *3* | *4* | *1* | *2* | *3* | *4* |
| **Studio Objects:** | | | | | | | | |
| *Presenter* | X | X | X | X | X | X | X | X |
| *Guest* | X | X | X | X | X | X | X | X |
| *table (main)* | X | X | X | X | X | X | X | X |
| *table (far end)* | X | - | X | - | X | X | X | X |
| *Monitor (TV)* | X | - | X | - | X | X | X | - |
| *Audio speaker* | X | X | - | - | X | X | X | X |
| *gaps in studio walls* | X | - | X | - | X | X | X | - |
| *Camera 2* | X | X | - | X | X | X | X | X |
| *Camera 3* | X | X | - | X | X | X | X | X |
| *Camera 4* | X | X | - | X | X | X | - | X |
| *Total:* | 10 | 7 | 6 | 6 | 10 | 10 | 9 | 8 |

### 3.1.1.4 Discussion

The quantity of think-aloud verbalizations made during the study was 130. 30 of the verbalizations were usability-related, and of these, 15 were judged in agreement to be high quality to designers of future versions of the desktop VE used in the study. Out of the total number of usability-related verbalizations, 10 (33%) were solicited using the questioning technique of co-operative evaluation. Of these, 7 were judged to be high quality usability related verbalizations, that is, almost 50% of the total high quality verbalizations were exteriorised following questions to users. Many of these however, may possibly have not been exteriorised without this additional probing technique. For instance, questioning the user during the study permitted the evaluator to immediately clarify certain issues or concerns raised during the study, or hesitations made in response to a user's performance with tasks. This additional probing technique proved to be quite an effective way to pursue further lines of inquiries, whilst the thoughts relating to these were still in the users' mind. In some cases, additional usability problems were identified that may have not been exteriorised otherwise. Although quizzing the user may provide the evaluator with a means to extract more information, the process of questioning the user whilst performing a task may however introduce further problems. Asking questions of the user is momentarily stopping the evaluation and users may view the questioning as intrusive to a task. For instance, users responding to questions may lose their train of thought, and possibly the contents of short-term memory may be altered or worst still, lost forever. Hence, it may take users some time to resume their current task following a question. However, during the evaluation of the desktop VR system, there did not seem to be any noticeable addition in time for users to resume their task following a question. Three out of four users said during the debriefing that they had "no problems" with the questioning technique, the remaining user said however, "asking questions bothered me while doing the task". One possible solution to this might be to postpone the questioning until the task is complete. Although, this is effectively now conducting a retrospective evaluation and may introduce associated problems, such as users forgetting and even worse, inventing things.

Three out of four users experienced no difficulties talking aloud and one of these added that it helps when learning new skills. Only one user had difficulties with talking aloud and had to be constantly reminded to talk aloud during the evaluation. In the debriefing, the user suggested that this was because of their shy personality. The same user also had difficulties answering questions during the study (see above). This seems to suggest it can be problematic to employ users of a shy or introvert disposition in evaluation studies using a think-aloud verbal protocol and in particular, the co-operative evaluation technique. However, whilst the user did have to be constantly reminded to talk aloud, was asked the most questions from the evaluator, and stated that asking questions was bothersome during the study, the same user highlighted the second most usability-related verbalizations and gave the greatest number of high quality verbalizations.

The method used in an attempt to capture a user's awareness of the spatial layout of the studio and objects, and their positions within the studio failed for two main reasons. Firstly, the plan view using the flying camera was drawn after the users had already navigated around the studio using camera "1". A cumulative effect may well have had an influence on these results, and so the accuracy of any comparisons that are made between the two is questionable. Secondly, users drew the map whilst they moved around the studio and therefore, this may not allow the user to fix in their minds or commit to memory the studio layout or objects' positions. The lessons learned from this study have been used to inform evaluation methods in an attempt to capture a user's awareness of the spatial layout of a HMD stereoscopic VR system (see: section 3.2). Following Endsley's (1988) technique to measure pilots' situation awareness (e.g. Spatial Awareness Global Assessment Technique - SAGAT), a more effective approach would be to allow the user to explore a VE for a predetermined period of time (i.e. unknown to the user). After this time has elapsed, the display screen is blanked (e.g. simulation stopped, display screen turned off, user's field-of-view obscured) and immediately following this, the user is asked to draw the layout of the VE and the objects and their positions within the VE from memory. A user's awareness of the spatial layout of the VE is then proportional to the accuracy of their plan view and number of objects and objects' positions.

## 3.2 Evaluation of head mounted display-based VR

Building on the results of a preliminary study of a desktop VR system (see: section 3.1) this section describes an empirical study to test the appropriateness and effectiveness of a think-aloud verbal protocol to evaluate HMD-based VR systems.

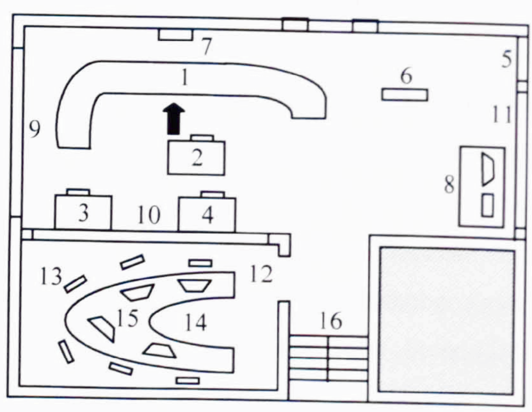
### 3.2.1 Study

An empirical study was conducted with 8 users employed in a summative evaluation of a stereoscopic HMD-based VR system. The purpose of the study was twofold. Firstly, to test the effectiveness and appropriateness of traditional usability evaluation methods employing a concurrent think-aloud verbal protocol to evaluate the usability of HMD-based VR systems. Secondly, as one of the main requirements of the test environment used in the study is to familiarise users with location and layout prior to their secondment at the real installation site, attempts were made to capture the transfer of spatial information from the virtual environment (simulation) to the user. For this, two methods were employed to capture users' awareness of the spatial layout of the virtual environment (i.e. plan drawing and pointing to unseen targets). Specifically, the following are the research questions the study attempts to answer:

i. is co-operative evaluation an appropriate technique for evaluating the usability of HMD-based VR and if so, how effective is it?

ii. can users' spatial awareness of the 3D virtual environment be captured?

**(a) point-of-view through head mounted display (indicated by arrow in 3.1b)**




**(b) bird's-eye view (see: table 3.8 for key to objects)**

**Figure 3.1 EISCAT: European Incoherent SCATer Radar Facility VE**

#### 3.2.1.1 Head mounted display-based virtual environment

Developed at Rutherford Appleton Laboratory, UK, the test environment for the empirical study of HMD-based VR is a simulation of a control room of the EISCAT (European Incoherent SCATter) radar facility. Refer to figure 3.1 for examples of a user's point-of-view seen through the HMD and a bird's-eye view of the EISCAT VE. One of the main purposes of the simulator is to familiarize scientists with the location and layout of the real installation based in Norway and train them in typical control procedures prior to their experimental programme, as described above. Due to the unavailability of typical end users (i.e. the scientists) over the period in which the study was carried out, general users were instead used in the study. The eight users, consisting of 4 males and 4 females, volunteered to participate in the study.

#### 3.2.1.2 Method

Three standard tasks were devised to test the usability, functionality and effectiveness of the stereoscopic HMD VR configuration and the EISCAT VE:

***Task 1: Familiarisation: Control and Movement***

Identify how to move around the control room.

***Task 2: Orientation: Navigation (and Spatial Layout)***

Explore the control and computing rooms until users feel confident about the layout of the rooms and the objects, and their positions within the rooms. Users were then asked to *draw a plan view* (bird's-eye view) of the control and computing rooms.

***Task 3: Object Identification: Search, Locate, Selection, Interaction***

There are fifteen instrumentation racks in the control room. Each rack controls a particular experimental control function of the EISCAT system. We are only interested in identifying the rack names that identify its function. Each rack is numbered - the number is located in the top centre of the rack. The users task was to locate and identify the names of three racks: "13", "7" and "2". The procedure for the selection of each rack is as follows:

1. Raise the 3D Mouse to a height that is approximately level with the Head Mounted Display. A virtual hand will appear.
2. Point at, and select the black button located in the top left of the rack.
3. The button turns green indicating that it has been selected.
4. Press the trigger button located on the front of the 3D Mouse.
5. Read the rack's function name that is displayed in front of the rack.

Following this, users were placed in a predetermined position and then asked to point in the direction of various objects or targets (obscured from user's point-of-view) located in the control and computing rooms.

#### 3.2.1.3 Procedure

To obtain information about how well the EISCAT VE supports the tasks, users were asked to adopt a concurrent think-aloud verbal protocol. Additionally, they were encouraged to ask the evaluator any questions about the VR system and the tasks that they were required to perform, and informed that the evaluator may ask questions at any time during the evaluation. This method of evaluation is the co-operative evaluation technique (as previously described) and using a similar method as that employed in section 3.1, the quantity and quality of users' think-aloud verbalizations is collated. The quantity is attained by counting all verbalizations, scoring a single utterance, statement, sentence (or group of these) relating to the same issue, as one; the quality of usability-related verbalizations is then judged as low or high (for criteria, see: section 3.1.1.2), by two evaluators (the study evaluator and an independent evaluator). Essentially, this provides a way to evaluate evaluation techniques employing a concurrent think-aloud verbal protocol by the occurrence (quantity) and severity (quality) of elicited verbalisations. Furthermore, as previously mentioned, from a practical point of view it enables the tabulation of usability problems (by occurrence and severity) and thus, presents the opportunity to assess concerns of usability and to make informed judgments about their causes and suggest potential solutions.

Finally, an attempt was made to capture user's spatial knowledge of the virtual environment. That is, the layout of the immediately surrounding environment and the objects and their positions within the environment. Two methods were adapted for use with participants of virtual environments. The first of these was informed from Endsley's (1988) work to measure pilot's situation awareness during sessions in flight simulators. Occurring immediately following task two, this involves "freezing" the simulation (i.e. the HMD removed) at a random point in time that is unknown to the user (e.g. 10 minutes). Users were then asked to draw a plan view (bird's-eye view) of the rooms and the position of objects within the rooms on grid paper. Secondly, immediately following task three, users were placed in the middle of the control room and whilst facing in the direction of the instrumentation racks (see: figure 3.1a) asked to point in the direction of five unseen targets (i.e. outside the user's field-of-view) surrounding them in the VE. Of interest to this study is a user's spatial knowledge of the small-scale environment that immediately surrounds them. That is, within the control, computing and adjacent rooms/exits. This study is only concerned with the approximate layout of the environment and the relative positions of the objects within the environment. Therefore, a simple marking system was devised to provide a rating of the user's mental map drawings and points to unseen targets within the environment. The marking system gave a score of "1" for each correctly identified and positioned (approximate) object and a score of "1" for the correct layout (approximate) of each room and their relative locations.

**Figure 3.2 Video recording of picture (user's POV within the VE)-in-picture (user in the real world)**

A video recording of the study was made for further analysis. As shown in figure 3.2, the video contained a picture-in-picture arrangement consisting of the user's point-of-view (POV) within the VE (as seen through the HMD) within a larger frame containing the user in the real world (refer to figure 3.1 to identify the user's exact location within the environment). This arrangement captured user's behaviour and performance *with* the HMD-based VR system configuration and *within* the virtual environment, prior to, during, and following the occurrence of a usability problem. Additionally, verbal reports were transcribed from audio taken from the video material. This provided information to identify and reason about usability problems.

### 3.2.1.4 Results

In reference to table 3.5, users' times to complete the study ranged from 15 to 31 minutes with a mean of 21.5 and standard deviation of 5.32 minutes. The evaluation produced a total of 338 verbalizations and 65 of these were usability-related. The 65 UPs are made up of 52 (user-volunteered) verbalised UPs and the remaining 13 (20%) were exteriorised following evaluator questions to the user. Additionally, 43 usability problems were observed during the study, giving a total of 108 verbalized and observed usability-related problems.

**Table 3.5 Verbalised and observed usability-related problems from evaluation of a HMD VR system**

| User: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Total |
|---|---|---|---|---|---|---|---|---|---|
| think-aloud verbalizations (mean time for each verbalisation in seconds) | 64 (21) | 54 (18) | 39 (23) | 42 (24) | 47 (30) | 42 (44) | 29 (50) | 21 (63) | 338 |
| user volunteered verbalised usability-related problems | 20 | 3 | 6 | 6 | 4 | 4 | 2 | 7 | 52 |
| evaluator prompted usability-related verbalisations | 4 | 0 | 2 | 1 | 2 | 1 | 2 | 1 | 13 |
| observed usability-related problems | 5 | 5 | 2 | 4 | 6 | 8 | 8 | 5 | 43 |
| verbalised and observed usability problems | 29 | 8 | 10 | 11 | 12 | 13 | 12 | 13 | 108 |
| evaluator questions to user | 19 | 1 | 9 | 5 | 4 | 2 | 2 | 1 | 43 |
| user questions to evaluator | 5 | 1 | 2 | 0 | 1 | 1 | 0 | 0 | 10 |
| reminded to talk-aloud | 6 | 0 | 3 | 0 | 1 | 0 | 1 | 1 | 12 |
| study time ~ *in minutes* | 23 | 16 | 15 | 17 | 24 | 31 | 24 | 22 | |

A confusion matrix to show the level of confidence for rating the "quality" of the 65 verbalised UPs, is shown below in table 3.6. From the confusion matrix, we have two different categories, low and high. There are 65 occasions when coding has taken place. With two observers, an agreement takes place when they both use the same code for the occasion. If they use different codes then that is in disagreement.

**Table 3.6 Confusion matrix: HMD VR verbalised usability problems**

| | | *Evaluator 1:* low | *Evaluator 1:* high | *Total* |
|---|---|---|---|---|
| *Evaluator 2:* | low | 14 | 8 | 22 |
| | high | 28 | 15 | 43 |
| *Total* | | 42 | 23 | 65 |

The pattern of agreements and disagreements is shown in the two-dimensional matrix in table 3.6. The diagonal from top left to bottom right indicate agreement; scores off this diagonal indicate their disagreement. The evaluators were in agreement 29 times, and of these, 15 UPs were rated high and 14 low. The remaining 36 were judged to be both high and low. Using Cohen's Kappa (K), the results of the confusion matrix provide a significance rating of 31%, which according to Fliess (1981) gives less than "fair" degree of confidence for the result (e.g. Robson 1995). Therefore, of the 65 verbalised usability-related problems, 15 were rated in agreement to be of high "quality" and of these, 4 (~27%) were exteriorised following a question from the evaluator to the user. In addition, two of the evaluator prompted UPs were rated in agreement to be low "quality".

Of the remaining 43 observed UPs, only 4 were judged in agreement. Although the main focus of the study was on the quantity and quality of users' verbalisations (to provide an assessment of the co-operative evaluation technique), the high levels of disagreement between the two evaluators (for rating the observed UPs) however, demonstrates a weakness of the criteria used in the study to rate the severity of UPs. This suggests a failing of VR evaluation research in general to identify exactly what a usability problem is in VR. In reference to table 3.7, further analysis of the 108 observed and verbalised UPs revealed 12 related, similar or duplicate categories into which each of the UPs falls. The 12 categories of UPs are divided into 3 columns: *effect (observed and verbalised), cause (most likely), and solution (potential),* and are numbered down the left hand column. These are cross-referenced with the full list of 108 UPs given in Appendix II. The transcript for each of the verbalised UPs – user verbalised (U) and evaluator prompted (E) - and details of the observed (O) UPs together with descriptive text of the events leading up, during, and/or following the occurrence of the UP made during the course of the study, is given also. The next set of columns in table 3.7 show the *severity rating* for the 108 UPs within their allotted categories. This shorthand method provides an indication of potential inconsistencies in evaluator ratings, highlighting where an evaluator may have rated the severity of identical UPs in different ways – both high and low. Although further analysis revealed similar UPs within the same category were sufficiently different to be rated as being both high and low, however, it was found that 2 (evaluator "1") and 7 (evaluator "2") identical UPs were rated both high and low. This points to either that the identification and severity rating of UPs is ineffective using this method (i.e. low or high) or highlights the evaluator's failing by inconsistently rating identical UPs, or both. This last point may perhaps reflect the difference in experience between the two evaluators. That is, evaluator "1" had more experience with usability evaluation studies and VR systems than evaluator "2".

**Table 3.7 Categorisation of think-aloud and observed usability problems into 12 related, similar or duplicate problems. "X" indicates the evaluator's severity rating**

| Usability Concerns | | | | | | | | Occurrence of Usability Problem by user | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *no* | Effect (observed / verbalised) | Cause (most likely) | Solution (potential) | Evaluator Severity Rating '1' L | '1' H | '2' L | '2' H | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Total Occurrence of Usability Problem |
| 1 | • user's physical movements are restricted | • HMD and/or 3D mouse cable entangled around user/chair | • restrict the chair's 360° swivel<br>• reposition cables in order to support and feed them in response to users' movements through the VE.<br>• employ a full-time cable attendant | - | X | X | - | 3 | 6 | 2 | 5 | 4 | 6 | 6 | 4 | 36 |
| 2 | • walking through or too close to objects<br>• user disorientation / appears startled<br>• getting lost / losing one's position momentarily | • no collision detect<br>• lack of knowledge for VE layout<br>• difficulty remembering the function of 3D mouse buttons | • implement collision detect<br>• user requires more experience interacting and exploring the VE<br>• decrease speeds of user movement | X | X | X | X | 7 | 0 | 3 | 3 | 3 | 1 | 1 | 4 | 22 |
| 3 | • virtual hand going through instrumentation racks<br>• virtual hand jitters<br>• awkward interaction with virtual hand | • no collision detect<br>• inaccurate hand tracking<br>• too far from tracker source<br>• user's reach too short | • implement collision detect<br>• check/recalibrate hand tracking<br>• ensure user in tracker's sensor field<br>• decrease speed of users' movements | X | - | - | X | 4 | 0 | 2 | 1 | 0 | 0 | 3 | 1 | 11 |
| 4 | • erratic movements through the VE<br>• hesitant movements in VE<br>• difficulty with movements | • incorrect selection of mouse buttons<br>• movements through VE too fast<br>• Compounding difficulties: operating 3D mouse, chair and head movements | • user requires more experience with the HMD and 3D mouse to co-ordinate movements within the VE<br>• decrease speed of movement through VE | X | - | X | X | 8 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 10 |
| 5 | • eye-level position Point Of View (POV) becomes higher/lower | • user is unaware that looking up/down whilst travelling through the VE changes the POV<br>• HMD too heavy: weighing down users' head | • user requires more experience controlling movements within VE<br>• disable height adjustment whilst in control and computer room<br>• use a lighter HMD | X | - | X | X | 3 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 8 |
| 6 | • menu appears occluding user's Field Of View (FOV).<br>• menu has no relevance to task/study | • selection of 3D mouse's middle button | • user requires more experience with the 3D mouse<br>• disable menu | X | - | X | X | 1 | 0 | 0 | 0 | 2 | 1 | 1 | 1 | 6 |
| 7 | • user supporting HMD with hand<br>• difficulties fitting / putting-on or wearing HMD | • HMD too heavy<br>• HMD incorrectly fitted<br>• HMD does not fit all head shapes/sizes | • use a lighter HMD<br>• ensure that the HMD fits securely | X | X | X | X | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 4 |
| 8 | • user cannot identify or misidentifies part of the VE model / graphics or its purpose / function | • inaccurate representation / model of real world object – *alcoves* | • *redesign/remodel the alcoves ensuring it's identity/purpose are explicit to user* | X | - | X | X | 2 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 4 |
| 9 | • caution signs ignored<br>• the purpose of the caution signs are not obvious to the user | • user may view text signs in a graphical environment as unnatural or unexpected<br>• interpretation of signs unclear | • make more explicit to user the reason for the cautions signs<br>• implement / develop more natural graphical techniques to blend with environment | X | - | X | X | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 2 |
| 10 | • graphic lag / delay in response to quick head movements | • too many models for VR system / HMD to handle<br>• frame rate too slow | • optimise graphics for a smooth and continuously animated display<br>• upgrade HMD / VR system | - | X | - | X | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 2 |
| 11 | • nausea | • HMD associated | • optimise graphics for smooth and continuously animated display<br>• lose the HMD | - | X | - | X | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 2 |
| 12 | • chair movements affecting user's interaction within VE | • chair permitted to move freely in all directions | • restrict chair movements to swivel only<br>• lose the chair | - | X | X | - | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| | | | Total: | 2 | | 7 | | 29 | 8 | 10 | 11 | 12 | 13 | 12 | 13 | 108 |

However, as demonstrated in the desktop VR study, the evaluators provided an "excellent" degree of confidence in rating agreement (83%). This suggests that it is not necessarily the evaluator who is at fault in rating the severity on UPs but is more likely to be a limitation in the criteria (i.e. "low" or "high") in identifying usability problems with HMD-based VR systems.

Shown in the last set of columns are the occurrence of UPs by user and the total occurrence of UPs. Finally, attempt was made to capture users' spatial knowledge of the VE, as previously described in section 3.2.1.3. Two separate methods were tested. Firstly, by getting users to draw a mental map of their immediately surrounding environment (control and computer rooms and objects within them) following task two. Secondly, following ask three users were placed in middle of the control room and whilst facing in the direction of the instrumentation racks (see: figure 3.1) asked to point in the direction of unseen targets surrounding them in the VE. Refer to tables 3.8 and 3.9 respectively. A simple marking system was devised to provide a rating of the user's map drawings and points to unseen targets within the environment. The marking system gave a score of 1 for each correctly identified and positioned object, and a score of 1 for the correct layout (approximate) of each room (and their relative locations). A score is indicated in tables 3.8 and 3.9 by a cross, a dash indicates that the object was omitted as in table 3.8 or that the user had no recollection for the object in table 3.9.

Wrongly positioned objects are indicated by the number of degrees (in a clockwise direction viewed from above) between the actual position of the object in the VE and the object's sketched position / direction of point. The number of correctly positioned objects in the map drawing test ranged from 8 (50%) to 15 (94%) out of a maximum of 16. The user with the second lowest scoring (user six with 60%) had the largest errors in positioning 2 objects at 180° and a third object at 85° from their actual positions. Furthermore, the same user correctly pointed to only one object out of a maximum of 5, which was the lowest. User six's remaining 4 points were each 180° from their actual positions. Of the remaining users' points, 6 were 100% accurate and 1 (user five) was 80%.

**Table 3.8 Mental Map: "X" indicates correctly identified/positioned object/room, "-" represents an object omitted from the drawing, and incorrectly positioned objects are shown in degrees of error from original (clockwise viewed from above)**

| No. | Locations/Objects: | User | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | *Control Room:* | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1 | instrument Rack | X | - | X | X | X | - | X | X |
| 2 | table 1 | X | X | X | X | - | - | X | - |
| 3 | table 2 | X | X | X | X | - | X | X | X |
| 4 | table 3 | - | - | X | X | X | X | X | X |
| 5 | door with 'no entry' sign | - | - | - | - | X | 85° | X | - |
| 6 | digital Clock | X | X | - | - | - | 180° | - | - |
| 7 | analogue Clock | X | X | X | X | - | - | X | - |
| 8 | oscilloscope/PC/table | - | X | X | X | X | X | X | - |
| 9 | window 1 | X | X | X | X | - | X | X | X |
| 10 | window 2 | X | X | - | X | - | - | X | X |
| 11 | window 3 | - | X | X | X | - | X | X | - |
| 12 | *Computer Room:* | X | X | 45° | X | X | 180° | X | X |
| 13 | chairs | X | - | - | X | - | X | X | X |
| 14 | table | X | X | X | X | X | X | X | X |
| 15 | computers | X | X | X | X | X | X | X | X |
| 16 | stairs/stairwell | - | X | 50° | X | X | X | X | X |
| | Total correctly identified: | 11 | 12 | 10 | 14 | 8 | 9 | 15 | 10 |

**Table 3.9 Pointing To Unseen Targets: cross indicates correctly identified object/room, dash indicates user had no recollection of the object, and incorrect direction of point is shown in degrees of error from the original**

| No. | Locations/Objects: | User | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 5 | *door with 'no entry' sign* | X | X | X | X | X | 180° | X | X |
| 6 | *digital Clock* | X | X | X | X | - | X | X | X |
| 8 | *oscilloscope/PC/table* | X | X | X | X | X | 180° | X | X |
| 12 | *Computer Room* | X | X | X | X | X | 180° | X | X |
| 16 | *stairs/stairwell* | X | X | X | X | X | 180° | X | X |
| | *Total correctly identified:* | 5 | 5 | 5 | 5 | 4 | 1 | 5 | 5 |

#### 3.2.1.5 Discussion

The quantity of think-aloud verbalisations made during the study was 338. 65 were usability-related and of these, 15 (23%) were judged in agreement by the two evaluators to be of high value or quality to the designers of the EISCAT VE. In reference to table 3.10, 13 (20%) out of the total number of usability-related verbalisations were solicited following questions to the user and of these, 4 were rated as high quality (27% of the total high quality UPs). In comparison, the desktop VR evaluation study produced more favourable results for the co-operative evaluation technique; 33% of the total UPs exteriorised following a question from the evaluator and of the total number of high quality UPs almost 50% were evaluator prompted.

**Table 3.10 Comparison of results from desktop and HMD-based VR studies**

| | Desktop VR-based system | HMD-based VR system |
|---|---|---|
| Evaluator questions prompting UPs (of total UPs) | 33% | 20% |
| Evaluator prompted high quality UPs (of total high quality UPs) | 50% | 27% |

In the absence of a similar study using only "thinking-aloud" (i.e. without questioning the user), it is perhaps a little naive and too hasty to make generalisations about the added benefits of using the questioning technique of co-operative evaluation to capture a higher quantity and quality of usability problems. That said, the results do show that although the number of additional UPs and their high quality rating for the HMD-based study is not as significant as the desktop-based VR study, the results at face value seem to suggest that the questioning technique enables the evaluator to probe further into concerns of usability and solicit more UPs than would have been possible by "thinking-aloud" on its own. Furthermore, questions to the user followed immediately after or as close to the concern of usability as possible and so the information relating to this (the contents of users' short-term memory) was verbalised.

It could be argued that the benefits of using the co-operative evaluation technique are entirely reliant on the evaluators' performance and expertise in formulating questions (concurrently) as the evaluation is being carried out and that the questions are delivered in a manner and at a pace that attempts to ensure the smooth running of the study. However, if the evaluator's attention is consistently diverted then this will almost certainly have a detrimental effect on an evaluator's ability to formulate questions effectively. For example, in the HMD-based evaluation study the most frequently occurring UP (i.e. encumbering HMD and 3D mouse cables) took a great deal of time and effort from the evaluator to ensure the smooth running of the study, and this was certainly detrimental to the questioning technique. Indeed, this is the most likely explanation for the lower results (percentage of evaluator questions, the prompting of usability problems and the lower percentage of high quality verbalisations) when compared to the evaluation of a desktop VR system. There is an obvious relationship between the number of UPs that require the attention of the evaluator and the effectiveness of the co-operative evaluation technique to evaluate the HMD-based VR system configuration used in this study. Whereby, too many UPs will force the evaluator to waste valuable time, shifting their focus of attention from the study to ensuring the smooth running of the evaluation, and hence, take away time and attention from the evaluator to formulate effective questions and removing the potential to solicit further UPs. In this situation, the study essentially oscillates between a co-operative evaluation (i.e. during the smooth running of the study) to simply "thinking-aloud" (i.e. when the evaluator's time and attention is allocated to fix UPs that will disrupt the smooth running of the study). Perhaps an obvious solution is to employ an evaluation study assistant to remove all low-level problems of usability (e.g. encumbering cables) that will hamper the smooth running of the study. Although, this would now effectively be using a "team" of evaluators in place of a "team" of users (see earlier discussion in chapter two), and would however, undermine one of the important claimed advantages of co-operative evaluation as a "low cost" evaluation technique (i.e. minimised costs due to the reduced "staff and training" and "time and resources needed to actually carry out the procedure" using only one evaluator and a single user) (Monk, Wright, Haber, and Davenport 1993 p. ix). Thus to sustain the "low cost" nature of the co-operative evaluation technique, it is necessary that evaluation studies employ one user and one evaluator. A more feasible solution may be to remove as many UPs as possible prior to going to the expense of an empirical evaluation study. Perhaps by initially conducting a usability inspection evaluation study (employing expert evaluators) to remove obvious or low level problems of usability, such as, encumbering cables. Steed and Tromp (1998) use a similar expert evaluation to evaluate a HMD-based VR system. However, failing the availability of a set of evaluation guidelines or criteria to identify UPs with HMD-based VR systems, an expert evaluation study would be entirely reliant on an evaluator's knowledge, experience and beliefs as to what are and what are not UPs in VR.

Similarly, this problem was further highlighted by attempts to rate the severity of UPs. That is, criteria were developed to inform evaluators in the categorization of UPs as either "Low" or "High" and provide a means to assess evaluation studies based on their quantity and quality (see: section 3.1.1.2). The criteria were a starting point to formulate evaluation criteria. Essentially, its underlying purpose was to determine that either the UPs are as a result of an inexperienced user (e.g. learning related problem) or that it was a potential problem with design. The difficulty with this method can be shown by considering that the most frequently occurring UP were rated differently by each evaluator – low and high. This points to either an inadequacy of the method in the identification and rating of UPs or highlights evaluators' inaccuracies. To overcome the limitations of the criteria a number of options could be considered. For instance, use an odd number of evaluators (i.e. three or more) and work on a majority rule basis (assuming that an increase in the number of evaluators will increase the likelihood of correct agreements being made and ensure that the correctly rated UP will prevail; although this solution is again at odds with the claimed "low cost" nature – see above discussion), increase the number of gradients to rate the severity of UPs and take the mean severity rating, or reformulate the criteria in an attempt to avoid ambiguous understanding of the criteria. Whilst the application of one or more of these methods may provide the necessary measures to overcome disagreements between evaluators' ratings, however, irrespective of whether attempts to overcome the limitations of the criteria are made, the evaluators are still reliant on their own experience and judgement to initially identify what a UP is in VR. This situation is obviously problematic and one that needs to be addressed if the detection of UPs in VR is to be based upon rigorous theoretical research and not the result of guesswork. Therefore, it is argued that the formation of additional guidelines is required to guide evaluators in the initial detection of UPs. The existing criteria (i.e. low or high) may then be used to distinguish between difficulties arising from novice, inexperienced or unfamiliar users from those of problems arising as the result of bad design. This latter method will be discussed further in the conclusion section.

Potential problems of the co-operative evaluation technique to evaluate HMD-based VR systems (and perhaps evaluation studies of most VE systems configurations) may arise as a result of the evaluator being external to the VE. That is, the user may feel uncomfortable wearing a HMD and performing tasks whilst at the same time communicating to the evaluator who is external to the virtual environment during the evaluation. A potential solution to this problem may be to place the evaluator within the VE, say as an avatar (virtual human) or something like a tannoy system (loudspeaker) or radio. The questions from the evaluator would then emanate from inside the VE and perhaps help to form a more natural form of dialogue between evaluator and user, and so assist in keeping the users' attention in the VE. Finally, a problem may result as a consequence of questioning the user during the study. Russo et al. (1989) (see: chapter two) shows that generating a concurrent think-aloud verbal protocol may prolong the response time of a task and more importantly may alter the accuracy of some tasks. In addition to concurrently "thinking-aloud", co-operative evaluation supports a questioning technique and hence, may subsequently have a compounding effect to the potential problems as outlined by Russo et al. (1989). Although during the study there was no indication that the accuracy of tasks was altered in any way, this remains an area of further investigation. One way of ensuring that the co-operative evaluation (or think-aloud) technique does not hamper the accuracy of tasks (for example, whilst taking performance measures) would be to postpone the co-operative evaluation technique whilst the measures were undertaken.

## 3.3 Conclusions: desktop and HMD VR

The results from the empirical evaluation studies demonstrate that the co-operative evaluation technique has the capacity to capture problems associated with usability of desktop and HMD-based VR systems. Additionally, the studies identified problems, limitations and recommendations for its effective future use. These include, the postponement of co-operative evaluation whilst performance related tasks are carried out; placing the evaluator within the VE (through an avatar, loudspeaker or radio) so evaluator questions emanate from inside the VE and perhaps help to form a more natural form of dialogue between evaluator and user, and so assist in keeping the users' attention in the VE; using (mental) map drawing and pointing-to-unseen-targets to capture user's spatial knowledge of the virtual environment more directly; the removal of usability problems prior to going to the expense of performing a user study, for example by, first conducting an expert evaluation. However, this brings us to the central and most important findings of the study. That is, the unavailability of a set of guidelines or criteria to identify and rate the severity of usability problems with VR systems. This will undermine the effectiveness of any evaluation technique in the evaluation of all VR systems.

Although the criteria that were developed to identify and rate the severity of UPs in VR systems seemed to be effective in the evaluation of desktop-based VR (83% confidence for rating the severity of UPs) similar criteria provided only a 31% degree of confidence for the severity rating of UPs occurring in the evaluation of a HMD-based VR system. Additionally, no observed UPs occurred with desktop VR in contrast to 43 occurring during the evaluation of HMD-based VR. This suggests that VR systems have intrinsic UPs that are specific to their configuration. For example, desktop VR runs on a display monitor, with mouse and keyboard, and as previously stated, this arrangement has the advantage of benefiting from an evolutionary period of development leading to an optimum blend of hardware and software and to the universally accepted standard configuration on which to support desktop VR applications. Hence, UPs are kept to a minimum. In contrast, most other VR configurations including, HMD-based VR are still evolving. That is, the optimum blend of hardware and software (VR enabling technologies) has still yet to be developed and until such time however, a greater number and variety of UPs are expected.

The failings of the evaluation criteria identified in this study seem to suggest that different VR configurations may require (although not necessarily – see argument below for identifying VR's overall goal to inform criteria of all configurations) their own specific set of criteria (to permit the capture of usability problems) or evaluation guidelines (for detection of violations to the guidelines). Attempts to identify the essential qualities and characteristics of all VR systems' configurations that would perhaps lead to the formation of a set of universal criteria for all VR systems for the identification and the rating of the severity of all UPs is very difficult. However, one way forward may be to identify the overall goal(s) of VR. Anything that impedes this goal(s) could be regarded as criteria to identify potential problems of usability. Perhaps one of the main goals of all interactions between humans and computers could be identified as keeping users' attention focused on their task at hand and thus allow them to "remain in the flow of their work" (Holtzblatt, Jones and Good 1988).

A badly designed input interactive device/style, interface, or design feature will draw attention to itself, pulling users' focus of attention away from the task at hand and hence, has the potential to disrupt or break a users' work. Identifying breaks presents opportunities to reason about problems in interface design. Indeed, with regard to the co-operative evaluation technique, Wright and Monk (1989) and Monk, Wright, Haber and Davenport (1993) talk briefly about breaks informed from Winograd and Flores (1986) who in turn were informed from philosophical works of Heidegger. In the next chapter the works of Heidegger and similar concepts to breakdown found in activity theory (e.g. Leont'ev 1981) are explored further as a way to identify potential problems of usability in virtual reality systems. This represents a move from task/action-based towards considering artefacts that mediate activity.

# Chapter Four Mediated artefact as functional organ

While limitations of a think-aloud verbal protocol have been identified (e.g. Russo, Johnson and Stephens 1989; Ericsson and Simon 1984) as discussed in chapter two, Russo et al. (1989) assert that "nothing can match the processing insights" provided by a concurrent think-aloud verbal protocol. Indeed the popularity and usefulness of this technique is demonstrated by its frequent appearance in the HCI literature to evaluate applications running on a personal computer or desktop configuration (e.g. display monitor, keyboard and mouse) and this would seem to suggest a concurrence with Russo et al's (1989) assertion. In chapter three, empirical studies demonstrate that the co-operative evaluation technique (i.e. a variation of concurrently thinking-aloud) has the capacity to capture problems associated with usability of desktop and HMD-based VR systems. However, two main inter-related concerns were identified with this approach. Firstly, used in isolation, the think-aloud method does not address directly all the salient characteristics, qualities and concepts that are essential to accurately assess and evaluate VR systems. For example, additional techniques were required to capture users' spatial awareness and as the following chapters argue, add-on methods are required to capture any experience induced and evoked in users during an encounter with technology. Secondly, the unavailability of VR evaluation guidelines makes it difficult to identify usability problems with all VR systems. That is, while the approach was more successful at capturing usability problems with VE applications running on a desktop configuration, it was less successful with head-mounted display-based VR. This may point to an underlying difference between standard desktop configurations and other VR systems suggesting the need for an alternative design agenda. Although these two main limitations are inter-related, as a way to disseminate research work already undertaken, this chapter will start by investigating ways to identify usability problems in VR. Subsequent chapters deal with the extension of these methods and the development of new methods for the accurate assessment of VR systems.

In an attempt to find effective ways to capture usability problems in VR systems this chapter looks to notions of transparent interaction in the use of computers-based systems. Transparency has a long history in the HCI community. Its meaning and use in HCI has come to be closely associated with the word "invisible" (Norman 1998). Whilst portraying an accurate high-level understanding, this may conceal or even obscure the essence and sometimes lead to an oversimplified or at worse, misuse of the word and its underlying concepts. In this thesis, transparency is used to describe interaction "that is supportive and unobtrusive, but which the user need pay little, if any, attention to" (Nardi 1996b p. 11). Similarly, Holtzblatt, Jones and Good (1988) use the term "experience of transparency" (to mean transparency in use) to describe interaction with applications running on a PC/desktop configuration that enables users to focus on the task at hand, keeping them in the "flow" of their work and consequently, "feel satisfied with how their work is moving along". Similar concepts to these are encapsulated in the tool mediation perspective and this is central to the philosophy of activity theory. The concepts and mechanisms underlying tool mediation in activity theory are elegantly captured in the formation of functional organs and this is discussed in detail in this chapter. For discussions on the contribution that functional organs made in informing analysis of IMEs in this thesis and limitations to this work refer to chapter nine (9.3.3).

Disruptions to transparent interaction potentially cause breakdowns or shifts in focus of attention from the task at hand to the cause of breakdown and potentially impede work. Hence, transparency may be considered an antidote to disruptions. Extending the concepts of transparency, functional organ and breakdown to VR systems, this chapter looks to activity theory to provide a way to model activities. Using this model, guidelines are developed and tested against usability problems captured in the empirical study of head mounted display-based VR system from chapter three. Finally, limitations are identified and extensions proposed to enrich activity theory's basic principals for the effective modelling and evaluation of VR systems' design.

## 4.1 Transparency in use: mastery of tools

Tools support humans in their work performed in the environment that surrounds them. According to Winograd and Flores (1986) for humans to perform work effectively, a tool and its operation should appear seamless or transparent, thus allowing attention to be focused on the task at hand. This almost paradoxical situation, whereby, for the tool to be effective it must be transparent, is the central premise behind any human work performed through tools. Winograd and Flores (1986) describe this situation well by drawing on the philosophical concepts of Heidegger's (1927) "Being and Time" (Heidegger 1962 for English translation). Heidegger asserts that everyday activities involving everyday objects are part of the *background.* By *background* he means "without explicit recognition or identification" (Winograd and Flores 1986 p. 36) and he uses the term *readiness-to-hand* to describe the state in which we are not consciously aware of our everyday interactions. Hence, we are immersed in *readiness-to-hand* in our everyday interactions in the world around us. To highlight this, Winograd and Flores (1986 p. 36) describe Heidegger's simple, illuminating and much-cited example of hammering a nail into a piece of wood: "to the person doing the hammering the hammer does not exist". That is, in normal use the hammer is transparent (i.e. "readiness-to-hand"). To elaborate, consider the example of the blind man's cane (Suchman 1987 p. 53; also cited in, Dreyfus 1991 p. 65).

> *"...We can hand the man the cane and ask him to tell us what properties it has. After hefting and feeling it, he can tell us that it is light, smooth, about three feet long, and so on; it is present-at-hand [aware of and reflect on] for him. But when the man starts to use the cane (when he grasps it in that special mode of understanding that Heidegger calls 'manipulation') he loses his awareness of the cane itself; he is aware only of the curb (or whatever object the cane touches); or, if all is going well, he is not even aware of that. Thus, it is that equipment that is ready-to-hand is invisible just when it is most genuinely appropriated".*

This is similar to the tool mediation perspective that is central to the philosophy of activity theory. Kaptelinin (1996b) asserts that by accepting the tool mediation perspective then there are two interfaces that should be considered between the human and the tool and between the tool and the environment as shown in figure 4.1. To elucidate this further, and as a way to draw comparisons with Heidegger's work, consider Bateson's (1972) blind man's cane quandary (cited in: Kaptelinin 1996a):

where does the cane start and end? That is, where is the boundary between the human who uses the cane and the external world? Is it with the human-cane boundary or with the cane-environment boundary?

human ←——→ tool ←——→ environment

**Figure 4.1 Two interfaces of human-tool environment interaction**

The mechanisms underlying tool mediation and "the activity theory answer to this question" (Kaptelinin 1996a p. 50) is elegantly described in the formation of "functional organs" (Leont'ev 1981). "Functional organs are functionally integrated, goal-oriented configurations of internal [mental, idea, heuristics] and external resources [things, material, devices]" (Kaptelinin 1996a p. 50). That is, "external tools integrated into functional organs are experienced as a property of the individual" (Kaptelinin 1996a p. 51). This is similar to Heidegger's readiness-to-hand. In normally transparent use, tools or artefacts such as the hammer and blind man's cane, become an extension of the human rather than belonging to the external world. Consequently, humans are able to focus on driving the nail or on moving through an environment and not on the operations of (or reflect on) the hammer or cane in use respectively. Conversely, "during the early phases of learning" a tool is "conceived of as belonging to the outer world" (Kaptelinin 1996a p. 51); similar to Heidegger's present-at-hand. The concept of functional organs provides a perspective in which we can consider that "external tools [following their mastery] support and complement natural human abilities in building up a more efficient system that can lead to higher accomplishments" (Kaptelinin 1996a p. 50). That is, just like the way in which "scissors elevate the human hand to an efficient cutting organ, eyeglasses improve human vision, and notebooks enhance memory" are examples of tools that enhance human activities in our everyday environment (Kaptelinin 1996a pp. 50-51). Zinchenko (1996 p. 296) takes the ideas of functional organs one step further by arguing that tools appear not just to extend or amplify human capabilities per se, but also, "as a continuation of the human soul". Zinchenko (1996 pp. 295-296) elegantly elaborates this by citing an interview quoted in Chernov (1994) in which a journalist asked the cellist Mstislav Rostropovich about the relationship with his instrument, a Stradivarius-Dupor:

> *"There no longer exist relations between us. Some time ago I lost my sense of the border between us. I've got two portraits of myself - one from long ago created by Salvador Dali, and another one made much later by Glikman, an amazing painter who lives in Germany, in his eighties now. So, in the Dali there I was with my cello; I held it and all was excellent. In Glikman's portrait, however, there I was - and my cello became just a red spot at my belly, like a dissected peritoneum [lining cavity of the abdomen]. And actually, I feel it now in this manner, much like a singer seems to feel his vocal chords. I experience no difficulty in playing sounds. Indeed, I give no report to myself on how I speak. Just so, I play music, involuntarily. The cello is my tool no more. Does it not feel offended at being so dissolved? Sure, it does! But so be it."*

Likewise, to do work with computers, humans require tools or artefacts. For work with computers to be effective, many writers in the HCI community advocate the seamless or transparent nature of tools, acting directly with the objective of a task rather than with an interface itself. For example, Rutkowski (1982) describes ideal interaction with computers as when "the user is able to apply intellect directly to the task; the tool itself seems to disappear". A similar concept is Shneiderman's (1982, 1983, 1987) idea of "direct manipulation" with objects of the interface and the resulting "feeling of involvement directly with the world of objects rather than of communicating with an intermediary" that is, the feeling of "direct engagement" (Hutchins, Hollan and Norman 1986 p. 114). This is similar to Laurel's (1993) idea of a first-person experience of interacting directly with an unmediated computer-generated environment and the resulting sense of "direct agency" (i.e. "the power to take action" p. 117) or "engagement" (1986 p. 69). Likewise, Bødker (1991), Norman (1998) and Winograd and Flores (1986) view the success of tasks by the way an interface remains transparent. Nardi (1996b p. 11) suggests that transparency is used in HCI "to describe a good user interface...one that is supportive and unobtrusive, but which the user need pay little, if any, attention to". Specifically relating to ubiquitous technologies, Weiser (1991) coined the term "calm technology" to refer to an invisible interface that "functions without calling itself to our attention...it stays out of sight, effectively not even noticed". Finally, but not least, Holzblatt, Jones and Good (1988) suggest that the "experience of transparency" (i.e. transparency in use) enables users to remain in "flow" and as a consequence, "focus on the accomplishment of their tasks, and feel satisfied with how their work is moving along".

Tools mediate between humans and their work with computers. For example, work with applications running on a standard PC/desktop configuration is performed using tools such as windows, icons, menus and a pointer (WIMP) within a graphical user interface (GUI). Kaptelinin (1996a p. 51) draws attention to the importance of tool mediation to computer-based systems by suggesting that "perhaps the central problem of HCI can be defined as that of optimal integration of computer tools into the structure of human activity". He suggests that the tool mediation perspective provides a "structure for human-computer interaction that is radically different from the information-processing loop" (Kaptelinin 1996b p. 111). This difference encapsulates not only the ideas of interaction as considered traditionally between a user and computer (i.e. through an-input-processing-output loop) but also the idea that the *objective* of a user's interaction is acting "through the interface" (Bødker 1991). That is, Kaptelinin (1996b p. 112) suggests that the information-processing loop can be "placed in the context" of the tool mediation approach. To emphasise this, Kaptelinin (1996b p. 112) cites Michael Cole (from personal communication) who suggests that "U.S. standard cognitive psychology is a reduced subset of a cultural-historical activity approach – without realising it". In reference to figure 4.2, accepting "the tool mediation perspective means that there are actually two interfaces that should be considered in any study of computer use: the human-computer interface and the computer-environment interface" (Kaptelinin 1996b p. 111). The integration of the two interfaces in activity theory, just like tools in the surrounding world as described earlier, is through the formation of functional organs and implies the extension of the user in their environment.

user ⟷ computer ⟷ environment

**Figure 4.2 Two interfaces of human-computer interaction**

Following mastery, transparency in use helps to prevent users' focus of attention from being diverted to the operation of the interface itself. A disruptive interface in use will shift users' focus of attention and may potentially impede the task at hand. Hence, transparency can be described as the antidote to disruptions. Winograd and Flores (1986) refer to disruptions as *breakdowns* stating that when an object or an environment becomes part of our consciousness then a *breakdown* has occurred. That is, "the interrupted moment of our habitual standard, comfortable *being-in-the-world*" (Winograd and Flores 1986 p. 77) and only when "*things*" do not perform or function in the way that they are intended to behave, do we become aware of their existence [italics added to emphasise Heidegger's terms] (Winograd and Flores 1986). Consider the use of a tool; it presents itself or becomes part of our consciousness only when some kind of breaking down has occurred. For example, when a hammer "slips from grasp or mars the wood, or if there is a nail to be driven and the hammer cannot be found". The hammer and the operations that are performed in its use are now described as *unreadiness-to-hand* or *present-at-hand* and are no longer part of the *background*.

Likewise, breakdowns with computer-based systems occur "when work is interrupted by something...the tool behaves differently than was anticipated" (Bødker 1996 p. 150). Although breakdown is a negative aspect of tool/interface use and wherever possible should be avoided, Winograd and Flores (1986) however, assert that the anticipation of breakdowns in the design of computer-based systems leads to opportunities for informing design. That is, breakdowns from the computer system shift a users' focus of attention from the task to the interface and thus, disrupt or impede the task. Identifying breakdowns provides opportunities to reason about their cause. A similar concept to that of breakdown are focus shifts. Bødker (1996 p. 150) describes focus shifts as a change in focus of attention "that is more deliberate than those caused by breakdowns." Bødker (1996 p. 149) elucidates its meaning through the example of a teacher instructing a novice about the technology, and hence, are opportunities or "openings for learning". In this chapter, breakdowns and focus shifts will be referred to under the umbrella term *breakdown in interaction* as described in the next section (Marsh, Wright and Smith 2001). Breakdown and focus shifts have been instrumental in the analysis of human-computer interaction (Bødker 1996) and facilitate the detection of usability problems of applications with traditional desktop-based systems. For example, to varying degrees, Bødker (1989, 1991, 1996), Holtzblatt, Jones and Good (1988) and Wright and Monk (1989) have demonstrated that the philosophy of transparency and breakdown can be successfully used to inform the design and evaluation of traditional computer-based systems.

Therefore, like work performed with tools in the world around us (e.g. as described by Heidegger and in the concept of functional organ) and with applications running on traditional computer-based systems (e.g. as described by Winograd and Flores 1986, and Kaptelinin 1996a & 1996b) it is argued that the mediating VR interface should appear seamless or transparent. Extending the concepts of transparency and breakdown may successfully inform the design and evaluation of VR systems. Disruptions to seamless or transparent interaction provide opportunities to identify and reason about potential problems of usability and to VR systems' design. That is, following Winograd and Flores (1986) anticipation of breakdown in the design of interactive virtual reality systems will lead to opportunities for informing design. The following sections explore breakdown as a way to capture usability problems in the evaluation of VR systems. Furthermore, an additional advantage arises from the fact that the enabling or mediating technologies should appear transparent irrespective of the underlying complexity. Thus, it is anticipated that evaluation of design based on the concept of transparency will support the wide range of VR configurations and the evolving nature of VR enabling or interactive mediating technologies. Continuing investigations on transparency, breakdown and tool mediation, the next section looks at activity theory in more depth. There are many advantages for looking to activity theory. Most important to immediate work is the encapsulation of the notion of transparency in the formation of functional organs within the tool mediation perspective. This, together with the dynamic levels of the hierarchical framework of activity theory provides an elegant way to model and reason about design through transparent interaction and breakdown in activities. In addition, activity theory is "a philosophical and cross-disciplinary framework for studying different forms of human practices" (Kuutti 1996 p. 25) and unlike traditional cognitive psychology analyses humans in their natural environment (Kaptelinin 1996b). This may perhaps provide a useful means for studying human practices in virtual or mediated environments (i.e. context of use) and is discussed later.

**4.2 Using activity theory to model and reason about interaction in VR**

Emerging in the 1920's and 30's, activity theory was largely the result of psychology based on Marxist philosophy that developed following the Russian revolution of 1917. The approach was formulated from Lev Vygotsky's "sociocultural" studies and continued by his colleagues A. R. Luria and A. N. Leont'ev (see: Leont'ev 1978, 1981; Vygotsky 1978). Three generations in the evolution of activity theory can be identified. The first with its roots in the work of Vygotsky is the development of the central idea of activity theory – mediation and the unity between consciousness and activity (Nardi 1996b). That is, the idea that the relationship between humans and things in their environment are mediated by cultural and social tools, signs and language, etc. Vygotsky (1978) used the term artefact to refer these; its use in HCI to refer to this wider perspective (i.e. "psychological tools") and not just to physical tools is prevalent (e.g. Bannon and Bødker 1991; Bødker 1989; Norman 1991). In the remainder of this thesis the use of the word artefact will be used in a way consistent with this wider perspective. In addition, unless the text refers to a specific type of tool, the use of the word tool will also refer to artefact. The second generation of activity theory sees the expansion of Vygotsky's (1978) ideas in the development of a division of labour and the distinction between activity, action and operation that became the basis of Leont'ev's (1978, 1981) hierarchical model of activity. Finally, more recently Yrjö Engeström and Michael Cole have extended the concepts of activity theory to a wider social and cultural audience and so, demonstrating its evolving nature (Cole 1999; Cole and Engeström 1993; Engeström 1987). Nardi (1996b p. 7) suggests that activity theory is more accurately described as "a powerful and clarifying descriptive tool rather than a strongly predictive theory". According to Kuutti (1996 p. 25) it is "a philosophy and cross-disciplinary framework for studying different forms of human practices". Kaptelinin (1996a p. 61) suggests that the main reason it has attracted the attention of many researchers is that it "integrates multilevel perspectives on human activities within a single conceptual framework".

From its inception to the present day, activity theory has evolved into an extensive and wide-ranging field of study and therefore the introduction and treatment of concepts in this and following chapters will be in a piecemeal fashion. This starts with discussing concepts that provide a way to model and reason about interactions with VR systems through consciousness and activity. Central to activity theory is Leont'ev's (1978, 1981) hierarchical framework of activity composed of: *activity,* *actions* and *operations*, and these are characterised by *objective, goals* and *conditions*, respectively, as described in more detail below. Processes within levels of the framework are dynamic and can move up or down the hierarchy. This provides a way to model shifts in focus of attention and consciousness arising from either, learning how to use a tool that is prior to its mastery or from disruption or breakdown in its operation. Changes between levels of the framework are illuminated in Leont'ev 's (1978) much cited example of the *activity* of learning to drive a car: changing the gears is a conscious goal-directed *action*; after time, these become routine and are then performed with minimal or no conscious effort; at such a point, they become *operations*. Likewise, operations become actions when something impedes their execution; for example, when gears slip or stick. Hence, the framework provides a way to model and detect shifts in focus of attention and consciousness arising from learning or from disruptions and breakdown.

Its application to activities in VR is best explained by way of an example. Consider for instance the activity of selecting a book from a bookcase in a virtual library (for educational/research purposes). In reference to figure 4.3, the activity is decomposed into the *activity* itself and is directed towards achieving an *object* or *objective*. The term "object-oriented" is widely used to denote this. Object is closely related to motive. These two considered together define an activity, the smallest meaningful unit of analysis in activity theory (Leont'ev 1981; Kuutti 1996). Marsh (2003a) identifies that interestingly (see: chapter 6.6.4), it appears that little, if indeed any work in HCI deals with these separately, either suggesting analysis of "object or motive" (e.g. Kaptelinin, Nardi and Macauley 1999), linking them together as illustrated through Christiansen's (1996 p. 181) term "objectified motives" or not dealing with motive at all. This is a very important concept in activity theory and a limitation in its treatment in HCI. Therefore, this will be returned to later in the thesis. For example, in the virtual library the motive is to say obtain a reference from a book. If it is found that the reference is not in the book or the book cannot be found then the outcome does not coincide with the motive. In which case it is not an activity. On the other hand, if the objective outcome of processes is to find the reference in the book then this coincides with the motive and is an "activity proper" (Leont'ev 1981 pp. 399-400). When the motive is fulfilled the activity presents itself (i.e. the existence of the activity is demonstrated) and at such a point an activity ends. The activity is made up of one or a combination of *actions*. Nardi (1996b) states that actions can be considered to be similar to what the HCI literature refers to as tasks. Actions are performed with conscious thought and effort, and are planned and directed towards achieving a goal. The goals of actions are sub-goals of the activity's objective. For example in the virtual library, these are the navigations (e.g. movements in-between chairs, tables and along the aisles of bookshelves) and explorations (e.g. searching for the book's subject category and scanning the shelves for the book's catalogue number), and object manipulations (e.g. moving obstacles en route and selecting the book). Actions may be made-up of further actions (which themselves may be made-up of actions) each with sub-goals that are to be fulfilled in order to fulfil the higher-level action.

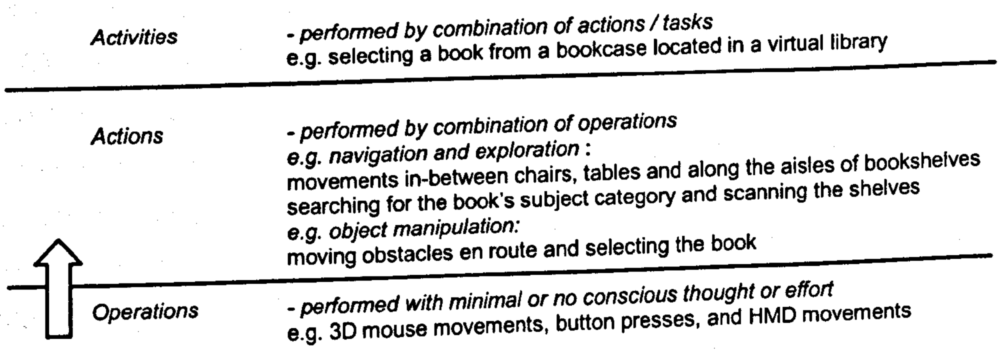



**Figure 4.3 Modelling VR interaction with activity theory: breakdown in interaction (i.e. shift in operations to actions - indicated by arrow)**

Actions are performed by a combination of *operations*. Operations are performed with minimal or no conscious thought or effort in the use of tools. For example, in virtual reality this is the actual 3D mouse movements, mouse button presses, and HMD movements. The early phases of learning to use a tool will have been performed with deliberate and conscious attention. At this point they are actions. When we become well practiced and experienced, actions become routine. That is, they do not need to be planned and at such a point are performed with little conscious thought or effort (i.e. actions become operations). These are issues relating to the mastery of external devices and tools (e.g. Leont'ev 1974). The hierarchical structure of activity theory is in many ways similar to the GOMS model of Card, Moran and Newell (1983). For example as Kaptelinin (1996a p. 60) points out, both address goal-directed behaviour with the goal, operators and methods of GOMS corresponding respectively to goal, operations and actions of activity theory. However, there are fundamental differences between GOMS and activity theory. Firstly, while activity theory puts operations, "goals and actions into the context of activities", "GOMS does not deal at all with the origin of goals" (Kaptelinin 1996a p. 61). For similar discussions that highlight the same refer to McCarthy, Monk, Watts and Wright (1998). Secondly, all levels within the hierarchical framework of activity theory (i.e. activity, actions, operations) are not fixed and can move up or down (Leont'ev 1978, 1981) whereas in GOMS the levels are static (Nardi 1996b). The dynamic nature of levels in the hierarchical framework of activity theory is central to the detection of usability problems through breakdown and shifts in focus of attention (Bødker 1996). For the purpose of this chapter, discussions will be restricted to the identification of shifts in operations to actions and vice versa. Anything that impedes or disrupts the execution of operations shifts a user's focus of attention from the task at hand to the cause of disruption and potentially breaks a user's flow of work. Operations are now conscious, that is, users have to think about their execution and hence, are planned and directed towards achieving a goal. At such a point, operations become actions as indicated by the vertical arrow in figure 4.3. This will be referred to henceforth as a breakdown in interaction.

Breakdown in interaction arise from either one of two situations. The first of these is a consequence of an unusual or unfamiliar interaction that requires more attention in its execution and hence, opens up opportunities for learning (Bødker 1996). For example, in producing figure 4.3 the inclusion of the arrow to illustrate a breakdown was an unfamiliar operation to the author, demanding more attention to learn the process by which to include it and hence, was itself a breakdown. Likewise to a novice user of VR, 3D mouse movements and button presses are planned and deliberate *actions* that will require conscious focus of attention until they have become routine. A question arising from these examples is what is an acceptable level of learning how to use an interface. These are standard issues of interface design relating to *ease of learning / ease of use* and related issues "with which new users can begin effective interaction and achieve maximum performance" (Dix, Finlay, Abowd and Beale 1998 p. 162). Although specifically devised for GUI WIMP-based interfaces, the underlying theme linking these issues and one that is in common in the design and use of perhaps any computer-based tool including those of a VR interface is the attempt to free the mind of the user. Thus, users are able to concentrate on the task at hand and remain in "flow" of their work. If an interface or tool demands excessive attention then it is not (and may never be) transparent and points to potential problems with design. The second example of breakdown in interaction highlights that something has gone wrong or broken down and points to the occurrence of a potential usability or design problem. Breakdowns and focus shifts to normally transparent operations provide a way to reason about VR design. Hence, in the following section guidelines will be devised from the model of VR interaction using activity theory (figure 4.3) providing a shorthand way to capture breakdowns in interaction in VR identified through concepts from activity theory and help distinguish between breakdowns resulting from unfamiliar operations (i.e. opportunities for learning) and those from usability problems.

## 4.3 Developing guidelines for the evaluation of VR design using breakdown in interaction

Breakdown and focus shifts are by their nature reliable only if accessed at the moment of their occurrence or whilst they are part of user' short-term memory. See earlier discussion in chapter two on the threat to validity of retrospectively collected data. Ideally, to gain access to this information a continuous and concurrent assessment method is required and one in which users are able to exteriorise their thoughts and data leading up to, during and following the incidence of a usability problem. Following chapter three, concurrently thinking-aloud is an effective way to trace cognitive thoughts (Russo, Johnson and Stephens 1989) hence, following the approach employed in empirical evaluation studies of desktop and HMD-based VR systems as described in chapter three, this can be used to evaluate for the design of transparency through breakdown. Specifically, it is anticipated that breakdowns and focus shifts can be detected through explicit verbalisations or complaints made about the normally transparent VR system, the enabling technologies or the VE, or questions from the user concerning operations or what action to take next. Additionally, users' difficulties with the interface could be identified through observation during the study or following analysis of video material. As a starting point, the concept of breakdown to transparency is applied to 108 usability problems (see: Appendix II) captured in the empirical study of the EISCAT HMD-based VR system (see: chapter 3.2).

On analysis all usability problems detected in this study could be identified as being a breakdown to transparent interaction [chapter six categorises further usability problems as being either breakdown in interaction or/and breakdown in illusion. In addition, subsequent chapters argue that breakdowns may occur as a result of user experience that is inappropriate or boring, etc.]. Furthermore, in reference to table 4.1 two overall categories of breakdown can be identified. First are breakdown in content: the imagery or graphics, that is, the visuals. This may occur with the VE/objects and their behaviour (e.g. colliding with objects, walking through objects or unusual or distracting object/environment behaviour). Although not a part of the VEs used in the studies, a further extension to breakdown in content could be made to incorporate sensory information (other than visuals) that provides additional cues about the virtual environment (e.g. audio and force-feedback). The second type of breakdown are disruptions caused by VR enabling or mediating technologies, for example, problems with display, interactive and tracking devices, or through fatigue whereby, interactive device/style demands constant or excessive energy, etc. As mentioned, breakdowns of this kind are best described as "equipmental breakdowns". As a shorthand way to identify potential causes of breakdown in transparent interaction (i.e. from operations to actions), table 4.1 lists categorizations that can be used to guide evaluators in the detection of usability problems in the design of VR systems.

**Table 4.1 Categorization of usability problems in VR: breakdown in transparent interaction**

| break in interaction |
|---|
| i. *content*: breakdown in imagery, audio, force-feedback, etc. |
| ii. *equipmental:* breakdown in VR enabling or mediating technologies |

As described in chapter three, to distinguish between difficulties arising from novice, inexperienced or users that are unfamiliar with an interface or application from those problems arising as the result of bad design, the application of the existing criteria (i.e. low or high) could be applied. Table 4.2 shows examples of breakdowns in transparent interactions from the HMD study and categorized as either low-level problems (i.e. learning difficulties: opportunities for learning) or high-level problems (i.e. potential usability/design problems). It is acknowledged that some usability problems may fall into more than one category or indeed a different category altogether, this is a concern for the evaluators, designers and clients.

**Table 4.2 Categorization of usability problems into appropriate types of breakdowns in interaction**

| | **Breaks in Interaction** | |
|---|---|---|
| | **low**<br>*learning difficulties* | **high**<br>*usability/design problems* |
| **content** | *User goes through wall to the outside.*<br>User: "I pushed the forward key, instead of backward" | |
| | *User goes through instrumentation rack.*<br>User: "just walked right through rack" | |
| | *Virtual hand mirroring 3D mouse movements goes through instrumentation rack:*<br>User: "my hand goes through objects as well" | |
| **equipment** | *User finds interaction difficult.*<br>User: "I'm no good at this" | *3D mouse, HMD cables become entangled restricting users' movements.*<br>User: "ah, seem to be snagging on something" |
| | | User: "I thought it might make me feel travel sick, and it does" |
| | | User: "it's moving slowly... graphics aren't moving as fast as I move my head" |

## 4.4 Enriching activity theory to incorporate context of use in VR

This chapter discusses the formation of functional organs, three hierarchical levels of activity and shifts between levels of the hierarchy that were used to identify breakdowns. This was an attempt to formulate a method to evaluate VR design through adopted concepts from activity theory and is, in essence, similar to concepts of transparency that have received much attention in HCI. While it can be argued that this was an effective approach at capturing all usability problems identified in the HMD study reported in chapter three and provides steps towards the formation of an arena in which to reason about mediated activity, there are however, limitations to these discussions. Most important was the failure to identify and consider the context of use and its influence on activity and artefact. Problematic situations that may arise from not considering artefacts in context are articulated by Nardi (1996b p. 14) as: "activity cannot be understood without understanding the role of artifacts in everyday existence, especially the way artifacts are integrated into social practice". Similarly, Cole (1999 p. 90) asserts that "artifacts cannot be considered in isolation. Rather they are interwoven with each other and the social lives of human beings they mediate in a seemingly infinite variety of ways. Considered in the aggregate, they constitute the unique medium of human life, the medium we know as culture". To emphasise the importance of considering the historical significance of the artefact Engeström (1999 p. 29) cites Wartofsky (1979 p. 205) who suggests that "the artifact is to cultural evolution what the gene is to biological evolution" (see also: Cole 1999 who adopts Wartofsky's 1979 ideas of *tertiary artifacts* to help bridge discussions of tool-mediated artefact and context). In other words, "artifacts carry with them successful adaptations of an earlier time ...such that in coming to adopt the artifacts provided by their culture, human beings simultaneously adopt the symbolic resources they embody" (Cole 1999 p. 90). In short, the historical or "cultural past" influences the "cultural present" (Cole 1999) and "tools [artefacts] are thus the carriers of cultural knowledge and social experience" (Kaptelinin 1996b p. 109). Cole (1999) suggests that this view of artefacts is not confined to cultural-historical and activity theorists but shared with anthropology (e.g. White 1959) and philosophy (e.g. Il'enkov 1977).

According to Engeström (1999 pp. 22-23) action-based theories "seem to have difficulty in accounting for the socially distributed aspects as well as the artefact-mediated or cultural aspects of purposeful human behavior". While an important advantage of activity theory is that it captures the "motivational basis of goal formation and problem finding", Engeström (1999 p. 23) argues that "it is not at all clear that those who use the concept of activity are actually able to overcome the *individualist* and *ahistorical* biases inherent in theories of action" [italics added for emphasis]. Therefore, Engeström (1987; 1999) extends the model of activity to social or collective use by inclusion of a "social" (i.e. "community", environmental and cultural), "divisions of labour" (i.e. responsibilities and variations in jobs roles) and "rules" (i.e. regulations in which activities are carried out). The applicability of this model to interactive mediated environments as discussed in this thesis is continued in chapter six. While limitations to activity theory as identified by Engeström (1999) may apply in the real world, it is not all that clear if these limitations extend to the mediated world. Interestingly, these discussions share similar arguments to those of affordances borrowed from J. J. Gibson and introduced to HCI by Donald Norman (1988) as discussed in chapter seven.

So how is it possible to consider artefacts in their socio-cultural context in mediated environments? The difficulties in attempting to consider these aspects arise from three areas. Firstly, identification of the boundary between the real and virtual as hinted at in the words of Kaptelinin (1996a p. 64): "the tool mediation perspective, which is considered the most important advantage of activity theory, can also impose some limitations...in virtual realities, for example, the border between a tool and reality is rather unclear". To all intents and purposes, users belong in two contexts implying that interactive artefacts are tied to both mediated settings that may depict the virtual past, present or indeed future, and to the real world context of use. Secondly, excluding revised versions or sequels of mediated environments or virtual characters (e.g. Lara Croft), mediated environments depicting real world representations that can infer familiar social-cultural contexts and features of mediated environments that carry with them some cultural/historical information, consideration of notions of history or "cultural past" of imaginary, fantasy or abstract environments that have artificially constructed social and cultural structures influencing activities and artefacts, are problematic. Hence, with the exceptions as given above, mediated environments are perhaps inherently "ahistorical" in real world terms. Of course however, this situation will change following frequent use and use over time of a specific mediated environment, genre or interactive mediated environment use in general. Finally, performing activities within artificially constructed mediated environments does not have to take place with other users and can of course be a solitary or "individualist" undertaking.

To begin to address these problematic areas, discussions are required to be extended to the user and their relation to the real and the mediated worlds, and identify the context of use. Performing activities with VR systems (e.g. from desktop, through to HMD and CAVE) either takes place exclusively within or inside a 3 dimensional virtual environment or between the real and the virtual environment. The display (e.g. monitor, HMD, stereoscopic glasses, projection screen, etc.) is the window or view port into the virtual environment and through either a first or third person perspective (Laurel 1993 pp. 116-119), users imaginatively or vicariously experience movement and interaction through and within a virtual environment. So, instead of considering "computers as a special kind of tool mediating human interaction with the world" (Kaptelinin 1996a p. 49) using activity theory we should perhaps consider VR systems as a special kind of tool mediating human interaction within the virtual or mediated world/environment. Extending the schematic representation of Kaptelinin (1996b) (figure 4.2) to VR, it is possible to visualise the two interfaces between the user and the tool and between the tool and the mediated environment as shown in figure 4.4.


**Figure 4.4. Two interfaces of human-virtual reality interaction**

Accepting that the context of use is the mediated environment, the question to arise from this is: where and how the real world environment fits into this structure? Of key interest to this thesis are computer-based activities that are performed successfully within a mediated environment without any contribution from resources external to it. Hence, the context of use is the mediated environment. Chapter six develops models to illustrate this. Perhaps the only consideration for the world external to the mediated environment is not to disrupt (e.g. through noise, etc.) the activities taking place within it. The extent and frequency of disruption from the world external to the mediated environment that would be considered acceptable to permit effective interaction in a mediated environment are questions relating to human attention. Furthermore, it is anticipated that acceptable degrees of disruption will perhaps vary across the range of VR configurations and these remain areas for further investigation that is beyond the scope of this thesis.

If this perspective is accepted, then, in addition to breakdown with normally transparent operations of interaction, breakdown may also occur to activities performed within the illusion of the mediated environment. Hence, a shift in user's focus of attention from the mediated to the real world may disrupt activities and impede users' experience of interacting within the mediated environment. This is similar to Laurel's (1986) idea of first person experience as described earlier, of interacting directly with an unmediated computer-generated environment and the resulting sense of "agency" (Laurel 1993 p. 117), and as captured in Lombard and Ditton's (1997) definition of presence as "perceptual illusion of non-mediation". Extending this idea we could argue that shifts or breaks in focus of attention from the mediated to the real world break the sense of "agency" or "presence". This is similar to Slater and Steed's (2000) "virtual presence counter" approach to evaluation of virtual environments. Therefore, it is argued that there is a need to take account of activities performed in the context of use and this is the mediated environment. The limitations imposed by activity theory to model interactions with VR are described by Kaptelinin (1996a p. 64) as "virtual realities present a problem to activity theory that probably cannot be solved without enriching activity theory's basic principles". By accepting the standpoint that the context of use is the mediated environment, then for the model of interaction (figure 4.3) to be accurate it is required to be enriched. In order to do this the next chapter looks to another artificial although highly successful visually mediated environment that has been depicting historical, cultural and social contexts of real and imaginary environments for over a century - film. One of the main goals of Hollywood film is to hold spectators' attention in the context or content of film within the borders of the projection screen. As a consequence, spectators are able to focus continuously on, and free from disruption, the varying levels and varieties of experience that provide meaning intended by filmmakers. Using film as a model, subsequent chapters work towards the formation of a framework of experience and use this as a way to consider socio-cultural context. This is used to enrich activity theory's basic principles in an attempt to model and reason about activities mediated by artefacts within interactive mediated environments.

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# Chapter Five Mediated environment: invisible style of film

*"As an audience, we no more want to see the wheels and gears and levers responsible for the effect the film is having on us than we want to see the pencil marks on an author's first draft or the invisible wires in a magic show" (Rosenblum and Karen 1979 p. 296).*

This chapter explores the similarities of another artificial although highly successful visually mediated environment – film. It is argued herein that film and the techniques of filmmaking can inform developments in VR. To draw similarities with film while at the same time highlighting its potential interactivity and similarities with other emerging computer-based media, VR environments will be referred to henceforth as interactive mediated environments (IME). Looking to earlier and more mature art forms or media to inform new and emerging kinds is commonplace and indeed, work is identified that traces the refashioning or remediation of art/media from pre-renaissance art through to film. Continuing ideas of remediation, this chapter draws a parallel between developments in film and interactive mediated environments. A framework of spectator's film experience associated with these developments is then identified and is used to inform a framework of user's experience of interactive mediated environments. Chapter eight describes studies that test this framework. To add further support to notions of remediation, a similar concept to transparency is identified, that is, the "invisible style" (e.g. Messaris 1994 pp. 150-154) of filmmaking. While transparency underpins much work in human-computer interaction, the "invisible style" predates it by over half a century.

This chapter investigates the invisible style and its associated techniques used to hold spectators' attention in visual storytelling, depicting social and cultural context through the illusion of film. A study is then described to identify what breaks spectator's illusion of film. This is used in subsequent chapters to enrich activity theory's basic principles in an attempt to overcome its limitations when applied to interactive mediated environments as identified in chapter four. Finally, guidelines informed from cinematic conventions are developed for the construction of virtual off-screen space to aid user comprehension of space and so aid users in navigating virtual space and attempt to reduce the occurrence of user disorientation. User disorientation has been identified as the cause of most problems in interacting with both desktop and HMD-based VR systems, as described in studies in chapter three. A study is then described to test the guidelines. Results suggest that the use of guidelines can help reduce the incidence of user disorientation. Thus, demonstrating that cinematic and editing techniques can inform the development of idioms or guidelines for interactive mediated environments. That is, remediation of VEs from film.

## 5.1 Filmmaking: shaping experience

Film is a highly successful and artificial visually mediated environment. It is entertaining, educational, informative and provides an excellent storytelling medium. Film has evolved over 100 years of technological and artistic developments and innovations, from its early beginnings to capture and project a smooth and continuous sequence of visual images providing the illusion of movement, into a complex textual "weave" of visual "montage" and audio (i.e. text). Central to this is the development of cinematic and editing techniques. This provided a way to escape from the restrictions of a still long-take style (i.e. similar to theatrical space, with the camera fixed in one position and the action taking place within the fixed frame captured by the camera) and introduced a system whereby the space and time of a scene can be manipulated from shot-to-shot. This ensures that the fragmented "cut up" or edits are presented in a coherent and continuous manner to maintain "continuity" (see below). This became the basis of a language of film narrative, providing a vehicle for storytelling and the making of films of "increasing complexity and power" (Laurel, Strickland, and Tow 1994; also published in: Laurel, Strickland, and Tow 1998 p. 188), and subsequently, orchestrated their wider adoption and acceptance as conventions (i.e. standard practice). The illusion of movement and its manipulation of time and space are hereafter referred to as the illusion of film. The reason for film's widespread success is that it encourages spectators to lose sight of the underlying artificiality of the mediating technologies to capture, manipulate and project film, and to pull and hold attention in the film projected within the borders of the projection screen. The screen is the window into the illusion of film as illustrated schematically in figure 5.1.

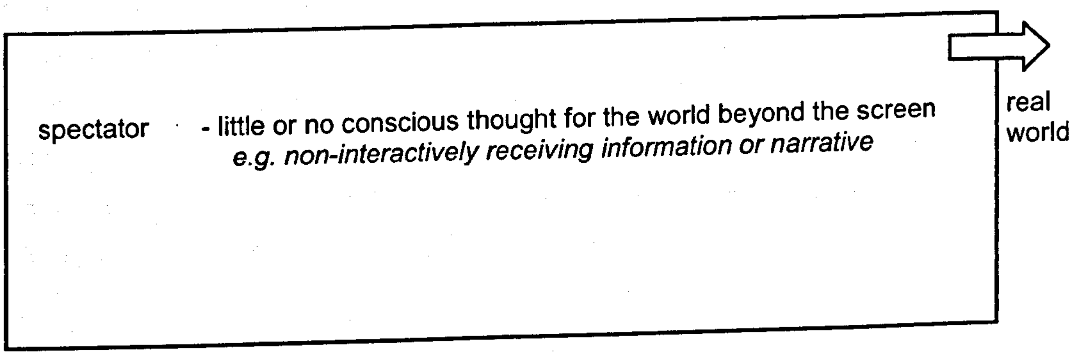


**Figure 5.1 Window to the illusion of film: arrow denotes breakdown in the illusion**

By grabbing and holding attention in this way spectators "become absorbed exclusively in the represented act itself" (Messaris 1994 p. 150) of the people, places and events, etc., of the narrative. Consequently, it is argued that the greater spectators' undivided and uninterrupted attention is focused on the illusion of film, then the greater they "feel and become aware of the richness and breadth of the film experience" (Potter 1990 p1).

### 5.1.1 Continuity in film

One of the most important goals of all media (e.g. radio, TV, film) is to maintain a continuous, coherent flow of content or narrative, that is, continuity. The Oxford English Dictionary (1989) defines continuity in cinema as "a detailed scenario for a film; also, the maintenance of consistency or a continuous flow of action in successive shots or scenes of a cinema or television film." Referring specifically to the Hollywood filmmaking process, Bordwell, Staiger and Thompson (1988 pp. 194-195) argue that continuity stood for "smoothly flowing narrative, with its technique constantly in the service of the causal chain". They suggest that "increasingly the conception of quality in films came to be bound up with the term 'continuity' ". Later, it came to specifically refer to a set of guidelines for cutting shots together. The present use of the term means both "quality" and "a set of goals and principles" (e.g. 180° rule, establishing shot, etc.) that underlie the entire film's visual storytelling process. While commonly used to refer to techniques to maintain continuity in editing (e.g. "continuity system" Bordwell, Staiger and Thompson 1988 pp. 194-195; also referred to as "continuity style" Bordwell and Thompson 2001) it is used also widely in film to refer to "continuity errors". These are mismatches in things, objects or props appearing on-screen (e.g. differences in the length of a burning cigarette, background clock displays jumps in time or clothes change or are removed from one shot to next) or in story/narrative (e.g. characters' name changes, firing of fifteen bullets from a six-shooter revolver). While "continuity style" in film is sometimes used synonymously with "invisible style", in this thesis invisible style refers to both transparency of interactive mediated environment enabling and supporting technologies (i.e. equipment) and to continuity of mediated environment or content (i.e. "the message").

**5.1.2 Film, effect and style**

Film and the effect it has on an audience isn't without criticism. In his essay, "Dream Machines: New Media as Intoxicants", Jos ten Berge (1999 p. 15) presents arguments that compare the experience of film and new media with that obtained from Art. In particular, he refers to the frequently cited work of the French writer Georges Duhamel (1930) who disparagingly described film as a pastime for "helots" who "seek solace in a type of entertainment requiring absolutely no effort". His remarks derive from the dynamics of moving images that he described as: "Too much noise. Too much movement!" requiring film spectators little chance for contemplation beyond the experience that is "predetermined". Consequently, he described the mental state of the spectator as "anaesthetised," "gorged," "paralysed," and "hypnotic". In contrast "true" Art for Duhamel (1930) was "something conquered by the mind with an effort" causing what Berge (1999 p. 15) describes as "a superior and active intellectual contemplation".

However, it can be argued that Duhamel's (1930) criticisms are not necessarily extensible to all filmmaking styles and are perhaps most applicable to the dominant mainstream filmmaking style of the day, that is, the "invisible style" of Hollywood. For example, Duhamel's (1930) arguments sharply contrast with early Russian filmmakers (e.g. Sergei Eisenstein) who would fiercely defend their films as Art brought about by the use of editing techniques to form a "montage" of visual imagery (Arnheim 1957 pp. 87-102). In addition, though more in-line with, and perhaps developing from Duhamel's (1930) arguments, are the development of later filmmaking styles such as, avant-garde, experimental and French New Wave. These provide an alternative to, and some intentionally "subverting" the invisible style (Messaris 1994 p. 152) by shifting the spectator from the entranced to a more active and contemplative role.

A fitting example to immediate discussions of what may best be described as somewhere between avant-garde and Hollywood style can be found in "The Last Movie" (1971) directed by Dennis Hopper, about a Hollywood film crew going into the Peruvian mountains and hiring local people to help shoot a cowboy film. The film's narrative centres round the local people's misconception of film, believing the film to be real and the Hollywood filmmakers quest to teach them of its artificiality. On another level, the film has a secondary more ingenious intention: by showing the film crew, techniques and mechanisms of film (e.g. lights, cameras, etc.) and by making references to its falseness (e.g. fake scars, etc.), it serves as a subtle reminder (to the spectator) of the artificiality of the film that they are actually watching. More obscure still is Guy-Ernest Debord's experimental film "Hurlements en faveur de Sade" (1952) (cited in Jos ten Berge 1999) that presented only a white screen for dialogue and a black screen for silence. Berge (1999) described spectators' feelings of boredom and frustration while they waited in anticipation for sensation or spectacle that never came. However, for Debord the film served its purpose; "at least they were irritated, critical, spontaneous, involved – in short, woken up". Probably the most successful style of filmmaking in contrast to the invisible style is French New Wave cinema. Pioneers of this movement (e.g. Jean-Luc Godard, François Truffaut) intentionally aim to draw attention to their films through devices such as voiceovers (e.g. "Band a Part", Godard, 1964) jump-cuts and repeated and reverse action (e.g. "A Bout de Souffle", Godard, 1959) in a way that makes spectators muse or question the filmmakers" intentions, the significance of the editing device and commentary used and how they relate to the film's meaning. For further discussion on editing, continuity and "invisible style" see for example: Bordwell, Staiger and Thompson (1988); Bordwell and Thompson (2001); Boorstin (1995); Rosenblum and Karen (1979).

Relating these discussions to the work of this thesis, an important question is: how much should users be made to think or contemplate? On the one hand, in the words of Krug and Black (2000), users should not be made to think, or to think "needlessly" about how to operate an interface (i.e. it should be easy-to-use) so not impeding the flow of interaction. On the other hand, if an interaction involves an element of intelligence or contemplation then it is argued that this may engage the user and provide the potential for mediated environments to be more satisfying and fulfilling beyond the experience that is "predetermined". Hence, trade-offs between these are required to be reached.

### 5.1.3 Breakdown in the illusion of film

Referring to the Hollywood or "invisible style" of filmmaking, Boorstin (1995 p. 8) states that the most telling criticism of film editors', camera operators' and actors' work is that it takes the spectator out of the picture – "when the audience is self-consciously examining its own responses, watching itself watch the movie, then all the razzle-dazzle in the world can't save the film". That is, a poorly made film has the potential to shift spectators' focus of attention from the film world to the real world. This will be referred to as a break in the illusion of film and is denoted by the horizontal arrow in figure 5.1. Other reasons for breaking the illusion are for instance, when an actor looks straight into the camera and so addresses spectators directly (i.e. breaking the fourth wall). As mentioned, the "invisible style" is in contrast to others that sometimes purposefully aim to break the illusion. For example, experimental film provides an alternative to, and sometimes intentionally subverts the "invisible style". However, to some degree all film, irrespective of style, employs techniques comparable to the invisible style (e.g. transparency of equipment and continuity of content). An interesting question to follow this line of thought is, following a break in the illusion of film (irrespective of the film's style, e.g. invisible, experimental, New Wave, etc.): what is it that pulls or grabs spectators' focus of attention back into the film presentation? There are perhaps a number of reasons as to how spectators' attention is drawn back into the illusion of film. It may for example, have something to do with the pleasure that comes from looking - scopophilia or "visual pleasure" (Phillips 2000; Mulvey 1975), or/and perhaps it is the pull of film stars that draws spectators "right back in" (Boorstin 1995 p. 197); see later discussion. Whatever the reason, spectators in most part want to see what happens next and to find out what happens in the end, to continue the experience and construct a greater meaning, or get their money's worth. Just how far spectators are pulled out of the illusion of film (e.g. totally into the real world or somewhere in-between) and exactly what draws spectators' attention back into the illusion of film is beyond the scope of this thesis and remains an area for further research.

The interest of this chapter is not so much in the deliberate use of artistic devices to break the illusion (e.g. French New Wave), but in the notion of "invisible style". It is possible to reason about the potential causes of shifts in focus of attention (i.e. breakdown) from the illusion of film to the real world. For example, from those occurring in the auditorium (e.g. noise, unusual or distracting behaviour of other spectators, uncomfortable surroundings, etc.), glitches in the technology used to capture and project the film (e.g. image or audio cuts out or has synchronisation problems, irritating flicker of the film projector, hair-in-gate, projectionist's synchronisation markers, etc.) to problems associated with the film itself (e.g. continuity errors, bad acting, story, script, or uninterested in the film's content or genre, etc.). To identify the causes of breakdown in spectators' attention in the illusion of film the next section describes a short study.

### 5.1.4 Study: identifying breakdown in the illusion of film

To identify the causes of spectators' shifts in focus of attention from the illusion of film to the real world (i.e. breakdown) a short study was carried out. Before it is possible to identify breakdown, a method is first required. Ideally, this would be concurrent and continuous while their cause remains a part of spectators' short-term memory. In an attempt to find such a technique, investigations of film, filmmaking, film review and rating techniques were carried out. Bouzereau (1994) describes one such approach developed in the 1940's and 50's to assess film presentations for market research was a technique developed by George C. Gallup's (i.e. of Gallup opinion polls) company Audience Research, Inc. (ARI). In this scheme, spectators activate a dial, slider or buttons to reflect their likes or dislikes during a film presentation. Results then provide the identification and assessment of a film's negative or positive components. More recently, a similar technique has been used to assess users' sense of presence in mediated environments. Users make on-line judgments using a sliding potentiometer to reflect their level of presence (Freeman, Avons, Davidoff and Pearson 1997; IJsselsteijn, Freeman, Avons, Davidoff, de Ridder, Hamberg 1997). One could argue that a shift totally to one end of the sliding scale may be used to indicate breaks in engagement or shifts in focus of attention from the illusion of film to the real world. Slater and Steed (2000) propose an alternative method in which users verbalise the occurrence of a shift in focus of attention from the virtual to the real world to indicate breaks in presence. The main drawback in common with these methods is the spectators' requirement to divide their attention between the mediated experience and the operation of the dial, buttons, slider, or to keep in mind the verbalization. Hence, the process of assessment (i.e. dial, buttons, slider, verbalization) may disrupt the assessment process itself and potentially be a cause of breakdown.

**5.1.4.1 Method**

One way forward is to allow spectators to view a film presentation in its entirety without having to divide attention. Following a film presentation focus group sessions or/and asking questions (e.g. interviews, questionnaires) with spectators may be conducted in an attempt to identify the causes of breakdown. These are simple, low-cost and unobtrusive methods that require no elaborate technological devices. Although retrospectively collected data such as this puts in question the potential threat to its validity (see: chapter two) it is argued that, until an accurate and unobtrusive continuous assessment method is developed, its advantages outweigh its disadvantages. Furthermore, it could be argued that the simple and uncomplicated nature of the data (e.g. the cause of shift in focus of attention from the film to the real world) requires little, if any, complex reasoning about the circumstances surrounding its occurrence. Added to this is the knowledge that the conditions under which the film is presented in a darkened auditorium with silent and almost motionless spectators could be likened to laboratory controlled conditions. Hence, it is argued that the cause of many disruptions will be unambiguous, easily identified and recalled (e.g. noise, unusual or distracting behaviour of other spectators, uncomfortable surroundings, audio or visual problems, or uninterested in the film's content, etc.). As a starting point, in an attempt to identify shifts in focus of attention from the film to the real world and breakdown to spectators' film experience, a short study with nine filmgoers of three different genres (comedy, drama, action/adventure) at two cinemas (art house and mainstream) was carried out. The method used was to ask spectators as they left the cinema auditorium *if anything had broken their focus of attention during the film's presentation.*

### 5.1.4.2 Results

The self-reported cause of breaks or shifts in attention varied between all spectators across each film and two spectators reported no breaks at all. In all, nine different types of breaks were reported. Figure 5.2 shows the number of spectators experiencing each type of break from: bad acting, bad script, sound too loud, projection flicker disrupting imagery, distracting noise in the auditorium from other spectators, awareness of other spectator's behaviour, movements and reactions, thinking of the time, thinking or planning past or future events. Irrespective of the frequency of their occurrence, reported breaks from each category count as one only per spectator.

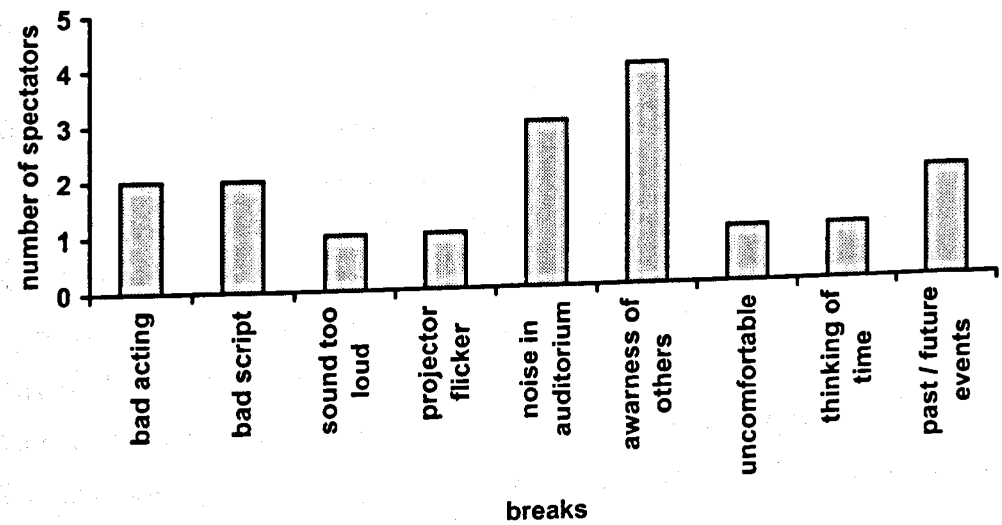


**Figure 5.2 Spectators' self-reported causes of breaks in the illusion of film**

On analysis, the cause of spectators' self-reported breaks in the illusion of film were conveniently categorised as being either: *internal* to the film, the filmmaking process, and projection of the film; *external* to the film; or a spectators' voluntary or *subjective* shift in focus of attention as described below. The frequency of spectators' shifts in focus of attention to the real world within these categorizations is shown in table 5.1.

i. *Internal breaks:* are anything relating to the film, the techniques and film making process, and equipment of filmmaking and its projection. This is divided into two subgroups. The first of these are breaks to content, that is, from the actual film itself. Although identified in the study as *bad acting* and *bad script* this could be extended to anything in the content from bad story, plot, sound, lighting, imagery and so on, to awareness of cinematic and editing conventions. These will be referred to as continuity breakdowns. Although perhaps not always in keeping with its true meaning and use in cinematography, this provides a convenient way to categorize breakdowns relating to content. The second is anything belonging to the film and the filmmaking process that is not intended to be within the film's content. This is the mediating technology used to capture and project the imagery and sound. The study identified that breaks in this category were from the *sound being too loud* from the speakers and *flicker from the projector* disrupting the imagery. Other examples are glitches in the technology or synchronization to project the film. It is acknowledged that some breaks fall in both groups (e.g. sound boom appears in frame or identifying back-projected or cut-out scenery). These will be referred to as "equipmental breakdowns".

ii. *External breaks:* are anything external to film. The study identified breaks in focus of attention as the result of *noise in auditorium, awareness of other people's behaviour, movements or reaction* and an *uncomfortable viewing environment.*

iii. *Subjective breaks:* these were identified in the study as a deliberate, automatic or voluntary momentary shift in focus of attention through the *contemplation of past or future events* and *thinking about the time.* Consistently occurring breaks from this category may point to an individual's lack of interest in the film presentation or genre.

**Table 5.1 Frequency of spectators' self-reported breaks by categorisation**

| internal | | external | subjective |
|---|---|---|---|
| content | mediating technology | | |
| 4 | 2 | 8 | 3 |

### 5.1.4.3 Discussion

The purpose of this short study was to identify potential causes of breaks to spectators' attention in the illusion of film. Analysis of the nine spectators' self-reported types of breaks revealed three dominant categories: internal, external and subjective and this division facilitates the simple and quick classification of breaks. The results of this study are used to inform a similar study to detect breakdown in the illusion of interactive mediated environments as described in chapter six.

Although we have identified and formed categories of the causes of many shifts in spectators' attention from the film to the real world (i.e. breaks) it is however, still unclear whether or not breaks are detrimental to spectators' film experience. Logic would suggest that spectators with more breaks in attention have a reduced transfer of experience than spectators with little or no breaks in the illusion of film. However, validity of this argument will require further research.

## 5.2 Remediation: from film to virtual reality

In a way, similar parallels can be made between the innovative and technological developments in computer-based mediated environments (i.e. from the 2D GUI to 3D VEs) and those of film. Indeed, various writers have explored the relevance of techniques in filmmaking to interface design (e.g. McKendree and Mateer 1991; May and Barnard 1995) and to the design of virtual environments (e.g. Laurel, Strickland, and Tow 1994; Pausch, Snoddy, Taylor, Watson and Haseltine 1995 & 1998; Persson 1998; Marsh and Wright 2000a). While the literature demonstrates the obvious enthusiasm, there appears to be little in the way of implementations or concrete examples arising from a clearly drawn out path from filmmaking to interface or content design. Exceptions can be found in the last two papers that develop guidelines from cinematography conventions to inform design, to improve user comprehension of space and so reduce the occurrence of user disorientation during navigation and exploration. Further to this, Marsh and Wright's (2000a) guidelines are subsequently validated in empirical studies (Marsh and Smith 2001a; 2001b). See: section 5.3 for further discussions on time and space in film and interactive mediated environments, and section 5.4 for study to test guidelines to reduce user disorientation.

According to Bolter and Grusin (2000), looking to film to inform visually mediated environments is unsurprising as all visual media is refashioned or remediated from old. For example, they discuss the remediation of photography from painting, film from photography, and so following this line of argument they suggest that a natural progression would appear to be the remediation of VR from film. A similar claim is made by David Hockney (2001) who traces a link from optical techniques (e.g. using devices like *camera obscura*) used to render images in pre-renaissance painting (e.g. Vermeer) through photography to film; with each new art form being informed from techniques developed from preceding art forms. To lend further support to the notion of remediation this section formulates a close mapping between developments in VR and those of film (Marsh 2001; 2003b) and develops a framework of experience that can inform the design and evaluation of VR.

In reference to figure 5.3, the developments in film are widely described by film-theorists as a progression from *recording* through *"cinema of attraction"* or *spectacle* to *narrative.* The first is the recording or actualities phase (e.g. documenting of actual or real life events: Auguste and Louis Lumière). A film presentation typical of this phase would consist of shots taken from different scenes or locations, say for example, a street scene with various events taking place and workers exiting a factory; these were simply joined together to form one continuous film presentation devoid of any continuity between shots.

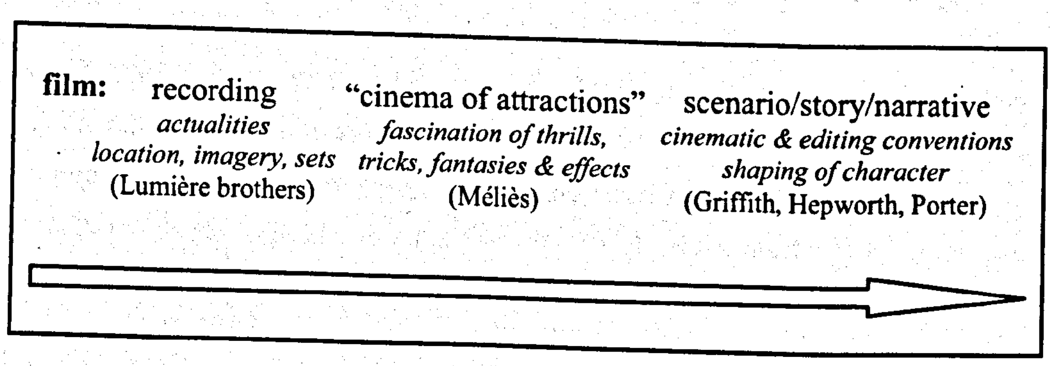


**Figure 5.3 Progression in developments of film**

The next developments in film can be described as an ephemeral experimental phase – testing or pushing the boundaries of the medium to see what works. Film characteristic of this phase are captured well in Gunning's (1990 pp. 56- 62) widely used term "cinema of attractions" (or spectacle) with its "fascination in the thrill of display" or spectacular virtues, "féeries" (i.e. magical spectacle/fantasies) and tricks (e.g. disappearing in a puff of smoke: Georges Méliès – although more recently his work is identified as having elements of narrative structure; for discussion see: Ezra 2000). Finally, to the emergence of scenario/narrative in cinema (e.g. construction of story: David W. Griffith, Cecil Hepworth and Edwin S. Porter) and the enhancement and shaping of character to provide experience (Boorstin 1995). Central to developments in narrative were cinematic and editing conventions to manipulate time and space. These arose in order to communicate experience and to serve as syntactic elements in the construction of meaning (Laurel, Strickland, and Tow 1994). Referred to by many names including, "classical cinema" and "invisible style" (see: section 5.1), to a large extent this style emerged from Hollywood in the 1910's, 20's and 30's and eventually came to dominate commercial narrative cinema (Kepley 1983). As mentioned, the main reason for the style's adoption is as Laurel, Strickland, and Tow (1998 p. 188) explain, that it was successful in forming a language that supports the creation of films of "increasing complexity and power".

It is interesting to note that Georges Méliès encountered a steady decline in audience numbers for his féeries to the emerging films of the day that contained scenarios. The central reason for this decline was the "dramatic compositions" of scenarios and their potential to evoke a greater wealth of experiences than those obtained from the spectacle of thrills, tricks and fantasies. The writers of these earlier film scripts were referred to as scenario writers (e.g. D. W. Griffith began his film career writing scenarios) and their emergence marks the beginning of narrative film (Loughney 1990).

Although developments in film are widely described as following a chronological progression (as shown in figure 5.1), some film-theorists however, would argue that in reality there is a blurring between these categories. Hence, the exact nature of developments in film is still under debate and is beyond the scope of this thesis. For further discussions on the tensions that exist between these categorizations the interested reader is referred to for example, Elsaesser (1990) and Ezra (2000). Although it is acknowledged that while some blurring between categorizations may exist, for the purposes of this thesis however, this provides firstly, a useful framework to deconstruct film using these categorizations and secondly, a way to draw comparisons with developments in interactive mediated environments. Furthermore, it should be emphasised that not all films necessarily contain elements from the last category (i.e. scenario/storytelling/narration) but are entirely dependant upon the film's genre and the kinds of experience that the filmmaker wishes to transfer to spectators. Hence, a film may contain elements of some or all three: recording/actualities, thrills/tricks/fantasies, and scenario/storytelling/narrative. The current trend for large budget commercial mainstream film (i.e. the so-called Hollywood blockbuster) is to concentrate more on spectacle or "attractions" (e.g. thrills, explosions, effects) and less on narrative and story. Subsequently, there is a widespread belief that this has had a detrimental effect on story and so increases the reliance on the "attractions" to carry the film. For an in-depth treatment of the historical progression and developments in film see for example: Arnheim (1957), Cook (1996), Elsaesser (1990), Parkinson (1995), Sklar (2002).

As previously stated, central to the success of film and encapsulated in the term "invisible style" is its ability to hold spectators' focus of attention in the illusion of film in a way that hides the underlying artificiality used to capture, manipulate and then project film within the borders of the projection screen (see: Messaris 1994; Rosenblum and Karen 1979). It is argued that the more spectators' undivided and uninterrupted attention is focused on the illusion of film then the more that they are able to receive continuously varying levels and varieties of experience that provide meaning intended by filmmakers. This raises a number of questions, in particular: What kinds of experience do spectators receive and how do filmmakers create these experiences? In an attempt to provide answers to these questions the next section draws upon work in film studies, feminism and filmmaking and develops a framework of experience that fits neatly with the progression in developments of film as described above.

### 5.2.1 Framework of film experience

What motivates an audience to watch films for hours on end? What makes a good film? These are topics of continuing debate. Much work in film studies has concentrated on analysing film as text, but not text as in the written word, but in "texture" or the "weave" of images and sounds from a variety of different sources. To aid our understanding of this, Phillips (2000) offers an alternative view and goes one step further by arguing film is more than text - it also provides "meaning" and "experience" for the spectator. In his concise treatise he discusses "pleasures" that come from "story", "spectacle" and "character" (p. 12), and in developing "a language [of film] that is capable of shaping and articulating what we know and experience" (p. 4). In addition, he talks about scopophilia - the pleasure that comes from looking – as a central and major aspect of spectatorship since the beginning of cinema. Similarly, Laura Mulvey (1975) developed the concept of "visual pleasure". Although the term originates from feminist literature to describe pleasure that arises from images with a sexual content (e.g. the first meaning of voyeurism given by the Oxford English Dictionary 1989), Ezra (2000 p. 5) argues that the term can be extended to include "any spectacular element of a film, from lush scenery to magic tricks designed to amaze and delight". Placing these elements (i.e. from lush scenery to magic tricks) within the progression of film (i.e. recording to spectacle respectively), as shown in figure 5.3, Ezra (2000) expands Mulvey's (1975) concept of "visual pleasure".

Another approach that encapsulates "visual pleasure" and also embraces Ezra's (2000) expanded proposal on Mulvey's (1975) work comes from Boorstin (1990, 1995). In his influential books: "The Hollywood Eye: What Makes Movies Work" (1990) and "Making Movies Work: Thinking Like a Filmmaker" (1995) he states that we don't watch films in one way but in three ways and as we watch a film the three compete in us. In reference to figure 5.4, Boorstin's (1990, 1995) three categories: "voyeuristic", "visceral" and "vicarious" (3Vs) that describe spectators' film experience link with some ease to the three categorizations in film's development (from: figure 5.3).

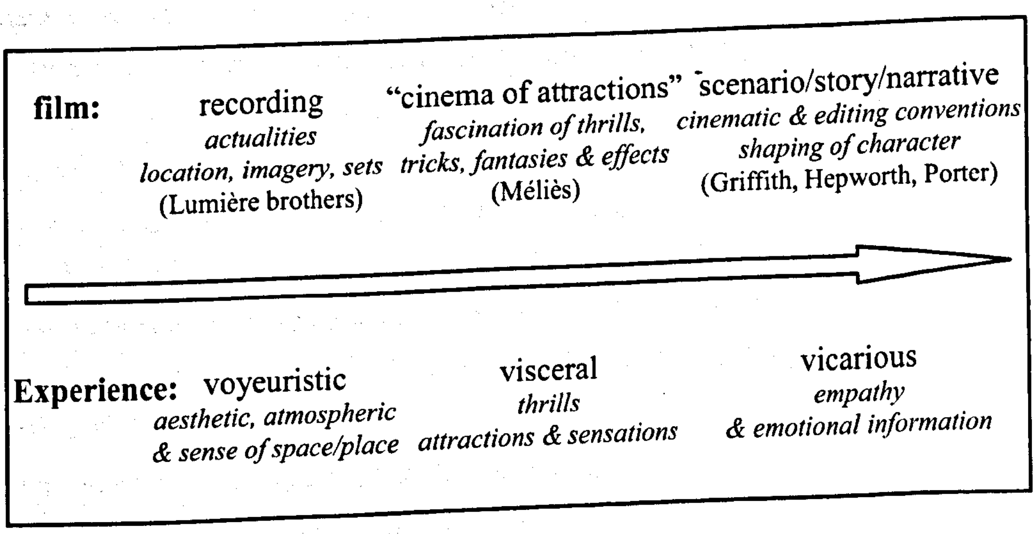


**Figure 5.4 Framework of spectators' experience from film developments**

There are similarities between Phillips' (2000 p. 12) categorizations of "story", "spectacle" and "character" and Boorstin's (1995) "voyeuristic", "visceral" and "vicarious" respectively. Indeed, Phillips' (2000) categorizations indirectly reference the progression of film as outlined in figure 5.3. Although a key difference is Phillips' (2000) emphasis on "visual storytelling" or "story" that "take place in locations, physical places or – to put more abstractly – in space" (p. 17). Here the space or places of locations – of the story – are of secondary importance to the story itself, while Boorstin (1995) talks about "story" and "place" with equal emphasis. The broad categories forming the framework are described as:

*i. Voyeuristic:* "the voyeuristic world is where movies began. Before anyone thought that film could portray character [i.e. vicarious experience], before the great innovators of the twenties had invented montage and tapped the visceral power of film editing" (Boorstin 1995 p. 151). The voyeur is the "prying observer" (p.12) and the voyeur's pleasure is the joy of seeing "the new and the wonderful" (p. 12). The fundamental components of voyeuristic are "place" and "story". Their use and meaning in the context of voyeuristic reflect the dynamic nature of film. Place refers to the geometric shape and space of the location, imagery, scenery and sets just like that identified in the recording phase of film (see: figure 5.3) and the atmospheric moods and aesthetic delights (in the creative, imaginative, realistic or accurate reproduction) created by these spaces. Story refers not to the transmission of emotional information through character like that of the vicarious experience (see below) but in the progressive advancement of the dynamic film. That is, "something has to happen" (p. 13). To emphasis this, Boorstin (1995 p. 47) draws an analogy with turning the pages of a storybook to find out what happens next; what E. M. Forster describes as "and then…and then". If there is nothing to provoke our curiosity and interest in both "story" or "place" of film then simply we get bored. Finally, this must occur within a credible flow of time and space. That is, the pace shouldn't be too slow to bore or too fast that we lose track of or get lost in the film and the film must be plausible – it must make sense.

*ii. Visceral:* the instinctive base sensations and thrills; these are gut reactions rather than emotions. For example, the roller coaster and helter skelter type effect, the sensation of movement (e.g. vection: visually induced illusion of self-motion), feelings of fear, disgust and nausea, as well as sensual and sexual feelings (i.e. "the surge in your loins" p. 114). More complex emotions require the vicarious (see below for definition) transfer of feelings. It's more simple with visceral; if it's not a thrill (it isn't visceral) and its main criticism is "it doesn't get me" (p. 114). This is because either we have acquired an increase in threshold for the visceral effect to kick-in or simply the design of the visceral effect is inadequate. Point-of-view (POV) is the gateway to the visceral and like vicarious experiences POV puts us in the scene (e.g. driving a racing car).

*iii. Vicarious:* is "[1.] experienced in the imagination through the feelings or actions of another person" (Oxford Concise 2001). Vicarious is closely associated to *empathy*. For example, Laurel (1993 p. 120) uses vicarious to explicate the meaning of empathy: "In drama, we experience empathy with the characters; that is, we experience *vicariously* what the characters in the action seem to be feeling." Indeed, looking to definitions of empathy we find strong similarities to that of vicarious. For example, "The Oxford Concise Dictionary" (2001) defines empathy as: "[3.] the state of being emotionally and cognitively "in tune with" another person, particularly by understanding what their situation is like from the inside, or what it is like for them"; "[4.] the ability to identify with and understand others, particularly on an emotional level." Although in searching for a deeper meaning of empathy, Levenson and Ruef (1992) point out, that "the experimental and theoretical literature on empathy has failed to agree on a single definition" (e.g. Eisenberg and Miller 1987; Wispé 1986), they state that "the most useful definition of empathy would emphasize the ability to detect accurately the emotional information being transmitted by another person". They add that "the ability to perceive accurately the feelings of another person is arguably the most fundamental aspect of empathy". Within film (and theatre e.g. Laurel 1993), the empathic or vicarious experience usually occurs between the protagonist (i.e. the hero, central character) and the spectator/audience. Boorstin (1995 p. 71) refers to the ability of an actor to convey or transmit accurate and believable emotions as "honest emotions". Boorstin (1995 p. 71) suggests that the vicarious experience stops working when a character is unbelievable, emotionally untrue or simply "he wouldn't do that". See discussions in chapter (7.4.3).

As spectators of a film, the voyeuristic, visceral and vicarious experiences are not necessarily mutually exclusively but may occur simultaneously and compete within us. Boorstin (1995) provides many descriptions of this. One example is the well-known shower scene from Hitchcock's film "Psycho" (Hitchcock 1960) and this shows how they can be applied to film. That is, how to identify and reason about the kinds of experiences induced in spectators and the effect and affect it has on them. Although predominately visceral, the scene clearly demonstrates how the spectator experiences one or a combination of the 3Vs:

*"The shower scene in Psycho is generally accepted as one of the scariest moments in movies. Yet much of the visceral shock of the shower scene comes from the skilful way Hitchcock plays it off against the vicarious and the voyeuristic".*
*"Hitchcock begins in a voyeuristic vein, using involvement in a story twist to set up his big visceral scene; that scene, in turn, sets up the crucial vicarious moment in the film"*
*"The sequence begins on a* ***voyeuristic*** *note – literally. Through a hidden peephole Tony Perkins watches Janet Leigh take off her clothes. There is an element of titillation in this, but basically we're in the world of story...Leigh then steps into the shower and in an extended sequence unwraps the soap, turns on the water, and lathers herself. We linger on her showering – again Hitchcock hints at titillation (this is a film about sexual perversion after all, and if our own sap is rising it will give the action more personal bite), but we're also wondering whether there isn't some story point involved. Is Perkins watching her again? Perhaps this time she'll discover him. Indistinctly, through the shower curtain, we see the bathroom door open. Our plot musings end abruptly – this must be Perkins, entering to make a pass at Leigh. Then the curtain is pulled aside – and it isn't Perkins, it's a woman, and she's holding a knife.*
*Suddenly, the scene is wrenched into* ***visceral****. The knife comes down, the violins scream, we see thirty-one images in the next twenty-two seconds, picture cuts cue to the slashing knife. We see the knife come down, then we see Leigh's screaming face – a* ***vicarious*** *image, as we feel her fear – then we're close on her screaming mouth, so large on the screen we're almost inside it – not a* ***vicarious*** *image, not a way to share her emotions but to trigger our own. We see the knife come down, we see her try to hold it off, three times more we see the knife come down and then we see her face as she is stabbed, we see the knife come down and we see it flash past her naked torso...we see her sink into a stupor. We see the killer leave.*
*Notice that while this is a* ***visceral*** *scene par excellence, Hitchcock spies the* ***visceral*** *with* ***vicarious*** *moments of Leigh's shock and fear as counterpoint to the mayhem. We are feeling the moment as our own – but we are also seeing it through her eyes. Not through the eyes of the killer. Hitchcock shrouds the killer in darkness, though in the actual lighting of the bathroom 'she' should be as brightly lit as her victim. The shots intercutting the two ricochet between an anonymous shadow plunging a dark knife and*

*flashes of Leigh's face in a classic empathic close-up, asking us to share her shock and pain." (pp. 139-142)*

In contrast, Boorstin (1995) describes Stanley Kubrick's "2001: A Space Odyssey" (1968) as perhaps the ultimate voyeuristic film. Although the film provides other experiences for the spectator (for example, the visceral experience in Douglas Trumbull's "StarGate sequence") it is in most part devoid of any complex story, character, or suspense. To keep us watching and maintain the illusion Boorstin (1995 p. 153) suggests "Kubrick keeps the pages turning simply by showing us one amazing sight after another". "As pure an example of a vicarious film" Boorstin (1995 p. 145) identifies Alan Pakula's "Sophie's Choice" (1982), particularly in the scene that prompts the film's title where "Sophie" played by Meryl Streep is forced to make a choice between her two children.

### 5.2.2 VR: remediated film

In reference to figure 5.5, similar developments in interactive mediated environments are identified to that of film. It is argued that modelling, from cubes (Sutherland 1965; 1970) to 3D worlds, is likened to film's recording or actualities phase. In film, this in most part refers to recording or capturing of actual everyday real life events and scenes by pointing a camera in the right direction to frame the scenery, sets and circumstances. Similarly, in mediated environments this is the computer-generated representation of real or imaginary (or abstractions of) objects and 3D environments. Although in mediated environments we don't have the benefit or advantage of being able to point a camera to capture content – we have to construct or model it. Furthermore, the camera captures a sequence of images that are presented to spectators whereas, in interactive mediated environments the user is active and chooses where to look and move. The additional interactive component is one of the central differences between film and interactive mediated environments and provides the means to view, move around and through the model.

Attempting to draw a parallel to film's next phase, "cinema of attractions", appears at first sight to be somewhat problematic. A way forward is to divide interactive mediated environments into two groups: computer games and entertainment systems, and VR (that in most part is in an experimental/scientific/research phase) that are both devoid of any complex narrative structure (see later). It is easier to draw a parallel with developments to the first of these, computer games and entertainment systems running on a PC or dedicated configuration (e.g. games consoles, video arcade games or VR entertainment systems) than with VR (i.e. experimental/scientific/research). This is because the goal of development is to provide entertainments for users and it is argued that this is described well as thrills, tricks and fantasies and hence, is directly analogous to that of film. Indeed, the inspiration of Gunning's (1990 pp. 56-67) term "cinema of attractions" can be found in the Russian Filmmaker Sergei Eisenstein's attempt to find a way to describe thrills/tricks/fantasies in film (Arnheim 1957). Eisenstein found the closest approximation to be with fairground "attractions" and especially to his favourite, the roller coaster or "American Mountains" (Gunning's (1990 p. 59). Thus, by drawing such an analogy, this is, in a way, taking the meaning of "attractions" back to its origins, the fairground (i.e. the arcade). So perhaps an appropriate way to describe this is interactive mediated environment or VR of "attractions".

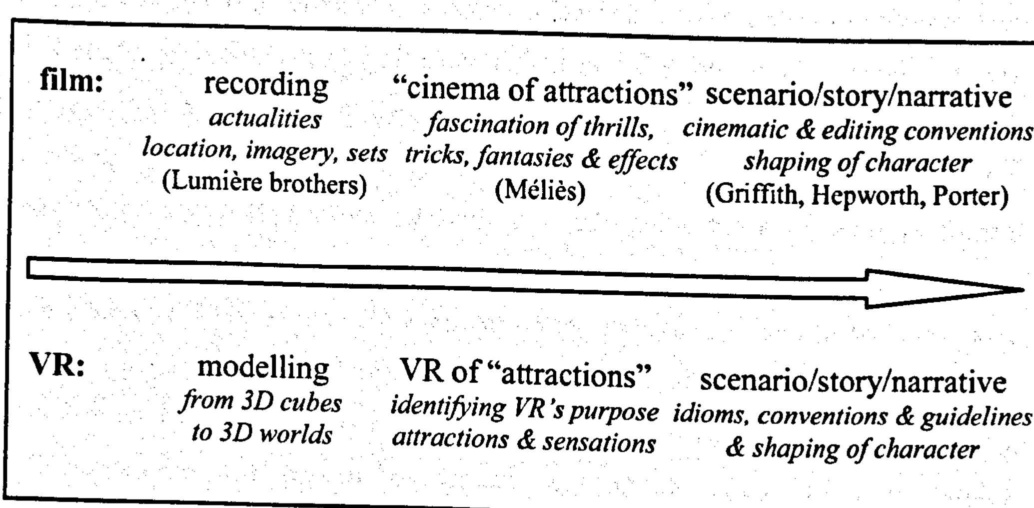


**Figure 5.5 Parallel/natural progression from film to VR**

With developments in VR (i.e. experimental/scientific/research) however, the analogy is not as apparent. The nature of this work which comes largely from the academic and research communities is experimental and just like that of the "cinema of attractions" it tests or pushes the boundaries of the medium to see what works (e.g. to identify optimal blends of hardware and software that are appropriate to the environment and purpose in which they are intended to be used) and to identify the purpose or goals of VR. Proponents of VR would perhaps argue that their environments are developed for real purposes: scientific, engineering, education and training, and medicine, etc. Any suggestion that these provide thrills, are tricks or can be described as fantasies in any way, shape or form would most likely be met with strong opposition. However, if one examines the purpose, goal or requirements of successful VR systems (some of which have been identified as in "routine production use" Brooks 1999: see: chapter seven) a common characteristic that can be identified in many of these is sensations, such as, driving, flying, fear inducing, etc. These can indeed be described as thrills, but thrills with purpose (e.g. ergonomic assessments, training and overcoming phobias respectively).

Finally, looking to the development of scenario, storytelling and narrative, this can be directly compared to that of film. One of the main drivers can be found with emerging computer games. Due to the commercial nature and associated profits, their underlying developments and mechanisms remain guarded in-house secrets and generally go unpublished. Work is beginning to appear that addresses the inherent tension between interaction and narration (for example see: Hales 2000; Mateas 2000; Young 2000). That is, in contrast to old media (e.g. literature, radio, and film), new media gives the user control of their encounter and so allows them to formulate their own non-linear narrative structure. Examples of innovative techniques that attempt to ease this tension and are commonly found in computer games are, multi-choice narrative paths, the suspension of interaction whilst story is updated, and essentially, these are examples of new kinds of idioms (e.g. phrase, vernacular, language or dialect) and are constructed with a lexicon (e.g. vocabulary, glossary). Pausch, Snoddy, Taylor, Watson and Haseltine (1998 p. 358) identify the lexicon of film between directors and spectators as "close-ups, cross cuts, flashbacks, etc.". They go on to suggest that over time a common lexicon will evolve for VR and it is argued that this will form a common language or idiom between VR designers and developers and users and may perhaps orchestrate their wider adoption and acceptance as conventions (i.e. standard practice). An investigation of how idioms in film may be used to inform the development of idioms in VR or interactive mediated environments is further explored in section 5.3. Laurel, Strickland, and Tow (1998 p. 188) suggest the motivation for this, just like that of film, is that it may lead to the formation of a language that supports the creation of virtual/mediated environments of "increasing complexity and power". Like film, this may provide a way to shape character and story and enhance users" experience. The focus for this final category as discussed in the next section is in experience induced/evoked in users through character.

At the time of writing, developments in interactive mediated environments can be identified as belonging to both an experimental phase (i.e. VR of attractions) and more recently to developing idioms for the manipulation of narrative. Although it is anticipated that the emergence of idioms will provide the means to create richer user experiences, this is however, by no means the goal of all interactive mediated environments and like film is determined by the application/genre, their requirements or purpose and the types of experience that are required to be induced in users for the construction of meaning. Consider for example potential applications such as, architecture/real estate where the requirements are to visualise 2D drawings by constructing 3D virtual *models or actualities* and then take a virtual tour to assess the suitability or applicability to support the intended real world use; entertainment where the *thrill/trick/fantasy* is of more importance to give participants a buzz or kick; and training (e.g. fire fighting or surgical) where both *thrill/fear* and *scenario/story/narrative* are the dominant requirement/purpose. However, like film and as suggested above, an application may have elements or blends of all three: model/actualities, thrills/tricks/fantasies, and/or scenario/story/narrative.

It could be said that identifying the developments of interactive mediated environments in this way as a linear progression from modelling through a kind of VR of attractions to the development of idioms may be an over simplification. However, it is argued that this is a useful and worthwhile exercise principally for two main reasons. First, because it provides a way to draw comparisons with developments in film: to see where we are, how far we need to go to get to the stage where interactive mediated environments provide experiences comparable with those of film and inform on how we might get there. Second, the three phases of development (as shown in figure 5.3) can be used as broad categorizations for the different kinds of experiences that are induced in users/spectators. Thus, providing a convenient way to develop a framework of experience and this can be used to inform the design and evaluation of interactive mediated environments.

### 5.2.3 VR framework of experience

In reference to figure 5.4, Boorstin's (1995) three categories: voyeuristic, visceral and vicarious (3Vs) which describe spectators' film experience, link with some ease to the three categorizations in film's development (figure 5.3). Following the identified paralleled development between film and VR (figure 5.5) this naturally forms broad categories for a framework of users' computer mediated experience as shown in figure 5.6. This builds on work initially developed during my Research Fellowship at the Human Interface Technology Laboratory (HITLab), University of Washington, WA, USA (August to November 1999), originally proposed in Marsh and Wright (2000b) and in an extended version (Marsh, Wright and Smith 2001). The framework is further developed in Marsh (2003b) and tested in studies as reported in Marsh (2001). Besides the work reported herein, the framework is also being applied to e-commerce (Wright, McCarthy and Marsh 2001), to inform "enchantments of technology" (McCarthy and Wright 2001, 2003) and "Emotional Design" (Norman 2004). The broad categories forming the framework herein are described as:

*voyeuristic experience* is the pleasure that comes from looking, the joy of seeing the new and the wonderful – the sensational. If there is nothing to provoke our curiosity and interest (in the location, scenery, imagery, sets or 3D world) then simply we get bored. Essentially, this refers to the aesthetic, atmospheric and sense of space or place. Additionally, this must occur within a credible flow of time and space – i.e. the pace (shouldn't be too slow to bore or too fast that we lose track of or get lost in the 3D environment / story / game / film) and plausibility (the 3D environment / story / game / film must make sense). Either of the above has the potential to disrupt or *break* users or spectators' attention in the mediated environment.

*visceral experience* is the instinctive base sensations and thrills, the gut reactions rather than emotions. Essentially these are the "attractions", sensations and thrills. The kinds of experience that fall into this category are for example, the roller-coaster type of feeling, sensations of movement (e.g. vection in mediated environments), sensual and sexual feelings and those of fear and disgust. The *breakdown* in the visceral is simply, if it's not a thrill, it isn't visceral and its main criticism is "it doesn't get me" either because we have acquired an increase in threshold for the visceral effect to kick-in or simply the design of the visceral effect is inadequate. Hence, this may result in the user or spectator to break their focus of attention.

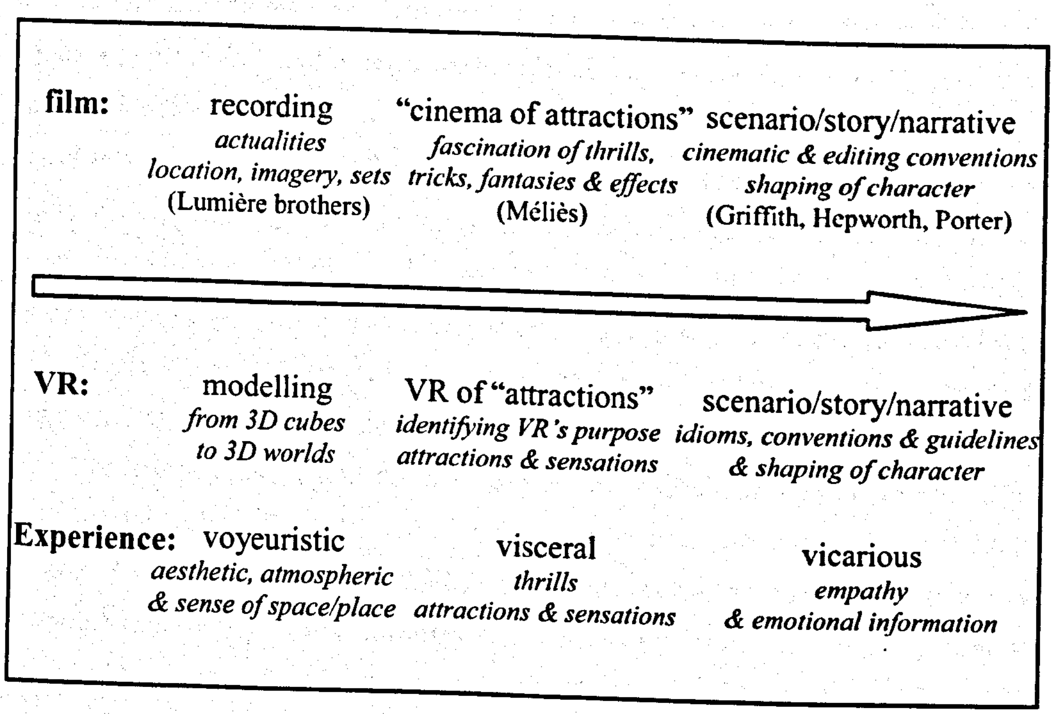


**Figure 5.6 Framework of user experience in film and interactive mediated environments**

*vicarious* is to imaginatively experience something through another person, being or object. Within a mediated environment interaction is performed vicariously through either a first or third person perspective. Resulting experiences are for example, the transmission of emotional information through empathy. This is to know what a person is feeling and to feel what that person is feeling (Levenson and Ruef 1992). The empathic process is transferred through actions, stories or anecdotes, or facial expressions usually from one person to another person. Within film (and theatre) the vicarious/empathic experience is induced through an actor's ability to convey "honest emotions". Potential *breaks* in empathy are the emotionally untrue. Many methods have been developed to capture or measure empathy. For reviews see for example: Levenson and Ruef (1992). However, in mediated environments another kind of empathy is identified - the transfer of emotions and personality traits from the user's virtual character (i.e. the character that the user controls or represents/takes the part of) to the users themselves. The higher the transfer of emotions the higher the empathy and the term "empathic accuracy" (Ickles 1993; 1997) will be used to describe this. Conversely, a weak transfer of emotions may result in a breakdown in focus of attention. The same approach may be used to provide a measure of the transfer of emotions between the user and other virtual characters within the mediated environment. This is the virtual actor's ability to convey "honest emotions" and again, a weak transfer of emotions may result in breaks to attention.

It is argued that user experience is a key concept in the evaluation and design of computer-based mediated environments. Therefore, this is used in chapter six to inform evaluation of design of VR. Chapter seven investigates how the experiences of the framework may be captured and in chapter eight a questionnaire is developed and tested in two empirical studies.

## 5.3 Future VR developments: idioms/conventions to articulate time and space

Film unfolds in time and space (Burch 1983). Cinematic and editing conventions (to manipulate time and space) "arose in order to communicate subjective experience and to serve as syntactic elements in the artistic construction of meaning" (Laurel, Strickland, and Tow 1998 p. 188). As previously stated, the main reason for the invisible style's adoption is as Laurel, Strickland, and Tow (1998 p. 188) explain, that it was successful in forming a language that supports the creation of films of "increasing complexity and power". To a large extent, the conventions to manipulate time and space in cinema are inseparable; they are intertwined. An editing technique to represent or articulate one of these may also have an effect on the other. Take for example, an edit used to represent a transition in space between scenes in different locations, using say a wipe, fade or dissolve. This may also infer a temporal transition, to denote going back in time or flashbacks, the passing of time or that time has elapsed, or travelling forward in time or flash-forwards.

In contrast, virtual environments unfold in continuous space and in real time in response to participants' interaction within the virtual or mediated space. That is, instead of receiving information or narrative as a spectator of film, in VR your interactive contribution determines the outcome. Participants of VR create their own journey or narrative through constant time and within mediated space. Or as Laurel, Strickland, and Tow (1998 p. 182) state, "the experience of VR hinges on human action and the environments response", and "in VR one is not done unto but doing". The additional interactive component of VR is a central concept that sets it apart from cinema. A user's interaction with a VR system occurs in real time, and thus, it is the interactive component that dictates the unfolding of smooth and continuously animated mediated space in real time. As a result, it is difficult to envisage how edits that represent temporal transitions can be applied in the design of VEs. That is, can VE design make use of conventions to suggest flashbacks or the passing of time? Future developments may well devise ways in which temporal transitions will be applied in the design of virtual environments, and these may feel natural and transparent to the user. Although, this is an area for further research, and its outcome remains to be seen.

Additionally, it is difficult to envisage how to apply the same on-screen editing techniques (for example, wipes, fades or dissolves) to support transitions in virtual space. Although it is easier to imagine the use of these edits as jump-cuts to relocate or teleport a user from one location to another in virtual space. For example, Laurel, Strickland, and Tow (1994) developed the concept of the portal (represented by a spiral) to transport people between three separate locations. The transition from one location to another takes around 10 seconds. To get around the problem of having to simulate the traversal of landscapes between locations, during each transition the participant is immersed in darkness and sound cues coming from "ahead" are introduced. However, Laurel, Strickland, and Tow (1998 p. 189) report that many questions need to be addressed such as: What is an acceptable transit time? - too long and perhaps people become fidgety and lose interest or with instantaneous teleportation "people might be too disorientated". Similarly, Pausch, Burnette, Brockway and Weiblen (1995) report on related problems of user disorientation in their proposed technique to manipulate space. In their scheme a user views a virtual environment or world in miniature, selects a location within that environment and is teleported to that new location. Likewise, Steed and Tromp (1998) describe problematic use of the "teleporter" metaphor in association with a holiday planning environment for virtual tourists in which users are teleported to potential holiday destinations (e.g. virtual Rhodes). Specifically, they report that the teleporter's three phases of operation: opening the teleporter, standing on the pad and pressing the teleporter button "was more akin to using a lift [elevator] and it might be better represented as such to make it easier to recognise the sequence of actions" for its successful operation.

Although the above published work reports on the problematic use of techniques to manipulate space it is not difficult to imagine further research in the near future overcoming these initial teething problems and to the development and successful future use of these and similar techniques. Perhaps one of the main difficulties implied in the above is the broadening of user's awareness and familiarity with techniques to manipulate space. Indeed this situation can be likened to those encountered in the development of filmic devices (i.e. edits). Whereby, the reaction of spectators confronted with a new film editing technique or device was likely to be one of bewilderment, shock or misinterpretation. Although following repeated viewing the device's meaning in the context of the film became more apparent and eventually forms part of the filmmaker's and spectator's vocabulary of film. In future research on VR it is not unrealistic to postulate the implementation of similar techniques to those described above for the manipulation of space and time. For example, from those designed to travel in time, H. G. Wells' "The Time Machine", in space using a "Wonkavator" from Mel Stuart's (1971) "Willy Wonka and the Chocolate Factory" (i.e. similar to a "teleporter"/elevator reported by Steed and Tromp (1998), "but a Wonkavator goes sideways and slantways and longways and backways and frontways and squareways and any other ways that you can think of...") and in both time and space, using the "Tardis" from BBC's "Dr Who", "teleportation" in "The Tomorrow People" or the "Transporter" in Star Trek. The development and implementation of these and similar novel techniques and metaphors to transport users/participants in time and space require further research and the outcome remains to be seen. Much of what has been learnt from studies of devices used in film to articulate time and space, from the implementation of devices or metaphors to transport or manipulate virtual space and suggested devices from fiction can be used to inform future work.

The overriding idea argued for in this section is one of naturalness and transparency and not to draw attention to a systems' underlying artificiality. Essentially this is arguing for a concept similar to that of the "invisible style". Like film, the implementation of such devices in interactive mediated environments should ideally avoid the reliance of extra information such as, signs, arrows, voiceovers etc., to aid comprehension. Burch (1986 pp. 486-488) coined the term "non-closure" to refer to the reliance on extra information in film such as, the hands of a clock spinning round or pages being torn from a calendar to suggest the passing of time, inter-titles between scenes or voiceovers to suggest shifts in locations. Similarities may be drawn here to

VE design, for example, in the use of devices such as signs, arrows and even flashing objects to guide users through virtual environments and to identify the interactivity or non-interactivity of virtual objects. Tromp and Fraser (1998) suggest that techniques of this sort "are not elegant solutions in a VE". Perhaps future developments in idioms for interactive mediated environments may see the reduction in use of techniques that instruct and direct users on what to do and where to go, and what not to do and where not to go. It is argued that the excessive use of these techniques may overpower users with extra information, draw attention to their artificiality (and that of the mediated environment) and has the potential to overshadow a visually pleasing rendering. As mentioned, some efforts have been made to develop more natural and transparent techniques through the positioning of objects according to guidelines to improve user comprehension of space (Marsh and Wright 2000a) and reduce the occurrence of user disorientation during navigation and exploration (Marsh and Smith 2001a; 2001b). As user disorientation is well known to be problematic in mediated environments (e.g. see: chapter three) and to demonstrate that cinematic and editing techniques can inform the development of idioms or guidelines in interactive mediated environments (i.e. remediation), a study is presented in the next section. Furthermore, it is anticipated that the results can be generalised to navigation of applications and other interactive mediated environments such as, the Internet and computer games.

Finally, while it is argued that cinematic and editing conventions may inform methods for the manipulation of temporal and spatial dimensions of interactive mediated environments, interestingly, we find that innovative mainstream presentations from film (e.g. "Rope", Hitchcock, 1948; "Cleo From 5 to 7", Varda, 1962; "Timecode", Figgis, 2000) and television (e.g. "24" 2000) have attempted to depict the unfolding of narrative in real-time just like that of interactive mediated environments. However, with the exception of "Timecode", all use cinematic conventions - to different degrees - to falsely reconstruct an illusion of real-time. "Timecode" using unedited shots from four digital cameras, presents a true real-time narrative. The enabling technology behind this innovative feat is the portable (i.e. not restricted to a still-long take style) digital camera allowing hours of footage to be captured. In contrast, Hitchcock's "Rope" (1948) was constrained by the camera magazine of the day that could only hold a ten minute roll of film; this was referred to as a "ten-minute take" (e.g. Truffaut 1986 p. 259). To hold spectators' attention, Mike Figgis uses split-screen devices to show either, the same event unfolding from different angles or different events unfolding concurrently. This represents a commercially successful attempt at developing a new cinematic language. As mentioned, the unfolding of narrative in real-time is similar to that of interactive mediated environment scenarios, so perhaps this innovative technique could be regarded as the refashioning or remediation of film from VR?

### 5.4 Design of virtual off-screen space

The work described so far has focused on conventions for the construction and articulation of space that is contained within the pictures that are framed by the borders of the projection screen. This is referred to as on-screen space or mise en scène. There is however, another kind of space in cinematography, the space that exists outside that of the projection screen and is referred to as off-screen space. To suggest to spectators the existence of off-screen space, cinematographic and editing conventions have been developed. Their purpose is to support the fragmented shots of the "classical Hollywood" style, to imply that additional space and action exists beyond that which is shown within the confines or boundaries of the screen and to aid the spectator's comprehension of cinematic space and hence, the narrative of film. It is argued that these conventions provide a means to inform the construction of off-screen space in virtual environments in present and continuous time, and this is consistent with the smooth and continuously moving animation within a VE. This section describes the development of guidelines informed from cinematic conventions for the construction of virtual off-screen space to aid user comprehension of space and so reduce user disorientation. A study is then described to test the guidelines. Results suggest that the use of guidelines can help reduce the incidence of user disorientation. Thus, demonstrating that cinematic and editing techniques can inform the development of idioms or guidelines for interactive mediated environments. That is, remediation of VR from film.

#### 5.4.1 Problem: user disorientation when navigating in virtual environments

Navigation in virtual environments can be difficult. Many usability problems associated with navigation and exploration of virtual environments are attributable to this. These include, the lack of navigation or wayfinding cues to guide users around the environment (Darken and Sibert 1996), problems when the whole display screen is reduced to one colour or texture whilst navigating too close to (Kaur, Maiden and

Sutcliffe 1999; Marsh and Wright 1999) or through virtual objects (see: chapter three) and the restricted field-of-view seen through the display screen (Neale 1997). Building on the conventions described below, guidelines are developed to inform the construction of virtual off-screen space. It is anticipated that guidelines will aid user comprehension of space during navigation and exploration and so reduce the occurrence of user disorientation.

### 5.4.2 Background

As mentioned, conventions for the construction of off-screen space in film supports the fragmented shots of the "classical Hollywood" style and implies that additional space and action exists beyond that which is shown within the confines or boundaries of the screen aiding the spectator's comprehension of cinematic space and hence, the narrative of film. Off-screen space is more complex than on-screen space and includes everything out of the frame, or not shown on the screen. In most part, this is purely imaginary. Burch (1983 pp. 17-31) identifies off-screen space as being divided into 6 segments. The 1st to 4th segments are determined by the edges of the screen. The 5th segment is the area behind the camera, and the 6th is the space that exists behind the set, the outer limit is beyond the horizon. He identifies three main conventions used to imply off-screen space in cinematography: *exit and entry points, points-of-view, and partially out of the frame*. In reference to table 5.2, the first of these is *exit and entry points*. In cinema, characters exiting or entering through one of these points will suggest to the spectator that there is space off-screen that leads to another area not shown on-screen. Theatre uses similar techniques to help audiences construct off-stage space that is additional to that which is seen on-stage. For example, as a play progresses and the story unfolds, the audience learns that the door to the left of the set leads to the kitchen and the door to the right leads to the back yard. Although the spaces contained off-stage are purely imaginary, the audience will however, construct a cognitive map of the off-stage space and this is essential for the development and understanding of the theatrical production. The second of these is *points of view*. In cinematography this convention is used frequently. Off-screen space is suggested to the spectator by a character on-screen looking somewhere off-screen, for example, either to an object, location, or talking to another person located off-screen. Finally, the third is *partially out of the frame*. In cinematography, a character or object is framed in such a way that some part of a character's body or a part or section of an object protrudes out of the frame to infer the space out of the screen. For example, a character sticking their head off-screen, say through a door or window to find out what is going on in the space we cannot see (Burch 1983). Or an object that is only partly seen on-screen constantly reminds spectators of the off-screen space where the rest of the object is contained.

### 5.4.3 Development of guidelines for virtual off-screen space

In reference to table 5.2, implementation of exit and entry points in VEs can be achieved by the use of graphical models or representations of: doors, paths, roads, etc. Their existence in the VE will trigger a participant's knowledge and experience. They imply that by taking this pathway a participant can reach other spaces that are not contained within the confines of the display screen. An example of a typical guideline for exit and entry points is shown in table 5.2 and this can be used to inform the design and the evaluation of virtual environments. Exit and entry points such as paths and roads are a special case or sub-group of partially out of the frame (see below). This is because only part or a section is shown on-screen.

**Table 5.2 Guidelines for design and evaluation of virtual off-screen space**

| cinematic conventions | cinema | virtual environments | guideline |
|---|---|---|---|
| exit and entry points | - character passing through door / corridor<br>- character moving out of the frame<br>- up / down stairs or in a caged lift | - doors, hallways, paths, windows, roads, etc. | - wherever possible, it must be clear to the user that there exists the option to exit the area contained within the confines of the display screen (HMD / monitor) |
| point of view | - talking to someone off-screen<br>- looking off-screen | - avatar gazing at / talking to, something / somebody off-screen | - where applicable, avatars should have the ability to look to space contained off-screen |
| partially out of the frame | - sticking part of body off-screen<br>- object partly on-screen | - familiar object shown partly in frame (HMD, display monitor) | - the placement of objects in the virtual environment should be such that there is always more than one object partially in the user's FOV |

With the introduction of characterization (e.g. virtual characters and avatars) in mediated environments the idea of *points of view* to suggest to the user that a character on-screen is looking somewhere off-screen (e.g. to an object, location or talking to another person located off-screen) becomes more realistic. This is similar to an idea suggested by Persson (1998). A set of typical guidelines for this might be as contained in table 5.2. The use of these guidelines will be especially useful in multi-user environments, such as, collaborative VEs and in video teleconferencing. Finally, an example of a typical guideline for *partially out of the frame* is shown in table 5.2. Techniques such as these may trigger a user's recognition of on-screen objects as being only a section of the whole object and thus implies that the rest of the object is in off-screen space. Persson (1998) suggests using a similar technique of using part of a human body as the background for a web page to suggest the potential to scroll to view more of the human body in off-screen space. Hence, implying that there is a larger web page than that seen through the restricted field of view (FOV) of the display screen.

It is anticipated that the application of the guidelines will provide users with visual cues to unconsciously predict the contents or shape of the immediate surrounding space in addition to that seen within the display screen's restricted field-of-view. That is, the space that is seen on-screen – within the display screen – implies additional space that is not seen through the current view port and is in off-screen space. Hence, users are provided with a greater knowledge of their immediately surrounding virtual space and it is proposed that this may aid navigation of virtual environments (VE). The next section describes a study to investigate the validity of two of the guidelines: *exit and entry points* and *partially out of the frame*. This focuses on the latter guideline and to a lesser degree the former. That is, the guideline *partially out of the frame* will be manipulated. Virtual characters were not incorporated in the test environment and are therefore, the guideline for *point-of-view* cannot be tested in this study. It is anticipated that the guidelines will appear natural and transparent, support user navigation by reducing the number of usability problems (wall collisions and walking through virtual objects) and hence, reduce user disorientation.

**5.4.3.1 Study**

The study consisted of two groups. Both were required to carry out a navigation task in a virtual environment, one with the design guidelines implemented and the other, in the same virtual environment without the guidelines. The test desktop-based virtual environment used in the study is a "virtual corridor" or maze implemented in the Windows version of GNU MAVERIK (1999). In this study, collision detection was turned off, that is, subjects are able to walk through virtual objects. The maze was implemented in conformity with the guidelines and featured pictures, picture frames, wall panels, and dado rails, etc. mounted along the walls of the virtual corridors. Their placement was in accordance with the guideline for *partially out of the frame*. The maze had neither windows nor doors, had one entrance, one exit and a corridor or pathway connecting them; these are the *entry and exit points* according to this guideline. As the *entry and exit points* were the same for both mazes, any future reference to the guidelines will therefore apply to those *partially out of the frame*. An example of a point-of-view with and without the guidelines is shown in figure 5.7.

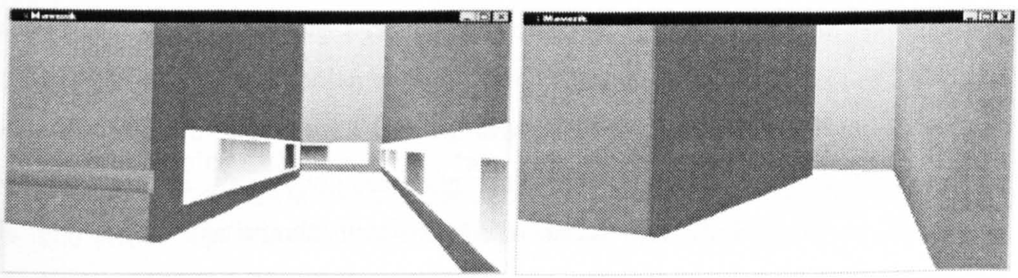

**Figure 5.7 A portion of the virtual corridors/maze with and without the guidelines**

The study will attempt to answer the following questions – does the implementation of the guidelines:

- appear natural and transparent
- provide visual cues to help guide participants through virtual space
- imply to users the existence of space other than that which is seen within the confines of the restricted field-of-view, that is, imply virtual off-screen space
- re-enforce the illusion of interacting within virtual space
- help maintain continuity of a participant's virtual reality experience

#### 5.4.3.2 Method

The study took place in a laboratory located on a University campus. One subject and one evaluator were present during each study session. Before the study task was given to each subject (see description below), they were required to complete a pre-study questionnaire. Refer to Appendix III for copy of pre-study questionnaire. Following completion of the pre-study questionnaire, a typed brief describing the study task was read all subjects. In the brief, subjects were asked to move through the corridors of a virtual building controlling their movements using the arrow keys on a standard keyboard until the exit was reached. Eighteen paid volunteers consisting of undergraduate, post-graduate and research students took part in the study and were recruited through University notice boards and an internal web site. These consisted of five females and thirteen males with ages ranging between eighteen and thirty-five. All had previous experience of computer games describing themselves in pre-study questionnaires as nine novices and nine experienced users. Three subjects had VR experience, two of desktop and one of HMD VR. Subjects were allocated study time slots and arbitrarily placed in one of the two groups with each group consisting of nine subjects. Steps were taken to ensure that subject's gender and age range were evenly divided between the two groups. So that two females were arbitrarily placed in one group and three in the other group, with the remaining males arbitrarily divided between the two groups, and a visual inspection carried out to make sure that the two groups did not contain a concentration of subjects with similar age ranges (e.g. all subjects under 25 years or all above 25 years). The choice of group that was to be tested with the guidelines implemented was arbitrary by getting a colleague to blindly select one. The group not selected was tested without guidelines implemented. Subjects were asked to carry out the task from a first person perspective (i.e. field-of-view as if one was in the environment). A video recording of the study was made for further analysis. To gauge user disorientation during the study navigation sessions and attempt to provide answers to the study questions (see: section 5.4.3.1), users were observed and notes taken during study sessions, analysis of a post-study questionnaire filled-out by each subject following the study (refer to Appendix III for post-study debriefing questionnaire) and video material was carried out.

**5.4.3.3 Results**

Twelve subjects rated the speed of movement through the corridors to be acceptable – neither too fast nor too slow. Three novice and two experienced subjects thought the movement was a little too fast, and one experienced subject found the movement a little slow. Sixteen subjects found the keyboard control easy to use and three novice users found it to be a little difficult. As shown in table 5.3, eight subjects out of each group collided with walls and this occurred a similar amount of times. Only three subjects with guidelines (33%) walked through the walls, in contrast to six without guidelines (67%).

In the debriefing questionnaire nine subjects acknowledged feeling disorientated at some point moving through the VE - three with guidelines (33%) and six without (67%). Identifying the cause as walking through walls for all three with guidelines and for those without: three identified walking through walls, two the colours of the walls, and one moving in a "closed environment – i.e. unable to get bearings" because there are no "windows or pillars, etc". Four subjects (just one with guidelines) said that they were aware of activities external to the study navigation task (e.g. people walking past or close to the study laboratory, the sound of typing in the distance and awareness of the study evaluator).

**Table 5.3 Summary of study results comparing (the number and percentage of subjects from) two groups' (one with and one without guidelines implemented) observed and reported problems occurring during navigation of the virtual corridors/maze**

| | subjects with guidelines | subjects without guidelines |
|---|---|---|
| subjects colliding with walls | 8 (89%) | 8 (89%) |
| subjects walked through walls | 3 (33%) | 6 (67%) |
| subjects feeling disorientated | 3 (33%) | 6 (67%) |
| subjects aware of external activities | 1 (11%) | 3 (33%) |

### 5.4.3.4 Discussion and conclusions

The purpose of the study was to find out whether or not the implementation of the guidelines would aid users in a study task to navigate through a virtual corridor/maze and to answer the research questions listed in section 5.4.3.1. In an attempt to shed some light on the effectiveness of the implementation of the guidelines and provide answers to the research questions, data on users' experience of the navigation task was collected. The concern of the study was not with measures to find out how fast subjects could complete the task but in measures that would tells us something about users' experience during navigation. Therefore, no attempt was made to collect timings of study sessions.

Although the same number of subjects from each of the two groups momentarily collided with the corridor walls and this occurred a similar number of times, those without guidelines however, walked through walls twice as many times as those with guidelines. This demonstrates that the guidelines used in the study were more effective in guiding subjects through the virtual corridors and thus, aided navigation in the virtual environment used in this study.

Only one subject acknowledged that the guidelines had momentarily caused them to break their attention from the study navigation task to admire the pictures on the walls. That is, the pictures placed on the walls in accordance with the guideline, "partially out of the frame", evoked interest and curiosity. Because the pictures are in the virtual environment and not part of the real world, this suggests that even though the subject's focus of attention was shifted from the study navigation task to pictures, the subject's attention was observed (by the evaluator) to remain focused in the illusion (i.e. the pictures) created in the virtual environment. Neither of the remaining subjects with guidelines mentioned that the guidelines and their placement had broke their concentration to the study task nor were they identified as having been the cause of disorientation. This suggests that the features included in order to implement the guidelines appeared transparent to most subjects and blended naturally with the study virtual environment.

Of the nine subjects who felt disorientated at some point within the virtual environment, only three had guidelines and all of these identified the cause as walking through walls. Those without guidelines identified various reasons: three identified walking through walls, two identified the colours of walls, and one subject identified the cause of disorientation as moving in a "closed environment" with no windows or pillars to get bearings. Finally, only one subject with guidelines acknowledged being aware of activity external to the navigation task during the study (awareness of the study evaluator) in contrast to three subjects without. Therefore, the results of the study suggest that guidelines help guide users and maintain continuity of navigating through the mediated environment, and this will help to maintain continuity of experience.

**5.5 Summary**

This chapter has explored film and the techniques of filmmaking and identified how they can inform the analysis and design of IMEs. This chapter has identified five main areas that advance the idea of remediation, from film to interactive mediated environments (IME). Firstly, by drawing a parallel between developments in film and those in IMEs. Secondly, by identifying a framework of spectator's film experience (associated with these developments) and using it to inform the "three Vs" framework of user's experience in IMEs. Thirdly, by identifying the similarities between the "invisible style" of filmmaking and the idea of transparency in HCI. Then arguing that the successful techniques of the "invisible style" used to hold spectators" attention in the illusion of film can be used to inform techniques to hold users' attention in the illusion of IMEs. Fourthly, by identifying in a study what breaks spectator's illusion of film and using the results in subsequent chapters to inform activity theory's basic principles, in an attempt to overcome its limitations when applied to IMEs (as identified in chapter four). Finally, by developing guidelines informed from cinematic and editing techniques to aid users in the construction of off-screen space. A study showed that these guidelines help users navigate virtual space, reducing user disorientation, and so allow users to continue maintaining their mediated experience. Thus, demonstrating that cinematic and editing techniques can inform the development of guidelines or idioms for IMEs (i.e. remediation of IMEs from film).

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# Chapter Six Interactive mediated environment: contexts within context

Limitations in the application of activity theory to VR systems were identified in chapter four. Central to this, were inadequacies associated with the concepts of activity theory: to model aspects relating to the context of use with VR systems, in the formation of functional organs within a mediated environment, and to identify the boundary between the mediated and real world environment. This chapter begins by developing models to identify and distinguish between interactive mediated environments according to their context of use. This provides a way to identify systems that are of interest to this thesis, that is, where the mediated environment is the context of use. Informed from work in film, it is argued that shifts in user's focus of attention from the mediated to the real environment are negative characteristics. As a consequence, this has the potential to disrupt the formation of functional organs and break user experience. A shift in user's focus of attention from the mediated to the real world is hereafter referred to as breakdown in illusion. This is problematic because, like film, it is argued that a central goal of interactive mediated environments is to provide experience. To account for these difficulties, this chapter describes ways of "enriching" activity theory's basic principles to overcome limitations when applied to interactive mediated environments. This is achieved by firstly, expanding the concept of functional organs to encapsulate the formation of physical interactive devices into virtual tools or artefacts within a mediated environment. Secondly, by expanding the model of activities with VR systems, developed in chapter four, to incorporate the context of use. Guidelines developed in chapter four are then enriched to reflect this work providing a way to reason about both breakdown in interaction and breakdown in illusion. Guidelines are then tested against usability problems identified in an empirical study of an HMD-based VR system.

## 6.1 Introduction

Breakdown in interaction provides a means to identify and reason about the cause of disruption and potentially inform design. Whilst the concepts of transparency and breakdown provide a foundation for the development of methods to evaluate traditional computer-based systems (as argued in chapter four), their effective use with VR systems will however be required to be extended to account for differences in the context of use. As a way to elucidate this situation more it is necessary to consider the position of the user, their relation with and respect to the interface and their environment whilst performing activities with interactive mediated environments.

In interactive mediated environments a user's interactive contribution determines the outcome. The outcome is the user's feedback in the form of dynamically changing content. Content refers to the substance, matter or contents (e.g. virtual objects and environment) and just like film, can be considered as a "textual" "weave" (i.e. text) of sensory information (e.g. imagery, audio and feedback cues from interactive devices, such as force-feedback) that shapes the three-dimensional mediated environment. Applications that are the central interest of this thesis are interactive mediated environments where the context of use is the mediated environment. For interaction to be effective in these mediated environments it is argued that users must maintain their focus of attention in the illusion created by the content (Hubbold, Murta, West and Howard 1995; Marsh and Wright 2000b; Marsh, Wright and Smith 2001; McGreevy 1994; Slater and Steed 2000; Usoh, Arthur, Whitton, Bastos, Steed, Slater, Brooks 1999). Two important and interrelated processes that are central to the success of interactive mediated environments result from this: first, is the ability to maintain supportive and effective interaction through the formation of functional organs in mediated environments and second, is the ability to experience the mediated environment through viewing, practice and in the accomplishment of activities. Shifts in user's focus of attention from the mediated to the real world have the potential to break functional organs and in turn break user experience and this is explored further in the following sections.

## 6.2 Boundary between real and mediated environments

As outlined in chapter four, Kaptelinin (1996a p. 64) draws our attention to the limitations of activity theory by suggesting that "the tool mediation perspective, which is considered the most important advantage of activity theory, can also impose some limitations...in virtual realities, for example, the border between a tool and reality is rather unclear". This situation arises because activities (e.g. involving interaction with people, and material or virtual objects) are either performed between the real and the mediated environments, or exclusively in the mediated environment. In order to identify the boundaries between the real and mediated environments, distinguish between the types of interactive mediated environments and identify those that are the focus of this thesis (i.e. user(s) interacting "within" and to a lesser extent "through" a mediated environment as described below), this section first elaborates Bødker's (1989; 1991, 1996) models of activities. The most notable modification to these models is in the use of the arrow to represent the interactive tool/artefact and incorporate the notion of functional organs in the integration of the user with the mediated environment and also, user with a group of people or/and material objects. That is, incorporating "a link that provides the integration of a computer tool [and artefacts in the mediated environment, such as, signs and language] into the structure of human activity" (Kaptelinin 1996b p. 111). Section 6.2.1 discusses the formation of a "link" between user and mediated environment. Furthermore, Bødker's (1989, 1991, 1996) use of the term "object" can seem at times to be somewhat ambiguous. Therefore, unless stated otherwise, from hereon in "object" and "objective" will be used interchangeably to mean both a physical object (i.e. "a thing having existence") and its "narrower, special sense" objective (i.e. "object of its activity") (Leont'ev 1981 p. 36). That is, processes of an activity directed towards both a physical object that leads to an outcome and to an objective outcome (Leont'ev 1981). Developing variations of these models it is possible to identify and categorize interactive mediated environments according to where the objective of processes of activities are directed toward and hence this informs ways to reason about and identify the context of use. This is by no means intended to be an exhaustive list but is a way to distinguish between categories and to identify interactive mediated environments that are the focus of this thesis. Three main categories are identified: *within* or *through* the mediated environment, or a *hybrid* between the real and the mediated.

### 6.2.1 Within the mediated environment

In reference to figure 6.1, the first identifies the objective of an activity to be within the mediated environment performed through an artefact (i.e. interactive) by a single user or group members (i.e. many individual users) without any contribution to, or from sources and resources external to it (i.e. from the real world). Hence, the context of use is the mediated environment. In this situation, effective interaction requires users to maintain their focus of attention within the mediated environment (Marsh and Wright 2000b; Marsh, Wright and Smith 2001) and applications of this type are the main focus of this thesis. This is similar to Bødker's (1989, 1991, 1996) example of interacting with a spreadsheet application running on a traditional computer-based system that "has no direct relation to objects [physical] outside the artefact [application]". The interactive tool/artefact as represented by an arrow is the "link" between the user and the mediated environment. Examples of mediated environments are in entertainment (e.g. single and multi-user computer games), training (e.g. vehicle/flight simulation), design (e.g. single or distributed designers designing within a mediated environment), and communication (e.g. between distributed users within a mediated environment). Furthermore, figure 6.1 represents systems such as the Internet, interactive TV and cinema..

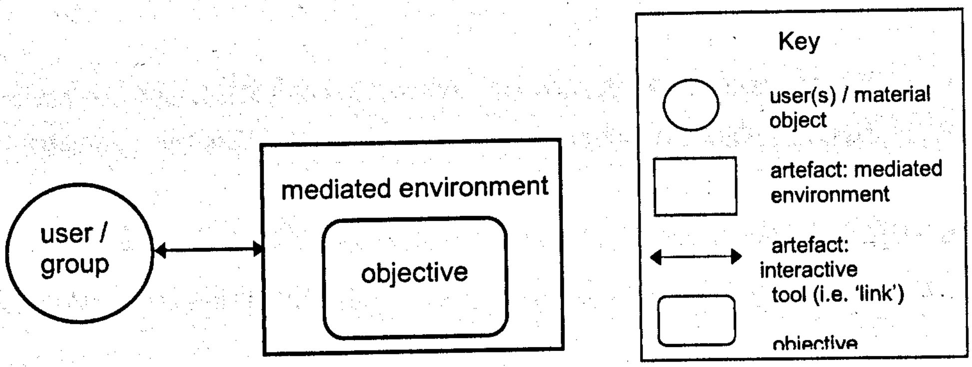


**Figure 6.1 Objective present within the mediated environment: e.g. computer games, design, communication, interactive TV and the Internet**

### 6.2.2 Through the mediated environment

The concept of presence has its roots in "telepresence" (see: Sheridan 1992; Steuer 1995). Telepresence is a sense of being in a remote or hazardous environment (e.g. space, deep sea diving). It occurs when a user or tele-operator's interactions with a device (e.g. force-feedback manipulator) are mirrored literally "through the interface" by a robot or mechanical arm within a remote environment. The interactive tool/artefact as represented by an arrow is the "link" between the user and the mediated environment. As a consequence, users describe a sense of acting directly within a remote environment. This effect can be described well through the formation of functional organs. The adoption of the concepts from telepresence provided a convenient way to describe the effects experienced by users interacting within virtual environments. Figure 6.2 illustrates activities performed through the mediated environment with a material object (e.g. tele-operation in a hazardous environments) or with another user (e.g. communication: cable or mobile). Furthermore, this represents Internet-based interaction through a camera located in a distributed location. The objective of the activity takes place literally "through the interface" in the environment in the real world where the remote user/material object/camera is located and hence the context of use in these situations is in the remote environment. This is similar to Bødker's (1989, 1991, 1996) control panel example with the exception that the user has no direct access to the distributed location of the user/material object.

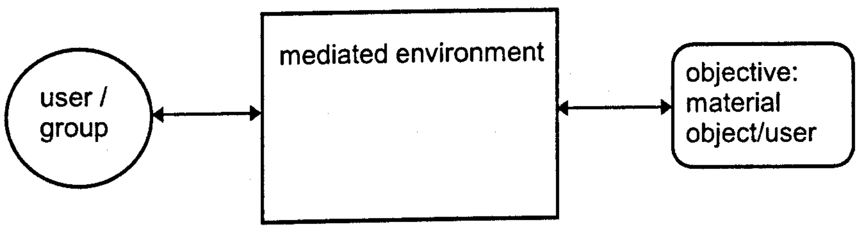


**Figure 6.2 Objective present in the distributed environment: e.g. teleoperation, communication**

### 6.2.3 Hybrid – mixed reality: between the real and mediated environments

The third broad categorisation is identified as that in which objectives of activities are performed through artefact use by a single user or a group in both the real and mediated environments. Although mediated environments of this type are not the focus of this thesis, and so the exact location of the objective and the context of use are of secondary concern, some examples are described to provide a contrast to interactive mediated environments whose activities are performed within (figure 6.1) or through (figure 6.2) the mediated environment. For instance, figure 6.3 represents individual users interacting with or upon a material object in the real world as well as interacting within a mediated environment. An example of this is in repair and maintenance training or instruction: an engineer interacting within a three-dimensional practice and instructional mediated environment prior to carrying out actions on the actual material object (e.g. car or aircraft engine, etc.). Here the objective is to repair the engine or/and to inform the user.

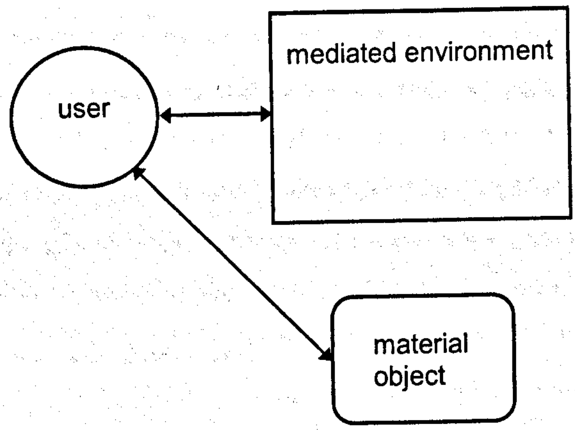


**Figure 6.3 Objective present in the real world environment: e.g. repair engine or/and inform user**

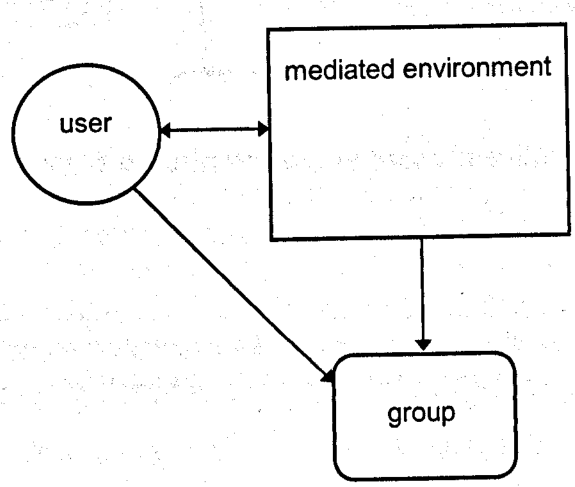


**Figure 6.4 Objective present in the real world environment: e.g. lecture / educate group**

Other examples can be found in mediated environments for demonstration, presentation and lecturing purposes (to a group) as shown in figure 6.4. Here only the user interacts with the mediated environment. The objective is to inform or educate the group. Variations on this are with group interaction between members and with the user in the real world as shown in figure 6.5. An example is in a discussion between a design team (objective in mediated environment) and in say, a tutorial question and answer session with a tutor (objective to educate group).

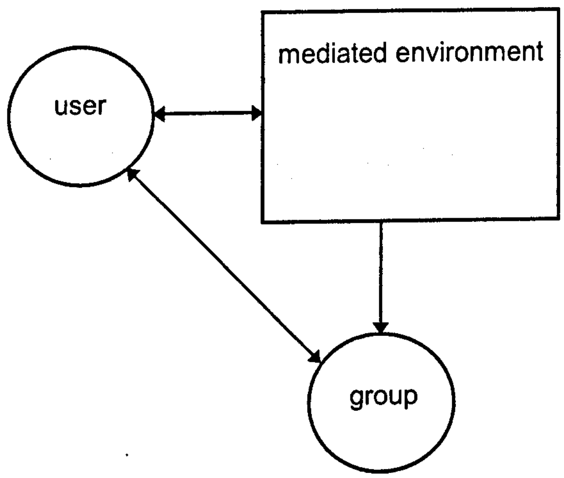


**Figure 6.5 Objective present in the mediated (e.g. design team) or real world (e.g. tutorial) environment e.g. team design or educate group respectively**

Here only the user interacts with the mediated environment. A final example is illustrated in figure 6.6 in collaborative interaction both within a mediated environment (perhaps in distributed locations) and between group members (and perhaps with material objects) in the real world environment for say, collaborative design, training or communication, etc. As well as these examples, interest in mixed reality, "shared space" (e.g. Billinghurst and Kato 1999) and augmented virtual reality systems sees the increased blurring of the border between the real and the virtual and an area of continued future research and development.

As mentioned, the objective and context of use of the examples in the latter two categories (figures 6.2 – 6.6) is either in the mediated or the real world, or divided between the two. Under normal use, user activities are performed exclusively in the real or mediated environments or shared between the two. With the exception of figure 6.2 in which activities are performed literally "through the interface", the latter situation (i.e. activities in both the real and mediated) entails the postponement of interaction in one environment while interacting in the other environment.

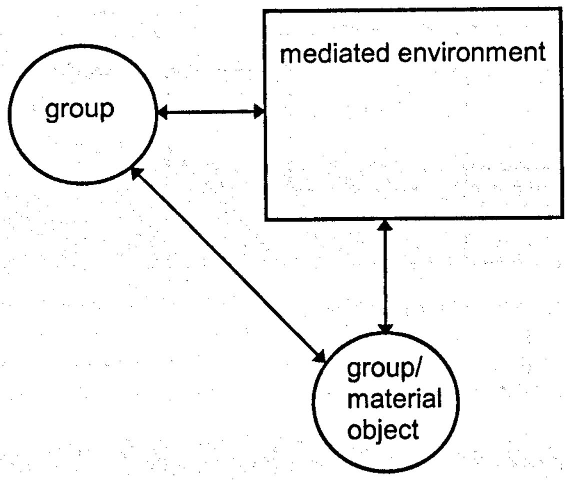


**Figure 6.6 Objective present in the mediated or/and real world environment e.g. collaborative design, training, communication**

Interesting questions to arise from this are, can the postponement be considered to be a disruption and if so, what effect, if any, does this have on the formation of functional organs (i.e. the interacting artefact). See related discussion on observations made during study one in chapter eight in which users in a networked game shout and look at other users in the real world and then return to activities with minimal, if any, noticeable disruption to the flow of their games playing. As mentioned, the interest of this thesis is in activities that exclusively take place within the mediated environment and this is the focus of work for the remaining chapters. Although the central focus is on interactive mediated environments as illustrated in figure 6.1, much of the work that follows equally applies to figure 6.2. In particular, in the formation of functional organs and the user experience that comes from performing activities within or through the mediated environment.

### 6.3 Formation of functional organs within mediated environments

Accepting the tool mediation perspective and that the context of use is the mediated environment as shown in figure 6.1, the key questions to arise are: Where does the interface (i.e. tool/artefact) start and end and where and how does the real world environment fit into this structure? By extending the schematic representation of Kaptelinin (1996b) to interactive mediated environments it is possible to visualise this situation and provide answers to these questions. In light of the above discussions, the answer to the latter question is simply that it doesn't. That is, in interactive mediated environments where all activities take place (e.g. figure 6.1), the external world has no consequence. The answer to the former question is not quite as straightforward.

user ←——→ computer ←——→ environment

**Figure 6.7 Two interfaces of human-computer interaction**

In reference to figure 6.7, Kaptelinin (1996b p. 111) argues that "the tool mediation perspective means that there are actually two interfaces that should be considered in any study of computer use: the human-computer interface and the computer-environment interface". Though, just like tools in the surrounding world and with a traditional computer-based configuration, it is argued that the integration of the two interfaces in interactive mediated environments, is through the formation of functional organs (following their mastery) to "support and complement natural human abilities in building up a more efficient system that can lead to higher accomplishments" (Kaptelinin 1996a p. 50). So while on the one hand the tool mediation perspective means that "two interfaces should be considered in any study of computer use", on the other hand considered as functional organs essentially implies that the interactive artefact in use remains transparent and as a consequence, sees that it is experienced as a property of the user acting directly with the mediated environment as represented in figure 6.8.

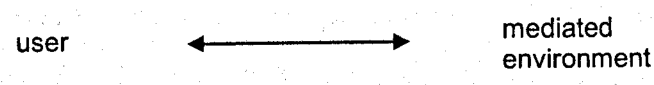


**Figure 6.8 Interacting directly within a mediated environment through the formation of functional organs**

However, in reference to figure 6.9, the integration of tools into functional organs in many interactive mediated environments may potentially involve an additional formation from the physical device to the virtual tool. That is, the integration between the user and the tool (i.e. physical interactive device: e.g. cursor keys, 2/3D mouse, VR gloves, specialised or novel device, etc.) transformed into a virtual tool (i.e. computer-generated or "electronic": virtual hand/arm/body/tool/artefact, etc.) – *the user-tool-boundary* - and between the virtual tool and the mediated environment – *the tool-environment-boundary.*

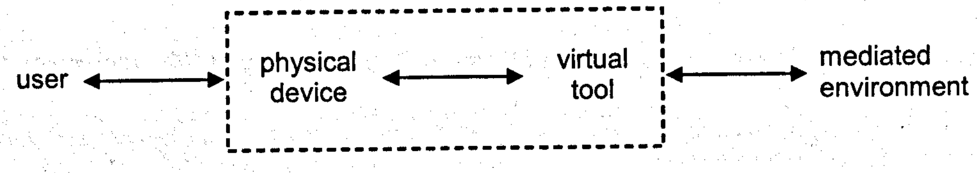


**Figure 6.9 Formation of interactive artefact in human-mediated environment**

Figure 6.9 provides a way to represent the often complex and highly novel interactive artefact of interactive mediated environments and a structure in which to reason about their design in use. For example, the deconstruction (into physical devices, virtual tools and their function within the mediated environment) of some of the commonly cited interaction techniques/devices from the VR literature that are used in navigation (e.g. "world-in-miniature", Pausch, Burnette, Brockway and Weiblen 1995) and in object selection (e.g. "go-go interaction", Poupyrev, Billinghurst, Weghorst and Ichikawa 1996), etc. Table 6.1 illustrates some simple examples. The intention here is not merely to provide a mapping between a physical device and a virtual interactive artefact; nor is it proposing the evaluation of interactive artefacts and their techniques of operation performed within artificially constructed tasks and considered in isolation from other enabling technologies and other parts of a mediated environment in which they are performed. But, it is proposing an extension to the philosophy of functional organs and a way in which to consider a shift to a wider framework of human practice within interactive mediated environments. This is arguing for an approach that incorporates a holistic perspective (e.g. Bannon and Bødker 1991; Kalawsky 1998; Winograd and Flores 1986) and this move is supported by, and encapsulated in the philosophy, concepts and frameworks provided by activity theory (e.g. Bødker 1991).

**Table 6.1 Examples of two interfaces of human-mediated environment interaction**

| study: user | interactive tool / artefact | | |
|---|---|---|---|
| | **physical device** | **virtual tool** | **function in mediated environment** |
| *Pierce et al. (1997)* | VR gloves | virtual hand | head crusher select |
| *Bowman et al. (2001)* | pinch gloves™ | virtual hand | menu selection |
| | | | travel: navigation |
| | | | text input |

To do this, this section has extended the concepts of functional organs and provided an alternative way to describe, inform and guide, and evaluate an interface by the way in which it supports natural human practice or use activity within a mediated environment. That is, the formation of functional organs sees that it is experienced as a property of the user acting directly with the mediated environment as illustrated in figure 6.8. So, just like the way in which "scissors elevate the human hand to an efficient cutting organ, eyeglasses improve human vision, and notebooks enhance memory" in our everyday interactions within our real environments, it is argued that interactions within mediated environments should be considered by the way in which they are integrated into functional organs that support and enhance human activities and that lead to "higher accomplishments". Furthermore, considering interfaces in this way neatly provides a way to package interactive devices and styles irrespective of underlying complexities.

### 6.4 Mediated environment as functional organ: formation of interactive mediated illusion for experience

A holistic approach means that the underlying individual enabling components blend together in some way to form a whole - this creates a mediated illusion. For the successful formation of an interactive mediated illusion it is argued that two things are necessary: first, the formation and integration of interactive devices into functional organs; second, the objective of processes of activities must be within (or through) the mediated environment. As illustrated in figure 6.10, the consequence of these two situations is that the user performs processes of an activity (with other users or/and mediated objects directed towards an objective) and these appear to the user to be unmediated by technology. At such a point, it is argued that the mediated environment should be considered as a functional organ to enhance natural human abilities to work, play, learn, shop and be entertained. As mentioned, while principally referring to interactive mediated environments as illustrated in figure 6.1 (i.e. within the mediated environment), most of these discussions are equally applicable to those captured in figure 6.2 (i.e. through the mediated environment).

For the continuation of a user's experience of the mediated illusion, a user must maintain attention in the mediated environment through the objective continuing to coincide with motive, encouraging users to stay there. Conversely, shifts in focus of attention from the mediated to the real world will disrupt or break the formation of functional organs. Likewise, disruptions or breaks in interaction (i.e. to a functional organ) may potentially (but not necessarily) break the illusion. It is argued that these interrelated issues are central to the successful use of interactive mediated environments and is therefore, investigated further in the next section.

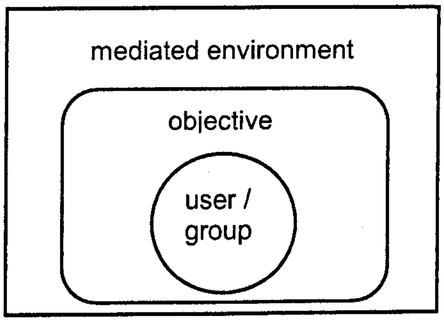


**Figure 6.10 Mediated environment as functional organ - experience of mediated illusion: objective present within mediated environment and formation of functional organs**

### 6.5 Maintain the illusion of the mediated environment

Breakdown in the mediated illusion occurs when a shift in user's allocation or focus of attention from the mediated to the real world reaches a point that is detrimental to activities performed in the illusion, and thus, impedes effective interaction. As a consequence, it is argued that in the same way disruptions or breaks to the illusion of film break spectators' experience (see: chapter five), disruptions or breaks to the illusion of interacting within a mediated environment potentially break user's experience (see next section). As mentioned, like film, it is argued that one of the main goals of interactive mediated environments (as illustrated in figure 6.1) is to maintain users' attention in the content or illusion (Marsh and Wright 2000a; Marsh, Wright and Smith 2001; Usoh, Arthur, Whitton, Bastos, Steed, Slater and Brooks 1999).

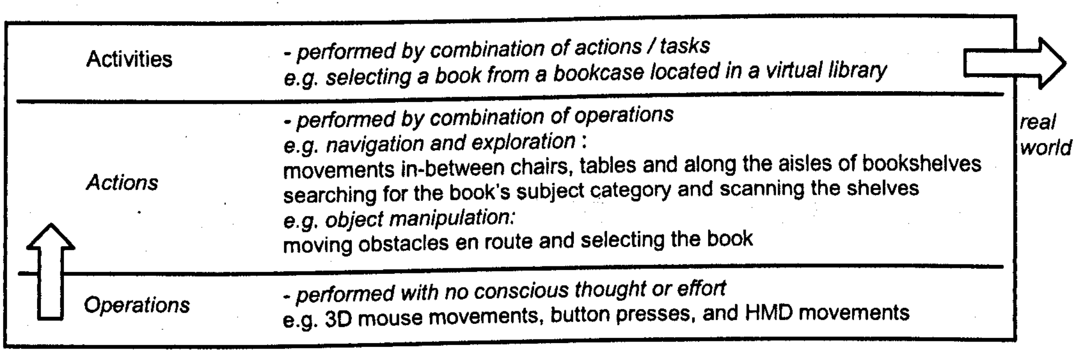


**Figure 6.11 Breakdown in interaction and illusion**

As a consequence, users are able to keep in flow of performing activities within the illusion of a mediated environment and this provides a mediated experience (see: chapter seven). This occurs without any constructive contribution from the world external to it and hence, as previously argued this is the context of use. Maintaining attention in actions (i.e. goals) of activities directed towards an objective in the context of use and in the formation of functional organs sustains the situation as illustrated in figure 6.10. Accepting this situation as encapsulating effective interaction in mediated environments provides ways to inform the hierarchical model of activities (developed in chapter four) with the concepts of illusion, context of use and an arena in which to consider the formation of functional organs. That is, providing a means to address the limitations that were identified in chapter four. The integration of these concepts is achieved by the addition of a rectangle to the hierarchical model of activities to represent the context of use (i.e. mediated environment) as shown in figure 6.11. Thus, providing an arena in which to reason about activities and identify potential problems in design through breakdown in interaction and illusion.

**6.6 Evaluation of VR using two levels of breakdown**

A central argument developed in this thesis is that the "experience of transparency" through the formation of functional organs keeps users in "flow" with their activities within a mediated environment and it is anticipated that this will lead to enhanced user experience. Conversely, breaks in transparency break the experience and this has informed the development of guidelines for the evaluation of interactive mediated environment design for user experience. As argued above and described in chapter 4.4, breakdown in VR occurs on two levels as illustrated in figure 6.12. The first is a breakdown in interaction. A user may or may not be aware that a breakdown has occurred. In situations in which a user is unaware that a breakdown has occurred they will continue without concern, perhaps until the breakdown disrupts their interactions. On the other hand, situations in which a user is aware that a breakdown has occurred, while this may interrupt or impede their interaction, they remain attached in the mediated illusion. The second type of breakdown occurs when a user's focus of attention shifts from the virtual to the real world. This can be either momentary or can be so severe as to shift a user's allocation of attention totally from the virtual to the real world. In reference to figure 6.12, a user's focus of attention can be considered to lie somewhere along a continuum from totally engaged in the illusion of the mediated environment without awareness or conscious thought for the world external to it (i.e. to the left, the mediated world; the further one continues, the closer one perceives to be interacting within an illusion that is inseparable to interacting in the real world - similarities can be drawn with Star Trek's "Holograph" or as depicted in the film "The Matrix" Wachowski and Wachowski 1999 - chapter seven returns to this subject and the potential implications of this situation in discussions on presence), to awareness of the world external to the mediated environment (i.e. to the right, the real world).

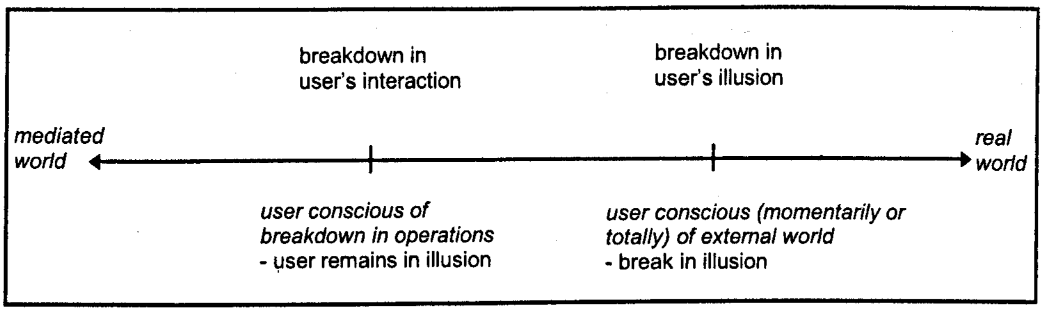


**Figure 6.12 Continuum of engagement in mediated environments. User experience comes from staying there: interacting to the left of breakdown in illusion**

Breakdowns in interaction and illusion are identified along this continuum and effective interaction (i.e. the participant remains in the illusion) is identified as being that which is carried out to the left of breakdown in illusion. Although a user may be consciously aware of external activities (e.g. distraction, or the presence of others around them), their allocation of attention may be such that, they are able to remain sufficiently attached to the illusion created by the VR system and thus, able to interact effectively in the scenario within the mediated environment. Just how much attention users need to allocate to the illusion for effective performance of activities in the mediated world is an interesting area for further research and is beyond the scope of this thesis.

### 6.6.1 Developing guidelines for the evaluation of VR design for user experience

Breakdown and focus shifts are by their nature reliable only if accessed at the moment of their occurrence or whilst they are part of user' short-term memory (e.g. Russo, Johnson and Stephens 1989). To gain access to this information a continuous and concurrent assessment method is required and one in which users are able to exteriorise their thoughts. Many presence measurement and assessment methods have been devised that may prove useful. For summaries see: IJsselsteijn, de Ridder, Freeman and Avons (2000). Of particular interest to the detection of breakdowns is the work of Freeman, Avons, Davidoff, and Pearson (1997) and IJsselsteijn, Freeman, Avons, Davidoff, de Ridder and Hamberg (1997) that adopt a simple continuous presence assessment method using a sliding potentiometer. User's make on-line judgements with regard to their level of presence and reflect this in the position of a hand-held slider. Slater and Steed (2000) propose a similar concept to that of breakdown in illusion in which a user verbalises transitions from the virtual "V" to the real world "R". Data collected indicates the incidence of breaks in presence, highlighting potential concerns of usability (i.e. causes of breaks in presence) and the duration of a users' sense of presence. For the assessment of presence, it could be argued that both methods suffer from the requirement of the user to divide their attention between the mediated illusion and the control of a hand-held slider and to keep in mind the verbalisation of the transition, respectively. However for present purposes, the interest of this thesis is not so much in the direct assessment of presence (or experience) but in methods that enable users to exteriorise their thoughts for the evaluation of interactive mediated design for experience of transparency and breakdown.

Following chapter four, one approach is for users to concurrently think-aloud whilst interacting within the mediated environment. Thinking-aloud is an effective way to trace conscious thoughts (Russo, Johnson and Stephens 1989) and may provide a rich source of information to evaluate for the design of experience through breakdown. As described in chapter four, breakdown in interaction will be detected through explicit verbalisations or complaints made about the normally transparent mediating system, the enabling technologies, or questions from the user concerning operations or what action to take next. Table 6.2 shows the guidelines for the detection of breakdown in interaction developed in chapter 4 (table 4.1). As mentioned, these were devised from the model of VR interaction using activity theory and provide a shorthand way to capture breakdowns to transparent interaction in VR identified through concepts from activity theory and help distinguish between breakdowns resulting from unfamiliar operations (i.e. opportunities for learning) and those from usability problems. To identify breakdowns in illusion and focus shifts in attention from the virtual to the real world, work in film (see: chapter five) provides a convenient framework for the categorization of the different kinds of breakdowns (as described below). These were identified as: internal, external or subjective from analysis of results from a short study (chapter 5.1.2) to identify breakdowns in the illusion of film. This is used to inform guidelines as shown in table 6.2 and together with guidelines to detect breakdowns in interaction it is anticipated that these can be used effectively to assess the design of interactive mediated environments for transparency.

i. *Internal breaks:* are anything relating to the interactive mediated system. These are similar to breakdowns in interaction (as described previously in chapter 4.3), however, here the experience of interaction is such that it shifts the user's focus of attention from the virtual to the real world. This is divided into two subgroups. The first of these is the content (i.e. the mediated environment). Breaks in content are from the imagery, sound and incorrect sensory information from interactive devices, such as force-feedback. To use a filmic term, these are best described as breakdowns in continuity. The second is anything belonging to the mediating technologies that supports the content and are best described as equipmental breakdowns.

ii. *External breaks:* are anything that is external to the interactive mediated system, drawing user's attention away from the mediated environment, such as external distraction or awareness of people surrounding them.

iii. *Subjective breaks:* are shifts in focus of attention, such as making a mental note of something or contemplating past or future events, or an individual's lack of interest for interacting within the mediated illusion.

In short, this division facilitates the simple classification of breaks as being internal or external to the interactive mediated system. If a break is internal, then this can be categorized as either a continuity breakdown to content or is part of the interactive mediated system (i.e. equipmental). Subjective breaks can be purposeful or involuntary automatic shifts in focus of attention, or perhaps reflect a user's lack of interest.

**Table 6.2 Categorization of usability problems: breakdown in interaction and illusion**

| break in interaction (remain in illusion) | | break in illusion | |
|---|---|---|---|
| *internal* | a. continuity breaks in content: imagery, audio, force-feedback, etc. | *internal* | a. continuity breaks in content: imagery, audio, force-feedback, etc. |
| | b. equipmental breaks in VR mediating technologies | | b. equipmental breaks in VR mediating technologies |
| | | *external* | a. noise/distractions external to VR system |
| | | | b. awareness of activities external to VE |
| | | *subjective* | a. lack of interest in interacting within VE |
| | | | b. attention wanders from VE |

### 6.6.2 Evaluation of VR using breakdown in interaction and illusion

In an attempt to test the concept of breakdown in interaction and illusion and overcome the limitations as argued in chapter 4.4 and 6.1, the guidelines listed in table 6.2 were applied to 108 usability problems (see: Appendix II) identified in the empirical study of a HMD VR system (see: chapter 3). The main aim of the study was to show that breakdowns could be categorized as either interaction or illusion. There was little doubt that all 108 usability problems (UP) could be classified as being a breakdown, either in interaction, illusion or falling into both categories as they were clearly identifiable using the guidelines as listed in table 6.2. As the main aim of the study was to test that UPs could be categorized in this way and so this was shown, confirmation of these results with another evaluator repeating the process was seen as an unnecessary extravagance. For brevity, UPs are grouped into 12 similar or duplicate categories as shown in table 6.3. For simplicity, internal sub-groups (i.e. break in continuity and break in enabling/mediating technologies) are grouped together. Those identified as being both a breakdown of interaction and illusion had a point or score divided between them (i.e. were each given half of one score). Identical usability problems were in some cases categorized differently for different users as well as for the same user. See table 6.4 for examples of the different categorization of usability concerns (e.g. UP no. 1 and 4 from table 6.3 using guidelines in table 6.2). This highlights the flexibility of this method to reflect the differences in use between users and their repeated occurrence with the same user. That is, usability problems are detected according to users' experience with the VR system in use and are dependant on the circumstances surrounding the breakdown. For examples of internal sub-groups and think-aloud verbalisations and observations that identify them as such, refer to table 6.4. The table is divided into two sections, breakdown in interaction and illusion. The first column shows the usability problems identified as internal (break in interaction and illusion), external and subjective (break in illusion).

The next column provides a cross reference with the reduced set of usability problems (into similar or duplicate groups) as shown in table 6.3. The final column gives details of the observed or verbalised breakdown. As shown, some examples of usability problems from similar or duplicate groups (table 6.3) may be categorized differently (i.e. either breakdown in interaction or illusion) according to guidelines (table 6.2). Thus, demonstrating that breakdowns are categorized according to the circumstances surrounding them (i.e. the use situation).

## Table 6.3 Categorization of causes of usability problems through breakdown

| Usability Concerns | | | Breakdown | | | | Occurrence of usability problems |
|---|---|---|---|---|---|---|---|
| *No.* | **Effect** *(observed / verbalised)* | **Cause** *(most likely)* | **Interaction** | **Illusion** | | | |
| | | | internal | internal | external | subjective | |
| *1* | • user's physical movements are restricted | • HMD and/or 3D mouse cable entangled around user / chair | 16 | 20 | - | - | 36 |
| *2* | • walking through / too close to objects<br>• getting lost / losing position in VE<br>• user appears startled / disorientated | • no collision detect<br>• lack of knowledge for VE layout | 17 ½ | 4 ½ | - | - | 22 |
| *3* | • virtual hand going through objects<br>• virtual hand jitters<br>• virtual hand interaction awkward | • no collision detect<br>• inaccurate hand tracking<br>• too far from tracker source | 9 ½ | 1 ½ | - | - | 11 |
| *4* | • erratic movements through the VE<br>• hesitant movements in VE<br>• difficulty with movements<br>• movement / interaction is abandoned | • mouse button selection in error<br>• movements through VE too fast<br>• compounding difficulties<br>• external disruption to VR system | 5 | 2 | 1 | 3 | 11 |
| *5* | • eye-level position point-of-view (POV) becomes higher/lower | • looking up/down whilst travelling through the VE changes the POV<br>• HMD too heavy | 7 | 1 | - | - | 8 |
| *6* | • menu appears occluding user's field-of-view (FOV) | • selection of 3D mouse's middle button | 6 | - | - | - | 6 |
| *7* | • user supporting HMD with hand<br>• difficulties fitting / putting-on or wearing HMD | • HMD too heavy<br>• HMD incorrectly fitted / doesn't fit all head shapes / sizes | ½ | 2 ½ | 1 | - | 4 |
| *8* | • user cannot identify or misidentifies part of the VE model / object or its purpose / function | • inaccurate representation / model of real world object | 2 ½ | ½ | - | - | 3 |
| *9* | • caution signs ignored<br>• the purpose of the caution signs are not obvious to the user | • text signs in graphical VE unnatural / unexpected<br>• interpretation of signs unclear | 1 | 1 | - | - | 2 |
| *10* | • graphic lag / delay in response to quick head movements | • too many models to update<br>• frame rate too slow | - | 2 | - | - | 2 |
| *11* | • nausea | • HMD associated | - | 2 | - | - | 2 |
| *12* | • chair's swivel movement effect user's interaction within VE | • chair permitted to move freely in all directions | - | - | 1 | - | 1 |
| | | *Totals:* | 65 | 37 | 3 | 3 | 108 |

**Table 6.4 Examples of usability problems identified as breakdown in interaction or/and illusion: int = internal, ext = external & sub = subjective**

<table>
<tr><th colspan="3">break in interaction</th><th colspan="3">break in illusion</th></tr>
<tr><th>type</th><th>no</th><th>details of breakdown</th><th>type</th><th>no</th><th>details of breakdown</th></tr>
<tr><td rowspan="4">int</td><td>2</td><td>a. break in continuity:<br>User goes through instrumentation rack.<br>User: "just walked right through rack"</td><td rowspan="2">int</td><td>10</td><td>a. break in continuity:<br>User: "it's moving slowly...graphics aren't moving as fast as I move my head"</td></tr>
<tr><td>1</td><td>b. break in enabling technologies: HMD cables become entangled restricting users' movements:<br>recurring observed problem</td><td>1</td><td>b. break in enabling technologies: 3D mouse/HMD cables become entangled restricting users' movements:<br>User: "ah, seem to be snagging on something"</td></tr>
<tr><td rowspan="2">3</td><td rowspan="2">a & b. enabling technologies and continuity:<br>Interaction with virtual hand appears awkward - mirroring the movements of the 3D mouse it goes through the instrumentation rack:<br>User: "my hand goes through objects as well"</td><td>ext</td><td>4</td><td>a & b. noise / distractions / awareness of activities external to VE:<br>Secretary enters study laboratory "would you like a cup of coffee"<br>User momentarily abandons current activity and waits for the talking to end</td></tr>
<tr><td>sub</td><td>4</td><td>a & b. lack of interest/attention wanders from VE:<br>User finds interaction difficult / tedious<br>User: "I'm no good at this"</td></tr>
</table>

### 6.6.3 Discussion

Extending concepts of activity theory, it was argued that breakdown in interaction through shifts in consciousness (i.e. from operations to actions) and breakdown in illusion through shifts in conscious attention (i.e. from activities in the mediated to the real world) provides opportunities to identify and reason about usability problems. Informed from this, guidelines were developed encapsulating the underlying concepts and extensions of activity theory, providing criteria for the identification of breakdown and a shorthand method to guide evaluation. Guidelines were applied to usability problems captured in an empirical study (i.e. through think-aloud verbalisations and observation) of a HMD VR system and shown to be successful in the categorization of usability problems as either a breakdown in interaction, illusion or falling into both categories. Hence, demonstrating the guidelines effectiveness to capture potential problems of usability, providing opportunities to reason about disruptions to the normally transparent VR system (i.e. mediating interactive devices and supporting technologies and VR content) and thus, a way in which to inform design.

While the guidelines proved effective to capture "internal" breakdowns (i.e. "equipmental" and continuity breakdowns) in both interaction and illusion, "external" (i.e. noise and disruptions originating from sources beyond the VR system) and "subjective breakdowns" (i.e. attention wanders from virtual to real world: voluntary or through user's negative appraisal from lack of interest, dislike or the system doesn't match up or deliver on expectations or purpose) in illusion were however, few and far between. As the study was conducted under laboratory conditions, this may account for the low occurrence of external breakdowns (e.g. lack of ambient noise and distractions). Whereas, infrequent subjective breaks may simply be as a result of the low breaks from this category, or as is suspected that the data collection methods (i.e. think-aloud comments and observation) are insufficient on their own to be able to capture the subtleties of users' individual subjective experience that comes from interacting in activities within the content of mediated environments and reason about their potential breakdowns.

A key argument of this chapter is that the "experience of transparency" (Holtzblatt, Jones and Good 1988) or put another way, "the transparency of equipment" (Dreyfus 1991) can be considered an antidote to "equipmental breakdowns" and keeps users in the "flow" of their activity. It is argued that maintaining the uninterrupted flow of activities will enhance user experience (Marsh 2001) and is one of the central goals of interactive mediated environment design (e.g. VR, the Internet, multi-media, computer games, interactive television) (Marsh and Wright 2000b; Marsh, Wright and Smith 2001). While the work above has shown that thinking-aloud and guidelines capture equipmental and continuity breakdowns, little in the way of subjective breakdowns were identified. Furthermore, it has been shown that traditional methods are insufficient used on their own, requiring specialised add-on methods for the capture and analysis of user experience that is appropriate for the assessment of the particular mediated environment under evaluation. For example, as shown in chapter three, methods additional to thinking-aloud and observation were devised to capture users' spatial awareness and provided a way to assess the EISCAT VR system in its ability to transfer spatial knowledge and reason about its use to familiarise scientists (i.e. intended end users) prior to their secondment at the real location in Norway. This points to the need for more specialised methods to capture individual subjective experience induced in users during an "encounter" with mediated environments and provide additional data necessary to make informed judgments about its success.

However, if subjects of the original study were typical end users (i.e. scientists) then we can reason that their intention for using the mediated environment was indeed to familiarise themselves with knowledge of the spatial layout (and in typical scientific control procedures) to aid them in their secondment at the real site in Norway. In which case, if users thought that the EISCAT VR system was ineffective in the transfer of spatial knowledge then this may generate a negative appraisal and feelings that it didn't match up to or deliver on expectations or purpose, and thus, identifying a potential cause of breakdown and potential problem with design. Furthermore, this highlights the limitations of using stand-in users and suggests a good case for using typical end users in evaluation studies of this type.

As suggested, other kinds of experience may be induced in users of mediated environments and these will require specialised methods for their capture and analysis. Consequently, it is argued that just like in the discussions above with the EISCAT VR system, these experiences have the potential to cause breakdown through user's negative appraisal from lack of interest, dislike or the system doesn't match up or deliver on expectations or purpose. Examples of experience are, in knowledge, training or familiarisation (e.g. EISCAT), and emotional and presence that has received much attention and is discussed at length in the following chapters. Indeed, Leont'ev (1981 p. 400) makes mention of experiences such as, "emotions and feelings" as "another important psychological feature of activity". The question now is, how to incorporate experience and experiential evaluation for the design of interactive mediated environments into the hierarchical framework of activity theory?

### 6.6.4 Conclusion

The treatment of activity theory up to this point has been piecemeal. Of course, the main reason for this is due in part to the progressive dissemination of work described in this thesis incorporating traditional methods of usability within a framework borrowed from activity theory. Furthermore, the enormous body of literature relating to a human activity theory approach from its roots in sociocultural studies (e.g. Vygotsky 1978; Wertsch, Del Rio and Alvarez 1995), its conception and translations from Russian to English (e.g. Leont'ev 1974, 1978, 1981), expansion to collaborative working environments (e.g. Engeström 1987; 1999) and application to many varying forms of human practice including HCI (e.g. Bødker 1996) that generally focuses on social and collaborative activities and working environments (e.g. CSCW – computer supported co-operative work e.g. Mwanza 2000; Turner, Turner and Horton 1999) makes it difficult to take-on in its entirety without a extensive and sustained research effort beyond the scope this thesis. The concern of this thesis is in the application of activity theory to computers (i.e. HCI) and in particular, to human practice and behaviour within interactive mediated environments as outlined in previous chapters. Hence, it is not useful and moreover, impracticable to consider all ramifications of activity theory. What is required is an arena in which to reason about: interaction within the content or context of mediated environments, the transfer of experience to users from behaviour or an encounter with an environment, and potential breakdowns as a result of, or the lack of, experience. This implies considering human practice and behaviour within mediated environments from a holistic perspective. That is, a perspective already argued for in this chapter and illustrated in figure 6.10. Furthermore, it is argued that to do this requires considering the analysis of human practice of the smallest meaningful unit of analysis in activity theory. That is, the activity itself. So while the application of the guidelines to the EISCAT system was successful in capturing breakdowns in equipment and continuity, the approach taken can be considered to be a hybrid between traditional task-based approaches and evaluation techniques (e.g. thinking-aloud) and setting this in a framework informed from activity theory.

In order to consider human practice and experience of mediated environments from a holistic perspective, a turn to activity-based analysis is necessary. Kaptelinin, Nardi and Macauley (1999) suggest that "systematic application" of "the hierarchical structure of an activity requires an analysis of its object [objective] or motive". Referred to by Christiansen (1996 p. 181) as "objectified motives". As mentioned, the transfer of spatial knowledge together with simulation of controlled scientific procedures is the purpose, goals or requirements of the EISCAT virtual environment. Using a task-based approach, the empirical study described in chapter three devised tasks to test these requirements and the success of the EISCAT system was then assessed by its ability to meet these requirements. Within activity theory, tasks can be considered to be equivalent to actions directed towards goals (Nardi 1996b) and their collective undertaking is directed towards the objective of an activity. That is, action(s) without activity are impossible (Leont'ev 1981). Within the empirical study of the EISCAT system, the collective undertaking of tasks (i.e. actions) may be considered (in activity theory terms) to be the objective of a users' activity. That is, directed towards a user's objective. The ability of the EISCAT system to fulfil a users' objective, which in this case is the transfer of spatial knowledge together with simulation of controlled scientific procedures, provides a way to assess its success (i.e. the requirements). Hence, a way in which to set task-based evaluation in an activity-based arena.

Finally, while concurrently thinking-aloud was successful at capturing breakdowns in equipment, it is argued that it should not be used during the capture and analysis of experience for two main reasons. Firstly, it is argued that giving a running commentary of processes will potentially distract users from the types of experience that a mediated environment is designed to induce. Continuing the analogy with film, consider for a moment giving a running commentary of the unfolding story of a film. It is not difficult in this situation to foresee that the actual processes involved in thinking-aloud will disrupt our ability to focus on the true intention of the film's presentation: i.e. to feel and experience the emotions that the director wants us to. Likewise, it is argued that the same can be said for thinking-aloud in interactive mediated environments. In the EISCAT VR study for example, thinking-aloud was postponed during the spatial awareness task as it was anticipated that it had the potential to interfere with the task. Secondly, and most importantly, while thinking-aloud provides "an opportunity to trace cognitive processes" (e.g. Russo Johnson and Stephens 1989) and in relation to immediate discussions, identify equipmental and continuity breakdowns associated with usability, however, both the normally conscious and unconscious processes will most likely be exteriorised. For example, in the EISCAT study some subjects verbalised everything from mouse movements (i.e. 3D mouse with six degrees of freedom) and button presses to head movements. Restricting subjects to action-level verbalisations by perhaps providing instruction of this difficult subject is problematic. This presents problems when considering an activity-based approach because it draws users' attention to operations that, following practiced or routinized behaviour, are performed with little conscious thought. Hence, this makes it impossible to understand user's behaviour under normal use with and within an interactive mediated environment from an activity theory perspective. That is, in the words of Kaptelinin (1996b p. 108) to understand the changes of user's "behaviour in different situations, it is necessary to take into account the status of the behaviour in question: is it oriented to a motive [activity], a goal [action], or actual conditions [operation]?" Using a think-aloud verbal protocol it is difficult to differentiate between actions and operations.

Therefore, it is argued that thinking-aloud be used to identify and ideally, to put right equipmental and continuity problems associated with usability prior to an experiential evaluation. That is, the two evaluation approaches be treated separately: firstly, equipmental and continuity evaluation to iron out problems associated with usability that will disrupt the second, experiential evaluation. Although, the restrictions imposed by the lack of resources, time and cost limit the work of this thesis and prevent a full-blown activity-based study of the EISCAT system to test all of the concepts devised. Even if this were possible, it is debatable whether pursuing the capture of experience (e.g. spatial and control procedures) using an activity-based approach is beneficial to elucidate the central arguments of this thesis. In particular, activities within the EISCAT VR system are restricted to work and work-related. Hence, pursuing these areas further will confine the central arguments of this thesis. However, it is argued that using the hierarchical framework and an activity-based arena in which to consider analysis from a holistic perspective makes it possible to reason about equipmental and continuity breakdowns while evaluation of experience is carried out. Chapter seven explores potential experience induced in users and proposes a method for its capture. Using an activity-based approach, chapter eight describes empirical studies to evaluate user experience and reason about usability of interactive mediated environments.

### 6.7 Activity-based scenarios

While the hierarchical framework of activity (HABS: figure 6.11) provides a way to model activities from the low-level physical (unconscious) operations through goal-directed actions to the activity itself (defined by objective and motive), the work so far is restricted to discussions about single activities. While this is sufficient to disseminate the chronological sequence of work carried out for this thesis up to this point, restricting discussions in this way would unnaturally inhibit the adopted concepts of activity theory to model human practice in interactive mediated environments and their related user experience. Engeström (1987; 1999) expands the basic concepts of activity theory (i.e. a *subject* performs processes towards an *object/objective* mediated by a *tool*) to encapsulate the social and cultural aspects of human practice and whereby, forming an arena in which to model and analyse a "web" of activities. To do this he introduces three inter-related components to the basic model to represent activity, including: "social" (i.e. "community", environmental and cultural), "divisions of labour" (i.e. responsibilities and variations in jobs roles) and "rules" (i.e. regulations in which activities are carried out). As mentioned, this approach has been taken up by many researchers in HCI (e.g. Bødker 1996; Kuutti 1996; Turner, Turner and Horton 1999; Mwanza 2000) to analyse activities of current human practice (i.e. in the real world) in which computer-based systems are to be upgraded or implemented. Generally, this takes the form of identifying "contradictions" (for original meaning see: Leont'ev 1978) that are a similar concept to that of breakdown but are used to identify inconsistencies between current activities and applying modification or upgrades and informing design for change. While this approach may provide a useful tool for the design and evaluation of interactive mediated environments in which a true representation or simulation of real world environments and work-related practice is important, however, the intension and scope of this thesis is not restricted to real world work-related activities. Whether this approach may be effectively extended to interactive mediated environments remains to be seen. Continuing the focus of this thesis, the hierarchical framework in interactive mediated environments (figure 6.11) is extended to model combinations of activities by drawing on an area of HCI that neatly fits with the arguments presented in this thesis – scenarios.

### 6.7.1 Scenarios and scenario-based design

A good way to describe activities in interactive mediated environments is through stories or scenarios. Indeed, a shift towards the representation of applications in a narrative-like structure has been proposed in analogy to film by Laurel Strickland, and Tow (1994), Pausch, Snoddy, Taylor, Watson and Haseltine (1996) and postulated in the progression of virtual reality development (see: chapter 5.2.2).

Scenarios and scenario-based design have a long history in the HCI community. The key advantage of scenarios is that they can be adapted to different styles of working (Karat 1995) or as Nardi (1995 p. 392) puts it "they would seem to rise to almost any occasion". In spite of their flexibility, Kuutti (1995) argues that there is no generally accepted definition and its use and scope in different contexts varies drastically. He divides these into two main approaches: the first is scenario as an external description of what a system does, for example, "to specify use scenarios that cover all possible pathways through the system functions" (Rubin 1994). The second approach sets scenarios in a wider context. For example, this is "the 'big picture' of how some particular kind of work gets done" in social settings, with resources, and goals of users (Kuutti p. 21 citing Nardi 1992b). The flexibility and scope of this latter approach makes it appropriate to describe activities in interactive mediated environments, encapsulating: context, setting, resources and user goals. In addition, they imply a temporal component or episodes (Wright 1992) just like the unfolding events of a film or play. The close similarities to narrative-like structures or scripts of a film or play and the important elements of scenarios in this wider context are elucidated well by Carroll (2000 pp. 46-47) saying, "scenarios are stories – stories about people and their activities". They "presuppose setting", for example, in "the accountant scenario, the setting is an office". Scenarios "include agents or actors" and "have a plot; they include sequences of actions and events, things that actors do, things that happen to them, changes in the circumstances of the setting, and so forth". "A set of interaction scenarios makes the use explicit". Nardi (1995 p. 393) describes scenarios succinctly as deriving from two things:

i. the inclusion of some user context and
ii. a narrative format, as in a text narrative or storyboard or video

She suggests that if these characteristics are missing, then the term scenario can seem very similar to "user requirement," or "feature," or "test pattern," or "system configuration," etc.

While work with scenarios is usually restricted to human practice involving work and work-related activities, a key advantage arising from their flexibility is their potential to describe a plethora of genres (e.g. training and education, entertainment, etc.) in a narrative or story-like structure. Furthermore, scenarios provide a means of "embodying and communicating user experience" (Nardi 1995 p. 396), offer "a rich view of …experiences of users," (Rosson and Carroll 1995 p. 268) and as suggested by (Nardi 1995 p. 398), "will undoubtedly remain a part of our design repertoire as we push forward toward more theoretical means of predicting and explaining user experience" (see also: Kuutti 1995).

While the flexibility of scenarios makes them useful for describing human practice in wider contexts (e.g. as argued for in their application to interactive mediated environments) this may however, also be a weakness. Kuutti (1995 p. 33) suggests that one problem lies in its ad hoc language and that a challenge for the future is to find "a more standard language" in which to talk about and structure scenarios. One approach is to provide a standard "template" in which to describe scenarios. For example, Fields, Wright and Harrison (1997) adopt the use of a "template" (i.e. agents, rationale, situation and environment, task context, system context, action, and exceptional circumstances) to describe scenarios "to help designers to reason about errors early in the design lifecycle for interactive systems". Similarly, Beyer and Holtzblatt (1998) provide five complementary models for describing work (e.g. flow, cultural, sequence, artefact and physical). Although, closer to arguments formulated here on scenario/narrative is Wertsch, Del RíO and Alvarez's (1995) adoption of Burke's method to study human motivation through analysis of drama. Burke's method called the "Pentad" includes five terms: agent, act, agency, scene, and purpose; used to breakdown statements of motives to the simplest level. Other potential approaches to structure scenarios suggested by Kuutti (1995 p. 33) are distributed cognition and activity theory. Continuing the work of this thesis, the next section looks to activity theory as a way of structuring scenarios to describe applications of interactive mediated environments. For historical perspectives, reviews of scenarios and their application to many different styles of working see for example, Carroll (1995, 2000), Kuutti (1995) and Nardi (1995).

### 6.7.2 Design and analysis of interactive mediated environments using activity-based scenarios

Scenarios provide a flexible way to describe human practice, while the concepts of activity theory in the form of the hierarchical framework in interactive mediated environments (figure 6.11), provides a structure in which to depict activities (i.e. from the low-level physical unconscious operations through goal-directed actions to the activity itself) defined by their objectives and motives. Hence, scenarios may consist of one or more activities, with each activity being fulfilled by a "chain" of actions. Actions determine conditions of processes that are required to be fulfilled. Following their mastery, these processes are performed with little conscious effort and referred to as operations. Humans have a "repertoire" of operations that enable interaction with their environment. The amalgamation of the two (i.e. scenario and activity) provides on one level a means to formally structure activities in a "template" (i.e. according to objective and motive) while on another, providing the flexibility to describe human practice from a single activity to highly complex stories with an array of activities (i.e. many objectives and motives). Hence, as illustrated in figure 6.13, combinations of activities provide ways to depict highlights of say, a day in the life. Furthermore, this is not only restricted to activities modelled from the real world but provides a framework in which to model, design and analyse fictional, imaginary, futuristic and dramatic worlds. This will be referred to as the hierarchical activity-based scenario approach (HABS). Describing scenarios in this way provides a structure in which to draw a closer analogy between scenarios of applications of interactive mediated environments and that of a scenario or script of a film or play. This similarity can be illustrated further by looking to the dictionary definition of scenarios in film and theatre: 1a. A sketch or outline of the plot of a play, ballet, novel, opera, story, etc., giving particulars of the scenes, situations etc; 1b. ...A film script with all the details of scenes, appearances of characters, stage-directions, etc., necessary for shooting the film; 2. A sketch, outline, or description of an imagined situation or sequence of events; esp. (a) ...outline of any possible sequence of future events; (b) an outline of an intended course of action; (c) ...circumstances, situation, scene, sequence of events, etc. (Oxford English Dictionary 1989). By drawing comparisons in this way, activities can be considered to be analogous to performing acts on stage in theatre (i.e. one or many acts forms a play) or scenes/slates of a film (i.e. one or many scenes/slates forms a film). That is, one or more acts, scenes/slates or activities forms a scenario of a play, film or application in an interactive mediated environment, respectively.

Although now the restriction imposed by this analogy is that acts/scenes/slates are now defined by an objective. A limitation implied in this model and indicated by the arrow in figure 6.13 is the sequential or linear ordering of activities from one to the next. That is, one activity (objective) is required to be fulfilled before the next is begun. However, just like the way in which Engeström's (1987) model supports the postponement of one activity while a different activity (i.e. actions of, or the whole activity) is carried out and then returning to the original activity at a later point, it is argued that this model also supports this feature. For example, consider the activity of going to a restaurant as shown in figure 6.13. The first action of this activity involves reserving a table. To ensure one can get a table at a desired time it is preferable to phone early, say from work. The reservation is not an action of the work activity but involves its postponement while the call is being made. This starts the restaurant activity. Following the phone call the work activity is continued. At this point, the restaurant activity is postponed until such a time that actions towards the fulfilment of the activity are carried out.

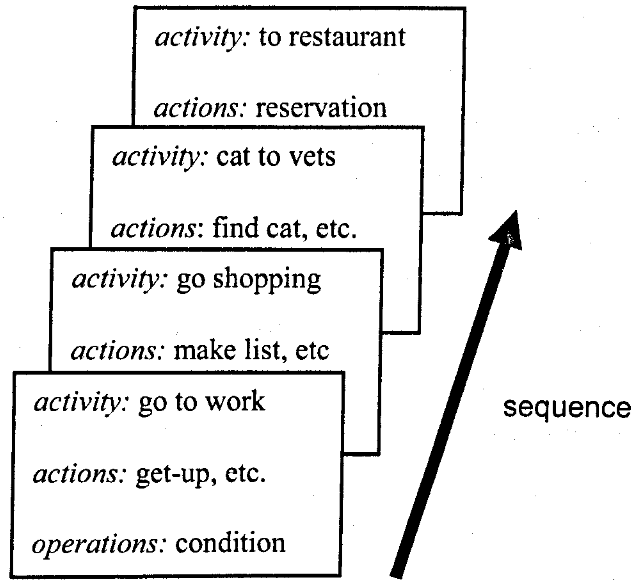


**Figure 6.13 Scenario: highlights of a day in the life**

### 6.7.3 Revisiting EISCAT: activity-based scenario

In the adoption of activity theory as a framework for the evaluation and design of interactive mediated environments, the thesis up to now has used as its starting point the activity itself. That is, objective and motive considered as one of the same and is an approach similar to much work in HCI as described above. For example, as suggested by Kaptelinin, Nardi and Macauley (1999) to analyse "object or motive" and as encapsulated in Christiansen's (1996) term "objectified motives". However, Leont'ev (1981 pp. 399-400) emphasises the analysis of both objective *and* motive, and only when they coincide is this "psychologically a process that we have agreed to an activity proper". In the event of them not coinciding means that the objective of a process or groups of processes are goals and in which case are actions.

The nature of interaction of interest to this thesis has been identified as being performed in contexts (i.e. mediated environment) within a context (i.e. the real world). That is, in the formation of functional organs and the objective lying within the mediated environment (figure 6.10) with the world external to it having little consequence for interaction performed within it. The assumption has been that the origination of objective and motive is within the mediated environment (i.e. objective as the collective outcome of actions performed within the mediated environment). However, if an activity-based approach is to be taken then consideration of both objective and motive is required. That is, to understand the "activity proper" requires identification of a user's process characterising the activity (performed in the mediated environment) as a whole (i.e. the objective) always coinciding with that which stimulates the user to this activity (i.e. the motive for interacting in a mediated environment) (Leont'ev 1981). So the question now is, does the motive originate from the scenario in the mediated environment or does it originate in the real world driving users to interact with the mediated environment? That is, does the user have a need that the mediated environment will fulfil or does a need or desire develop as a result of interacting within the scenario of the mediated environment?

To highlight this point, consider for example, the activity of sending an email. The motive stimulating processes is to communicate with the mail's recipient. The objective outcome of processes (i.e. actions: open mail package, compose mail, connect with server, send mail) is to communicate with the mail's recipient. Hence, the objective coincides with motive and forms "activity proper" and this is the smallest meaningful unit of analysis in activity theory. Within the EISCAT VR study however, it is arguable whether the objective outcome of user's processes (within EISCAT's mediated environment) coincide with that which had stimulated the processes, i.e. the motive for using the EISCAT VR system. As discussed, the reason for this is that users volunteered to take part in the study. Their motives for volunteering are not in the outcome but are more likely to be for financial rewards, get out of work or classes, for the good of the company or department, maintain harmony with colleagues, etc. That is unless of course a user has a genuine interest in the technology under study. In which case the objective outcome of processes may perhaps coincide with motive. This raises an interesting and related point that will be returned to later in the thesis, that is, can the actions of a scenario within a mediated environment form an activity?

One approach to overcome the limitation in activity-based evaluation studies is to impart a motive to subjects encapsulated in a scenario in an attempt to create "psychologically a process that we have agreed to an activity proper" (Leont'ev 1981 pp. 399-400). This should be narrated to subjects in a pre-study briefing session. For example in the EISCAT VR study this may be something on the lines:

> *"you are a scientist about to embark on an expedition to Norway to carry out a number of laboratory-based scientific studies. To provide training in your studies prior to your departure, you are required to carry out a number of procedures within a simulation of the real laboratory. These are: to familiarise yourself with the laboratory, its layout and the equipment that you will be using."*

A good deal of complex information is contained in this short scenario. The most important of which is to provide:

- a setting, a context i.e. a laboratory in Norway
- an identity for the subject i.e. scientist
- a motive for using the EISCAT VR system i.e. to receive training
- an objective outcome i.e. familiarise with the laboratory, its layout and equipment for experiments

Hence, users are encouraged to become actors and adopt personas. This echoes similar arguments to that advocated by Bannon (1991). In reference to the hierarchical activity-based scenario illustrated in figure 6.14, it is now possible to assess the success of the EISCAT system in use and its effectiveness for the user by reasoning about how well a users' objective coincides with their motive. That is, the degree to which the productive outcome of the objective (i.e. to familiarise with the laboratory, its layout and equipment for experiments) coincides with the motive (i.e. to receive training). Scenarios provide a framework in which to describe, plan and reason about activities. In addition, the extension of the hierarchical framework and functional organs provides a framework that allows us to zoom-out to reason about a holistic scenario (see next section) or activity-based level and zoom-in to a goal or lower operation level, and hence, a way of informing analysis and design of interactive mediated environments. Furthermore, it is argued that using the hierarchical framework of activity, guidelines (table 6.2) and scenarios provides the foundation for informing both analytic and empirical evaluations. That is, analytic by performing evaluations with evaluators similar to that of heuristic evaluations and walkthroughs, and empirical with users in both laboratory and field studies.

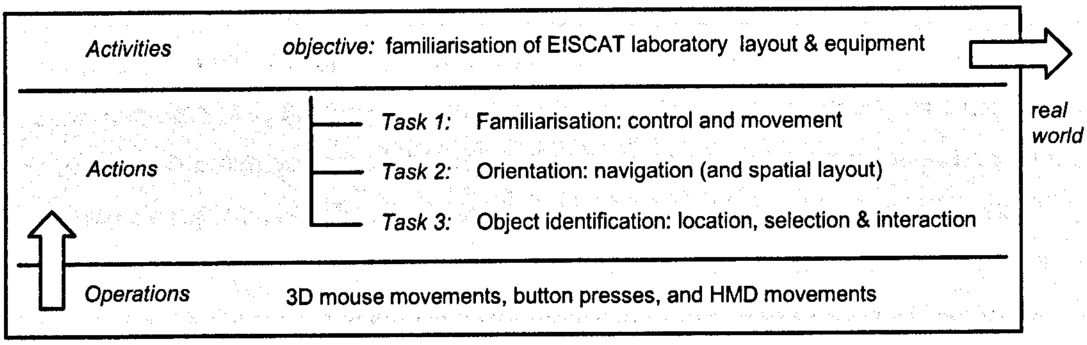


**Figure 6.14 Activity-based scenario of EISCAT VR system**

#### 6.7.3.1 Narrative design using activity-based scenarios

The fulfilment of an objective marks the end of an activity. Because activities are freestanding units (i.e. defined by the coincidence of objective and motive) it may be possible to undertake them in different orders. This is of course dependant upon critical paths and social and cultural rules and constraints (e.g. time constraints, availability of resources, opening hours, appointments, shift work, etc.). For example, in the scenario shown in figure 6.13 it would be considered out of the ordinary to go to the restaurant for an evening meal before one goes to work (i.e. unless one works night shifts). Though, if this activity was amended say to: satisfy hunger, then eating before work or indeed at any time would of course be considered socially acceptable. Likewise, the activities of shopping or taking the cat to the vets may be constrained by opening times and appointments. If no restrictions were placed on these activities then they can be undertaken at any time and in any order as illustrated schematically in figure 6.15a. Furthermore, following on from previous discussions, the postponement of activities while other activities are started (and perhaps completed) and then returning to complete the original activity could be treated much in the same way as a task scheduler or a stack system in a microprocessor. Figure 6.15b illustrates the modelling of non-linear action-level (& sub-action-level) processes carried out within constraints to fulfil the activity to *go shopping* for groceries. This same approach can be used recursively to model the non-linear lower-level repertoire of operations to fulfil actions. Therefore, providing a flexible way to plan, describe and model non-linear narrative that typically characterises new and emerging media such as interactive mediated environments.

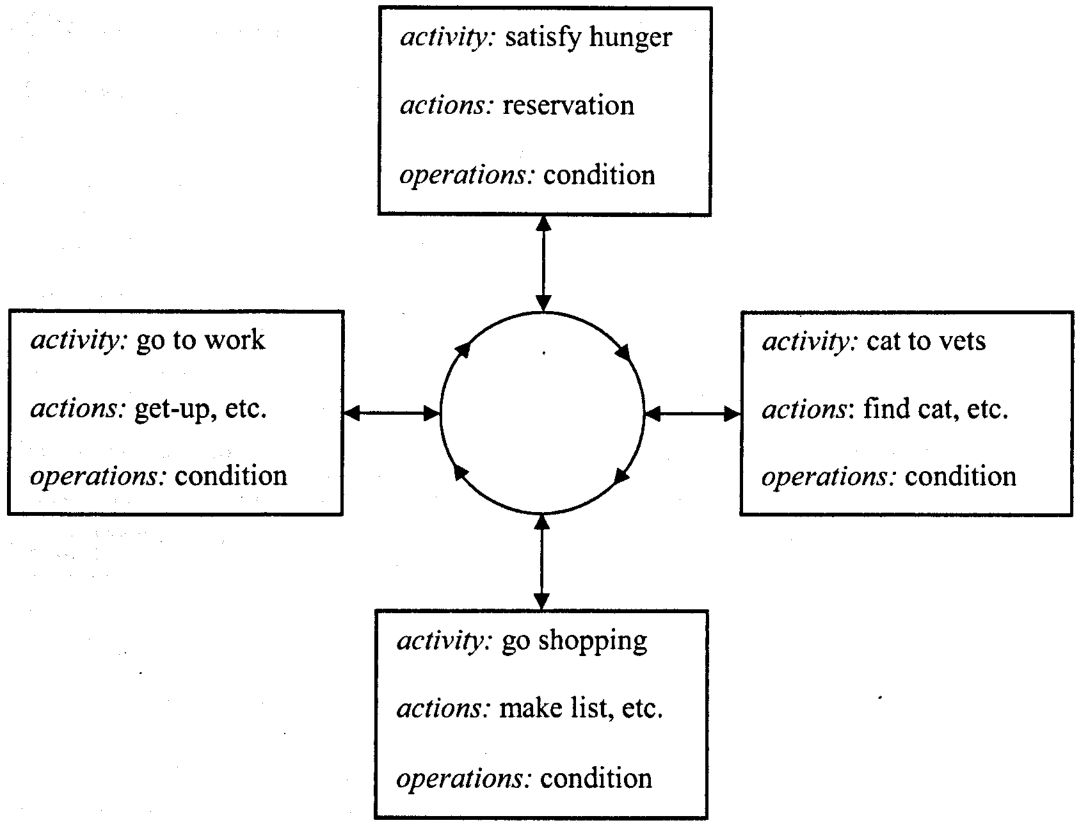


**Figure 6.15a Activity-level: non-linear narrative design of a day in the life using activity-based scenario**

This simple example demonstrates the decomposition of activities, actions and recursively to operations. Although shown in print the model appears static, the dynamic and non-linear nature of processes must be emphasised. Finally, I draw an analogy between the potential to structure non-linear narrative using this activity-based scenario approach and to very similar concepts depicted in William S.

Burroughs' collage for "The Third Mind" (1965) (e.g. Berge 1999). Berge (1999 p. 22) argues that "Burroughs saw the "cut up" as a weapon against the illusion of a static and linear universe" of media providing a "flowing and simultaneous universe of spliced storylines, multiple points of view, kaleidoscopic perspectives, fluid borders between present, past and future, and a cacophony of voices."

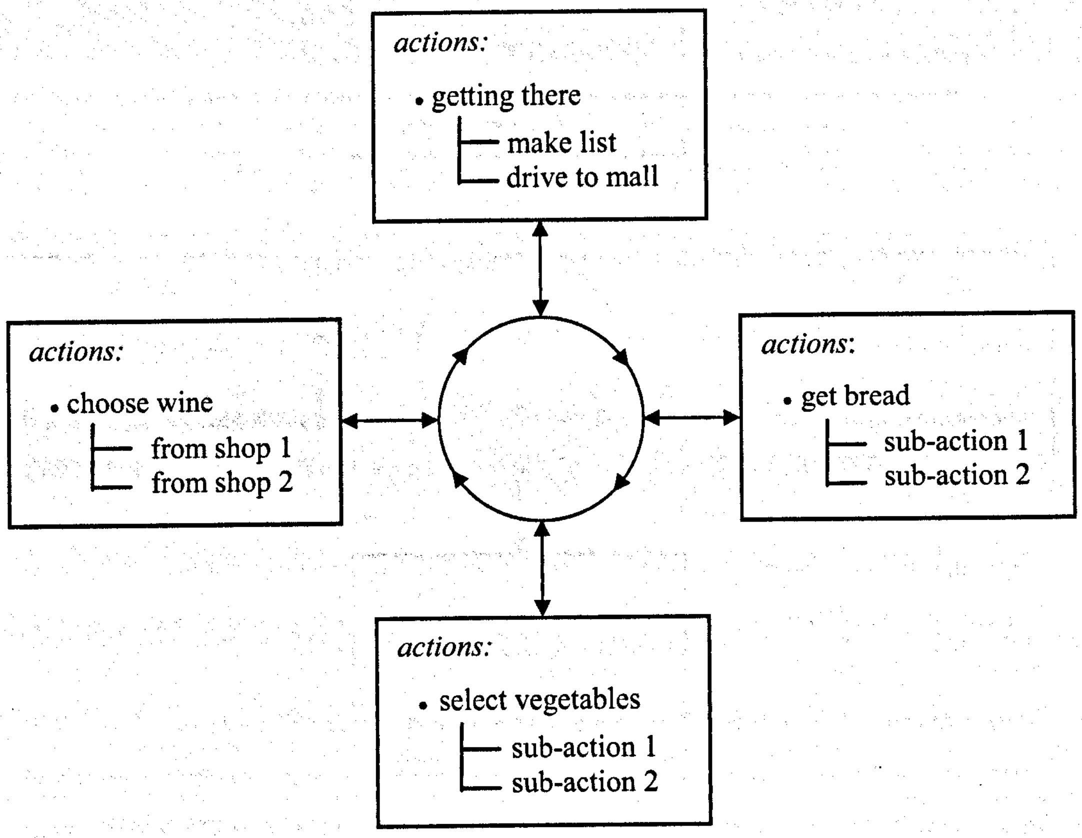


**Figure 6.15b Action-level: non-linear narrative design of *shopping* in a day in the life scenario**

# Chapter Seven Interactive mediated experience

Informed from work in HCI and film, chapter six extends the concepts of activity theory to interactive mediated environments. Central to this is that the "invisible style" of interaction (i.e. transparency of equipment and continuity of content) and incorporating the notion of formation of functional organs helps keep users in continuous "flow" (I refer to Holtzblatt et al's 1988 use of the term "flow" as discussed in chapter two) of their activities in the scenario within a mediated environment. As a consequence, it is anticipated that this will enhance user experience. Conversely, disruptions or breaks in transparency and continuity have the potential to break the continuous "flow" of activities, shifting users' focus of attention from the task at hand to the cause of disruption or/and to the real world, and potentially breaking users' experience. Extending the hierarchical framework of activities in activity theory, a model supporting activities with interactive mediated environments has been developed. Through breakdowns in activity and focus shifts in consciousness, the model provides opportunities to identify and reason about potential usability and design problems. To encapsulate this, guidelines developed in chapter four were extended and shown to be successful at classifying usability problems of a HMD VR system as either a breakdown in interaction, illusion or falling into both categories. While it was demonstrated that the guidelines provide a simple, quick and effective way to detect potential problems of design, limitations to this approach were identified. Most significant was the inadequacy to directly capture either breaks to, or provide assessments of, individual subjective user experience that comes from interacting within the content of mediated environments. As argued in previous chapters, it is anticipated that interactive mediated environments, like film, have the potential to induce experience and evoke emotions in users. For example whether emotions are innate (i.e. not learnt) and universal (termed "basic emotions" by Ekman 1992 e.g. happiness, sadness, disgust, surprise, anger and fear), are culturally defined (e.g. Harré 1986) or are "higher cognitive emotions" (e.g. love, guilt, shame, embarrassment, pride, envy, jealousy e.g. Griffiths 1997). In order to inform ways to assess users' experience from interacting within mediated environments, this chapter continues reviews on experiential work of computer-based systems from chapter two and extends the framework of experience developed in chapter five. This provides an approach to formulate a language that allows users to articulate experience, evaluators to capture experience, designers to judge their designs for experience and an alternative to considering presence and the social and cultural context. The next chapter develops a questionnaire to capture the framework and studies are carried out to test the effectiveness of the questionnaire.

## 7.1 Extending continuity to reason about culture, constraints and context through experience

Chapter four (4.4) identified difficulties in considering the socio-cultural structure of mediated environments because of their potential to create imaginary and artificial virtual worlds. Borrowing from the words of Engeström (1999 p. 23), it was argued that unlike the real world, mediated environments can be "individualistic" and "ahistorical" so consideration of artefacts that are shaped by successive successful adaptations and that in turn effect activities is problematic. While any attempt to formulate methods to analyse the socio-cultural context of mediated environments is beyond the scope of this thesis, an alternative approach is to consider the environment, objects and user by their behaviour in response to interactions, and user experience in response to this. That is, performing, conforming, reacting and responding appropriately within the constraints governed by the scenes, settings, circumstances and scenario.

As mentioned in chapter four, interestingly, these discussions share similar arguments with those on affordances borrowed from J. J. Gibson and introduced to HCI by Norman (1988). "The affordances of an object refers to its possible functions: A chair affords support, whether for standing, sitting, or the placement of objects. A pencil affords lifting, grasping, turning, poking, supporting, tapping, and of course, writing" (Norman 1993 p. 105-106). Nardi (1996b p. 14) suggests that the difference is that activity theory calls for an understanding of artefacts integrated into social practice and that this "contrasts with Gibson's notion of affordances". However, there is some conflict between Nardi's (1996b) brief assessment of affordances and that emphasised in Norman's (1999) attempt to elucidate his use of the concept of affordances. While Norman (1999) acknowledges limitations of earlier discussions (contained in: Norman 1988) that may have lead to some misunderstandings (e.g. arguing that what he was really talking about was "perceived affordances" as opposed to "real" or physical affordances), he adds that to his "great surprise" (Norman 1999 p. 39) the HCI community enthusiastically took-up the idea of affordances while generally disregarding related concepts of constraints and culture (see: Norman 1988). He asserts that much discussion in HCI on affordances is really about conventions and behavioural constraints i.e. "physical" (Norman 1988 p. 84), "logical" (p. 86) and "cultural" (p. 85), and the latter two in particular, are shaped by their "shared" practice that "inhibits some activities and encourages others" (Norman 1999 p. 41). However, Norman's (1988; 1999) discussions on concepts of constraints and culture are very brief and need developing if they are to be useful to inform interface analysis and design.

Many variations in definitions of culture exist. To varying degrees, it is defined through commonalities shared by a group limiting the behaviour of members. The approach to considering culture by constraints is described well in Poortinga's (1992 p. 10) definition: that culture "manifest in shared constraints that limit the behaviour repertoire available to members of a certain socio-cultural group, in a way different from individuals belonging to some other group". That is, people tend to restrict their behaviour to what is considered appropriate and acceptable depending on which group they are participating in. For an enlightening and informative review of culture and cultural definitions see for example, Matsumoto (2000). Likewise, it is argued that a user participating in a scenario within a mediated environment is likely to adhere to certain social and cultural norms. For example, as observed in studies to be described in chapter eight, in a medieval castle environment a user follows social and cultural behavioural patterns that are different from those in a first person shooter game. Any deviation from these patterns can be considered inappropriate or out of place or character in the environment. That is, a witch and her behavioural patterns from a medieval castle game do not belong in a first person shooter game, and visa versa. Furthermore, a user would expect a mediated environment and objects contained within it to respond appropriately to interactions. For example, any switches, drawers, windows and doors that are inoperative or do not respond as they should within a scenario, can be considered inappropriate or out of place. To encapsulate the notion of constraints that limit the behavioural repertoire of artefacts and users formed by a socio-cultural context, the concept of continuity is henceforth extended. Thus, it can be reasoned that if something or someone behaves appropriately within constraints determined by context then it has continuity and if not, can be considered as having discontinuity. While the added concept of constraints determined by the socio-cultural context (i.e. scene, setting and scenario) to previous developments (i.e. hierarchical activity-based scenario approach) provides a framework to reason about design through the behaviour of artefacts in use (i.e. shifts in consciousness), it is difficult to see how it is possible to reason about user's behaviour in context. To assist in reasoning about user or virtual character behaviour, the remainder of this chapter works towards the development of a framework of experience that may be induced in, or witnessed by users during an encounter with a mediated environment. So that, appropriate experience will be said to have continuity, and no, reduced or inappropriate experience has discontinuity. Thus, discontinuity potentially points to limitations in design or a user's dislike for the mediated encounter.

## 7.2 Experiential design of computer-based systems

Probably the most intensive and continued body of research in experiential design of computer-based systems has been from work in presence. Reviews of presence and presence research can be found in: Lombard and Ditton (1997); IJsselsteijn, de Ridder, Freeman and Avons (2000); IJsselsteijn, Freeman and de Ridder (2001). Presence research has been carried out in relative isolation from more traditional work in HCI and has at best been sidelined, and at worst ignored by that community. The reasons for this could be that they regard presence as highly specialised, ill-defined, and best left in the realms of fantasy and science fiction. However, much work in presence has moved away From its original highly specialised focus, towards a wider arena that allows us to describe the experience that is witnessed or evoked in users of mediated environments. Likewise, work in HCI has seen a shift away from performance-based and work-related tasks towards a more experiential design focus encompassing both a work and a non-work-related emphasis. Indications of this shift can be seen in emerging texts advocating pleasure (Jordan 2000), fun (Blythe, Monk, Overbeeke and Wright 2003) and emotion (Norman 2004) in design of computer, media, technological devices and products. The shifts in research from both presence and HCI to wider experiential perspectives in which to set user activities with computer-based systems may identify similar research goals between these traditionally disparate communities, potentially orchestrating moves towards the development or merging of a related or shared design agenda. This section begins by presenting some of the significant contributions to experiential research from both HCI and presence. This work may inform work to capture experience witnessed or evoked in users of interactive mediated environments.

### 7.2.1 Experiential design in human-computer interaction

As mentioned in chapter two, interaction with computer-based systems has long been identified as having the potential to induce experience in users. Experiential work aside from (or related to) that of presence (see next section) is appearing rapidly. For example, in HCI (Hassenzahl, Platz, Burmester and Lehner 2000), digital media (Laurel 1993; McLellan 2000; Murray 1997; Picard 1997), interactive mediated environments and VR (Heeter 1995, 2000; Marsh and Wright 2000b; Marsh, Wright and Smith 2001; Marsh 2001; Marsh 2003b; Robertson 2000; Pierce, Pausch, Sturgill and Christiansen 1999) and the Internet (Höök, Persson and Sjölinder 2000; Wright, Belt and Lickorish 1998). Specific experiences have been identified as being induced in users through empathy and catharsis (Laurel 1993), emotional and affective (Picard 1997), curiosity, interest, entertaining and aesthetic (Höök, Persson and Sjölinder 2000) and fun and enjoyment (Hassenzahl, Platz, Burmester and Lehner 2000). The common driver in this work is the attempt to provide a pleasurable interaction for users. Furthermore, a linking theme in much of this work and argued in chapter five (Marsh 2001; 2003b) is the introduction and development of characterisation, for example, in: digital media (Laurel 1993; Murray 1997; Picard 1997), interactive mediated environments and VR (Robertson 2000; Pierce, Pausch, Sturgill and Christiansen 1997) and the Internet (Persson 2000; Wright, Belt and Lickorish 1998).

### 7.2.2 Experiential design in interactive mediated environments

Performing activities within virtual or mediated environments is widely believed to induce experience in users. Although no consensus definition of this experience yet exists, the thrust of research has been toward that which is commonly described as a sense of "being there" or "being in" the illusion created by 3D virtual space. Referred to as presence, it is seen as a primary driver for design and evaluation of mediated environments (e.g. in VR: Tromp 1995; Slater and Wilber 1997; Bystrom, Barfield and Hendrix 1999) and consequently, has prompted much research in an attempt to elucidate its underlying determinants and find measures for their assessment. For example see: IJsselsteijn, de Ridder, Freeman and Avons (2000) for reviews. While research continues to develop an increasing array of methods that attempt to capture a user's sense of presence, the presence community is still however, some way off formulating a consensus definition for this concept in mediated environments. To highlight some of the difficulties, this section discusses key arguments from the presence literature and identifies limitations in the generally accepted philosophy surrounding this concept that may have hampered experiential research.

The concept of presence has its roots in "telepresence" (see: Sheridan 1992; Steuer 1995). Telepresence is a sense of being in a remote or hazardous environment (e.g. space, deep sea diving). It occurs when a user or tele-operator's movements or interactions with a device (e.g. an exoskeletal force-feedback manipulator) are mirrored literally "through the interface" by a robot or mechanical arm within a remote environment. As a consequence, users describe a sense of acting directly within a remote environment. This effect can be described well through the formation of functional organs. See figure 6.2 chapter six. The adoption of the concepts from telepresence in VR provided a convenient way to describe the effects experienced by users interacting within virtual environments. See figure 6.1 chapter six. As mentioned, although the interest in this thesis is primarily concerned with interactive mediated environments that are categorized by the objective within the mediated environment, most of the work discussed is equally applicable to the former (i.e. "through the interface": where the objective is in the remote or distributed environment and in the formation of functional organs: e.g. human operator-exoskeletal manipulator-robot arm-remote environment). In both categories, the real world in which the user's body is physically positioned has little or no consequence to activities or their objectives.

To represent these two categorizations a schematic, as shown in figure 7.1, was devised to illustrate the conditions in which a mediated illusion may arise. Using the concepts formulated in chapter six, it is argued that this experience occurs when the user acts directly within a mediated environment and this is a consequence of the objective laying within the mediated environment and in the formation of functional organs. As mentioned, at such a point, it is argued that the mediated environment should be considered as a functional organ to enhance natural human abilities to work, play, learn, shop and be entertained. If the objective continues to coincide with motive then this will help to maintain this experience, encouraging users to stay there.

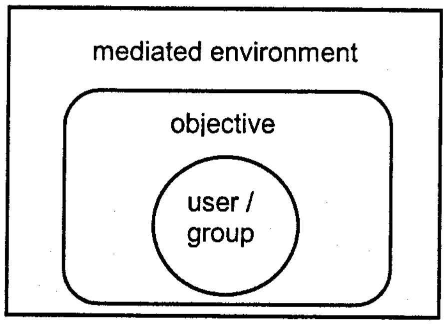


**Figure 7.1 Experience of interactive mediated illusion: objective present within mediated environment and formation of functional organs**

### 7.2.2.1 How do users experience a sense of presence?

While some research has argued that fidelity of stimuli (e.g. visual, aural, tactile and force-feedback, etc.) is not necessarily linked to a sense of presence (for example: Whitelock, Brna and Holland 1996; Brna 1999; see also, Lombard and Ditton 1997 who discuss other forms of presence e.g. social), a common belief held amongst VR workers is that increasing the fidelity of stimuli will lead to a sense of presence (Barfield, Zeltzer, Sheridan and Slater 1995). This implies that on reaching some level or threshold of fidelity a sense of presence will then be induced in participants. Consider for a moment the stage at which this threshold may occur. Firstly, is it in the replication of the world in every conceivable detail? This may provide participants of virtual environments with the ultimate sense of presence indistinguishable from that obtained in the real world. Perhaps this can be considered to be the closest that we can get to Licklider's (1960) visionary ideas towards a "man-computer symbiosis". This is similar to Nozick's (1974) idea of plugging humans directly into an "experience machine", prompting many philosophical discussions and providing a more literal meaning to the term "plug and play" (pp. 42-44):

> *"Suppose there were an experience machine that would give you any experience you desired. Superduper neuropsychologists could stimulate your brain so that you would think and feel that you were writing a great novel, or*

> *making a friend, or reading an interesting book. All the time you would be floating in a tank, with electrodes attached to your brain. Should you plug into this machine for life, preprogramming your life's experiences? If you are worried about missing out on desirable experiences, we can suppose that business enterprises have researched thoroughly the lives of many others. You can pick and choose from their large library or smorgasbord of such experiences, selecting your life's experiences for, say, the next two years. After two years have passed, you will have ten minutes or ten hours out of the tank, to select the experiences of your next two years. Of course, while in the tank you won't know that you're there; you'll think it's all actually happening... Would you plug in?"*

However practical difficulties aside (e.g. in terms of time, effort, complexity of models, memory requirements, not to mention the costs), even if this were possible, the question to ask is: Does it matter that users don't know whether or not they are in a mediated world? Phillips (2000 p. 143) raises similar points in analogy to the film "The Matrix" (Wachowski and Wachowski 1999) in which people are "living" in an illusion that is indistinguishable from the real world set in 1999. In considering the potential for recreating such a virtual world he suggests that, "...if we were not able consciously to locate the virtual experience as being different [from our sense of the real], we would not be able to take pleasure in it as an event". Laurel (1993 p. 120) elegantly elucidates a similar argument through the description of a child experiencing a simulation ride (i.e. "a wild ride combining flight simulator technology with Star Wars content"), pausing momentarily during a shriek the child shouts, "if this was real, I'd be scared!" Likewise, it is precisely the unreal that allows subjects with phobia-related disorders to confront their fears; it is difficult to imagine them agreeing to spend much time in, or even enter an environment indistinguishable from the real world where their fear exists. Similarly, it is the unreal that allows trainee pilots to practice take-offs and landings, etc., and games players to fly fighter jets or race formula-one cars. If they had to be as highly trained as a jet fighter pilot or as talented as a racing car driver, games would not be enjoyable or at worst, be unplayable. Hence, it is argued that people take comfort from knowing that a mediated environment is mediated and an environment in which they can act out situations, confront fears, make mistakes and experience things that would not be possible in the real world without causing untold fear, harm or damage to oneself or others. Support for this can be found in Scheff's (1977) very similar arguments of experiencing emotions and cathartic release from a best aesthetic distance. Therefore, it is argued that the ability to identify and locate the virtual or mediated world from the real is a necessity that provides a safe distance enabling users to gain experience and pleasure.

Secondly, consider if the threshold of presence experienced in a mediated environment was determined by a resourceful blend of hardware and software, and judged according to participants' induced experience. Either one of two situations would arise from this: that a scaled continuum of presence from low (threshold of presence) to high (the absolute level being the replication of the world in every conceivable detail) may exist. Manipulating the causes of presence shifts the level of participants' experience back and forth along this continuum. This implies that presence is multi-layered existing on many levels from low to high. In contrast, the second situation assumes that we are either present or not present in an environment. That is, to think of more or less, or low to high levels of presence is nonsensical. Whether or not there exists a threshold of fidelity that should be reached before a sense of presence is induced in participants, or whether or not presence exists on just one or many levels, remains to be seen. However, it is worth considering the potential outcomes that may arise from this:

*1. Replication of the world in every conceivable detail*

The sensory information is such that participants are presented with an all encompassing array of stimuli by which they make a total switch from stimuli in the real world and attend only to sensory information from the virtual world. Identified are two situations that could arise:

*i. natural switch in cues:* participant's total acceptance of the stimuli from the mediated environment (e.g. as in the film "The Matrix")

*ii. conflicting switch in cues:* while stimuli from the VE indicate one thing, a participant's common sense and memory suggests otherwise. That is, no matter how accurate the stimuli appears the participant knows that they are in an unreal environment in view of the fact that they can remember going from the real to the virtual world. The question to ask here is, can participants maintain this situation for long periods of time or will a point be reached at which the participant may feel some detrimental or hazardous effects to their health. Such as those caused by the withdrawal from the real world, experience a kind of claustrophobic effect, paranoia or worse?

*2. Blend of hardware and software VR enabling technologies*

Participants receive sensory information from both the real and the virtual worlds. Identified are two potential situations that may arise from this:

*i. suppression of real world stimuli* external to the VR system and attend only to stimuli internal to the VR system; or a *blending of stimuli* from the real and virtual worlds in some way to create new and balanced sensory information to the participant. For example, most VEs use a participants' sense of gravity from the real world to inform their physical orientation in the virtual world.

*ii. conflict of sensory information* from the real and virtual worlds. Whereby, a participant is unable to suppress or blend the sensory information that is external to the VR system. For example, encumbering equipment, distractive noise, etc. that is external to a virtual environment and mismatches between cues such as, what the user's virtual hand feels or manipulates and what their real hand is feeling or manipulating have the potential to disrupt a user's illusion.

On examination of the above, common sense would advise avoidance of the design and development of mediated environments that provide conflicting sensory information from both the real and the virtual worlds, such as the situations described in (1ii) and (2ii) above. Conflicting sensory cues will break any illusion we have for interacting in a mediated environment, drawing attention to itself and make us aware of the artificiality of the medium, as argued in chapter six. Additionally, for the reasons suggested above, e.g. the time, effort, complexity, memory requirements and costs makes the replication of the world in every detail, as in (1i) above, an unsatisfactory option. Furthermore, as mentioned, even if this were possible: How can we take pleasure in a mediated environment and activities performed within it if we can't distinguish it from the real?

It is argued that trade-offs are required to be made and compromises reached. Therefore, it is argued that design and development of interactive mediated environments attempt to suppress real world stimuli or blend stimuli from the real and virtual worlds as described in (2i) above. As mentioned, it is argued that experience occurs when the user acts directly within a mediated environment and this is a consequence of the objective laying within the mediated environment and in the formation of functional organs – as shown in figure 7.1.

Although much work in presence has been focused on VR, recently an attempt has been made to extend this concept to non-interactive broadcast and viewing systems such as, television and cinema (Freeman and Avons 2000). More recently still, attempts have been made to shift this concept to an ever increasing array of technological and communication media, devices and applications including, visual: Internet, television, cinema and non-visual: telephone, email, etc. (IJsselsteijn, Freeman and de Ridder 2001). Whether or not presence extends well to these wider technological systems remains to be seen. However, the belief argued for in this thesis is that any definition of a sense of presence in mediated environments should be closely related to, and underpinned from our beliefs as to what presence is in the real world ("being present; place where person is" Oxford English Dictionary 1989). Thereby, forming a benchmark, allowing analogies and comparative studies to be made with this problematic and seemingly elusive concept.

Implied in notions of "being there", "being in" or "perceptual illusion of nonmediation" is the widely held view that a sense of "presence occurs during an encounter with technology and not before or after this encounter" (e.g. Heeter 2000). However, Heeter (2000) goes on to suggest that "consequences/effects of presence can occur after" an encounter. Considering these arguments and furthermore, that this is widely believed to occur in an "instant by instant" "continuous manner" it is difficult to ascertain what is meant by the after consequences/effects within the boundaries of the concept of presence without shifting towards a wider experiential arena in which this can be described. Accepting this concept as being grounded in the real world meaning of presence, if one considers any past event or situation occurring in some location from the real world in which we were actually present: What is it that we remember from this encounter? What are the after effects or consequences? and how can we describe these? Is it, on the one hand, the ability to recall a gestalt of information that contributes to make one feel as if they have actually been present in time/event/situation/location or is it on the other hand, that a consequence of having been somewhere is to form an impression, impact or create feelings that impinge on our psyche? Perhaps these are different parts of the same thing occurring along a continuum. However, irrespective of whatever this turns out to be, the question to ask now is: Can these after effects or consequences be described within the boundaries or concepts from the presence community that is commonly accepted as a sense of "being there" occurring in an "instant by instant" "continuous manner" and if not, how can they be described?

The difficulties drawn out in these discussions and tension elucidated through Heeter's (2000) arguments highlights the imprecisely defined nature and elusive characteristics of this concept. Lombard and Ditton's (1997) definition is an attempt to provide an alternative to the views that originate, in most part from research in virtual reality. Central to their definition is the extent to which "a person fails to perceive or acknowledge the existence of a medium" and as a consequence of this, they experience an illusion that is (perceived to be) unmediated by technology. This reframes this concept to various traditional and emerging electronic visual media and technologies, both interactive and non-interactive, including: television, cinema, IMAX, the Internet, multi-media, computer games, simulation rides and VR. Furthermore, the "perceptual illusion of nonmediation" captures well the experience that comes not only from passive visual systems (e.g. television and cinema) as suggested by Freeman and Avons (2000) but also to non-visual systems (e.g. telephone, email, etc.) as suggested by IJsselsteijn, Freeman and de Ridder (2001).

Relating to interactive media, these are issues relevant to those of transparency of equipment as advocated by many in the HCI community (see: chapter four). Only, as well as being able to focus on the task at hand, the additional factor suggested in Lombard and Ditton's (1997) definition is that as a consequence of the experience of transparency of mediated technologies people experience an illusion. While this definition encapsulates a wider perspective on user experience extending beyond the boundaries imposed by presence as a sense of "being in" or "being there" within a mediated illusion, the term "perceptual" within this definition refers to "continuous (real time) responses of the human sensory, cognitive, and affective processing systems". Thus, restricting this definition to user experience that occurs during an encounter with technology. Therefore, the question still remains to be answered: How can the after effects or consequences that are witnessed or evoked in users of interactive mediated environments be described?

Finally, Heeter (2000) offers a slightly different perspective on presence by introducing spatial and temporal dimensions saying that a sensation of presence may occur fleetingly or continue for a longer duration. She provides the example of "jumping when a dinosaur on the movie screen lurches toward you suggests, in that moment, you felt spatially and temporally located with the dinosaur". Continuing with the logic of this argument and drawing upon my own film viewing experience, does this mean that I was actually in the water with sharks when I saw the film "Jaws" (Steven Spielberg 1975), have fought with a "Gladiator" (Ridley Scott 2000) and had a couple of rounds with Jake La Motta in "Raging Bull" (Martin Scorsese 1980)?

### 7.2.2.2 Wider experiential perspective in interactive mediated environments

While transparency of mediating technologies is highly important for keeping users in "flow", it is argued that if the content is uninspiring, dull or boring to interact with or watch, it won't hold or engage users' attention in the illusion for long periods of time. Turning to non-interactive media, the issues of transparency are very similar if not the same as those underlying the "invisible style" of editing and cinematography techniques and the resulting experience that is derived from the illusion of film. As illustrated in chapter five, the "invisible style" of film predates the concepts of transparency from the HCI and presence communities by over half of a century and so this is one of the reasons that this thesis has turned to the model of film to inform the evaluation and design of interactive mediated environments. Hence, the approach that has been argued for in previous chapters as a way of overcoming the difficulties of keeping users engaged in the illusion of a mediated environment is, like film, to enhance user experience (Marsh, Wright and Smith 2001; Marsh 2001; 2003b).

The key difference between a sense of presence that is commonly referred to as "being there" or defined as "perceptual illusion of non-mediation" and that of experience occurring from interaction within a mediated environment can be illustrated through identification of the boundaries or scope of each. It is argued that, like presence, experience also occurs during an encounter with a mediated environment in a moment-by-moment manner, as well as, with the unfolding of events, episodes or over the entirety of the mediated encounter, that is, the "big picture". Similarly, like presence, experience does not occur before an encounter. However, a user having previously encountered a particular mediated environment can recall memories, associations and form apprehensions or anticipations of the experience that is about to occur prior to its re-encounter. This will most likely have influence on a user's experience, both positively (e.g. in training and entertainment through an increased skill level achieved through prior encounters) and negatively (e.g. in entertainment in which the suspense, excitement or visual pleasures are dulled due to prior exposure). Furthermore, unlike presence, any after effects or affects can be described by the experience and emotions evoked in users. That is, what you take away with you in memories and associations. In sum, it is argued that the texture (i.e. make-up or weave) of a mediated experience is a corollary of interacting within a mediated environment's content and any experience that a user brings with them prior to the mediated experience; for instance, a user's inherent disposition, their moods and feelings prior to an encounter and previous experience of interactive mediated environments (i.e. naïve versus expert users) or a particular mediated environment/genre may all have an influence on a user's mediated experience during as well as after an encounter with an interactive mediated environment. Placing these into more manageable categories, mediated experience can be considered as occurring on both micro and macro levels. For example, micro levels occur in a moment-by-moment manner (e.g. attractions: fright, surprise, humour, jolt, jump, etc.) or on a macro level as a consequence of a sequence of events or the build up of information and knowledge given in dialogue or actions in events of scenarios or over the entirety of the mediated experience. Following interaction, it is argued that experiences can be recalled on both micro and macro levels. In this sense experience can be viewed on two levels: that which occurs continuously as the mediated experience unfolds and that which we take away with us, the big picture of a story/scenario, and what users have learnt through the transfer of spatial information and knowledge. Perhaps this is what is meant by the after effects/affects/consequences following an encounter with technology (e.g. Heeter 2000). However, it is argued that this is not a necessary consequence of a sense of presence in mediated environments and furthermore, cannot be effectively described within the commonly accepted notion of a sense of presence as "being there" or in the definition "perceptual illusion of nonmediation".

A sense of presence is seen by many to be an important goal (e.g. Tromp 1995; Slater and Wilber 1997; Bystrom, Barfield and Hendrix 1999) with dedicated publications (e.g. Presence: Teleoperators and Virtual Environments, MIT Press, 1992-present) and workshops (e.g. International Workshops on Presence, 1998-present) providing a platform for the dissemination of presence research. This is in contrast to related but alternative work on other kinds of user experience in virtual environments that generally are not discussed within these specialised forums. While some research that argues for alternative experiences to that of a sense of presence is beginning to find a platform within this literature (Marsh 2003b), the quantity of work amassed on presence from this community (i.e. published and presented in the journal and workshops as mentioned above) demonstrates that the emphasis on design and evaluation of user experience in virtual environments has been directed towards the creation of a sense of presence. It could therefore be argued that experiential research on a sense of presence has perhaps overshadowed or even overlooked other experiential work. Rather than viewing a user's effects or affects within the restricted boundaries of a sense of presence, it is argued that a more useful way to describe and reason about these is to consider presence as experience (Marsh 2001; 2003b). This is not arguing against the existence of the concept of presence, but arguing for a shift towards a wider arena in which all experiences that are or have been witnessed or evoked in users of interactive mediated environments can be placed. While future work may perhaps formulate a more precise definition of this more specialised experience of a sense of presence and methods for its capture, until such time is reached, this chapter argues for a more useful and usable way to inform methods for the design and assessment of mediated environments. Furthermore, it could be argued that experiences provide an alternative and indirect way to assess presence (Marsh 2001; 2003b). That is, experiences and the activities that provide them are associated with the virtual places (i.e. the context of use: the scenes, sets and settings) where they were encountered. Conversely, we associate a virtual place with experiences where they occurred and this may enforce the illusion of having been somewhere in another environment other than where the mediating system resides (e.g. home, lab). In short, experiences encountered in virtual places (i.e. spaces within mediated environments) may provide a sense of having been present somewhere else. Hence, finding ways to capture user experience may provide an alternative to the vast accumulation of proposed techniques for the measurement of presence and it is argued that this is a key concept in the evaluation and design of interactive mediated environments.

Accepting these arguments raises a number of questions. In particular: What kinds of experience will be induced in users? How do we enhance experience to grab and hold attention and perhaps provide the motivation to want to experience more interactive mediated environments for long periods of time? and how can we design and evaluate to create these experiences?

**7.3 Experience from performing activities within scenarios**

As argued in chapter six, like that of film, interactive mediated environments create experience and have the potential to evoke universal human emotions in users. So, just like the way in which film experience provides pleasures to spectators that entice or motivate them to sit for hours on end and is central to the reason why spectators go back and view more films, perhaps the same is true for interactive mediated environments. The question now is: How can interactive mediated environments be designed for experience? Well, to a large extent the VR and computer games communities have been designing mediated environments for experience in some shape or form for some time. Indeed, it is argued that the success of the computer games industry is because of the experience that computer games create for users. Not quite as obvious though, is experience design in VR. Consider for example potential applications and scenarios that have been designed to, or may benefit from enhanced user experience in VR. A survey of VR systems identified some of these genres as being in "routine production use" (Brooks 1999).

- Education: history and geography - enable users to visit different places or past civilizations and experience them first hand
- Training: fire fighting (e.g. Tate, Sibert and King 1997; Romano and Brna 2001), medical (e.g. Stansfield et al. 1998), surgical (e.g. Ota et al. 1995) etc. - induce a feeling of concern or perhaps agitation and fear of the risks attached to the task at hand, flight simulator – feel what it's like to take the controls of a 747 passenger aircraft (e.g. see: Brooks 1999)
- Entertainment: become a character and feel the emotions of interacting with the virtual world and with other characters (e.g. Laurel 1993; Springel 1999) during the rehearsal of a play (Slater, Howell, Steed, Pertaub, Gaurau and

Springel 2001) or as an invisible observer (spectator) moving in-between the unfolding story, action and narration

- Engineering: vehicle design - go beyond ergonomic assessments and feel and experience what it's like to sit behind the wheel and drive a car that is yet to be built
- Psychotherapy: in the treatment of phobias - allow patients to overcome their fears through gradual exposure to the cause of their anxiety (fear of heights e.g. Hodges et al. 1995, fear of flying, e.g. Hodges, Rothbaum, Watson and Kessler 1996, treatment of burn patients e.g. Hoffman, Patterson and Carrougher 2000, and dental pain e.g. Hoffman, Garcia-Palacios, Patterson, Jensen, Furness and Ammons 2001)
- e-commerce: in a shopping mall or supermarket - absorb the atmosphere as you pass by stores and through shopping aisles with ambient sounds of check-out tills, eclectic muzak and announcements of price reductions.

Although experiential design in interactive mediated environments is beginning to appear and is additional to work of presence, this has not however, been well captured or formalised. That is, very little work has identified, collated and categorized experience into some kind of framework. In analogy to the historical developments in film, chapter five proposed that VR has followed a similar progression of developments from: modelling through attractions/thrills to the development of story/scenario and character. These three broad categorizations create different experiences in spectators and this has been proposed as the basis for informing a framework of experiences that can be induced in users. In order to inform methods for design and evaluation of user experience in interactive mediated environments the next section again looks to film whose central goal is the shaping of experience (Boorstin 1995).

### 7.4 Framework of experience

In reference to figure 7.2, the three phases of film and VR's development (formulated in chapter five) and the corresponding experiences that are induced in users exposed to these phases provide a convenient way to develop a framework of experience. In turn it is argued that the framework provides a way to inform the design and evaluation of experience of interactive mediated environments.

| | | | |
|---|---|---|---|
| **film:** | recording<br>*actualities*<br>*location, imagery, sets*<br>(Lumière brothers) | "cinema of attractions"<br>*fascination of thrills,*<br>*tricks, fantasies & effects*<br>(Méliès) | scenario/story/narrative<br>*cinematic & editing conventions*<br>*shaping of character*<br>(Griffith, Hepworth, Porter) |
| **VR:** | modelling<br>*from 3D cubes*<br>*to 3D worlds* | VR of "attractions"<br>*identifying VR's purpose*<br>*attractions & sensations* | scenario/story/narrative<br>*idioms, conventions & guidelines*<br>*& shaping of character* |
| **Experience:** | voyeuristic<br>*aesthetic, atmospheric*<br>*& sense of space/place* | visceral<br>*thrills*<br>*attractions & sensations* | vicarious<br>*empathy*<br>*& emotional information* |

**Figure 7.2 Framework of experience in film and interactive mediated environments**

That is, the three categories: voyeuristic, visceral and vicarious (Boorstin 1995) that elegantly describe spectators' film experience link with some ease to the three categorizations in film's and VR's development (i.e. modelling, attractions and story/scenario/narrative respectively) and hence, naturally form broad categories for a framework of users' mediated experience. The next section describes these three broad categories of experience and describes how they relate and can inform the design and capture of experience in interactive mediated environments.

### 7.4.1 Voyeuristic experience

Boorstin (1995 p. 12) describes the voyeur as the "prying observer" and their pleasure is the "joy of seeing the new and the wonderful". If there is nothing to provoke our curiosity and interest in the scenario or visual pleasures then simply we get bored. That is, the unfolding film should be *unexpected.* Exceptions are when we want to experience a film's presentation over and over again. In such cases, this is testament to the quality and thoughtful nature of a film's crafting. A further important factor of a successful film is its credible treatment of the flow of space and time. Failings in either of the above are negative characteristics that have the potential to break our interest and attention in the mediated environment.

Like film, the articulation of time and space in interactive mediated environments is artificial, that is, it is constructed (see: chapter five for discussions on time and space in film and VEs). This permits the creation of just about anything that we care to construct and is only constrained within the bounds of human imagination (i.e. within technological limitations). The only limiting condition that must apply is that the *flow of time and space is credible*. To elucidate this point, consider for example, the films: "The Wizard of Oz" (Fleming 1939) and "2001: A Space Odyssey" (Kubrick 1968). These are totally fictitious stories played out in completely unreal environments, though, they work for the spectator, that is, they make sense, because the flow of time and space is held together in such a way through cinematic and editing conventions to make them credible.

This leads to a similar and inter-related issue - *pace*. The pace of a game, story/scenario and the movement through a mediated environment must also be credible. That is, the unfolding of game/scenario played out through causal events that push/pull it along in situations (e.g. moment-by-moment, action-to-action, mission-to-mission, start-to-end) should occur at an optimum pace. The pace should not be so slow that it becomes boring, confusing or frustrating for users, and not so fast that users lose track of, or lose their way in the scenario, game or environment. Of course, all of this relates to issues of *interaction* within mediated environments. For it to work well there must be an optimum level of *predictability* of movement within the environment and with objects and their related behaviours. Furthermore, a user's level of *autonomy* in performing activities should not be too heavily constrained and, where appropriate, should be an optimum balance between interaction and narration.

Finally, mediated environments and the scenarios played out in them should provoke interest and curiosity so as not to lose or break user's attention. For mediated environments to do this they need to create "visual pleasures" and evoke appropriate moods and feelings. These are issues related to the geometric *space* of a mediated environment and objects within them. That is, the sets, scenes and settings are characterised through *aesthetic (i.e. artistic) and atmospheric (i.e. ambience) pleasures*, all combining to provide a *sense of space* and perhaps *place* for users. Two dominant features were identified in the voyeuristic experience:

| | |
|---|---|
| **interaction:** | *pace* of the unfolding game/story/scenario/environment<br>*predictability* and credibility of movement through the environment and with the behaviour of objects and environment.<br>level of *autonomy* – balance between narrative and interaction.<br>*plausibility* – make sense of the game/scenario/environment.<br>*unexpected* - the new and the wonderful |
| **place:** | *aesthetic* (i.e. stylish, creative), *atmospheric* (i.e. ambience) and *sense of space.* |

### 7.4.2 Visceral experience

This experience refers to the instinctive base sensations and thrills. These are gut reactions rather than emotions. For example, this is the helter-skelter or roller-coaster type effect, the sensation of movement (e.g. vection: visual illusion of self-motion), feelings of fear, disgust and nausea, as well as, sensual and sexual feelings (i.e. "the surge in the loins" Boorstin 1995 p. 114). Point-of-view (POV) is the gateway to the visceral (p. 115). Like vicarious experiences, POV puts us in the scene, for example in VR this occurs through a first person perspective (although, we can also experience visceral thrills through a third person perspective, e.g. driving a racing car in a computer game from behind the car). More complex emotions require the empathic process of the vicarious. The breakdown in the visceral is simply, if it's not a thrill then it isn't visceral and its main criticism is "it doesn't get me" (Boorstin 1995 p. 114). This is either because we have acquired an increase in threshold for the visceral effect to kick-in or simply the design of the visceral effect is inadequate. This will hereafter be referred to as thrilling experience. Although many kinds of experience fall in this category (i.e. both pleasurable and those associated with negative situations or experience), as described above, for the purposes of the studies (see: chapter eight) two dominant features were identified to capture this:

| | |
|---|---|
| **sensations of movement:** | driving, flying, walking, running, jumping, falling |
| **feelings of fear and disgust:** | frightening, nauseating, disgusting, shocking |

### 7.4.3 Vicarious experience: emotions, moods, traits and empathy

Vicarious is to imaginatively experience something through another person, being or object; for example, in the transfer of emotional information in movements, behaviour, gestures, dialogue and facial expressions. Within a mediated environment all interaction is performed vicariously through either a first or third person perspective. This puts us in the mediated environment (as well as the visceral point-of-view, see above). Without the vicarious experience we wouldn't be there. Simple vicarious experiences are for example, the transfer of spatial knowledge (see: chapter three) and object manipulation/interaction such as, opening and closing windows and doors and selecting buttons, etc. As technological and artistic innovations are developed, the vicarious experience will become more complex by the transmission of emotional information through *empathy*. Empathy is beginning to attract increased attention. For example, continuing discussions from chapter five (5.2.1), works in philosophy and psychology (e.g. see: Thompson 2001) have identified empathy as one of the fundamental aspects of consciousness itself (e.g. being and self awareness). Other examples illustrating the importance of empathy include Goleman's (1995) book on "Emotional Intelligence" that identifies empathy as one of the key characteristics in predicting success in life (also cited in: Picard 1997; Preece and Ghozati 2001).

Levenson and Ruef (1992) provide a good review of research in empathy. According to Levenson and Ruef (1992), empathy comes in three forms. "Cognitive empathy" is to know what someone is feeling, but does not automatically imply kindness (e.g. a torturer can know how you feel and intensify the pain). "Compassionate empathy" is responding kindly to someone, for example, comforting (i.e. consoling, reassuring, etc.). Thirdly, "emotional empathy" is to know what a person is feeling (i.e. similar to cognitive empathy) but also, to feel what that person is feeling. Emotional empathy is the meaning of empathy as used in this thesis. Empathy may be transferred through actions, stories and anecdotes or facial expressions usually from one person to another person. The more one person feels what another is feeling the higher the degree or accuracy of "emotional information being transmitted". The term "empathic accuracy" (e.g. Ickles 1993; 1997) was coined to describe this.

Preece and Ghozati (2001) argue that while empathy plays a significant role in human communication, there is however, "moderate research literature on empathy" and it appears even fewer research publications on computer-mediated communication. Notable exceptions include their own work in "on-line communities" (e.g. listservs, bulletin boards) using textual (e.g. words, use of capitalization and characters) communication (Preece 1999; Preece and Ghozati 2001), and Picard's (1997) influential work on "Affective Computing".

In a virtual environment empathy is transferred through either our own interactions or through those of other beings (e.g. agents and avatars) or objects. Within film (and theatre) the vicarious/empathic experience is induced through an actor's ability to convey "honest emotions" (Boorstin 1995 p. 71). Potential breaks in empathy are the emotionally untrue. Many methods have been developed to capture or measure empathy. For reviews see for example Levenson and Ruef (1992). However, this chapter identifies another potential kind of empathy that is unique to interactive mediated environments. That is, the transfer of emotions and personality traits from a user's virtual character (i.e. the character that the user controls or takes the part of - from a first or third person perspective) to the user themselves. The higher "the emotional information being transmitted" from the character to the user then the higher the "empathic accuracy" (Ickles 1993; 1997). This is described further in the next chapter. The next section investigates ways in which the experiences of the framework may be captured.

## 7.5 Previous-work: capturing experiences of the framework

As previously argued, user experience occurs during and after an encounter with interactive mediated environments. Consider first experiences that occur during an encounter. These are dynamic and transitory, that is, occur moment-by-moment and over the entirety of a user's encounter. The use of concurrent (i.e. as the mediated environment is experienced) and continuous (i.e. uninterrupted) assessment techniques would facilitate the capture of experience as it happens. Furthermore, this provides the potential to identify causal relationships (i.e. the cause of user's experience). However, the implementation of such a technique is problematic as described in the following review of potential techniques. An approach developed by George C. Gallup's (i.e. of Gallup opinion polls) company Audience Research Inc. (ARI) to assess film presentations for market research in the 1940's and 50's seems most appropriate here and will provide an entry point to these discussions (Bouzereau 1994). In this method, spectators activate a dial, slider or buttons to reflect their likes or dislikes during a film presentation. Results then provide the identification and assessment of a film's negative or positive components. More recently, a similar technique has been used to assess presence. Whereby, users make on-line judgments using a sliding potentiometer to reflect their level of presence (Freeman, Avons, Davidoff and Pearson 1997; IJsselsteijn, de Ridder, Hamberg, Bouwhuis and Freeman 1998; Freeman and Avons 2000). However, for interactive mediated environments it could be argued that the additional physical operations of the dial, buttons or slider on top of the operations for controlling the interactive device (e.g. mouse movements and mouse button presses) may overload the user. Another method to assess users' sense of presence was proposed by Slater and Steed (2000). In their scheme users verbalise the occurrence of a shift in focus of attention from the virtual to the real world to indicate breaks in presence. Although this provides a concurrent assessment of presence it is discrete in nature (i.e. verbalisation from the virtual to the real world) rather than continuous. As described previously, another verbalising technique is thinking-aloud which is both concurrent and continuous. However, giving a running commentary of experience will potentially distract users from the types of experience that a mediated environment is designed to induce. Continuing the analogy with film as given in chapter five, it is not difficult to foresee that the actual processes involved in thinking-aloud or giving a running commentary of experience induced in spectators/users will disrupt their ability to focus on the true intention of the mediated presentation: i.e. to feel and experience the emotions that the director or designer/developer wants us to experience. The main drawback in common with all the above mentioned methods is the user's requirement to divide their attention between the mediated experience and the operation of the dial, buttons or slider, or keep in mind the verbalization, or the verbalising of experience itself respectively. Hence, the data collection methods (i.e. dial, buttons, slider, verbalization) may disrupt the actual thing that we are trying to measure (i.e. presence or experience).

Alternative schemes that are concurrent, continuous, and furthermore, do not require the user to perform any additional operations are for example, facial analysis and physiological measures. Recently, Höök, Persson and Sjölinder (2000) used a facial analysis technique, counting users' positive and negative responses (i.e. smiles and frowns) to provide assessment of user experience of animated characters. However, as Levenson and Ruef (1992) suggest, there is no one-to-one correspondence between facial expression and feelings and so, what is felt internally (i.e. in the mind) may not necessarily be exteriorised through facial expressions, hence, not an accurate measure of experience. Indeed, Höök, Persson and Sjölinder (2000) suggest problematic results obtained with this method because people have different body language, the use of a video camera may make some people smile more and some less, and smiling may mean different things (e.g. showing a liking to, laughing at or because something is silly). More accurate data collection techniques may be provided by objective physiological measures such as, alpha brain waves (using an electroencephalograph: EEG), skin resistance or temperature and heart rate. Correlations between physiological data and events within a mediated environment provide a means of assessing presence through for example, users' levels of fear (e.g. Dillon, Keogh, Freeman and Davidoff 2001; Meehan, Insko, Whitton and Brooks 2001). However, with all of the above examples it is difficult to imagine how the many components and variables of experience can be measured using only a binary scale (e.g. on/off), with inaccurate and not always predictable facial expressions or along just one dimension (e.g. low to high). It is argued that the measurement of experience needs to be assessed along many scales to reflect the various kinds of experience that a mediated environment is capable of inducing in users, or at least, for the assessment of experiences that are the requirement or purpose of the mediated application. Hence, it is difficult to foresee how these techniques may be extended to capture accurately the many different kinds of experience without overloading or encumbering the user.

Looking to today's film review process, we find that as production costs have increased in line with the many technological advances, the review process has on the contrary shifted from its earlier technologically driven methods and devices towards the simplest forms: pen, paper and questionnaires, and focus groups. These are retrospectively collected methods and as outlined in previous discussions (see: chapter two) are reliant on users' memory and hence, may produce problems of forgetting, and even worse, inventing things (Russo, Johnson and Stephens 1989). Their obvious limitation is the loss of data to reflect the dynamic and transitory nature of experience over the duration of a presentation or interactive encounter. However, the main advantages are firstly, spectators and users' ability to experience a presentation (i.e. mediated environment) in its entirety without having to divide attention, secondly, the measurement of experience can be obtained on several dimensions, and thirdly, these dimensions can be directed towards experiences occurring during an encounter and those that spectators and users take away with them (i.e. the big picture). Focus groups have recently found favour in studies that seek subjects' opinions and preferences. Possibly the main limitation that can be levelled against methods of this kind comes from group dynamics within focus group sessions. For example, the louder, boisterous, more articulate members of a group may lead the discussion and get their say, or at worse, potentially influence other group members. While quieter, inarticulate members of a group (whose opinions and experience may perhaps be more enlightening) remain unheard. In contrast, questionnaires can extract individual subjective opinions, attitudes, preferences and experience, as well as, providing summary data of groups. Interest in questionnaire development to measure presence has received much attention. For summaries see: Lessiter, Freeman, Keogh and Davidoff (2001) and Lombard and Ditton (2000). Of interest to this chapter is not so much the measurement of a sense of presence but to capture experience induced in users of interactive mediated environments. However, as argued, this may provide an indirect way to assess presence. Therefore, as a starting point to capture the broad experiences of the framework, the next chapter develops a questionnaire and describes two studies that were carried out to test it.

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# Chapter Eight Studies: experience, experiential and equipmental breakdown

This chapter describes the development of a questionnaire to capture the framework of experience. Two studies are described to test the effectiveness of using the questionnaire and the hierarchical activity-based scenario approach incorporating functional organs to reason about human practise and experience, in particular through artefacts in use, assessments of experience, equipmental, continuity and experiential breakdown.

## 8.1 Development of a questionnaire to capture user experience

The development of a questionnaire follows investigations of the voyeuristic, visceral and vicarious (see: chapters five and seven) as applied to mediated environments (i.e. interactive and non-interactive), in particular, to film, computer games and virtual reality/environments. Initially, this involved investigations of film reviews and rating techniques, and a short pilot study with filmgoers of three different genres (i.e. comedy, drama, action/adventure) at two cinemas (i.e. art house and mainstream) using an original version of the questionnaire appropriate to mediated environments (i.e. non-interactive). Simple arithmetic and statistical methods were carried out (e.g. percentage of users reporting a particular experience). As the central purpose of the pilot study was to identify any unforeseen difficulties with language, flow and layout, results are not reported. Following amendments to the mediated environment experience questionnaire, work began on incorporating an interactive component. This involved investigation of computer games magazines and reviews, interviews with a games design manager and players in arcades and University campus to identify the language, descriptions and rating procedures. In addition, an investigation of empirical studies, questionnaires and related published work on presence and experiential design and evaluation from the HCI literature (see: chapters two and seven) applied to both interactive and non-interactive mediated environments was conducted.

### 8.1.1 Questionnaire design

The questionnaire was arranged from the general to the specific (refer to Appendix IV for copy of questionnaire and to Appendix V for a child-friendly version). That is, from personal details and general questions about computer and games usage, genre and preferences, to questions relating to experience within the broad categories or scales of the framework. In addition, an attempt was made to capture breaks to experience. It is anticipated that the identification of reduced experience (i.e. where we would expect to see experience) may have the potential to shift user attention from the mediated to the real world. In order to do this, wherever possible, the questionnaire used a variation on a semantic differential question design (Osgood, Suci and Tannenbaum 1957). Semantic differentials use adjectives, phrases or statements with opposite meanings placed at either end of a scale (e.g. confident or unconfident). Generally, numerical scales (e.g. five or seven points) are used to measure the intensity of an attitude or opinion. To assist younger users in their responses, numerical scales were replaced with bipolar-like comparative terms (e.g. a little/low, quite/medium, very/high). Semantic differentials were used for two reasons. Firstly, they naturally incorporate both positive and negative components to represent experience and its opposite respectively. Users' responses within the two components then provide data to reason about user experience against anticipated or expected experience induced from interacting within the scenario of the mediated environment. Secondly, they conserve design layout and so assist in reaching an optimal questionnaire length of two pages. Likert scales were used to capture some voyeuristic questions where semantic differentials were inappropriate. Finally, as it is inconceivable to evoke negative visceral experiences (e.g. movement and sensations), these were measured on a positive scale. The application of the three experience scales: the voyeuristic, visceral and vicarious to the questionnaire are described below.

#### 8.1.1.1 Voyeuristic experience

In an attempt to capture the dominant features of this experience as outlined in chapter seven, questions used either a semantic differential bipolar-like seven-point scale or seven-point Likert scale to rate the strength of agreement with a statement and both incorporated a central neutral option. The format is dependent on their simplicity and clarity for users' understanding when formulated into questions. Two dominant features of the voyeuristic were identified in the voyeuristic experience:

| | *Refer to question number in Appendix IV* | |
|---|---|---|
| **interaction:** | *pace* of the unfolding game/story/scenario/environment | *(8)* |
| | *predictability* and credibility of movement through the environment and with the behaviour of objects and environment | *(9)* |
| | level of *autonomy* – balance between narrative and interaction | *(10)* |
| | *plausibility* – make sense of the game / scenario / environment | *(11)* |
| | *unexpected* - the new and the wonderful | *(14f)* |
| **place:** | *aesthetic* (i.e. stylish, creative), *atmospheric* (i.e. ambience) and *sense of space.* | *(13)* |

### 8.1.1.2 Visceral experience

In an attempt to capture features of this experience as outlined in chapters seven, users were asked to rate the degree of sensation on a 3-point scale from low to intense or on an additional option for no sensation. Potential difficulties and perhaps cause for concern are when no (or perhaps low) visceral experience is reported when we would expect visceral experience to be induced in users. It is anticipated that this may indicate failings in design to provide a particular mediated sensation or feeling, or that a user's threshold has been reached from say, high exposure to the sensation. As outlined in chapter seven, although many kinds of experience fall in this category, for the purposes of the studies, two dominant features were identified to capture this:

| | *Refer to question number in Appendix IV* | |
|---|---|---|
| **sensations of movement:** | *driving, flying, walking, running, jumping, falling* | *(16)* |
| **feelings of fear and disgust:** | frightening, nauseating, disgusting, shocking | *(17)* |

### 8.1.1.3 Vicarious: emotions, moods, traits and empathy

Vicarious is to experience imaginatively through another person, being or object (see discussions and reviews in chapters 5.2.1 and 7.4.3). In an attempt to capture this experience, this thesis will focus on firstly, the transfer of emotions, moods and traits to users and secondly, users' empathy from interacting with their own character and other characters within the mediated environment, as discussed below.

**i. emotions/moods/traits**

In order to capture this, questions were placed on a seven-point semantic differential scale incorporating a mid-point neutral option and arranged in a matrix format. Due to restrictions in the size of the questionnaire (i.e. two pages), only eight questions were asked (see below). These eight questions were designed to illustrate the extent to which emotions, moods and personality traits could be induced in users. Further discussions on the limitations of this approach and potential sources to inform this work are discussed in chapter nine (see sections: 9.4.3 & 9.4.4). Although ratings were obtained by directly relating to a user's character and asking questions in the following format: "while controlling your character [*users character inserted*], did you feel [e.g. confident or unconfident, etc.]", it is anticipated that this approach could be used to elicit users' emotions, moods and traits without users' knowledge of controlling a character in a mediated environment - if indeed, there is a character to control.

*Refer to question number in Appendix IV*

*confident, relaxed, calm, happy, strong, courageous, assertive, cheerful* *(12)*

**ii. empathy matrix:**

In an attempt to capture empathy the development of the questionnaire builds on discussions from chapters five (5.2.1) and seven (7.4.3) and the literature review provided by Levenson and Ruef (1992). In particular, they describe methods developed for use during marriage guidance counselling sessions. The idea is an attempt to identify couples' relationship and communication difficulties. In it, one half of the couple (the listener) views a video recording of their spouse (the talker) and rates the spouse's (the talker) feelings and emotions. The spouse (the talker) then views the video recording and rates what they believe to be their own feelings, moods and emotions expressed during the recording. That is, their feelings at the time when the video was shot. The correlation between the couples' rating (i.e. between talker and listener) then provides an indication of the accuracy of "the emotional information being transmitted" between the talker and listener.

The higher the correlation, the higher the accuracy of "emotional information" "transmitted" from one person to another; the term they use to describe this is "empathic accuracy" (e.g. Ickles 1993; 1997). In further developments of this method

Levenson and Ruef (1992) describe a study to assess subjects' empathy while viewing a video (i.e. in real time) using bivariate analysis. The correlation between the videoed subjects' rating and the viewing subject then provides an indication of the empathic accuracy.

In interactive mediated environments however, it is not feasible to ask the virtual character of their own feelings to provide correlation data. One option could be to ask the designer of the virtual character to rate its characteristics in terms of emotions. However, this is open to bias and inaccuracies as the designer could see or read things into their artistic creations that others don't. To overcome these drawbacks, users were asked to rate their virtual characters' emotions/moods/traits. The correlation between this matrix (*refer to question number "15" in Appendix IV)* and the matrix describing their own emotions/moods/traits (i.e. in "i" above) provides a measure of empathy between a user and their character. That is, the higher the correlation between the two matrices, then the greater the empathic accuracy. A weak correlation between the two may point to a weak attachment or lack of engagement between user and user's character. The same approach was used in the second study to provide a measure of empathic accuracy between the user and other virtual characters within the mediated environment. This is the virtual actor's ability to convey "honest emotions".

The matrix data was obtained by initially posing the questions: "...in a moment I'm going to ask you for words to describe your character", then, for each semantic differential pairing: "...would you say that your character [*user's identified character inserted here]* was: "confident" or "unconfident" etc. After a response [e.g. "confident"], users were then asked to provide a rating: "would you say that your character was a little 'confident', quite 'confident' or very 'confident' ". To avoid ambiguity, the evaluator offered alternative corresponding ratings as "low", "medium" and "high". Questioning in this way continued until all eight emotions/moods/traits were identified and rated. Next, users were asked to rate their own feelings while controlling their character using the second matrix. As mentioned, the correlation between this matrix and the matrix describing their character's emotions/moods/traits provides a measure of empathy between the two.

#### 8.1.1.4 Involvement, enjoyment and disruptions

While the questionnaire attempts to capture user experience within the framework, it says nothing about users' levels of enjoyment, engagement, involvement, agency (e.g. Laurel 1993) and similar terms identified in published literature on experience and presence in mediated environments (i.e. interactive and non-interactive) that are commonly used to describe users' levels of absorption in a mediated environment. Therefore, to provide an indication of levels of absorption for comparison with user experience, items for *involvement and enjoyment* were added to the questionnaire (see below). The questions used a semantic differential scale as described above. Additionally, to make a comparison with that observed, open-ended questions relating to disruptions were added. The categorizations for disruptions are informed from a short study presented in chapter five to identify the causes of shifts in spectator's focus of attention from the illusion of film (i.e. mediated environment) to the real world. Subsequently, in chapter six these categories were used to classify usability problems captured in an empirical study. It is acknowledged that there is a potential crossover between some of these categories. For example, disruptions may be categorised as either external or subjective (e.g. uncomfortable surroundings). To overcome this, the predominately distinguishing characteristics were used; that is, things external to an interactive mediated environment as opposed to subjective thoughts (i.e. in the mind; e.g. thinking of past or future events) that could potentially break or disrupt interaction. The main purpose of this additional section of the questionnaire was to see if there was any association between items of involvement, enjoyment or disruptions, and that of the experience scales. These components and their corresponding items are:

*Refer to question number in Appendix IV*

| | | | |
|---|---|---|---|
| **involvement:** | | | |
| | *engaging, absorbing, interesting, stimulating and* thought-provoking | | *(14)* |
| **enjoyment:** | *enjoyable, exciting, satisfying, challenging and fun* | | *(14)* |
| **disruptions:** | **internal:** | *display, interactive, audio;* | *(18)* |
| | **external:** | *ambient noise, awareness of others, uncomfortable surroundings;* | *(18)* |
| | **subjective:** | *attention wandering e.g. thinking of time, past or future events, or things you should be doing like chores or homework.* | *(18)* |

## 8.2 Studies

Two studies were carried out with desktop-based VR systems (Marsh 2001). One with a networked "first-person perspective shooter" (point-and-shoot) game and the other with a prototype (i.e. one-off and largely in an experimental or design phase) role-playing and storytelling environment in which users speak to each other via microphones and earpieces. The purpose of the studies was to capture users' experience within the broad framework of the voyeuristic, visceral and vicarious. Furthermore, the hierarchical activity-based model (incorporating functional organs) provides an arena in which to assess and reason about interaction with and within mediated environments, from low-level operations through actions to the activity itself.

Both environments incorporated virtual characters so permitting the framework of experience to be tested on all scales. The studies were undertaken in users' natural context (i.e. computer-games club and school) in which the mediated environments are, or intend to be, used normally. Data collection was carried out with as little disruption as possible to users. That is, they were able to experience the mediated environment in its entirety without being prompted or interrupted for a response from the evaluator. During study sessions observations were made and notes taken. Following each study session the evaluator read-aloud and filled out each question of the questionnaire. The questionnaires from each study differed slightly: the wording of questions in the questionnaire for the first study was made suitable for teenagers and young adults (see: Appendix IV) while the questionnaire for the second study was more suitable for children (see: Appendix V). This allowed for further explanations where necessary and in an attempt to ensure that each user understood the questions in the same way. The studies attempted to answer the following research questions:

1. to what extent is experience within the broad categorisations of the developed framework evoked in users, and overall how effective is the questionnaire at capturing user experience in interactive mediated environments?
2. what assumptions can be drawn about the extent to which inaccurate or deficient experience potentially breaks or shifts users' focus of attention from the mediated to the real world?

3. do users' self-reported disruptions correspond with those observed by the evaluator during the study, the experience data from the questionnaire, or point to potential breaks or shifts in users' focus of attention from the mediated to the real world?
4. what conclusions can be drawn about the effectiveness of the matrices to capture user's:
    a. emotions, moods and traits
    b. empathy with their own character and secondly, with other characters in the mediated environment (second study only)
5. are there any correlations between components or items of the questionnaire?
6. did the hierarchical model of interaction and the extension of the notion of functional organs provide an appropriate and effective arena in which to reason about the design of interactive mediated environments and their potential to provide experience?

Data gathering commenced during (i.e. observation) and after (i.e. questionnaire) an encounter with the mediated environment in an attempt to provide answers to the questions above. That is, the qualitative ethnographic data from study sessions took two forms, from observation and from questionnaire results. Using the scenario-based activity approach developed in chapter six, the scenario of the game can be hierarchically decomposed into activity (i.e. objective), actions (i.e. goals) and operations (i.e. low-level control of interactive devices, etc.). This makes it possible to model and trace every process from low-level operations to holistic activity perspective.

### 8.2.1 Study one: computer game mediated environment

The first study was conducted at a computer games club and so providing available subjects under the same roof in their natural playing environment. It was arranged in confidence with the games club supervisor with players having no prior knowledge that a study was to be carried out. The test environment was a first-person perspective shooter game played on networked personal computers and considered as a "standard" by the study's subjects. It was selected from several different stand-alone (i.e. individual users) or networked games and genres on the particular night the study was carried out. The evaluator had no influence over the selection of the game.

#### 8.2.1.1 Method

The study evaluator entered the games club approximately half way through a gaming session and was introduced informally to the players. The purpose of the evaluator's visit was briefly described (by the games supervisor) as in connection with a "University project". Players were given the option to assist with the "project". Eight out of ten male computer games members with ages ranging from thirteen to twenty-two volunteered to take part during time-out from the game after being "shot" or "hit". During quiet moments in between questionnaire sessions with each subject, the evaluator used the HABS approach and guidance to categorize breakdowns in interaction and illusion (see: 6.6.1) discreetly observed the players and made brief notes.

#### 8.2.1.2 Results

All users could be categorized as expert games players with approximate playing times ranging from seven to twenty-eight hours per week (14.5 mean). Users variously categorized their top three preferred computer games genres as: action/adventure, simulation, role-playing, strategy, point and click, and first-person shooter. Of these, five users rated first-person shooter as their favourite genre. In addition to playing games at the club, four users played exclusively at home and four played both at home and in arcades. In support of game playing outside the home, most users suggested that home playing on its own is "isolated", "unhealthy" or "sad" (i.e. probably best described as a propensity to be socially inept) and so better to go to a games club with "like-minded" people.

When asked to identify their character in the game, most seemed initially perplexed. Though after slight prompting (e.g. "what character did you control?" and "who were you in the game?") all users immediately responded "I was a…": "terrorist", "counter-terrorist" or "British SAS [Special Air Service]". Attempting to elicit from players an overall objective that would best characterise the activity as a whole proved difficult. For example, when asked what was the objective of the game, users' responses were direct, if not somewhat unnerving, saying: "kill people", "shoot opponents" and "kill other team". While these are indeed users' processes in the game, it is questionable whether they form part of the activity (i.e. action/goals) or characterise the activity process as a whole (i.e. objective) (Leont'ev 1981 pp. 399-400).

Hence, the problem is identifying actions (i.e. goals) and deciding upon the most appropriate process to describe the objective outcome of the activity. Furthermore, an interesting question that arises is, what motives do users have that drives them to play the game and do they coincide with the objective outcome to form an "activity proper"? (Leont'ev 1981 pp. 399-400). What's more is the motive in the real world, the mediated world or perhaps a combination of the two and should these be considered in the assessment of user's activity and the assessment of interactive mediated environments? This is a very important issue and therefore, will be returned to later in the discussion and conclusion sections.

One way forward is to choose an objective that is appropriate at the required level of detail necessary for the assessment of the mediated environment. While each character in the game can be identified as having a set of goals that are to be fulfilled in order to achieve their own objective outcome determining their activity, this could also be identified as being a shared objective. This is similar to Leont'ev's (1981 pp. 210-214) highly cited example of hunting and gathering and a way in which to inform collective (i.e. more than one user) activities. That is, "terrorists" having a shared objective (e.g. offensive) and "counter-terrorists" having another objective (e.g. defensive). At a more general level that is appropriate for the required level of detail necessary for the assessment of users' experience and the mediated environment, the objective of all the characters could be characterised by that which was described succinctly in a debriefing session as to "protect colleagues and kill enemies" as illustrated in figure 8.1. In order to achieve this objective, many actions/goals were involved in moving around the mediated environment using "search and destroy tactics". Finally, the users' link and functional organs in order to achieve these goals within the mediated environment are the low-level transparent (i.e. in normal use) operations of mouse movements (i.e. character's movement) and keyboard presses (i.e. firing of weapons). The trigger for operation of functional organs is determined by the conditions (i.e. situations and circumstances) of the action.

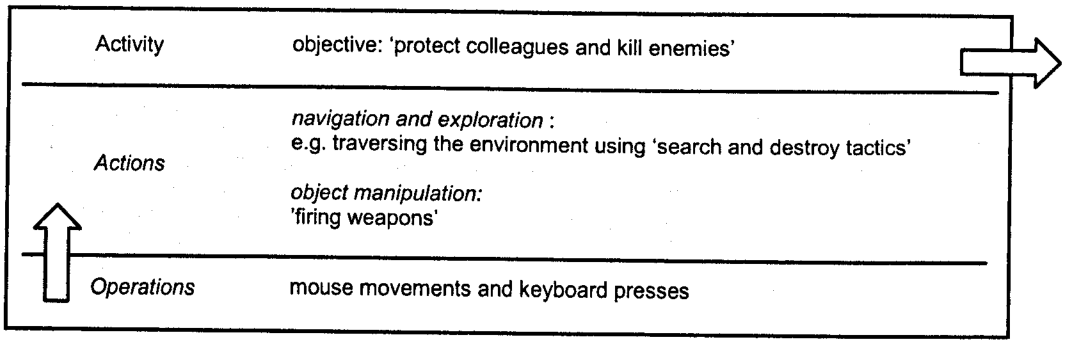


**Figure 8.1 Activity-based scenario of first-person perspective shooter game**

For all users the operation of standard keyboard and mouse appeared seamless throughout the gaming session. That is, considered within the concepts of the formation of functional organs, the interactive artefact in use appeared to remain transparent and as a consequence, seemed to be experienced as a property of the user acting directly within the mediated game environment. However, during the unfolding scenario users were observed to seamlessly break out of the game's activity, for example, to peer at others' screens (identified as "cheating" by the games players) and call to other colleagues, etc. in the real world (i.e. breaking the illusion) and then return back to actions of the activity within the game without any noticeable disruption to their flow. Finally, there was minimal variation in users' responses to items of *Involvement* and *Enjoyment* (e.g. engagement, fun and enjoyment, etc.) with almost all ratings being a maximum and so not helpful in the analysis of design.

#### 8.2.1.2.1 Voyeuristic experience

Users had no difficulty providing responses to any voyeuristic questions. Refer to section 8.1 for a description of the development of the voyeuristic questions to capture the voyeuristic experience as described in chapter 7.4.1. Cronbach's (1970) Alpha was 0.702 and a correlation matrix revealed two associations but these made no sense within the context of the scale. Refer to figures 8.2a to 8.2d for responses (i.e. experience and breaks) to the voyeuristic scale: *interaction and place*. In reference to figure 8.2a, users' ratings for *interaction* were *plausibility* (1.9) with the highest mean, followed by *autonomy* (1.75), *unexpected* (1.25), *pace* (1) and *predictability* (0.5). The mean value of total ratings for *interaction* was 1.32. Ratings for *place* were *space* (1.375), followed by *atmospheric* (1.25), *stylish* (0.75) and *creative* (-0.125). The mean value of total ratings for *place* was 0.813. In reference to figure 8.2b, five users considered the *pace* of the game to be acceptable, two users "mildly agreed" that it was "too fast" (four and eight) and user three said they were "unsure". Five users thought the objects and environments behaviour in response to interaction was *predictable*, two thought that sometimes it was *unpredictable* (three and four) and user two was "unsure". All except user four who was "unsure" said that they had *autonomy* to move around and do (i.e. with the features provided) what they wanted to in the mediated environment. All except user six thought that the unfolding scenario of the game made sense (i.e. *plausibility*). Six users thought the unfolding game was *unexpected* and two (users four and six) could tell in advance the outcome of the game. Four users considered the visuals of the game to be *stylish* and four "a little" *unstylish* (users: three, four, six and seven). Six thought the game was *atmospheric* (i.e. ambience) and for two users (six and seven) it was *un-atmospheric*. Three each thought the visuals of the game were *creative*, three *unimaginative* (users: three, four and six) and two were "unsure". All but one (user four) thought that the mediated environment provides a sense of space. In reference to figure 8.2c, the lowest mean of individual users' *interaction* ratings was user four (-0.8), the remaining users' mean values were all positive from 1 to 2.2. For *place* the lowest mean of individual users' ratings was users four and six (-0.75), followed by user three (-0.25) and the remaining users' mean values were all positive from 0.5 to 2.75. Figure 8.2d shows the total breaks for each subject. Four users gave negative ratings for *interaction* and of these, user four reported three, user six reported two, and users three and eight, one each. Four users gave negative ratings for *place* and of these, users six and four reported three each and users three and seven reported two. In total user four had six breaks, user six with five, user three with three, seven had two breaks and user eight with one.

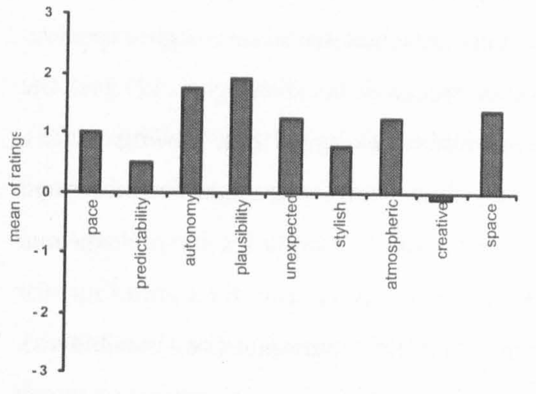


**Figure 8.2a Mean voyeuristic item ratings**

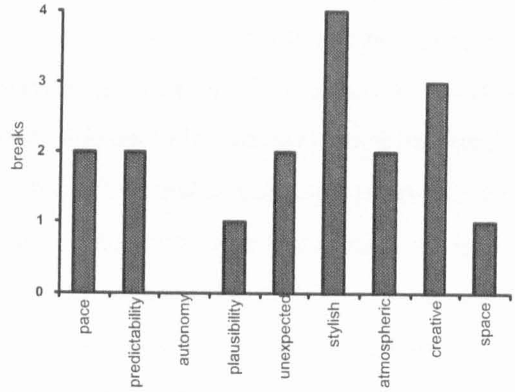


**Figure 8.2b Breaks per voyeuristic**

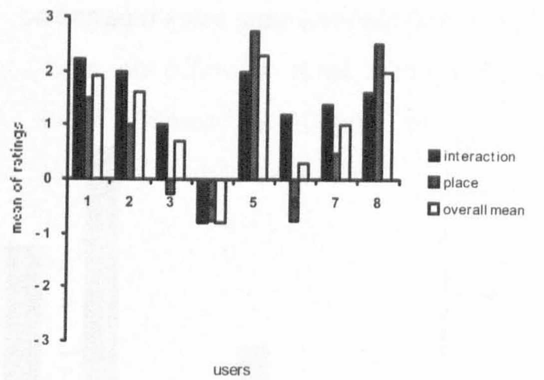


**Figure 8.2c Mean voyeuristic rating per user**

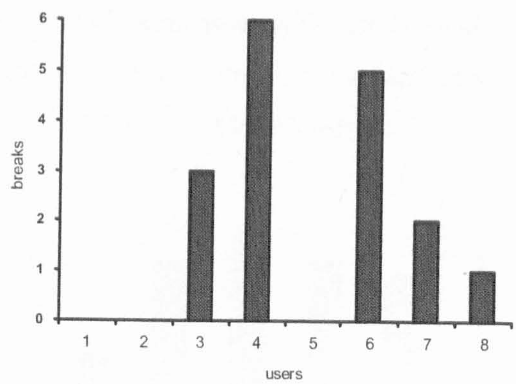


**Figure 8.2d Breaks per user - voyeuristic**

### 8.2.1.2.2 Visceral experience

Users had no difficulty providing responses to any of the visceral questions. It consisted of two components: *sensations of movement* (e.g. driving, flying, walking, running, jumping, falling) and *feelings of fear, disgust, nausea and shocking*. With only one user rating "driving" (i.e. no other users drove a vehicle) and none responding to "flying" (i.e. no aircraft involved), "disgust" or "shocking" these were dropped from the scale. Cronbach's Alpha was 0.693, dropping items "frightened" and "nauseated" from the scale gave 0.833. Thus, emphasizing the two constructs. A correlation matrix of all responses revealed two associations, one between "running" and "falling", and the other "running" and "jumping". This may indicate that this is tapping into the same thing. Potential cause for concern is where no or low visceral experience is reported when we would expect visceral experience to be induced. It is anticipated that this will point to either inadequacies in design to provide sensation and feeling, or that a user's threshold has been reached from say, high exposure. Refer to figures 8.3a to 8.3d. In reference to figure 8.3a, *running* (2.12) had the highest mean value, followed by *jumping* and *walking* (1.87), *falling* (1.75), *frightened* (0.87) and *nauseated* (0.25). Figure 8.3b shows responses for *movement* were all rated non-zero except one (running: user four). Responses for *feelings and sensations* were more variable with three zero ratings (users: one, three and four) for *frightening* and only two users rated feeling "a little" nauseous (i.e. breakdown). Figure 8.3c shows that the lowest mean value for individual users' ratings was user four (0.5), the remaining users' mean values ranged from 1 to 2. Finally, in reference to figure 8.3d, the highest number of reported zero ratings were from users four and three (two), followed by users five and one (one) and the remaining users reported no zero ratings.

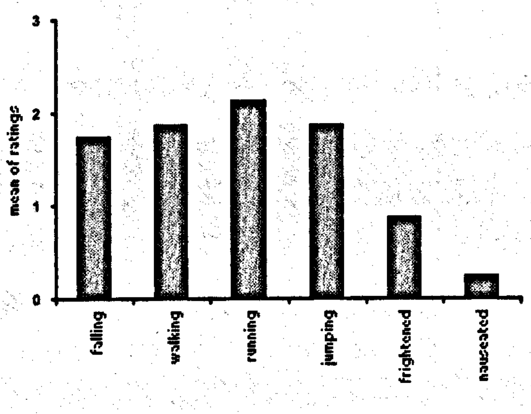


**Figure 8.3a Mean visceral item ratings**

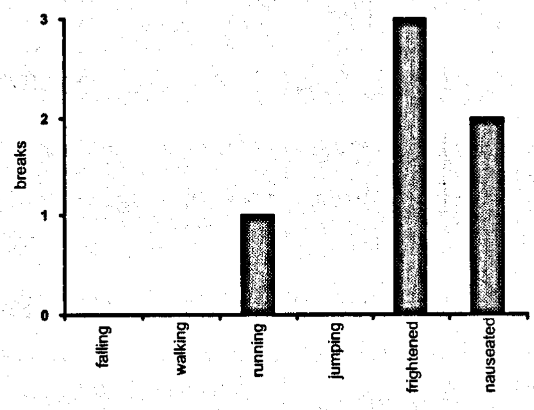


**Figure 8.3b Breaks per visceral item**

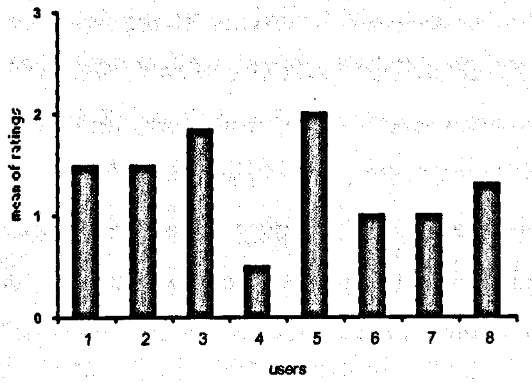


**Figure 8.3c Mean visceral rating per user**

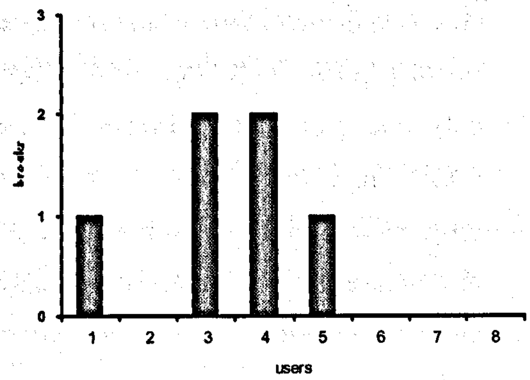


**Figure 8.3d Breaks per user - visceral**

### 8.2.1.2.3 Vicarious: empathy, emotions, moods and traits

Users responses for emotions, moods and traits while controlling their character during the game differed from one another. The greatest variation of users' ratings ranged from "very jovial or cheerful" to "very serious". Users had no difficulty in providing ratings except for the anchors for "happy" – "sad" in which four users were unsure or didn't feel that either was appropriate. The same problem was encountered when rating their characters: see below. All users responses differed from one another and there was no apparent difference between user's ratings for offensive/attacking characters and users' defensive characters. Consider the following as an example of this and of the responses. User five whose role was attacking rated themselves as: "quite confident", "very tense", "mildly angry", "unsure" if "happy" or "sad", "quite strong", "quite courageous", "very assertive" and "very serious". In contrast, user eight on offensive rated themselves: "quite confident", "quite relaxed", "mildly calm", "unsure" if "happy" or "sad", "quite strong", "quite courageous", "very assertive" and "quite serious".

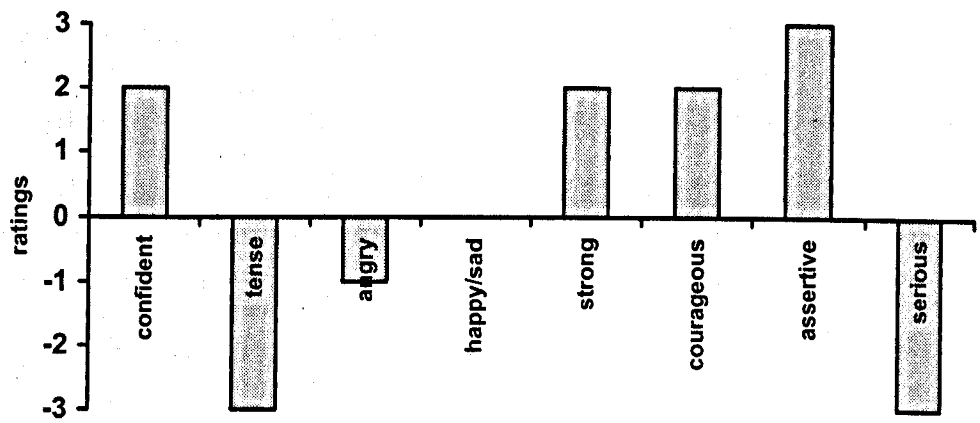


**Figure 8.4 User five - offensive: emotions and traits ratings**

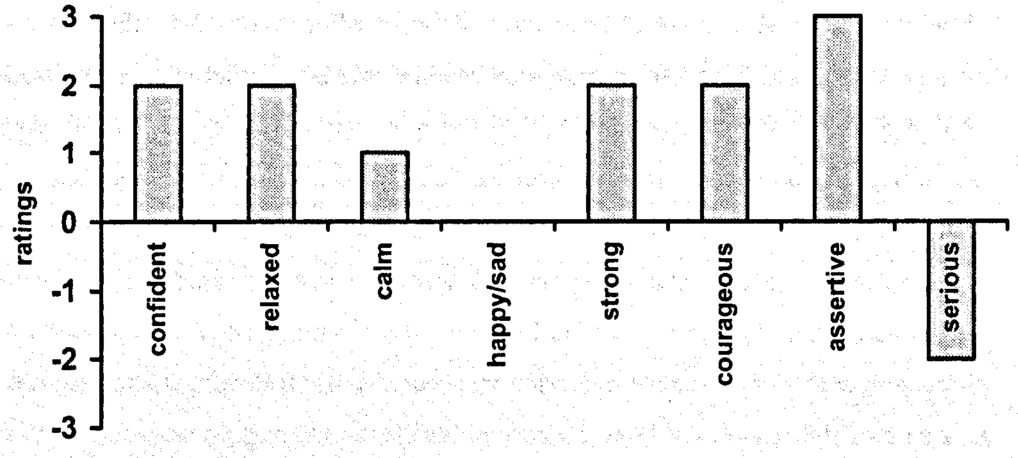


**Figure 8.5 User eight - defensive: emotions and traits ratings**

#### 8.2.1.2.3.1 Empathic accuracy

This was an attempt to match user emotion and traits with their characters and hence, provide a measure of the extent to which users adopted a character's persona within a social and cultural framework. User's ratings for their characters' emotions and traits differed from one to another. Users had no difficulty in providing ratings except for the anchors for "happy" – "sad" in which all users were unsure or didn't feel that either was appropriate. As shown in table 8.1, correlations of ratings between users' (while controlling their character) and character's emotions and traits show strong association for users five ($r = 0.934$), six ($r = 0.815$) and seven ($r = 0.856$). Users five and seven significant at $p < 0.01$ and six at $p < 0.05$ (Zhar 1967). While the high correlation for users five and seven seem to reflect the data well, other correlations do not seem representative of data. So while correlations provide a single value to reflect association between pairs of users' ratings it tells us nothing about the direction, frequency of matches and variation between each of the users' paired ratings. For example, while data show user eight ($r = 0.477$) to have what could be described as medium association ranked fifth highest, the exact matches being second tied highest (4) and corresponding positive or negative pairs of ratings in the same direction are second highest (4) in the data set. Similarly, user three has a medium association ($r = 0.510$) ranked fourth highest in the data set with no matched pairs and three negative pairs of ratings in the same direction. Contrasting this with user one with no correlation shown in the data set ($r = -0.032$), although having five negative or positive ratings in the same direction. This suggests inconsistencies of using correlations in an attempt to reflect empathic accuracy from the data set. That is, where the opposing poles of questions are used to indicate opposite states of emotions, moods and traits. Consequently, it is argued that correlations used in isolation do not provide as detailed an interpretation of the data that is necessary to reflect users' empathic accuracy. Therefore, to provide a more accurate interpretation of the data it is argued that each pair of ratings is required to be analysed separately. However, this also presents some difficulties. Similar difficulties are found taking the mean of users' responses from paired ratings with opposing directions. For example, taking user two's identification of their character as "serious" and themselves as "jovial or cheerful" would give a mean value that corresponds to "jovial or cheerful" and visa versa for user four. The analysis of data in this manner is clearly unsatisfactory.

Furthermore, taking exact matched pairs on their own as a measure of users' empathic accuracy gives a misleading reflection of data as this tells us nothing about other pairs having the same direction that may point to similar emotions, moods and traits between character and user. Other difficulties arise with the use of the neutral option. The main purpose for its inclusion was not to force users to go in either direction (i.e. positive or negative) that may clearly be at odds with the actual experience encountered. Neutral options were used to indicate one of two situations: firstly, as "unsure" or "don't know" options and secondly, to show that during a mediated encounter a user or character experienced both positive and negative emotions and traits during the unfolding scenario.

For example, some users and characters were rated as being both happy and sad during the unfolding scenario. The difficulty here is to ensure that a user's response is interpreted correctly. Given that a "don't know" option is clearly identified by a user as just that (i.e. "unsure"), then it is perhaps reasonable to suggest that a particular rating tends towards the positive or negative. Likewise, the same approach can be taken with responses that suggest both the positive and negative. However, while some of the users were some of the time quite specific about the reasons for choosing the neutral option most were not and so neutral options were only counted as exact matched pairs. Therefore, for the reasons discussed above, the measure of empathic accuracy between user and character was derived from the addition of exact matches pairs to pairs having the same direction (positive or negative) as shown in the right hand column of table 8.1.

**Table 8.1 Empathic accuracy: correlation and matched pairs**

| users | spearman rho | exact matched pairs | positive/negative matched pairs | total |
|---|---|---|---|---|
| 1 | -0.032 | 0 | 5 | 5 |
| 2 | -0.077 | 3 | 1 | 4 |
| 3 | 0.510 | 0 | 3 | 3 |
| 4 | 0.301 | 4 | 1 | 5 |
| 5 | 0.934 | 4 | 3 | 7 |
| 6 | 0.815 | 2 | 2 | 4 |
| 7 | 0.856 | 5 | 2 | 7 |
| 8 | 0.477 | 4 | 4 | 8 |

**8.2.1.3 Discussion**

Players seemed not to take any notice of the evaluator seated in the corner of the room and judging by the excitement (i.e. shouting, laughing, screaming, etc.) generated by the game, seemed quite unperturbed by his presence. The questionnaire seems quite effective to capture both experience and breaks to voyeuristic and visceral scales. Breaks identify negative characteristics by pointing to potential limitations in design or user's dislike for the mediated environment and should be investigated further. For vicarious experience, a method was developed to capture user's and group's emotions and traits. Furthermore, a method is developed to provide user-character empathic match. Using the vicarious matrix it is more difficult attempting to detect breakdowns because either of the positive and negative bipolar adjectives may be used to describe user's emotions and traits. Although if a mediated environment does not provide experiences for which it was originally designed then it may have been unsuccessful. That is, if the mediated environment's main objective is to provide training within a typical combat scenario then we would expect experiences associated with that scenario to be induced in users. For example, feeling scared and tense should be induced in users as opposed to say feeling relaxed and happy. Leaving aside the case of users with a disposition that will never allow them to feel these, if users do not experience these or other feelings uncharacteristic of the scenario then either they have reached a high threshold through prior exposure or the mediated environment or scenario is inadequately designed. Problematic use of the questionnaire was identified with the neutral option. Future versions of a questionnaire should attempt to incorporate a scheme to detect variations or mood swings in emotions and traits between say happiness and sadness during the unfolding of a mediated experience. In study two the neutral option is omitted in an attempt to overcome this.

Interaction with this fast paced game appeared through observation to be seamless for all users. This was anticipated and is not all that surprising considering the game is considered a "standard", using a standard configuration (i.e. display, keyboard and mouse) and played by expert users. Interestingly, users were observed to break seamlessly out of the game's activity, for example, to peer at others' screens (e.g. to find-out their locations) and call to other colleagues in the real world (i.e. breaking the illusion) and then return back to activities within the game without any noticeable disruption to their flow. These are voluntary breakdowns and not a consequence of any technological disruption or what could best be described as "equipmental breakdowns" (Koschmann, Kuutti and Hickman 1998). Indeed, observation concurs with questionnaire responses in that hardly any breakdowns were self-reported. Finally, one user said that they had other things in mind while playing the game (i.e. "homework") but this did not seem to have an observed effect on their interaction. The lack of equipment breakdowns contrasts with the second study with a prototype (i.e. one-off and in an experimental phase) role-playing mediated environment using novel interaction (i.e. speech using microphones and headsets, as well as, mouse and keyboard) in which many equipmental breakdowns were observed and reported.

An interesting question to arise in attempting to identify the objective within the game and following discussions in chapter six is what motives do users in the real world have, outside that of the games' scenario that drives them to play the game in the first place? That is, the potential existence of a motive in the real world encapsulating and driving users' game playing activity. This additional motive arises from the nature of the context of interactive mediated environments played within the context of the real world (e.g. games club, home, laboratory, etc.). This additional motive may be for fun, enjoyment, entertainment, experience seeking or perhaps belonging to a peer-group with "like-minded people" such as that found in being a member of a computer games club. The question to ask now is what, if any, consequence this has for immediate discussions and whether this should be considered in the assessment of user's activity and assessment of interactive mediated environments? The simple answer is most likely to be that it depends on the type of mediated environment configuration, its purpose or of that of the user. In the first-person shooter game, the users' reported objective in the games' scenario was to "protect colleagues and kill enemies". This sounds quite disturbing taken on its own out of context of the game, though it could be argued that the outcome of the scenario's objective for users was for fun, enjoyment and entertainment-seeking and in this case coincides with a motive of pleasure-seeking or perhaps belonging to a peer-group. Put another way, the outcome of a user's process characterising the activity (i.e. performed in the unfolding mediated environment's scenario) as a whole (i.e. the objective) always coinciding with that which stimulates the user to this activity (i.e. motive for playing a game) (Leont'ev 1981 pp. 399-400). Conversely, if interacting in the games' scenario (e.g. "protect colleagues and kill enemies") is not fulfilling for users (i.e. boring, dull, not stimulating) or other members of the group are not "like-minded" then it does not coincide with the motive of pleasure-seeking (i.e. motive driving the games playing activity), it is argued this may potentially shift or break users' attention. That is, interacting in contexts (i.e. the scenario in a mediated environment) within a context (i.e. the real world) creates a unique condition and the non-concurrence between these (i.e. objective outcome does not coincide with the motive) may potentially have negative consequences for users' game playing activity. That is, potentially shift users' attention from the mediated to the real world.

### 8.2.2 Study two: role-playing and storytelling educational mediated environment

The second study was conducted with a desktop-based VR prototype role-playing environment in which users speak to each other via microphones and earpieces. Its intended purpose was as a children's educational storytelling and story creating environment. As mentioned, the purpose of this study is to assess experience evoked in users, experiential breakdowns and analysis of use of this prototype environment through concepts developed in this thesis. This is through the framework of experience captured using a questionnaire, hierarchical activity-based scenario model of interaction (HABS) and in the extension of the notion of functional organs to interactive mediated environments. Building on the commercially available Unreal gaming engine (Epic Megagames) comprising rich graphics, music and atmospheric sound effects, the environment incorporates seven characters (Girl, Boy, Witch, Granny, Old Man, Dog and Monster) into a role-playing genre designed to appeal to children. The rich interaction between characters, including speech meant that the empathic matrix could be tested against a user's character as well as other characters in the mediated environment.

#### 8.2.2.1 Method

Twenty-four nine to eleven year old school children (fourteen female, ten male) from several classes and grades volunteered to take part in the study. Children had no prior experience with the study's mediated environment. During the four days in which the study was carried out, the school's staff and children taking part were asked not to divulge any "secrets" of the environment so as not to spoil other children's adventures.

Within each role-playing session two children were placed back-to-back and facing their computer screens. From a first-person perspective, each assumed the role of one of two characters (i.e. Girl or Boy). The assignment of character was random by getting children to select objects (i.e. toy animals) that represent Girl and Boy. Correspondence between toy and character was intermittently swapped. Characters' movements within the environment were performed using arrow keys (i.e. forwards, backwards, right and left) and mouse (i.e. up/down point-of-view tilt). In addition, "item"/function keys (e.g. pick-up virtual objects, open a book, swimming, jumping, operate force-field, etc.) were selected through the keyboard. Furthermore, speech between characters was supported through microphone and earpieces. Full-sized headphones placed over the earpieces relayed background music and atmospheric, object and behavioural sound effects (i.e. Foley-type effects) and additionally, provided a degree of sound proof from the world external to it. As described in the next section, the objective of the scenario given to the children was to search for Granny by exploring the castle and picking-up clues en-route. To drive the game along instructions and clues were interwoven into a story by an actress playing the role of several characters (Woman/Witch, Old Man and Granny). A study assistant controlled the movements of these characters (except Granny with a voice only role) as well as those of Dog and Monster.

A wizard-of-oz type set-up was developed whereby the actress and study assistant were separated from the children by a partition screen. This arrangement attempted to conceal the artificiality of the mediated environment and give children the impression of autonomously responsive characters within an automatically responsive environment. Following each session the experience questionnaire was interview administered (i.e. read out to children) to provide an opportunity for further explanations where necessary. Slight modifications including the exclusion of some questions in the questionnaire as used in the first study were made to further ensure that each item had the same meaning to every child. For example, the most changes were to the voyeuristic scale. First, in order to make the *interaction* component easier for the children to understand, responses to questions were categorical to obtain breakdowns (i.e. negative characteristics) or no breakdowns. The second voyeuristic component *place* was seen to be potentially problematic because of the difficulty children may have comprehending items such as, atmospheric, creative and stylish. In an attempt to capture the *place* component users were asked if they found the castle "interesting", had a "sense of space" and "at any time did you feel that you were inside the castle" or "at all times you felt you were playing a game in a room". Although the latter question could be regarded as resorting back to standard presence type questions, without further investigation the two questions were seen to provide an alternative to tap into this component within the limited questionnaire space. Furthermore, additional items were added to the questionnaire in order that analysis through breakdown of the novel and highly interactive nature of this prototype using speech (i.e. microphone and earpiece/headphones), keyboard, arrow and mouse could be carried out. The neutral option was omitted from the matrix following the problems encountered in the first study.

At the beginning of each session, children were introduced to their colleagues' and their own characters. During five to ten minutes training or practice session (i.e. depending on the children's ability, skill and prior experience) they watched themselves move around as seen on their colleagues' display (i.e. from a third-person perspective) and through their own screens from a first-person perspective. However, during the study children were instructed to view only their own screens, that is, they were encouraged to take a first-person perspective. During study sessions the evaluator informed by HABS and guidelines to categorize breakdowns in interaction and illusion (see: 6.6.1), observed the participants, made brief notes and recorded any breakdowns.

#### 8.2.2.1.1 Role-playing story/scenario

*The setting is formally at the foot of a drawbridge leading up to a castle where the role-playing game is predominately set. The scenes were full of character in-keeping with that of an eerie castle. The game starts with the voice of an old woman (Granny) telling the children to "come and see me...just enter the castle and you'll be met and given instructions on how to find me." The children's first goal is to enter the castle. They do that by walking up the drawbridge and passing through the main gateway. The voice of Granny tells them to explore the castle by walking through a series of corridors to a courtyard. On entering the courtyard they encounter an old man with his dog who warns them about a Witch in the castle. He then gives them a phial of magic potion to use in case they meet the Witch. They then hear a voice coming from a book asking to be picked up, saying it can show them where Granny is. They pick the book up and it gives them directions to an underground chamber. They then climb into a boat. If they miss the boat or fall out they have to swim. Once they reach the other side they are told by the book to cross the bridge and enter the temple. Once inside the temple the woman whose voice is coming from the book transforms into the Witch. She tells them "You thought I was Granny, but you've helped me to escape from a spell that had been put on me trapping me inside the book. I tricked you into taking me to the temple where the spell was reversed." She tells them "You've helped me in my plans to take over the world." The children have the choice of using the magic potion given to them by the old man. If they apply the potion it will create a force field that will destroy the Witch.*

#### 8.2.2.2 Results

Analysis of the questionnaire responses revealed that users had varying levels of computer skills. All but one had home computers, mostly used for games playing. Nineteen users played computer games between one to five hours per week, four users played 6 to 10 hours and one didn't play computer games. Users variously identified their preferred computer games genres and these were categorized as: action/adventure, simulation, role-playing, point and click, and first-person shooter/point-and-shoot. While the test environment's intended future use was educational, because it incorporates many attractive features (e.g. rich graphics, sound, character interaction) the environment could also be regarded as a role-playing "game". Indeed, most children referred to it as such. In response to the question: "what was *your* character" in the game, all identified their character as being the boy or girl without any difficulty. As mentioned, the overall objective given to users at the beginning of the game that characterises the activity process as a whole (Leont'ev 1981 pp. 399-400) was to search for Granny. As illustrated in the hierarchical activity-based scenario in figure 8.6, in order to achieve this objective many actions/goals were involved in moving around and exploring the castle picking-up clues en-route that were relayed through characters: Woman, Old Man and Granny. Although users were given the impression of complete autonomy to move around the castle, the game was in-fact directed by a human operator (i.e. actress) responding to users' movements and steering them in one direction. Hence, the game in this respect was more akin to a linear rather than non-linear narrative structure. Therefore, the hierarchical model that was sketched out during and following study sessions reflects this with a tree and branch-like structure. In reference to figure 8.6, five higher level or primary actions were identified: enter castle, explore inside castle, explore courtyard, cross the river and apply force field. Each of these actions was in turn made up of sub-actions and so on. The fulfilment of sub-actions is necessary in order that primary actions are fulfilled. The fulfilment and objective outcome of primary actions is to locate Granny that in this particular scenario is the Witch incognito. Finally, the users' link and functional organs in order to perform actions within the mediated environment were operations of arrow keys (i.e. character's movement), mouse movement (i.e. up/down point-of-view tilt) keyboard presses (i.e. "item"/function selection: pick-up objects, open a book, swimming, jumping, operate force field, etc.) and microphone (i.e. speech). The trigger for operation of functional organs is determined by the conditions (i.e. situations and circumstances) of the action.

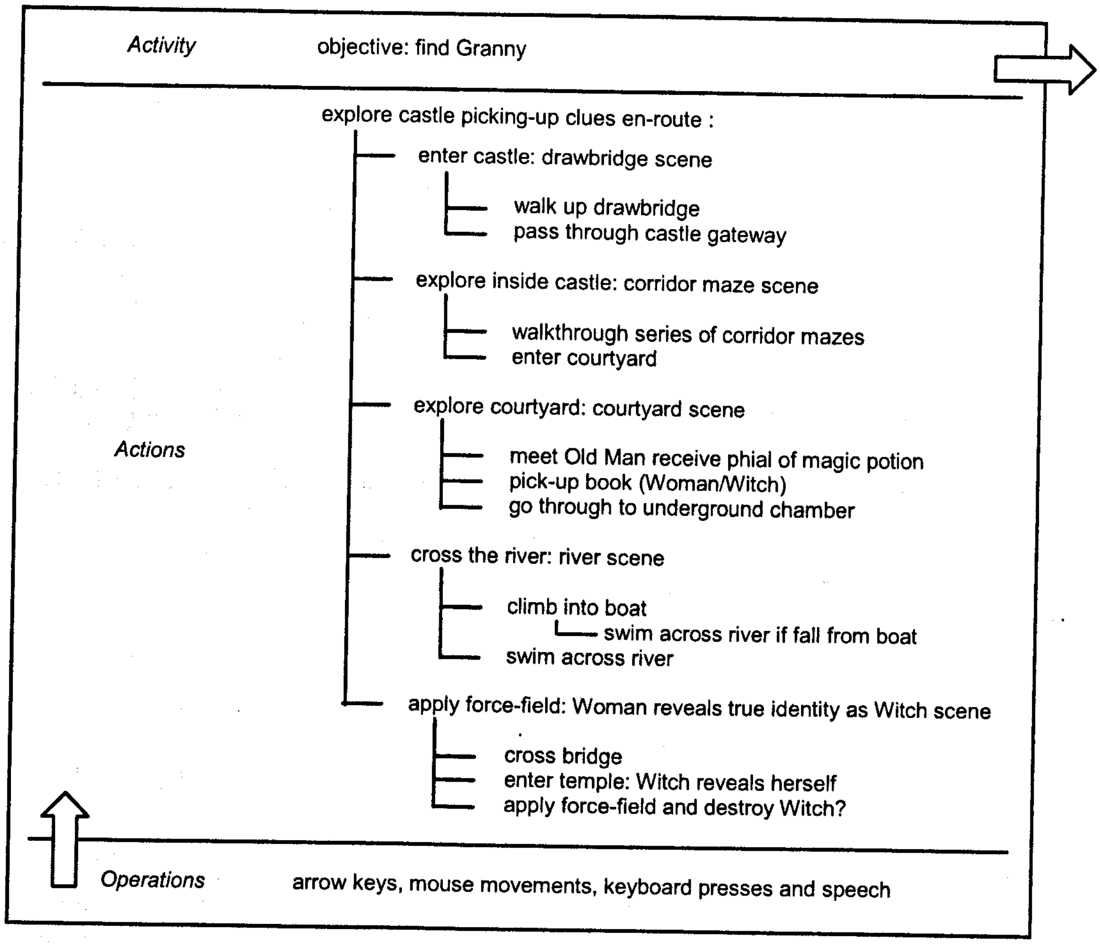


**Figure 8.6 Activity-based scenario of role-playing environment**

#### 8.2.2.2.1 Breakdowns

As illustrated in figure 8.7, 50% of users (twelve) reported problems associated with speaking. The cause was reported as being the unfamiliarity of speech interaction, the effort involved in communicating through microphones or a dislike of this form of interaction, for example, as one user put it "I don't like speaking out loud". 37% (nine) reported interference with the display (i.e. glitches in image). Interference from microphone use was invariably identified through observation and post study examination as being the cause. 33% (eight) of users reported interference to audio and 33% reported difficulty using the keyboard to select "items"/functions (e.g. pick-up objects, operate force-field, swimming, jumping, etc.). Three users (12.5%) reported difficulty using the arrow keys to move around the environment and no problematic use of the mouse was reported. In addition, many breakdowns were observed some concurring with those identified by users.

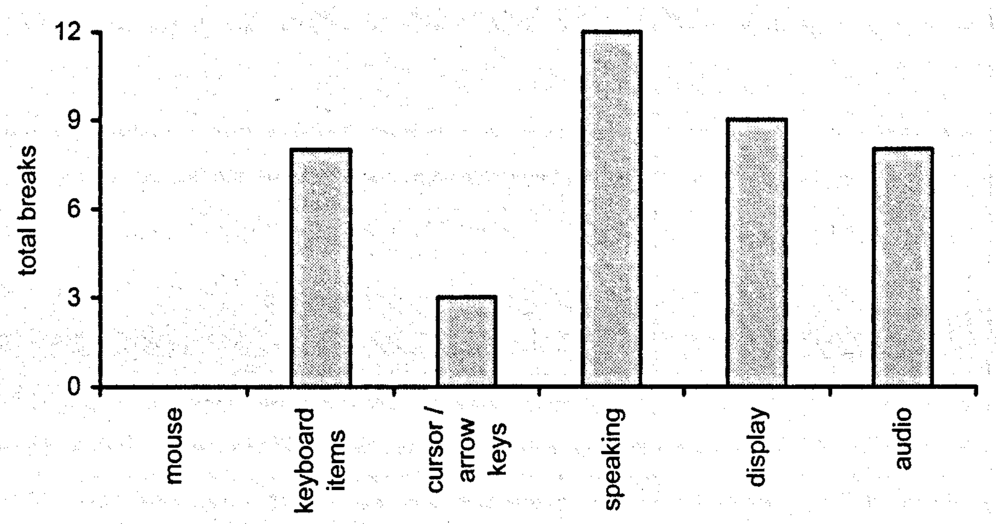


**Figure 8.7 Interactive breakdowns**

#### 8.2.2.2.2 Voyeuristic experience

Users had no difficulty providing responses to any voyeuristic questions. Refer to figures 8.8a and 8.8b for responses (i.e. experience and breaks) to the voyeuristic scale: *interaction and place*. In reference to figure 8.8a, users' categorical breakdown ratings for *interaction* were: *predictability* (i.e. of movement and object behaviour) with eleven (46%), *pace* (i.e. optimal rate of unfolding of story) and *autonomy* (i.e. with movements and functions) with two breakdowns (8%); *plausibility* (i.e. made sense), *unexpected* (i.e. couldn't guess what happened next) and feelings of *inside the castle* one each. All but one user rated no breaks to *place* and hardly any variation of responses for *space* (2.95 mean) and *inside the castle* (2.75 mean). As shown in figure 8.8b, in total, user four gave three negative ratings, users three, seventeen, eighteen and twenty reported two, and seven users reported one.

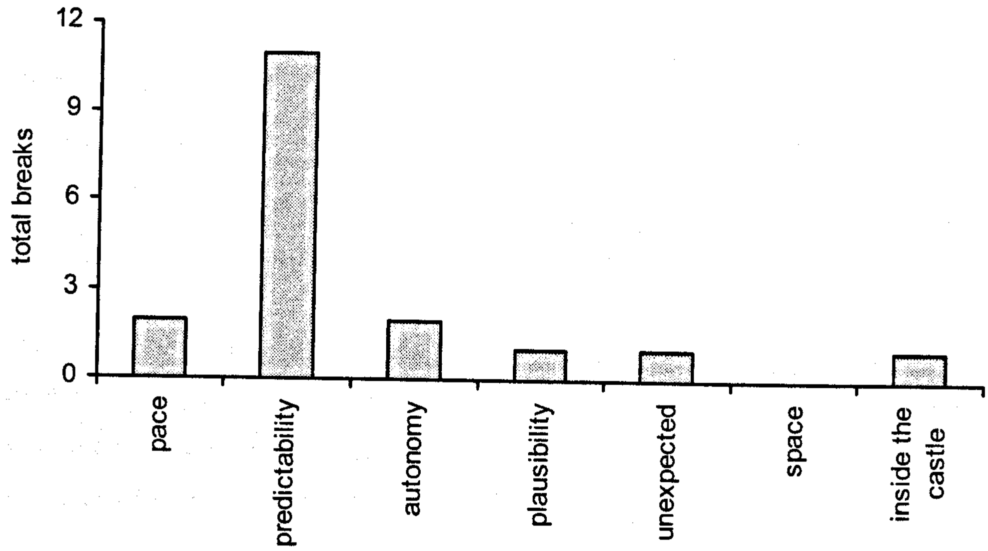


**Figure 8.8a Breaks per voyeuristic item**

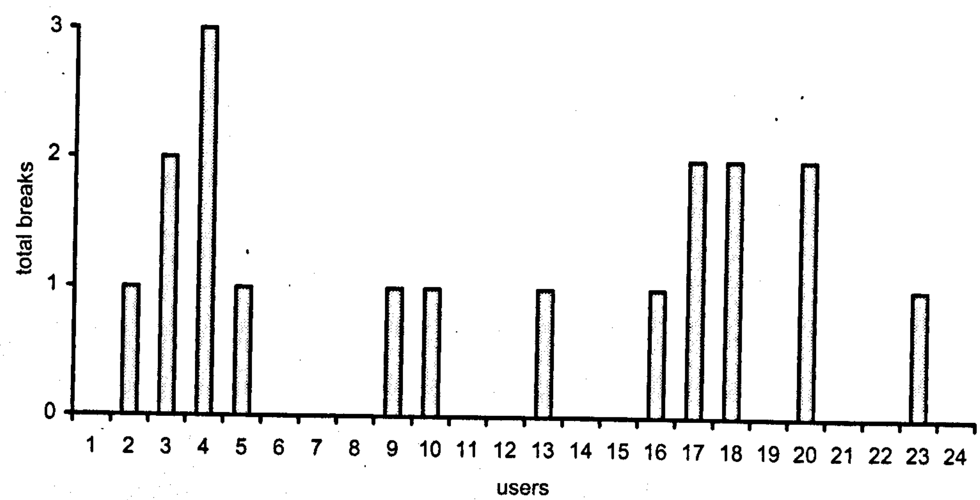


**Figure 8.8b Breaks in total per user - voyeuristic**

**8.2.2.2.3 Visceral experience**

Users had no difficulty providing responses to any of the visceral questions. As mentioned, it consisted of two components: *sensations of movement* (e.g. walking, running, falling, jumping) and *feelings of fear, shock and nausea.* Potential cause for concern is where no visceral experience is reported where we would expect visceral experience to be induced. It is anticipated that this will point to either inadequacies in design to provide sensation or feeling, or that a user's threshold has been reached from say, high exposure. The items walking and running produced almost identical responses implying they tap into the same thing and so were merged. In reference to figure 8.9a, *jumping* (2.3) had the highest mean value, followed by walking/*running* (2.12), *falling* (1.75), *shocked/surprised (1.5), frightening* (1.4) and *nauseated* (0.25). Figure 8.9b shows four breaks to *falling* (users: four, eight, twenty-two and twenty three) and one break to walking/running (user ten) for *movement.* Responses for *feelings/sensations* were more variable with five zero ratings (users: two, four, five, fourteen and fifteen) for *shocked/surprised,* four to *frightening* (users: two, three, four and five) and two users said they felt "a bit" "sick" or *nauseous* (i.e. breakdown). Finally, figure 8.3c shows that the highest number of reported zero ratings were from user four (three), followed by users two, five and nine (two), seven reported one zero and the remaining thirteen users reported no zero ratings.

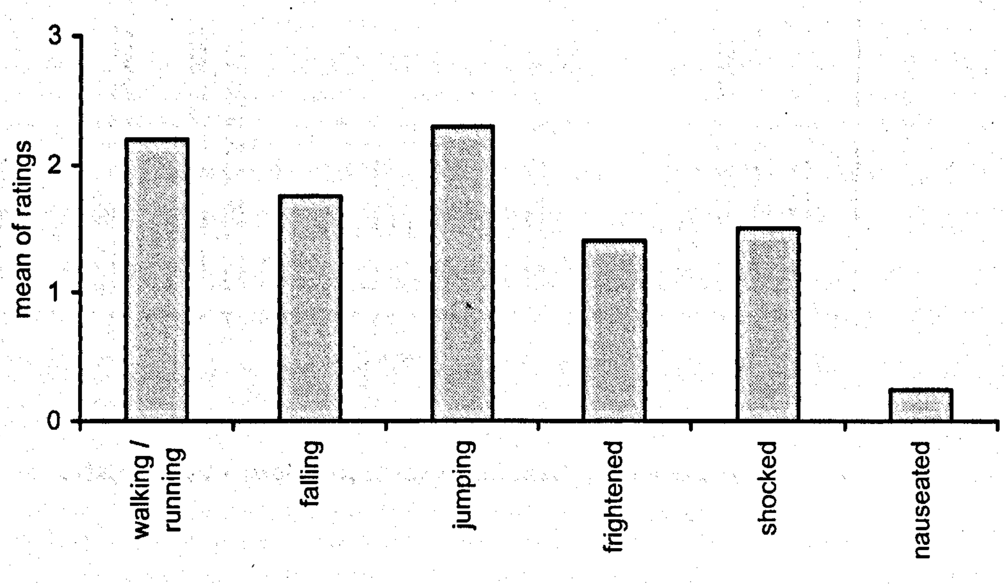


**Figure 8.9a Mean of users ratings - visceral**

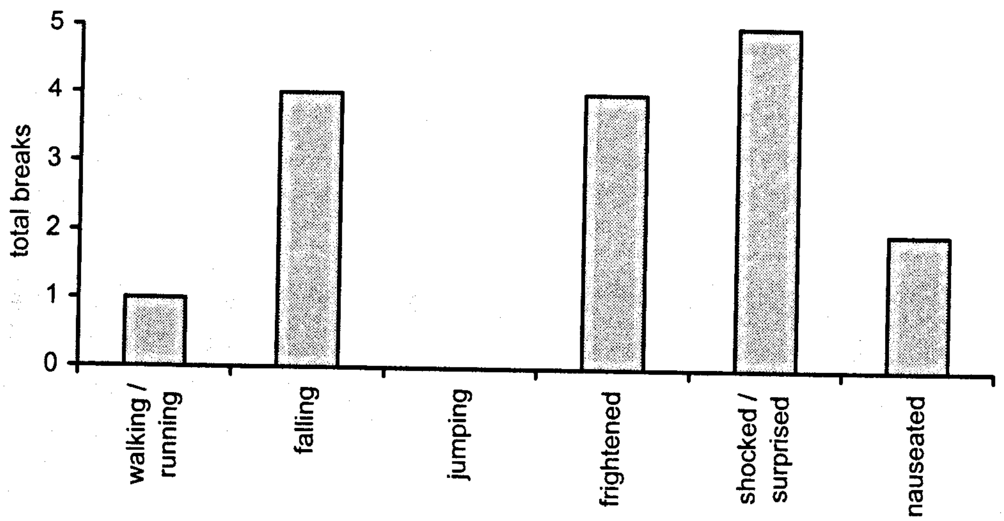


**Figure 8.9b Breaks per visceral item**

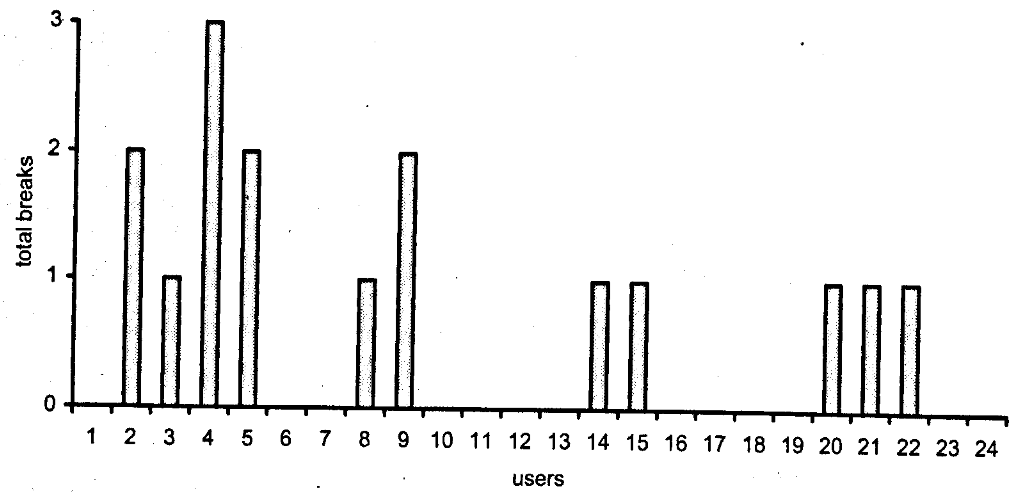


**Figure 8.9c Breaks per user - visceral**

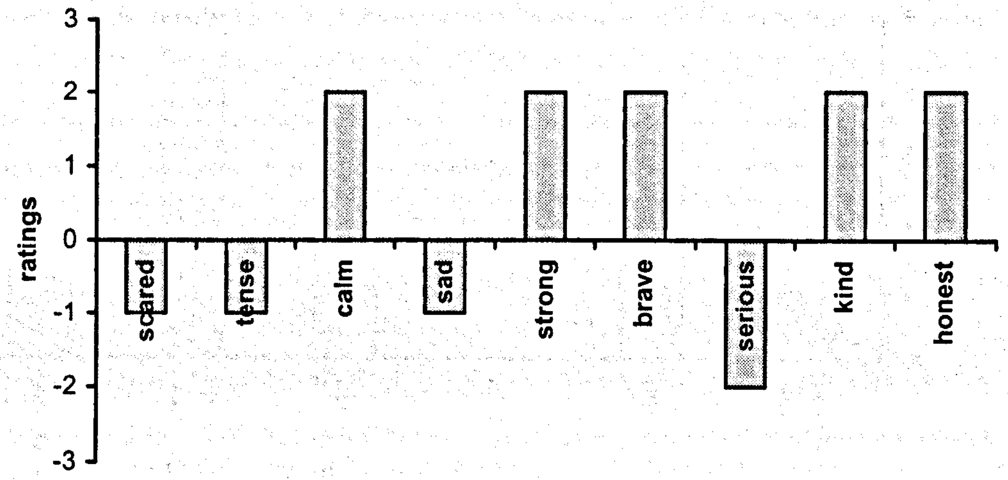


**Figure 8.10a User seven (Boy): emotions and traits ratings**

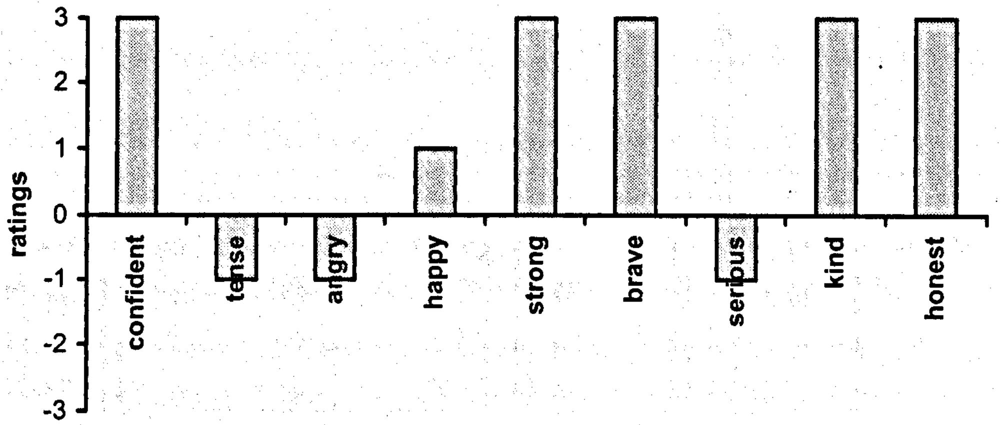


**Figure 8.10b User thirteen (Girl): emotions and traits ratings**

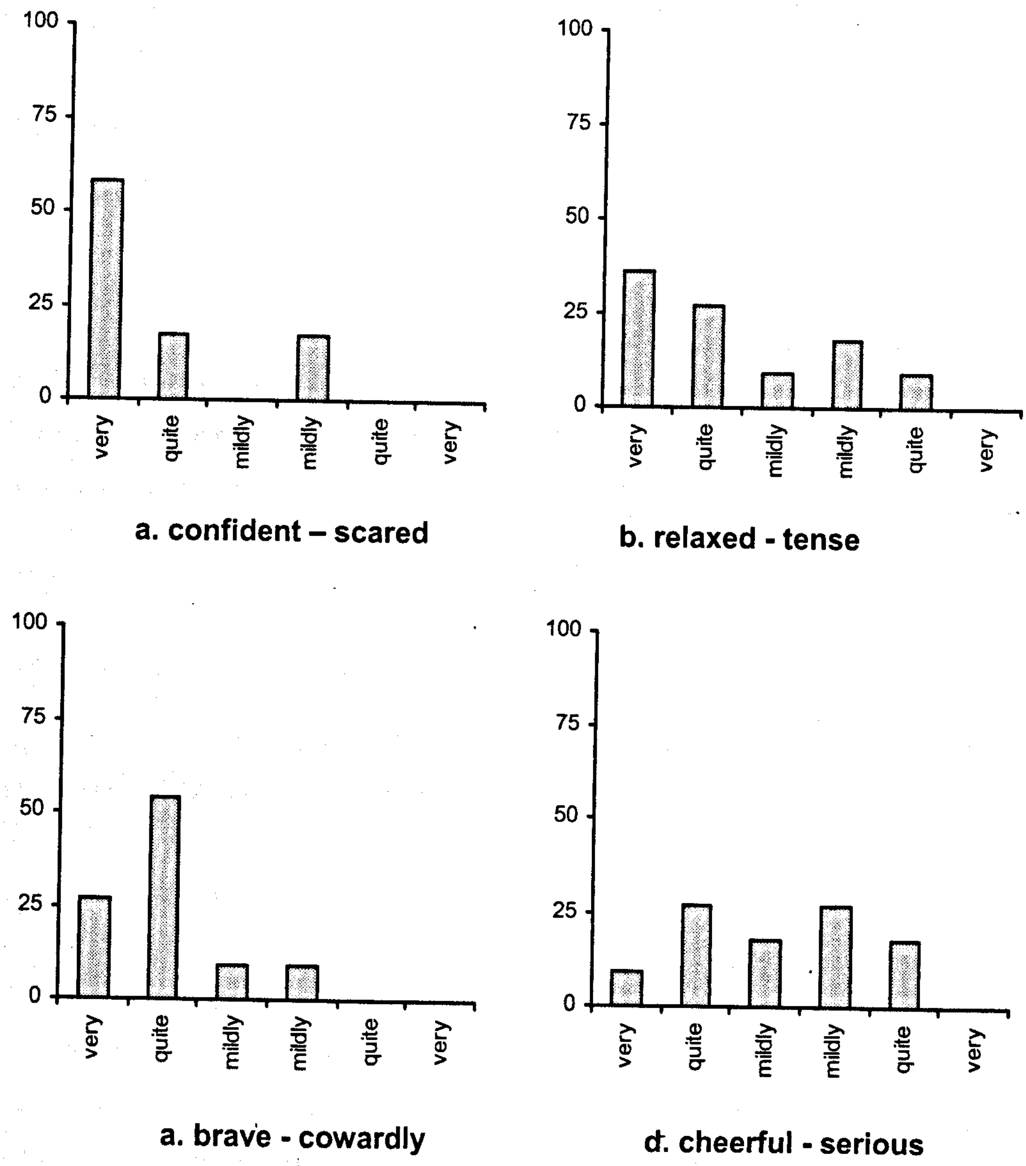


**Figure 8.11 Examples of % ratings for Boy character's emotions and traits**

**8.2.2.2.4 Vicarious: empathy, emotions, moods and traits**

Users had no difficulty in providing responses for their emotions, moods and traits while controlling their character (i.e. Boy and Girl) during the game. Users' responses differed from another and there was no apparent difference between ratings for users playing Boy characters and those playing Girl. Figures 8.10a and 8.10b illustrate typical responses for users (e.g. seven and thirteen). All users rated themselves as feeling *kind* and *honest*. 83% said they felt *brave* and the same for *strong*, and 70.8% said they were confident. Even though the neutral option was omitted from the matrix following the problems encountered in the first study, some users said they felt "a bit of both" during the encounter. For example, to the anchors *relaxed–tense*, *calm–angry*, *happy–sad*, *strong–weak*. Figures 8.11a to 8.11d show examples of total percentage of users' responses to bipolar adjectives.

#### 8.2.2.2.4.1 Empathic accuracy

This is an attempt to match user emotion and traits with their characters and hence, provide a measure of the extent to which users adopted a character's persona. The measure used is that argued for in the first study, that is, adding exact matched pairs to pairs having the same direction (i.e. negative or positive). Users had no difficulty in providing ratings. Table 8.1 shows empathic matches for users with Boy, Girl and Woman/Witch. Users "1" to "12" assumed the role of Boy and users "13" to "24" the role of Girl. So for example, reading from left to right, user "1" who took the role of Boy had empathic accuracy with their character for eight out of nine paired adjectives, likewise eight with Girl and five with Woman. Empathic match for both Boy and Girl for all users was very similar ranging between five and nine. In contrast, the empathic match with Woman/Witch for all users was comparatively smaller from one to six. Matches for Boy and Girl for users "1" to "12" (i.e. Boys) were significantly correlated (*rho* = 0.84) and not significant (*rho* = 0.17) for users "13" – "24". No other significant correlations were found. Finally, as reported in the first study, there was minimal variation in users' responses to items of *Involvement* and *Enjoyment* (e.g. engagement, fun and enjoyment, etc.) with almost all ratings being a maximum.

**Table 8.2 Empathic accuracy of role-playing characters: users 1-12 played Boy characters , users 13-24 played Girl characters**

| users | Boy | Girl | Woman/Witch |
|---|---|---|---|
| 1 | 8 | 8 | 5 |
| 2 | 7 | 7 | 4 |
| 3 | 9 | 9 | 6 |
| 4 | 8 | 9 | 2 |
| 5 | 9 | 8 | 6 |
| 6 | 7 | 7 | 5 |
| 7 | 6 | 6 | 5 |
| 8 | 8 | 9 | 2 |
| 9 | 6 | 4 | 1 |
| 10 | 6 | 5 | 3 |
| 11 | 5 | 5 | 2 |
| 12 | 9 | 8 | 4 |
| 13 | 7 | 7 | 5 |
| 14 | 9 | 9 | 5 |
| 15 | 7 | 9 | 6 |
| 16 | 8 | 7 | 2 |
| 17 | 7 | 6 | 3 |
| 18 | 9 | 8 | 2 |
| 19 | 7 | 6 | 4 |
| 20 | 9 | 7 | 3 |
| 21 | 5 | 7 | 4 |
| 22 | 6 | 7 | 6 |
| 23 | 7 | 7 | 6 |
| 24 | 9 | 6 | 1 |

**8.2.2.3 Discussion**

The game engendered excitement and emotions that were heard through utterances of most users. This was reflected in the items: exciting, fun, engaging, interesting and enjoyable in the questionnaire which all users rated to be almost a maximum. However, during study sessions many breakdowns were observed. Many of these concur with those identified by users in the questionnaire. As a consequence of breakdowns users' attention was frequently observed to shift from activities in the mediated environment to attend to disruptive causes in the real world. In many cases users appeared momentarily bewildered, not knowing what to do until a study assistant intervened or the user themselves sought assistance from study staff. Some breaks were identified as being opportunities for learning because users hadn't mastered the interactive artefacts in use. Many of these appeared to be caused by the excessive number of operations that users were required to perform or they were just too awkward to master. For example, some "item"/function selections via the keyboard were difficult to operate and persistently functioned incorrectly. Furthermore, other equipmental breakdowns were observed such as display interference invariably caused by microphone use and interference to audio, to more catastrophic breakdowns such as the computer crashing. Fifty percent of users reported problems associated with speaking using microphones. The cause was reported as being the unfamiliarity of speech interaction, the effort involved in communicating through microphones or a dislike of this form of interaction, for example, as one user put it "I don't like speaking out loud".

It can be reasoned that because of the observed and reported equipmental breakdowns, causing constant disruption to interactive artefacts in use, the potential for the user to experience acting directly within the mediated environment through the concept of formation of functional organs is compromised. Consequently, the potential for continuous experience induced/evoked in users is also compromised. The considerable number of observed and reported breakdowns may put in question the reliability of the experiential data collected in this study and may point to problematic use of the questionnaire. In an attempt to smooth-out or remove any potential for equipmental breakdowns that may cause disruption, the mediated system should undergo a thorough evaluation before administering the questionnaire. As mentioned, items such as: exciting, fun, engaging, interesting and enjoyable provide no indication of this.

To assess the success of an interactive mediated environment the questionnaire responses should be compared with its requirements and purpose and shortcomings in design should be investigated further. The questions devised for voyeuristic and visceral seemed quite effective in capturing both experience and experiential breakdowns. Breaks identify negative characteristics by pointing to potential limitations in design or user's dislike for the mediated environment and, as mentioned, should be investigated further. For vicarious experience, a method was developed to capture individual and group's emotions and traits. Furthermore, a method is developed to provide user-character empathic match with their own and other characters in the mediated environment's scenario. While there was little difference in empathic match between user and their colleagues' characters (i.e. Boy and Girl), as expected, this was higher than empathic match with the Witch. So while data demonstrates that the method can distinguish between protagonist and antagonist, it does not distinguish between user and colleague (i.e. protagonists). This may either be because of the close proximity of user and colleague throughout the game or suggests a limitation in the method (i.e. matrix correlation) to detect this. As mentioned in study one, using the vicarious matrix it is more difficult to detect breakdowns because either the positive or negative bipolar adjectives may be used to describe user's emotions and traits. However it can be argued that if a mediated environment does not provide the experiences for which it was originally designed then it may have been unsuccessful. For example, users reporting uncharacteristic emotions and traits such as rating the Witch as honest and kind as opposed to being dishonest and evil. In which case a mediated environment or scenario may point to inadequacies in design and should be investigated further. Due to problematic use of neutral options identified in the first study they were omitted. This arrangement goes some way to overcoming difficulties in detecting variations or mood swings in experience and emotions and traits between positive and negative adjectives during the unfolding of a mediated experience. That is, users saying things like "a bit of both" instead of giving throwaway answers like "don't know" without any explanation, as identified in study one.

Although the study did not deduce conclusively the reasons for study participants volunteering, it can be reasoned that some, if not mostly all of the participants were enthusiastic about taking part in the study. In some cases though, the most likely motives could be for example: skipping class, to gain popularity with school friends or to seek approval from teacher, etc. These motives initially drive users' game playing. So, irrespective of the games scenario, the objective outcome of playing the game is the passing of time, gossip to share with classmates or to please teacher, etc. and coincides with motive to form an "activity proper" (Leont'ev 1981 p. 399-400). Following pre-study training, the study session began by providing the objective within the game's scenario to search for Granny. However, even if the objective outcome within the role-playing game was fulfilled and users found Granny, the objective (in the virtual world) will not match the motive in the real world that drove the user to the mediated environment and so it is an action. Put another way, a user's process characterising actions in the mediated environment (i.e. to search for Granny) as a whole (i.e. the objective), does not coincide with that which stimulates the user to their activity (i.e. motive for playing a game) (Leont'ev 1981). That is, interacting in contexts (i.e. the scenario in a mediated environment) within a context (i.e. the real world) creates a unique condition and the non-concurrence between these (i.e. objective does not coincide with the motive) means that the role-playing game is not "activity proper" (Leont'ev 1981 pp. 399-400). Activity is the smallest meaningful unit of analysis in activity theory (Kuutti 1996). This implies that the motive in the real world that stimulates the user to play the game used in the study has to be considered in the analysis of interactive mediated environment use. However, according to Leont'ev (1981) a special case arises in activity theory when an action is so stimulating that it drives itself and transforms into an activity. This transformation takes place when "an action's result [outcome] being more significant…than the motive that actually induces it" (Leont'ev 1981 p. 403). Hence, it can be postulated that if role-playing and indeed any outcome of interactive mediated environment use is stimulating enough then, users do it because they want to and so transforms into "activity proper" and becomes the true smallest meaningful unit of analysis.

## 8.3 Conclusion

Two complementary approaches have been described to provide a way in which to reason about human practice and experience with and within interactive mediated environments. Firstly, by using the hierarchical activity-based scenario approach, complex narratives can be précised in a hierarchical structure and so provides a way to model and trace the progression of users' activities from low-level operations through goal-directed actions to a holistic activity perspective characterized by objectives coinciding with motives. Furthermore, using HABS and informed from the guidelines/criteria (for the categorization of disruptions) made it possible to reason about shifts in consciousness and a framework to capture breakdowns.

Secondly, to gauge users' attitudes a framework of experience was developed. The framework of experience (i.e. voyeuristic, visceral, vicarious) provides one possible approach in an attempt to capture experience. It provides a language that makes it possible to reason about the experience induced in users that comes from interacting in scenarios within interactive mediated environments. One advantage of this approach is that we don't have to deal with the complexity of scenarios whether they have an unlimited number of movements, actions, gestures or utterances. Instead this approach may be used to look at the experience it provides for users and this provides a way to inform and guide analysis and design of interactive mediated environments. On the other hand, if it is necessary to trace actions, gestures or utterances, etc., then the framework of experience can be used to complement the hierarchical activity-based model. In an attempt to capture the framework of experience, a questionnaire has been developed that allows users to articulate experience, evaluators to capture experience and inform redesign for experience. The simplicity, portability and unobtrusiveness of administering the questionnaire permit users to experience a mediated encounter in its entirety and in their natural environment.

The non-correlation of experiences and breaks between different scales may point to limitations in the questionnaire, its components or items. Similar non-correlations have been reported in studies attempting to measure experience using facial expressions, time spent with a mediated environment and questionnaire responses (Höök, Persson and Sjölinder 2000). Perhaps the results in this paper are as Höök et al. (2000) suggest that in attempting to capture the overall experience, the voyeuristic, visceral and vicarious in fact measure different aspects of experience. This would seem to concur with Boorstin's (1995) appraisal suggesting that we don't watch films in one way but in three ways. That is, when interacting in mediated environments users experience the voyeuristic, visceral and vicarious. He goes on to suggest that as we watch a film they compete in us. This may be so, but the results suggest no association between them. Chapter nine (9.4.4) suggests directions and challenges for future research to formulate a richer understanding of the constituents of the voyeuristic, visceral and vicarious to inform analysis and design of IMEs.

One of the main limitations of the questionnaire is the non-equivalence of items. For example, users' low ratings for something like creative, do not have as major an impact on the user as do feelings of nausea. This relates to another disadvantage of predetermined bipolar items. So while a variation on Osgood et al's (1957) semantic differential provided a means to gauge users' attitudes, its disadvantage is that it provides respondents with universal items that may not necessary or ideally reflect adequately a user's attitude. That is, according to George Kelly (1955), because we all have a different repertory of constructs, it may be more appropriate to let respondents choose their own. To this end, Kelly (1955) developed Personal Construct Psychology to overcome these limitations. This has already been applied in a study to capture children's experience of role-playing characters within a computer game. Constructs were elicited from the children by asking simple questions like "what words would you use to describe [insert character's name]" and then obtaining the opposite of the child's response. Using these as biploars, children were asked to rate each character against each elicited construct while at the same time showing pictures of each character. This may go some way to overcoming children's difficulty of not understanding or misunderstanding some of the items and constructs in the questionnaire. However, this is not reported in this thesis.

Another limitation of the questionnaire is its inability to measure or detect variations or mood swings in experience and emotions between positive and negative adjectives during the unfolding of a mediated experience. In an attempt to overcome users using the neutral option to give throw away answers by saying things like "don't know" without any explanation as identified in the first study, they were omitted. So that, users were forced to say things like "a bit of both" and hence, demonstrate the dynamic nature of emotions during the unfolding story/environment of a mediated encounter. Chapter nine (9.4.3) provides further discussions on the limitations of a questionnaire-based approach and suggests directions and challenges for future research.

The framework provided a way to reason about a mediated environment and user and virtual character behaviour through experience. In both studies observed behaviours that were in keeping with the context (i.e. scene, setting and scenario) of the game were said to have continuity and no, reduced or inappropriate experience, discontinuity. That is, people tend to restrict their behaviour to what is considered appropriate and acceptable depending on which group they are participating in. For example, in the medieval castle environment users followed behavioural patterns different from those in a first-person shooter game. This was one approach that it was argued consider social and cultural constraints depicted within the context of the mediated environment and captured well in Poortinga's (1992 p. 10) definition of culture. Thus, discontinuity potentially points to limitations in design or a user's dislike of a mediated environment, encounter or scenario.

Finally, while many observed and reported equipment breakdowns occurred in the role-playing study, users generally enjoyed their encounter as detected through many items of the questionnaire. However, if the study was only concerned with the analysis of experience by using data gathered through the three Vs questionnaire (without any questions relating to disruption caused by equipment or being informed from HABS or guidelines) or using another experience framework then, it can be reasoned that the results would present a positive appraisal of users' encounters. While there can be no disputing that users generally enjoyed their encounter, if no effort is made to identify, capture or reason about disruptions caused by difficult to use or malfunctioning equipment, etc. through the questionnaire or observation, then it could be argued that results would present only a partial analysis of a user's encounter and have a limited usefulness to inform redesign.

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# Chapter Nine Staying there through an invisible style

The motivation for this thesis has been to find ways to evaluate three-dimensional interactive mediated environments (e.g. virtual reality, virtual environments and computer games) for usability and user experience. Film is one of the underlying themes throughout this thesis, and by fusing concepts from human-computer interaction and film, this thesis has proposed an "invisible style" of computer-mediated activity through transparency of "equipment" and continuity of content. Irrespective of the underlying complexity of supporting or enabling technological configurations and genre of mediated content, an invisible style aims to be antidote to disruptive interaction and inform an approach for the analysis of interactive mediated environments by the way in which they allow users to continue interacting within a mediated environment and receive appropriate and/or stimulating experience (the meaning of these is discussed in sections 9.1 and 9.3) so encouraging them in *staying there*. Hence, staying there through an invisible style and appropriate and/or stimulating experience, are positive characteristics of IME design in use and conversely, disruption, distraction, inappropriate and un-stimulating experience are negative characteristics that can cause breakdown in interaction and breakdown in illusion.

While it is acknowledged that traditional usability evaluation methods can be both useful and effective for evaluating IMEs, through argument and in studies carried out herein, it has been shown that usability alone is not fully able to go beyond work-related tasks to an experiential perspective that is demanded from IMEs. While it could be argued that one approach is to evaluate IMEs using a collection of techniques (supplementing traditional usability evaluation with methods to address the experiential), this thesis worked *towards* the development of ways to reason about usability and mediated experience (e.g. learning and training, entertainment, psychotherapy-related, shopping, etc.) in a single framework. Furthermore, this thesis argued that one approach to consider experience requires that we consider user's intention and so prompting moves from task/goal-based to an activity/objective-based analysis. However, moves to an activity theory-based and experiential approach using tried and tested techniques such as the "think-aloud" verbal protocol technique were shown to be problematic. Therefore, to overcome these limitations concepts from activity theory were extended to encapsulate an invisible style to formulate the hierarchical activity-based scenario approach (HABS). Through the concept of staying there HABS links various concepts, models and tools in logical relation to each other, working *towards* a single framework to analyse IMEs.

HABS provides a hierarchical framework in which to model and trace dynamic linear and non-linear scenarios from low-level operations through goal-directed actions to a holistic activity perspective characterized by objective and motive (i.e. "activity proper" Leont'ev 1981 pp. 399-400). The degree to which objective outcome coincides with the motive that stimulates the user to a mediated encounter provides a way to reason about the success of scenario and experience. Furthermore, stimulating mediated encounters may generate new motives, encouraging users in staying there. To provide a way to reason about experiences that are induced/evoked in, or witnessed by users of IMEs, a framework of experience (i.e. three Vs: voyeuristic, visceral, vicarious; Marsh 2001; 2003b) informed from Hollywood filmmaking was developed. To capture the three Vs experience a questionnaire was developed. The complement of HABS and the questionnaire (i.e. framework of experience) provides ways to reason about transparency, continuity and experience, and so, identify limitations in, and inform design for, usability and experience.

This chapter will synthesise the work contained in this thesis, highlighting advantages and limitations with these approaches and provide a coherent view of the studies in relation to them. There are four main sections in this chapter that fit together with the aim of providing a foundation to inform research and practice for the analysis and in turn design of IMEs for usability and user experience. Section 9.1 discusses the concepts of invisible style (transparency of equipment and continuity of content) informed from film to encourage users in staying there experiencing the mediated environment, it shows how studies carried out throughout this thesis relate to the main themes of the thesis (i.e. staying there through an invisible style) and to the HABS approach and how they provide ways to reason about disruptions to an invisible style; section 9.2 highlights limitations of existing usability evaluation methods and approaches as identified in previous research, through argument and in studies carried out throughout the thesis and makes recommendations towards overcoming them; section 9.3 discusses the HABS approach and framework of experience which address the limitations of usability methods and provide a structure in which to reason about scenarios, experience, context, concepts of staying there and the invisible style in a single framework. Finally, limitations are discussed and recommendations for future research directions and challenges are presented in section 9.4.

## 9.1 Staying there

This thesis has worked towards the development of ways to analyse IMEs by the way in which they encourage users to continue interacting in the mediated environment and so continue to experience (see next section) the mediated environment. Considered from a user's perspective, the term *staying there* was coined to refer to this positive characteristic of IMEs (Marsh 2003a; 2003b). *Staying there* has been used synonymously in this thesis with the expression maintaining the illusion.

### 9.1.1 Experience as a goal of interacting with and within an IME

Although users may interact with IMEs on the spur-of-the-moment and this is for the most part unplanned, users invariably interact with IMEs not only for work-related tasks per se, but also for a variety of other reasons, purposes or goals. As argued herein, users interact within scenarios (see: section 9.3.2.1) for example, to fulfil "some special need", "to understand", "to comprehend", to be informed, for interest, fun, enjoyment, or pleasure, etc. and this may be for education, learning and training, entertainment, engineering, psychotherapy-related or e-commerce. Because of the difference in purpose in interacting with two-dimensional graphical user interface (i.e. GUI), windows, icons, menu and pointer (i.e. WIMP) based applications and three-dimensional IMEs, interacting with IMEs has been referred to throughout this thesis as an encounter. During an encounter we experience an IME through our senses and after an encounter users have memories of their experience with an IME. The focus of this thesis has been primarily on imagery (i.e. what is seen) and (in studies in chapter 8.2.2) the audio (i.e. what is heard). This relationship between encounter and experience can be illustrated by looking to the Oxford English Dictionary (2001) that defines experience as "actual observation of or practical acquaintance with facts or events; knowledge or skills resulting from; event that affects one; fact or process of being so affected (I learnt by experience)."

Like encounter, as suggested in this definition, human experience occurs during or over the course of the performance of mental and physical processes through the act of looking or "observation" and doing, interaction or "practical acquaintance with" facts and events, as well as, following or "resulting from" the performance of processes in the form of "knowledge or skills" (i.e. what users take away with them in memories). Furthermore, this definition suggests that humans are "affected" (e.g. moved, touched, disturbed, have an emotional impact) through "events" and "facts". Therefore, it has been argued that experience comes from an encounter with an IME or conversely, an encounter with an IME provides experience. As discussed in chapter 7.2.2.2, it is acknowledged that users bring to an encounter knowledge and experience(s) that will most likely have influence, effect or affect on their encounter, both positively (e.g. in training and entertainment through an increased mastery or skill level achieved through prior encounters) and negatively (e.g. in entertainment in which the suspense, excitement or visual pleasures are dulled due to prior exposure). Hence, consideration of user's prior knowledge, experience and encounters will be essential in analysis of some IMEs. Throughout this thesis the word encounter has been used synonymously with the term "use". While "use" is commonly used in HCI to refer to interaction with computer-based systems, like encounter (as described above) it has been used in this thesis to imply experiential use or that experience comes from use. Conversely, use or an encounter with an IME can be considered as experience. Hence, irrespective of whether use or an encounter with an IME is for learning and training (e.g. control procedures and awareness of spatial layout as in the EISCAT VR system from studies in chapter 3.2), entertainment (e.g. computer games playing from studies in chapter eight), etc., use or an encounter with an IME can be considered as experience.

### 9.1.2 Staying there through an invisible style: transparency of equipment and continuity of content

This thesis has argued that maintaining a user's illusion of interacting in a mediated environment or in its shorter form, "staying there" is a consequence of two things: transparency of equipment and continuity of content. The duality of these was informed from the "invisible style" of Hollywood filmmaking (e.g. Messaris 1994 pp.

150-154), whose central goal like that of staying there, is to hide the mediating technology (invisible) and uphold continuity in the delivery of content. This provides filmmakers with a way to shape experience for spectators and hold their focus of attention in the illusion of film. The Hollywood style of filmmaking is neatly encapsulated in the words of Rosenblum and Karen (1979 p. 296) who say:

> *"as an audience, we no more want to see the wheels and gears and levers responsible for the effect the film is having on us than we want to see the pencil marks on an author's first draft or the invisible wires in a magic show".*

That is, as Messaris (1994 p. 150) states, the aim is to hold a user's focus of attention in a film's presentation (i.e. illusion of film), so that spectators "become absorbed exclusively in the represented act itself" of the people, places and events, etc., of the scenario/narrative and not in the filmmaking process itself.

It was acknowledged in chapter five that other styles of filmmaking exist (e.g. French New Wave) that contrast to the Hollywood invisible style by the way in which spectators' focus of attention is shifted between the filmmaking process (e.g. filmic and artistic devices) and the film's presentation/content (i.e. the illusion of film). The interest in this thesis however has not been so much in artistic devices to shift spectators' or users' focus of attention, but in concepts similar to those captured in the words of Rosenblum and Karen (1979) and Messaris (1994). This has in turn informed concepts of staying there, interacting in a mediated environment through an invisible style of transparency of equipment and continuity of content. That is, similar to spectators of a film, the aim is to hold a user's focus of attention in a mediated environment, so that they not only "become absorbed exclusively in the represented act itself" (Messaris 1994 p. 150) of the people, places and events, etc., of the scenario/narrative per se, but they also interact with and within it. Therefore, it was argued that one of the main goals of IMEs is to allow users to have continuous encounters with IMEs, free from disruption, providing users with the potential to continuously experience a mediated environment and encourage them in staying there. Hence, transparency and continuity are positive characteristics of IME design in use and these are antidotes to disruptive interaction that are negative characteristics and may disrupt, distract or impede a user's interaction and so disrupt experience.

As mentioned, the key advantage to considering invisible style through transparency and continuity to encourage users in staying there is that it provides us with a way to consider a range of IMEs irrespective of the underlying complexity of supporting or enabling technological configurations and genre of mediated content. For example as shown in this thesis through studies with standard and novel desktop-based systems, and HMD-based VR configurations. The concepts of transparency and continuity and how they relate to HABS are discussed further in section 9.3.

The idea of invisible style (transparency and continuity) for users staying there is similar to other research that argues for the relationship between users'/spectators' focus of attention remaining in the mediated content, free from distraction and as a result they continue to experience a mediated environment. Conversely, disruptions may potentially break the experience. This work is reflected in many commonly used terms referring to both interactive (e.g. VR and computer games) and non-interactive mediated environments (e.g. film and theatre). For example, informed from work in theatre, Laurel's widely cited terms, "engagement" (1986 p. 69) and "agency" (1993 p. 117) means that a user can experience a "mimetic illusion" (e.g. representation or mimicry through real or virtual medium) "directly, without any mediation or distraction". Conversely, distraction would "explode the mimetic illusion" (1993 p. 116). Similarly, Lombard and Ditton's (1997) definition of presence as "perceptual illusion of non-mediation" that emphasises that the experience of a sense of presence comes from an unawareness of supporting or mediating technologies (i.e. "non-mediation") of a mediated environment system as described below in section 9.1.4.

#### 9.1.2.1 Transparency of equipment

The idea of transparency as used in this thesis refers to enabling or mediating technology and "equipment" in use, that following mastery is (borrowing from the words of Nardi 1996b p. 11) "supportive and unobtrusive, but which the user need pay little, if any, attention to", so that, it disappears from the main focus of a user's attention; or in Norman's (1998) words, becomes "invisible". As discussed in chapters two and four, similar concepts have informed human-computer interaction (e.g. Bødker 1991; Holzblatt, Jones and Good 1988; Koschmann, Kuutti and Hickman 1998; Rutkowski 1982; Shneiderman 1987; Suchman 1997; Weiser 1991; Winograd and Flores 1986). However, it has been argued that concepts provided by transparency alone and in particular those from traditional HCI (e.g. Bødker 1991;

Holzblatt, Jones and Good 1988; Norman 1998; Rutkowski 1982; Shneiderman 1987; Winograd and Flores 1986) are not fully able to account for aspects related to time-based media and the shift to an experiential perspective. The work in this thesis shares similar ideas to those from virtual environments and interactive media (e.g. IJsselsteijn, de Ridder, Freeman, Avons 2000; Laurel 1986, 1993; Lombard and Ditton 1997; Mallon and Webb (1997; 2000); Slater and Steed 2000) that link notions of transparency of equipment in use to experiential use. As discussed in chapters two, five, six, and seven, in order to inform analysis of IMEs to reason about transparency and experiential encounters with interactive time-based media, this thesis adopted and developed ideas of continuity. So in contrast to transparency of equipment, continuity provides ways to reason about aspects of the mediated content or environment that should continuously remain noticeable, in-focus or "visible" to the user.

#### 9.1.2.2 Continuity of content

Continuity is the continuous and coherence of content (e.g. this can be the imagery or audio, etc.) that shape the three-dimensional space. This provides a way to consider time-based media and an approach that allows us to reason about continuity of user's experience of interacting with and within the content of a mediated environment. This work is informed from "smoothly flowing narrative" that is one indication of "quality in [Hollywood] films" (Bordwell, Staiger and Thompson 1988 pp. 194-195) and cinematography conventions that inform interface design by "preserving thematic continuity" (May and Barnard 1995), as well as, in the design of smooth animation "to maintain an illusion of a perceptually consistent [virtual] world" to provide continuity of experience (Hubbold, Murta, West and Howard 1995) and similarly continuity of presence (McGreevy 1992; 1994).

##### 9.1.2.2.1 Continuity in design: constraints

Chapters four (4.4) and seven (7.1) discussed difficulties in considering the socio-cultural structure of mediated environments because of their potential to create imaginary and artificial virtual worlds. Borrowing from the words of Engeström (1999 p. 23), it was argued that unlike the real world, mediated environments can be "individualistic" and "ahistorical" so consideration of artefacts that are shaped by successive successful adaptations, and that in turn effect activities, is problematic. While any attempt to formulate methods to analyse the socio-cultural context of mediated environments (i.e. scene, setting and scenario) would require a sustained research effort and therefore was beyond the scope of this thesis, it was argued that an alternative approach was to consider the environment, objects and user by their behaviour in response to interactions performed in scenarios, and user experience in response to this. That is, performing, conforming, reacting and responding appropriately within the *constraints* governed by the scenes, settings, circumstances and scenario of IMEs.

As mentioned in chapter seven (7.1), interestingly, these discussions share similar arguments with those of affordances borrowed from J. J. Gibson (1979) and introduced to HCI by Norman (1988). On reflection, Norman (1999 p. 39) expressed his "great surprise" that the HCI community enthusiastically took-up the idea of affordances while generally disregarding related concepts of constraints and culture. He asserts that much discussion in HCI on affordances is really about a convention or behavioural constraint that "inhibits activities and encourage others" (Norman 1999 p. 41). Searching for a deeper understanding to consider culture and artefacts by constraints and commonalities shared by a group that influences the behaviour of members, this thesis turned to Poortinga's (1992 p. 10) definition that states, culture "manifest in shared constraints that limit the behaviour repertoire available to members of a certain socio-cultural group, in a way different from individuals belonging to some other group". That is, people tend to restrict their behaviour to what is considered appropriate and acceptable depending on which group they are participating with.

Informed from this, the idea of continuity was extended to provide ways to reason the notion of constraints that limit the behavioural repertoire of artefacts and users formed by a socio-cultural context in two ways: firstly, the mediated environment's behaviour in response to user's interactions and secondly, user's behaviour performed in scenarios. So a user would expect a mediated environment and objects contained within it to respond appropriately to interactions. For example, any switches, drawers, windows and doors that are inoperative or do not respond as they should within a scenario, can be considered inappropriate or out of place. Secondly, it was argued that a user participating in a scenario within a mediated environment should also adhere to certain social and cultural norms. For example, as observed in studies described in chapter eight, in a medieval castle environment a user follows social and cultural behavioural patterns that are different to those in a first person shooter game. Any deviation from these patterns can be considered inappropriate or out of place or character in the environment. That is, a witch and her behavioural patterns from a medieval castle game do not belong in a first person shooter game, and visa versa. Thus, if something or someone behaves appropriately within constraints determined by context then it has continuity and if not, can be considered as having discontinuity.

While the added concept of constraints determined by the socio-cultural context (i.e. scene, setting and scenario) to previous developments (i.e. HABS: see section 9.3) provided a way to reason about design through the behaviour of artefacts in use (i.e. shifts in consciousness), it is difficult to see how it is possible to reason about user's behaviour in context. To assist in reasoning about user/virtual character behaviour, a framework of experience (i.e. voyeuristic, visceral, vicarious: see section 9.3.2.2) that may be induced in, or witnessed by users during an encounter with a mediated environment was developed. So that, appropriate experience will be said to have continuity, and no experience, reduced or inappropriate experience has discontinuity. Thus, discontinuity potentially points to limitations in design or a user's dislike for the mediated encounter. Similar arguments to these and a potential source for further investigation are found in Ortony's (2001) work on "believable" virtual characters. He argues like continuity, appropriate responses in character's behaviour and emotions in context should be ensured.

**9.1.2.2.2 Continuity in design: guidelines to improve user comprehension of space during navigation**

In reference to table 9.1, three guidelines informed from cinematography and editing conventions from the Hollywood "invisible style" of filmmaking were developed (see: chapter 5.4) for the construction of virtual off-screen space to aid user comprehension of space in smooth and continuous real-time animation and so maintain continuity of experience (Marsh and Wright 2000a). These guidelines can be used to inform evaluation and can be used with the HABS approach (see: section 9.3 and table 9.5). The proposed guidelines were developed to provide users with visual cues to unconsciously predict the contents and shape of the immediate surrounding space in addition to that seen within the display screen's restricted field-of-view. That is, the space that is seen on-screen (within the display screen) implies additional space that is not seen through the current view port and is in off-screen space. Hence, users are provided with a greater knowledge of their immediately surrounding virtual space and it is proposed that this may aid navigation of virtual environments.

Because user disorientation was identified as being the cause of some of the most frequently occurring problems in interacting with both desktop (Marsh and Wright 1999) and HMD-based VR systems (as described in studies in chapter three) one of the guidelines, *partially out of the frame,* to inform design for the placement of objects in mediated environments and so aid users in navigating virtual space and attempt to reduce the occurrence of user disorientation was tested. A typical guideline for *partially out of the frame* is shown in table 9.1. The idea of this is to trigger a user's recognition of on-screen objects as being only a section of the whole object and thus implies that the rest of the object is in off-screen space. Results of a study described in chapter five (5.4.3.1) suggest that the use of this guideline can help guide users and maintain continuity of navigating through the mediated environment, reducing the incidence of user disorientation (e.g. wall collisions and walking through virtual objects) and this will help to maintain continuity of experience (Marsh and Smith 2001a; 2001b). Furthermore, the guidelines appeared transparent to users. Thus, demonstrating that cinematic and editing techniques can inform the development of idioms or guidelines for interactive mediated environments as proposed in the progression of virtual reality development (see: chapter 5.2.2). That is, remediation of mediated environments from film and a good case for further investigation. The guideline *partially out of the frame* can be used to identify the causes of many difficulties or disruptions (e.g. wall collisions and walking through virtual objects) in user's navigation in both desktop and HMD-based VR studies (chapter three) and can be used to inform evaluation with the HABS approach (section 9.3). Indeed, the guideline was used in the role-playing study in chapter eight to predict the cause of users getting "stuck" when the whole display screen is reduced to one colour or texture while navigating too close to a specific wall in the mediated castle. The repeated occurrence of this suggests this specific wall may present a problem in design.

In reference to table 9.1, implementation of *exit and entry points* in VEs can be achieved by the use of graphical models or representations of: doors, paths, roads, etc. Their existence in the VE will trigger a participant's knowledge and experience implying that by taking this pathway a participant can reach other spaces that are not contained within the confines of the display screen. An example of a typical guideline for *exit and entry points* is shown in table 9.1 and this can be used to inform the design and the evaluation of virtual environments. Exit and entry points such as paths and roads are a special case or sub-group of *partially out of the frame*. This is because only part or a section is shown on-screen. While this guideline has only been partially tested in connection with *partially out of the frame* (see: 5.4.3.1), and so requires further validation, these guidelines have been used to inform users of locations off-screen on displays with mobile hand-held devices (Baudisch and Rosenholtz 2003).

**Table 9.1 Guidelines to inform analysis and design of virtual off-screen space**

| cinematic conventions | cinema | virtual environments | guideline |
|---|---|---|---|
| partially out of the frame | • sticking part of body off-screen<br>• object partly on-screen | • familiar object shown partly in frame (HMD, display monitor) | • the placement of objects in the virtual environment should be such that there is always more than one object partially in the user's FOV |
| point of view | • talking to someone off-screen<br>• looking off-screen | • avatar gazing at / talking to, something / somebody off-screen | • where applicable, avatars should have the ability to look to space contained off-screen |
| exit and entry points | • character passing through door / corridor<br>• character moving out of the frame<br>•up / down stairs or in a caged lift | • doors, hallways, paths, windows, roads, etc. | • wherever possible, it must be clear to the user that there exists the option to exit the area contained within the confines of the display screen (HMD / monitor) |

Finally, with the introduction of characterization (e.g. virtual characters and avatars) in mediated environments the idea of the guideline *points of view* to suggest to the user that a character on-screen is looking somewhere off-screen (e.g. to an object, location or talking to another person located off-screen) becomes more realistic. A typical guideline for this might be as contained in table 9.1. It is anticipated that the use of this guideline will be especially useful in multi-user environments, such as, collaborative VEs and in video teleconferencing. While many characters existed in the mediated environments used in studies in chapter eight, they lacked sophistication in movement and direction of eye gaze for this guideline to be effective.

### 9.1.3 The studies and how they relate to staying there through an invisible style

This section will provide examples of how the studies carried out throughout the thesis relate to each other and to the main themes of the thesis i.e. staying there through an invisible style continuing to experience a mediated environment. It provides examples of disruptions (building on the work of Winograd and Flores 1986 and Bødker 1991, disruptions are termed breakdowns: see discussion later) and the varying effects that they have on users. Furthermore, it indicates how these disruptions were or can be captured using methods developed in this thesis, either through: the hierarchical activity-based scenario approach (HABS: see section 9.3), the three Vs questionnaire incorporating HABS and activity theory concepts, or studies and guidelines informed from or used with HABS. Further discussions on the HABS approach, three Vs questionnaire and guidelines are continued in section 9.3. Next, this section shows through example that it is possible for users to have multiple strands of thought while interacting in a mediated environment without necessarily disrupting interaction. Finally, it talks about guidelines used in a study to reduce user disorientation and so maintain continuity of users' experience.

As argued, experience is one of the main goals for users to interact with an IME and breakdown or disruptions have the potential to break or impede experience. What the study results tell us about breakdown/disruption provides ways to reason about transparency and continuity (i.e. invisible style) and staying there. While this thesis argues that IMEs should not disrupt users, it is acknowledged that breakdown/disruption can inform design, concurring with a similar argument made by Winograd and Flores (1986). Additionally, following Bødker (1991) breakdown may also identify opportunities for learning (i.e. novice users or unfamiliar interaction). The studies throughout this thesis show that disruptions have the potential to interrupt the flow of user's interaction, and this may, depending on the severity of disruption, compromise their ability to continuously experience the mediated environment i.e. disrupt the invisible style. (Likewise as identified in studies in film as described in chapter five and below, if there is no disruption, then spectators have the potential to continue to watch a film's presentation and continue to experience it.) As shown in examples below, breakdown is used to refer to many levels of severity of disruption to a user's interaction. It refers not only to catastrophic disruptions/breakdowns (e.g. computer crashes, power failure, etc.) but also as shown below to disruption/breakdown that has: *no noticeable effect upon user's interaction, momentarily impedes user's interaction* as well as, *totally disrupts a user's interaction*:

**i. no noticeable effect upon user's interaction**

- *in de-briefing sessions* in the study in chapter five (5.4.3.1) to test guidelines to reduce user-disorientation in a desktop-based VE: some users said that they were aware of background noise and other people but this did not have an *observed* (by the evaluator) effect on their interaction. The guidelines inform design and evaluation of mediated environments and can be used with HABS.
- *using the (post-study) three Vs questionnaire (incorporating HABS concepts)* in the "point-and-shoot" desktop-based computer game study in chapter eight (8.2.1): a user said that they had other things in mind while game-playing (e.g. homework) that did not have a noticeable or *observed* effect on their interaction.
- in the desktop-based role-playing study in chapter eight (8.2.2): as identified in the *(post-study) three Vs questionnaire (incorporating HABS concepts),* users said that there were some disruptions that did not have a noticeable effect on their interaction (e.g. glitches in display, interference to audio).

**ii. momentarily impede user's interaction**

- in the EISCAT HMD-based VR study in chapter three (3.2): when a colleague not involved in the study had entered the study laboratory, a user was *observed* to momentarily discontinue interaction until they had left the room. Using *guidelines* in studies in chapters four (4.3) and six (6.6.2) informed from activity theory, HCI and film (chapter six only) these results were identified as disruptions (i.e. breakdown).
- in the HMD-based EISCAT study in chapter three (3.2): as identified through both *observation* and users' *think-aloud verbalisations*, users' physical/virtual movements were momentarily impeded by 3D mouse/HMD cables becoming entangled. Using *guidelines* in studies in chapters four (4.3) and six (6.6.2) (informed from activity theory, HCI and film) these results were identified as disruptions (i.e. breakdown).
- in *interviews* with spectators of film in chapter five (5.1.4): they self-identified disruptions that momentarily broke their attention during a film's presentation. Three categorizations were identified: internal (e.g. discontinuity of film's content and

awareness of mediating technology), external (e.g. anything external to film's presentation and enabling technology/equipment) and subjective (e.g. contemplation of something other than the film or lack of interest in the film presentation/genre). These provided a way of classifying the causes of disruptions in IMEs (as discussed further below) as used in chapters four (4.4) and six (6.6.2), and they can be used with HABS approach.

- in *de-briefing sessions* in the study in chapter five (5.4.3.1) to test guidelines to reduce user-disorientation in a desktop-based VE: as identified by users and through *observation*, disruptions (e.g. walking through virtual walls) caused some users to momentarily break their attention in interacting in the mediated environment. As mentioned, the guidelines inform evaluation of IMEs and can be used with HABS.

- in the desktop-based role-playing study in chapter eight (8.2.2): informed from HABS as identified through *observation* and *three Vs questionnaire,* users' interaction was momentarily disrupted (e.g. difficulty using "item"/function keys ).

**iii. totally disrupt a user's interaction**

- in the HMD-based EISCAT study in chapter three (3.2): as identified through both *observation* and users' *think-aloud verbalisations,* tangled 3D mouse or HMD cables brought to a standstill users' physical and virtual movements. Using *guidelines* in studies in chapters four (4.4) and six (6.6.2) (informed from activity theory, HCI and film) these results were identified as disruptions (i.e. breakdown).

- in the desktop-based role-playing study in chapter eight (8.2.2): as identified through both *observation (using HABS concepts)* and in the three Vs *post-study questionnaire (incorporating HABS concepts),* users' interactions were brought to a standstill until a study evaluator had fixed, sorted out, instructed them to ignore, etc. a cause of disruption (e.g. inoperative "item"/function keys, computer crashed).

As identified in "i" above, it is acknowledged that a user (or spectator) may be aware of disruptions and have multiple strands of thought but these won't necessarily interrupt their encounter and potential to continue experiencing a mediated environment. For example, while playing a computer game a user may at the same time think about a pending chore (e.g. wash the dishes, clean the car, or thinking about "homework" as articulated by a user in the de-briefing session of the "point-and-shoot" study in chapter 8.2.1) and be aware of an inappropriately responding interactive artefact (i.e. physical or virtual) as identified by users in the role-playing game in chapter eight. These separate strands of active thought may be present in a user's mind without causing any disruption to the game/role-playing (or task at hand). They will not necessarily disrupt interaction unless they become pronounced or become the main strand of thought and so then may interfere with playing/interacting with the game/environment as identified in "ii" and "iii" above. See related discussion in section 9.3.4.

As mentioned, one way of classifying the causes of breakdown in IMEs (following a study in chapter five (5.1.4) in which spectators' self-identified disruptions to a film's presentation) was to formulate three categories: internal (e.g. discontinuity of content and awareness of mediating technology), external (e.g. awareness of anything external to an IME/film's presentation and enabling equipment) and subjective (e.g. contemplation of something other than the IME/film or lack of interest in the presentation/genre). Of these categories of breakdowns, some are difficult or impossible for the evaluator or IME designer to control. For example, in debriefing sessions in the study to reduce user disorientation in chapter 5.4.3.1 (see below), many subjects reported noise external to the study laboratory environment (e.g. people walking close to the study laboratory, the sound of typing in the distance etc.). Additionally, designers and evaluators have no control over what a user is thinking while interacting in an IME (e.g. considering homework i.e. subjective). One of the goals of an IME is to provide experience that makes users want to remain interacting in the mediated environment and encouraging them in staying there. While there can be little control over external (e.g. ambient noise and disruptions that are external to an IME) and some subjective breakdowns (i.e. contemplation of something other than the mediated environment), there can be considerably more control over the internal (i.e. IME configuration and content).

This thesis has been primarily concerned with internal and some aspects of subjective (i.e. IME design to maintain user's interest) and what we learn from internal (transparency of equipment and continuity of content) and subjective (e.g. interesting scenario/experience) can inform redesign for staying there through an invisible style. As discussed in section 9.3.2.2, to provide a language to reason about and capture experience (i.e. subjective), the three Vs framework of experience and questionnaire were developed. The questionnaire was informed from the concept of breakdown. So that, no experience, reduced or inappropriate experience may have the potential to not hold user's attention and so break a mediated encounter and break experience.

In addition to the study described above to find out what breaks spectators' attention in the illusion of film, research was also carried out to identify techniques that hold spectators' attention in a film presentation. Guidelines were then developed, informed from cinematography and editing techniques, and a study was carried out to inform the construction of VEs to reduce user disorientation (studies of desktop and HMD-based VR in chapter three identified this as one of most frequently occurring usability problems) during navigating in virtual environments. Results of the study showed that guidelines aid users in maintaining continuity of navigating through the mediated environment, and this will help to maintain continuity of experience. In turn, guidelines can be used in evaluation studies to reason about causes of user disorientation and also, can be used with the HABS approach (see: section 9.3).

### 9.1.4 Difference between "staying there" and "being there"

The previous section discussed the importance of continuing to interact in the mediated environment and so maintain continuity of experience. So rather than talking about a user's sense of presence or "being there" in the mediated environment, this thesis focused on "staying there" (Marsh 2003a). While Lombard and Ditton's (1997) definition of a sense of presence, "perceptual illusion of non-mediation" is similar to "staying there", like other terms that refer to the concept of presence, it restricts descriptions of experience and encounter to those that occur "instant by instant" or in a "continuous (real time) ..." moment. This makes it difficult, if not impossible, to describe unfolding events, episodes, the "big picture" of a scenario and the after-effects/affects/consequences of a mediated encounter with IMEs within the boundaries imposed by definitions of presence; see for example discussions by Heeter (2000). Staying there is a shift towards a wider arena (than "instant by instant" encounters) in which to reason about experience that is induced/evoked in, or witnessed by, users of IMEs. It is a similar concept to that used to hold spectators" attention in film and theatre, the concepts of which have attracted interest in informing user-interface design. For example, Laurel's (1986; 1993) ideas of engagement, direct agency and mimetic illusion, borrowed from theatre (see: section 9.1.2), and ideas borrowed from filmmaking to inform the design of virtual environments (e.g. Laurel, Strickland, and Tow 1994; Pausch et al. 1998; Marsh and Wright 2000a).

### 9.2 Limitations of traditional HCI evaluation approaches and techniques to evaluate usability and user experience of IMEs

This section identifies limitations of traditional usability evaluation methods when applied to IMEs. It makes recommendations to overcome some of these limitations and suggests how they can be used to complement user experience. While usability has been successful in the assessment of design in use and in iteratively informing redesign since the inception of human-computer interaction, through argument, reference to relevant literature and from the results of studies carried out herein, this thesis has shown that usability alone is not fully able to go beyond work-related tasks demanded from interactive mediated environments towards an experiential perspective.

#### 9.2.1 Limitations of usability approaches and methods

As discussed in chapter two and in reference to table 9.1, limitations with commonly used usability methods and approaches have been echoed in the virtual reality and virtual environment communities. For example, Kaur (1998) states that guidelines borrowed from standard user interface design, such as, ISO 9241 (ISO 1997) are "likely to prove inadequate because they do not address the range of interactive behaviour afforded to by VEs". Gabbard, Hix and Swan (1999) suggest that "incompatibilities between GUIs and VEs may render" "proven" and "well-tested" usability design and evaluation methods "inapplicable" to VEs. They suggest that while "heuristics are considered the defacto standard for GUIs we have found them too general, ambiguous, and high-level for effective and practical heuristic evaluation of VEs". Likewise, Steed and Tromp (1998) suggest that heuristic evaluation and cognitive walkthrough need to be extended to account for interactive capabilities in three-dimensional virtual environments. (See also: Steed, Tromp and Wilson 2003 and Sutcliffe and Kaur 2000). To overcome these limitations it is recommended that appropriate guidelines are needed to guide evaluators in usability studies of IMEs.

In further discussions in chapter two limitations with heuristic evaluation were identified as illustrated in table 9.2 and 9.3. In reference to table 9.3, close examination of each usability guideline/heuristic from the set of ten (derived from a factor analysis of published usability problems that suggests which set of guidelines provide the best coverage) proposed by Nielsen and Mack (1994) revealed that while some heuristics do make sense in the context of VR (e.g. "*Visibility of System Status*" *and "Make Objects, Actions, and Options Visible"*) and so could be made applicable or mapped to three-dimensional virtual environments and objects, however, some of the ten heuristics do not make sense in the context of VR and so were seen to be inappropriate for use with VR. For example, it is difficult to see how *"Flexibility and Efficiency of Use"* and *"Help Users Recognize, Diagnose, and Recover from Errors"* that recommend fast-paths and help systems respectively, could be supported in the context of VR. One line of future research could be to investigate the effectiveness of the ten heuristics that are considered appropriate or make sense in the context of VR. However, considering that Nielsen and Mack's (1994) guidelines were obtained from extensive studies of eleven published projects, and the resulting set of ten usability guidelines were obtained from an analysis of 249 guidelines, it would seem inappropriate, and possibly a little naive, to tweak or tinker with the guidelines in the hope of making them appropriate for the evaluation of VR systems.

Furthermore, limitations with the "think-aloud" verbal protocol technique were identified in studies in chapter three to investigate its suitability when applied to desktop VR and head-mounted display based VR (as summarized in table 9.1). The evaluation method used was the co-operative evaluation technique (that is a variation of the "think-aloud" technique), observation during study sessions and analysis of video material made of the study. As discussed in chapter two, the co-operative evaluation technique was used in an attempt to overcome problems associated with low "quantity" (i.e. frequency) and "quality" (i.e. low value to an interface designer) of verbalisations in studies with single users and single evaluators as highlighted by Hackman and Biers (1992). The co-operative evaluation technique does this by encouraging dialogue between a single user and evaluator in the form of questions - pertaining to the study's application or task under evaluation. The co-operative nature of this approach is designed to make single users feel a part of an evaluation, as a co-evaluator and not a subject under evaluation. Hence, this attempts to overcome the "unnaturalness" of single user studies whilst at the same time building in a means to coax further verbalizations from the user – prompting for further verbalizations where necessary - and thus provides the opportunity to probe further lines of inquiry relating to concerns of usability.

**Table 9.2 Research/chapter identifying limitations of, and suggesting recommendations for, existing techniques/approaches to usability evaluation when applied to IMEs**

| Research / chapter | Limitations identified by researcher(s) / chapter | Study results and recommendations proposed in thesis |
|---|---|---|
| Kaur (1998) | guidelines, such as, ISO 9241 (ISO 1997) are "likely to prove inadequate because they do not address the range of interactive behaviour afforded to by VEs" | guidelines / criteria appropriate for IMEs are needed to guide evaluators in usability evaluation studies |
| Gabbard, Hix and Swan (1999) | "incompatibilities between GUIs and VEs may render" "proven" and "well-tested" usability evaluation methods "inapplicable" to VEs. While "heuristics are considered the defacto standard for GUIs we have found them too general, ambiguous, and high-level for effective and practical heuristic evaluation of VEs". | heuristics / guidelines / criteria appropriate for IMEs are needed to guide evaluators in usability evaluation studies |
| Steed and Tromp (1998) | heuristic evaluation and cognitive walkthrough need to be extended to account for interactive capabilities in three-dimensional VEs | heuristics / guidelines / criteria appropriate for IMEs are needed to guide evaluators |
| Chapter Two | as elaborated in table 9.3, some heuristic guidelines do not make sense in the context of VR and therefore, it was argued that (without further research) heuristic evaluation using guidelines proposed by Nielsen and Mack (1994) are inappropriate for use with VR | heuristics / guidelines / criteria appropriate for IMEs are needed to guide evaluators |
| Chapter Three: VPP & EISCAT study | 1. unavailability of appropriate criteria / guidelines means a reliance on the evaluator's knowledge to capture and code the severity of usability problems<br>2. additional methods to the "think-aloud" technique were used in order to capture more directly user's knowledge of the spatial layout that was accumulated during their encounters | 1. develop guidelines / criteria for IMEs to guide evaluator in IME usability evaluations<br>2. formulate ways to capture/assess/reason about what users get from encounters with IMEs i.e. spatial or any kind of user experience from an IME encounter |
| Chapter Three: EISCAT study | 1. when the evaluator's attention was disrupted to fix UPs, the evaluation technique oscillated between being a co-operative evaluation and a traditional "think-aloud" method, so limiting the usefulness of co-operative evaluation technique<br>2. perform analytical/expert evaluation to remove as many usability problems as possible before doing a more costly empirical study with users | 1. usability evaluation method should be able to cope with all types of breakdown i.e. the evaluation technique itself should not breakdown<br>2. heuristics / guidelines / criteria appropriate for IMEs are needed to guide evaluators |
| Chapter Four: EISCAT study with activity theory | adoption of activity theory's hierarchical framework encapsulating tool mediation and transparency (antidote to breakdown and shifts in focus) did not address the experiential aspects and issues of context of use associated with IME | formulate ways to reason about user's experience from encounters with IMEs and to address the context of use |
| Chapter Six: EISCAT study with activity theory incorporating context of use | 1. "thinking-aloud" may interfere with a user's ability to fully appreciate a mediated environment and so potentially disrupt (i.e. interrupt, interfere, etc.) a user's experience<br>2. limitations with "thinking-aloud" when moving from task-based to activity-based (to be able to consider intentional aspects of user's interaction); operations that are verbalised may become indistinguishable from actions and so detection of breakdowns is problematic | 1. the method to evaluate aspects of usability should not interfere with a user's experience<br>2. use methods other than "thinking-aloud" when using an activity-based approach for analysis |
| Chapters Six and Eight | remove as many usability problems as possible by doing an analytical/expert evaluation or empirical study prior to experiential evaluation | use guidelines / criteria / developed herein to guide usability evaluations (see: section 9.3.4) |

**Table 9.3 Limitations with heuristic evaluation to evaluate the usability of virtual environments**

| Heuristics make sense in the context of virtual reality systems | Heuristics that don't make sense in the context of virtual reality systems |
|---|---|
| *Visibility of System Status:* display to users through (e.g. visual / visible) three-dimensional environment and objects | *Flexibility and Efficiency of Use:* support accelerators or fast-paths for both experienced and inexperienced users |
| *Make Objects, Actions, and Options Visible:* visual/visible three dimensional environments and objects suggesting actions and options to users | *Help Users Recognize, Diagnose, and Recover from Errors:* to express error messages in plain language |

Because of the lack of guidelines/criteria for the evaluation of IMEs, a "low" (i.e. problems associated with learning) and "high" (i.e. potential problems with design) coding system was developed in order to capture and rate the severity of usability problems following the work of Hackman and Biers (1992). The results showed that the co-operative evaluation technique used in connection with the coding system (i.e. "low" and "high" criteria) provided an effective way to identify, capture and categorize usability problems of desktop VR. Using Cohen's Kappa, there was an 83% agreement between evaluators' severity ratings of usability problems of desktop VR. However, these methods were not as effective in studies with HMD-based VR for three main reasons. Firstly, using Cohen's Kappa, there was only a 31% agreement between evaluators' severity ratings of usability problems. This suggests that the coding system is not as effective when applied to HMD-based VR. Secondly, when the evaluator's attention was disrupted to fix UPs, the evaluation technique oscillated between being a co-operative evaluation and a traditional "think-aloud" method, so limiting the usefulness of the co-operative evaluation technique.

Finally, because of limitations in humans' ability to verbalise spatial descriptions (e.g. Coventry and Mather 2002) of their encounter, additional methods to the "think-aloud" (i.e. co-operative) technique were used as discussed further in section 9.2.2. As argued in section 9.1.1, whether the goal of an encounter with an IME is to provide users with awareness of a spatial layout of an environment (e.g. the EISCAT facility in Norway) or for entertainment (e.g. computer games playing as in studies in chapter eight) an encounter with an IME can be considered as experience. Therefore, it is necessary to formulate more direct ways other than the "think-aloud" technique to capture, assess and reason about experience that users get from encounters with IMEs (e.g. spatial or otherwise).

In summary, while the co-operative evaluation technique seems effective in capturing usability problems with both desktop and HMD-based VR, many limitations were however, identified in its application to HMD-based VR. That is, the unavailability of appropriate criteria/guidelines meant a reliance on the evaluators' knowledge to capture and code the severity of usability problems. Secondly, concurring with Steed and Tromp (1998), in order to ensure the smooth running of an evaluation study and in an effort to prevent the evaluator's attention from being disrupted (as recommended herein), it was recommended that an analytical/expert evaluation be carried out prior to going to the expense of conducting an empirical study with users.. However, the lack of appropriate guidelines meant this was problematic. Indeed, in reference to table 9.2, the recommendation to develop guidelines/heuristics/criteria that are appropriate for use with IMEs was raised seven times. Section 9.3 discusses an approach to evaluate IMEs that in turn informed the development of guidelines for IMEs. These guidelines were used in task-based evaluation studies (using co-operative/"think-aloud" evaluation technique) to capture breakdowns in interaction (chapter 4.3) and then extended to capture breakdown in illusion (as well as breakdown in interaction) in chapter six (6.6.2) (see: section 9.3.4).

### 9.2.2 Limitations of traditional usability evaluation methods to evaluate user experience that comes from interacting with and within IMEs

The move to an experiential perspective that in some cases is an attempt to overcome limitations with usability applied to emerging interactive technological devices, products and environments is demonstrated in recent texts that argue for pleasure (Jordan 2001), fun (Blythe et al. 2003), presence (Riva et al. 2003) and emotion (Norman 2004) in design. While IMEs can be identified as one group of emerging interactive systems whose goal this thesis has argued is experiential (see: section 9.1.1), all of the aforementioned VE evaluation research activity (e.g. Gabbard, Hix and Swan 1999; Kaur 1998; Steed and Tromp 1998) focuses primarily on usability evaluation.

One of the main purposes of the evaluation studies of VR applications (i.e. VPP and EISCAT) described in chapter three was to provide users with awareness of the spatial layout of the virtual environments during their encounter. The co-operative evaluation technique (i.e. a variation on the "think-aloud" verbal protocol) was employed in these studies. However, because limitations in humans' ability to verbalise spatial descriptions that could be used to assess spatial awareness are well known (see for example: Coventry and Mather 2002), additional methods to the "think-aloud" technique were therefore used in order to capture more directly user's knowledge of the spatial layout that was accumulated while navigating/exploring the mediated environments during their encounters (as mentioned in section 9.2.1 and summarized in table 9.2). These additional methods were plan view sketches (i.e. bird's-eye view) of both the desktop and the HMD-based VEs and pointing to unseen targets in the HMD VE.

Furthermore, as shown in table 9.2, by comparison to film it was argued in chapter six that the actual process of giving a kind of running commentary through "thinking-aloud" may interfere with (i.e. hamper, impede) a user's ability to fully appreciate a mediated environment and so potentially disrupt (i.e. interrupt, interfere, cut short, break up, etc.) a user's experience. Furthermore, questions from an evaluator (e.g. co-operative evaluation technique) could also interrupt a user's experience. Therefore, it was argued that "thinking-aloud" should be postponed while a user's experience of an encounter with a mediated environment is evaluated. It was proposed that one way forward could be to perform a two-step approach. Firstly, by carrying out a usability evaluation study. This can be an analytical/expert or an empirical study to remove as many usability problems as possible and then perform a second evaluation for experience (following an empirical study different users should be used because of a potential leaning effect) as recommended in chapters six (6.6.4) and eight (8.2.2.3) and listed in table 9.2. Similarly, as previously mentioned (see: table 9.2), it was argued in chapter three (3.2.1.5) that an analytical/expert usability evaluation study be performed before going to the expense of using users in a usability evaluation study.

In the conclusion of chapter six (6.6.4), it was argued that in order to reason about mediated experiential encounters with IMEs it was necessary to consider user's intention and this required moves from task-based to activity-based approaches to evaluation (see section 9.3 for discussions on the hierarchical activity-based approach). However, in using a think-aloud verbal protocol both the normally conscious and unconscious processes are likely to be exteriorised. For example, in the

EISCAT study some subjects verbalised everything from mouse movements and button presses to head movements. This presents problems when considering an activity theory-based approach because it draws users' attention to operations that, following mastery (i.e. practiced or routinized behaviour), are performed with little conscious thought. This makes it impossible to understand user's behaviour under normal use with and within an interactive mediated environment. Hence, there is a conflict in using a think-aloud verbal protocol with an activity theory-based approach because it is difficult to differentiate between actions and operations.

### 9.2.3 Discussion

It could be argued that one approach to formulate ways to evaluate IMEs is to use a collection of techniques using those that were shown to be appropriate in studies carried out throughout this thesis (while of course, taking into consideration the suggested limitations and recommendations to these techniques). For example those techniques that identified breakdowns as illustrated in section 9.1.3, using the "think-aloud" (or co-operative evaluation) in a task-based usability evaluation study, observation and post-study debriefing sessions as well as, the questionnaire to capture the framework of experience as mentioned in section 9.3.2.2. However, there are many limitations to usability evaluation methods and approaches to evaluate IMEs, some of which have been echoed in the VR community and which have been identified in this section and are listed table 9.2. Therefore in order to address the limitations of usability methods, provide a structure in which to reason about experience, concepts of staying there and the invisible style (transparency and continuity) in one complete framework, the hierarchical activity-based scenario approach (HABS) was developed, as discussed in the next section.

## 9.3 HABS, three Vs framework of experience and guidelines to analyse IMEs for users staying there: concepts, models and tools

The previous sections have outlined the proposed concept of staying there for users to continue to receive experience and, through argument, reference to relevant literature and from the results of studies carried out in this thesis, outlined the limitations of traditional usability evaluation methods and approaches when applied to IMEs to address both usability and user experience. To address these, concepts from activity theory were extended and fused with those from film and HCI to formulate the hierarchical activity-based scenario (HABS) approach. Through the concept of staying there (invisible style: transparency of equipment and continuity of content), HABS links concepts, models and tools (developed in this thesis) in a single framework and provides ways to reason about usability and user experience. Of significant importance to this thesis is the three Vs framework of experience and a questionnaire to capture the three Vs. These tools provide a way to operationalise experience. As discussed in this section, the key advantages of using the HABS approach and the three Vs framework of experience questionnaire are that they provide ways to:

- encapsulate concepts of staying there through an invisible style: transparency of equipment and continuity of content
- trace and model linear and non-linear scenarios during an encounter to the level of detail required by the evaluator
- reason about the success of scenarios
- reason about user experience from performing scenarios within a mediated environment
- reason about breakdown in interaction and illusion
- generalise to a range of IME configurations and applications

As demonstrated in studies in chapter eight (8.2), additional advantages of using HABS and the questionnaire are that they can be used in users' natural environment, can be carried out using observation during an encounter and questionnaire following an encounter, and so disrupt as little as possible in the user's environment and do not interrupt users during a mediated experience. Guidelines/criteria are described in section 9.3.4 that were developed to provide a shorthand way of encapsulating HABS and activity theory concepts to guide evaluators in the capture of negative characteristics (i.e. breakdown in interaction and illusion) that are violations to an invisible style and staying there. It is anticipated that guidelines/criteria can be used with traditional usability methods and approaches as shown using the "think-aloud" technique with a HMD-based VR study in chapter six (6.6.2). Furthermore, HABS/activity theory and the guidelines/criteria were incorporated in the three Vs questionnaire. Limitations, recommendations and future research directions to inform analysis and design of IMEs are discussed in section 9.4. Finally, section 9.5 provides a table that synthesises concepts, models and tools adopted, adapted and developed in this thesis. The following research questions which studies in chapter eight attempted to answer are addressed in this section:

1. to what extent is experience within the broad categorisations of the developed framework evoked in users, and overall how effective is the questionnaire at capturing user experience in interactive mediated environments?
2. what assumptions can be drawn about the extent to which inaccurate or deficient experience potentially breaks or shifts users' focus of attention from the mediated to the real world?
3. do users' self-reported disruptions correspond with: those observed by the evaluator, the experience data from the questionnaire, or suggest breaks or shifts in focus of attention from the mediated to the real world? See also: section 9.1.3.
4. what conclusions can be drawn about the effectiveness of the matrices to capture user's vicarious experience?
5. are there any correlations between components/items of the three Vs questionnaire?
6. did the hierarchical model of interaction and the extension of the notion of functional organs provide an appropriate and effective arena in which to reason about the design of interactive mediated environments and their potential to provide experience?

### 9.3.1 Extended concepts of activity theory to reason about staying there

This section discusses firstly, concepts of activity theory that provide the foundation for studying human practices in a single hierarchical framework. Activity theory has long informed research in HCI and much of this work has been cited herein (see: chapters four and six). Its adoption has been attributed to its usefulness as "a powerful and clarifying descriptive tool" (Nardi 1996b p. 7), its suitability "for studying different forms of human practices" (Kuutti 1996 p. 25), coupled with its capacity to integrate "multilevel perspectives on human activities within a single conceptual framework" (Kaptelinin 1996a p. 61). Next, it discusses the extension of activity theory to IMEs to formulate the HABS approach in which to reason about: staying there through an invisible style (transparency of equipment and continuity of content), breakdown in illusion, context of use and fulfilled, appropriate and/or stimulating scenarios, encounters and experience, how HABS is used in this thesis and how it can generalise to a range of IMEs irrespective of genre.

**9.3.1.1 Hierarchical framework of activity theory: activity, actions, operations**

As illustrated in figure 9.1, central to activity theory is Leont'ev's (1981) hierarchical framework of activity composed of: *activity, actions* and *operations* and characterized respectively by *objective, goals and conditions*, as discussed below. It must be emphasised that the hierarchical structure is not static but dynamic or continuous with shifts between activity, actions and operations determined by situations and circumstances of the mediated scenario. The *activity* is directed towards achieving an *objective* as denoted by "a". The objective is a process characterizing the activity as a whole. As discussed further in section 9.3.1.2.1, objective is closely related to motive and while both have to be considered in the analysis of "activity proper" (Leont'ev 1981 pp. 399-400), Marsh (2003a) identifies (see: chapter 6.7.3) that little, if indeed any work in HCI deals with these separately. The relationship between activity, objective and motive provides ways to consider experience that comes from performing scenarios with IMEs and a structure in which to reason about their success (see: section 9.3.1.2.1).

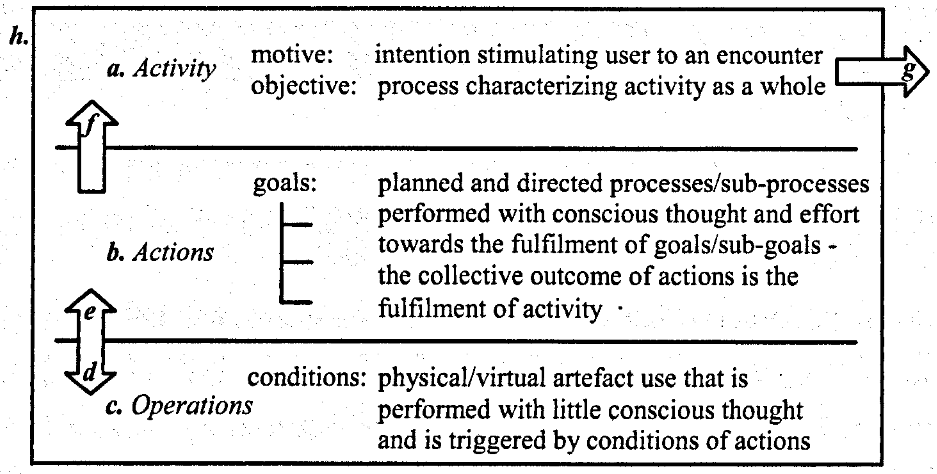


**Figure 9.1 HABS: hierarchical activity-based scenario**

The activity is made up of a combination of *actions* as denoted by "b" in figure 9.1. "Activity is what gives meaning to our actions" (Bannon and Bødker 1991 p. 242). Actions are processes performed with conscious thought and effort, and are planned and directed towards achieving a *goal*. Nardi (1996b) states that actions can be considered similar to what the HCI literature refers to as tasks. Actions may be made up of sub-actions directed towards sub-goals. The collective outcome of processes is the activity's objective. Each sub-action/goal has to be fulfilled in order to fulfil the higher-level action. As discussed in chapter 6.7.2, this provides a framework in which to model and trace a "chain" of actions determined by situations and circumstances during an encounter that describe a scenario. As discussed in section 9.3.2.1, because interaction in mediated environments is autonomous (i.e. constrained by technological, artistic and scenario aspects), users are able to choose where to look and move and hence, the structure of a scenario may be non-linear as well as linear.

Actions are performed by a combination of *operations*. Operations are processes performed with little conscious thought or effort in the use of artefacts (i.e. physical and virtual) triggered by conditions of actions as denoted by "c" in figure 9.1. The early phases of learning to use an artefact will have been performed with deliberate and conscious attention. At this point they are actions. When they become well practiced and experienced, actions become routine. That is, they do not need to be planned and at such a point are performed with little conscious thought or effort (i.e. actions become operations) as represented by the downward pointing vertical arrow "d" in figure 9.1. This provides a way to reason about the *mastery of artefacts/tools* and *transparency*. Conversely, operations become actions when something breaks down, impedes execution, or is associated with user learning difficulties (i.e. novice or unfamiliarity with interaction or interface) as represented by the upward pointing lower vertical arrow "e" in figure 9.1. Following the work of Bødker (1996) and Winograd and Flores (1986) this provided a way to reason about "focus shifts" and "breakdown" and was referred to in this thesis as *breakdown in interaction.* Disruptions/breakdown may also be the cause of shifting user's focus of attention from the mediated environment to the real world and this was referred to in this thesis as *breakdown in illusion* as denoted by the horizontal arrow "g".

### 9.3.1.2 Characterizing "activity proper" to reason about scenarios and appropriate and stimulating experience with IMEs

This section discusses how the adoption and extension of concepts from activity theory formulates a framework for the analysis of *"activity proper"* Leont'ev (1981 pp. 399-400) in IMEs. The advantages of this are that it provides a way to reason about a user's intention and the fulfilment of intention by considering what stimulates a user to an encounter with an IME and drives a user to fulfil an objective.

Furthermore, stimulating encounters may create new motives. Either or both these may encourage users in *staying there.* In activity theory terms (Leont'ev 1981), these are considered through firstly, objective outcome coinciding with motive (section 9.3.1.2.1) and secondly, stimulating experience as denoted by the vertical arrow "f" and discussed further below (section 9.3.1.2.2). This in turn provides a way to reason about the success of scenarios, experience that users get from performing scenarios in IMEs and an approach to overcome limitations of traditional usability evaluation methods. The difficulties in trying to elicit objectives and motives from users are discussed in section 9.4.3.

**9.3.1.2.1 Objective outcome coincides with motive**

Objective is closely related to *motive*. The motive stimulates a user to an encounter or to continue an encounter in an IME. Both the objective and motive have to be considered in the analysis of activity (Leont'ev's 1981), the smallest meaningful unit of analysis in activity theory (Leont'ev 1981; Kuutti 1996).

If the outcome of the objective does not coincide with the motive it is not an activity (Leont'ev 1981), it is an action that is part of another activity. On the other hand, if the objective outcome coincides with the motive then in the words of Leont'ev (1981 pp. 399-400) it is "activity proper". When the objective is fulfilled the activity ends. Marsh (2003a) identifies that interestingly (see: chapter 6.7.3), it appears that little, if indeed any work in HCI deals with these separately, either suggesting analysis of "object or motive" (Kaptelinin, Nardi and Macauley 1999), linking them together as illustrated through "objectified motives" (Christiansen 1996 p. 181) or not dealing with motive at all. This is a very important concept that provides the basis to consider "activity proper" (Leont'ev 1981 pp. 399-400).

In activity theory, an activity without motive does not exist (Leont'ev 1981). For example, a user's motive for using an IME may be, for example, for "some special need", interest, "to understand", "to comprehend" (p. 36), to feel emotions, for fun, enjoyment, or pleasure. If the objective outcome of performing processes of an activity with IMEs is the inducement of appropriate (and/or stimulating: see below) experience, the objective outcome will coincide with the motive that stimulated the user to an encounter. Consequently, it has been argued in this thesis that users' attention is maintained in pursuing their objective outcomes (i.e. continue the experience e.g. stimulating computer game) and/or an encounter until they have fulfilled the intention that drove them to the encounter in the first place. Either way, the encounter is successful. Conversely, if the objective outcome does not provide appropriate (and/or stimulating: see below) experience because it doesn't match up or deliver on expectations or purpose, or it is dull, boring, uninteresting, then it does not coincide with motive. This may potentially not hold a user's attention and shift their focus from the mediated environment to the real world. That is, a *breakdown in illusion* as denoted by the horizontal arrow "g".

#### 9.3.1.2.2 Stimulating experience: doing it because we want to

Extending concepts from activity theory, this thesis developed a way to reason about actions/goals that are so stimulating that they become new motives and drive encounters with IMEs. Borrowing from Leont'ev (1981), this thesis argued that this arises when an action is so stimulating that it drives itself and transforms into an activity. This transformation takes place when "an action's result [outcome] being more significant…than the motive that actually induces it" (Leont'ev 1981 p. 403). Hence, it can be postulated that if actions performed within mediated environments are stimulating enough, then users do it because they want to and so transforms into "activity proper" as illustrated by the upper arrow "f" in figure 9.1. This new activity then becomes the smallest meaningful unit of analysis (Leont'ev 1981). To provide a way to reason about encounters that are stimulating for users, the three Vs framework of experience and questionnaire to capture the three Vs were developed as discussed in section 9.3.2.2.

### 9.3.2 Structuring scenarios and reasoning about experience

This section discusses how this thesis has adopted and extended concepts from activity theory to IMEs in order to consider activities/scenarios and the user experience that comes from performing activities/scenarios with IMEs and a structure in which to:

i. structure *scenarios* through the hierarchical activity-based scenario approach (see: figure 9.1 and section 9.3.2.1) as well as reason about their success (fulfilment of purpose, goal or objective of the scenario) through firstly, objective outcome coinciding with motive (9.3.1.2.1) and secondly, stimulating actions that transform into activities (as discussed in section 9.3.1.2.2).

ii. reason about *experience* that is induced/evoked in, or witnessed by users from performing scenarios/activities in IMEs (see: section 9.3.2.2) through firstly, objective outcome coinciding with motive (section 9.3.1.2.1) and secondly stimulating actions that transform into activities (as discussed in section 9.3.1.2.2).

**9.3.2.1 Scenarios**

It can be argued that without a purpose a user's interest for interaction in an IME is limited. So, users have to have, or develop during an encounter, a reason, purpose, goal or objective for interacting with an IME. The steps/actions taken to reach a goal or objective and the fulfilment of this goal or objective provide users with experience. In addition, it should be emphasised that experience not only comes from users performing actions, but their environment, setting and other people also provide experience.

Chapter six (6.7.1) argued that a good way to describe steps/actions in interactive mediated environments is through stories or scenarios. A scenario-based approach provides a way to model and trace user's interactions with IMEs to inform analysis. In turn this provides ways to inform design of IMEs as discussed further in section 9.4.4. Describing scenarios in this way provides a structure in which to draw a closer analogy between scenarios of applications of interactive mediated environments and that of a scenario or script of a film or play. A shift towards the representation of virtual environment applications in a scenario/narrative-like structure has been proposed in analogy to film by Laurel Strickland, and Tow (1994), Pausch, Snoddy, Taylor, Watson and Haseltine (1996) and postulated in the progression of virtual reality development in chapter five (figure 5.6) and chapter seven (figure7.2).

From work in HCI, Carroll (2000 pp. 46-47) emphasises the close similarities between scenario/narrative-like structures and scripts of a film or play saying, "scenarios are stories – stories about people and their activities", "presuppose setting", "include agents or actor" and "have a plot; they include sequences of actions and events, things that actors do, things that happen to them, changes in circumstances of the setting and so forth". "A set of interaction scenarios makes the use explicit".

While scenarios provide a flexible way to describe activities (see: chapter 6.7.2) concepts from activity theory were extended to form the hierarchical activity-based scenario approach in interactive mediated environments as illustrated in figure 9.1 (see also examples listed below), to provide a structure that can be considered as "a standard language" (Kuutti 1995 p. 33) in which to depict activities (i.e. from low-level physical/virtual operations through goal-directed actions to the activity itself) characterised by their objectives and motives (see: 9.3.1.2.1).

Scenarios may consist of one or more activities with each activity being fulfilled by a "chain" of actions and in turn, actions are accomplished by a "repertoire" of operations. With just one activity, the main body of the scenario is described by actions. With more than one activity, the activity itself also becomes part of the scenario as illustrated in "a day in the life" scenario in figure 6.15a in chapter six (6.7.3.1). That is, the amalgamation of scenarios and hierarchical framework of activity provides on one level, a means to formally structure activities according to objective and motive while on another, providing the flexibility to describe human practice with and within IMEs from a single activity (figure 9.1) to an array of activities with many objectives and motives (as described and illustrated in chapter 6.7.3.1). As mentioned, because of this flexibility an activity-based scenario approach can be used to describe, model and trace linear and as well as non-linear narrative structures as discussed in chapter six (6.7.3.1).

A key advantage arising from their flexibility is their potential to describe a plethora of genres (e.g. learning and training, entertainment, psychotherapy-related, shopping, etc.) in a narrative or story-like structure to the level of detail required by the evaluator/evaluation. For example: from simple high-level overviews categorizing the range of potential actions as in the virtual library (chapter 4.2 and illustrated in figure 6.11) and the point-and-shoot game (chapter 8.2.1 and depicted in figure 8.1), through depictions with strongly defined actions/tasks (see more on this below) as in the EISCAT HMD VR-based training system (chapter 6.7.3 and illustrated in figures 6.14), to more elaborate descriptions as with the role-playing game (chapter 8.2.2 and illustrated in figure 8.6). As discussed in section 9.3.1.2.1, it is possible to assess the success of a user's encounter by reasoning about whether the objective outcome of performing a scenario coincides with the motive that stimulated a user to an IME. For example: in the virtual library application this would mean reasoning about how well a users' objective outcome of the scenario (e.g. to find an article, reference or poem in a book) coincides with their motive (e.g. education, information, pleasure).

However, even if the objective outcome of performing a scenario does not coincide with motive, it does not necessarily mean that an encounter with an IME has been unsuccessful. An interesting or stimulating scenario will encourage users in *staying there.* That is, firstly, if an action/task becomes more stimulating than the objective then it transforms into a new motive driving the game (i.e. action to activity: arrow "f" in figure 9.1). Secondly, if the experience induced/evoked in, or witnessed by users from performing scenarios is stimulating enough that it drives the game along. This is explored further in section 9.3.1.2.2. For example, in the role-playing game the objective given to users was to search for Granny. This drove the game along (together with other narrated clues and plot-points of the game). However, Granny (who had a voice only part and was never seen by the users) was actually the Witch incognito. Hence, the outcome of the objective of the scenario (to find Granny) could never be fulfilled and so could never coincide motive.

A key advantage to using an activity-based scenario approach is that an evaluator is able to model and trace scenarios on many levels either zooming-in to focus on the detail (i.e. to operations) of a scenario or zooming-out to a more holistic perspective (i.e. to activity). The level of detail or degree of focus/magnification for analysis of a scenario (that is required to be modelled/traced) should correspond to the accuracy required by the evaluator/evaluation. For example, if an encounter is running smoothly with users interacting, doing what they want to do (within constraints of the IME), without disruption and receiving appropriate and/or stimulating experience then the evaluation may not be required to zoom-in and focus on the detail. On the other hand, if there are any disruptions (observed by an evaluator or impede interaction) then the evaluator will want to identify the cause and circumstances surrounding disruption by zooming-in on the detail or zooming-out to an overview or more holistic perspective of the activity.

The close connection between scenarios and the experience users get from performing them is expressed in the words of many HCI researchers. For example to reiterate from chapter six (6.7.1), scenarios provide a means of "embodying and communicating user experience" (Nardi 1995 p. 396), offer "a rich view of...experiences of users" (Rosson and Carroll 1995 p. 268) and as suggested by (Nardi 1995 p. 398; see also: Kuutti 1995), "will undoubtedly remain a part of our design repertoire as we push forward toward more theoretical means of predicting and explaining user experience". The framework of experience (three Vs) and questionnaire to capture experience are discussed further in section 9.3.2.2.

Furthermore, with reference to the EISCAT study, this thesis recommended a way to move from task to an activity-based scenario approach by imparting an objective to general users employed in the study (who were not typical end users i.e. scientists) and so providing a means to assess objective outcome coinciding with motive as discussed in chapter six (6.7.3).

**9.3.2.2 Three Vs framework of experience: voyeuristic, visceral and vicarious**

This section discusses the framework of experience (three Vs: voyeuristic, visceral and vicarious) and questionnaire that were developed in this thesis to capture experience induced/evoked or witnessed by users interacting in scenarios in IMEs. Thus contributing towards overcoming limitations of traditional usability methods and approaches to capture and reason about experience. Limitations to a questionnaire-based approach to capture the three Vs framework of experience in unfolding scenarios of mediated environments are discussed in section 9.4.3. Section 9.4.4 suggests future research directions towards formulating a richer understanding of the constituents of the voyeuristic, visceral and vicarious to inform analysis and design of scenarios and experience in mediated environments.

This thesis has argued that one of the main goals of IMEs is to provide experience for users. If experience from an encounter is appropriate and/or stimulating then this can encourage users in staying there, hence an encounter can be judged to be successful. Conversely, if experience is inappropriate, un-stimulating, dull, boring, etc. then it may not hold user's interest and shift or break their focus of attention. Extending concepts from activity theory to IMEs provided ways to reason about experience through objective outcome coinciding with motive and stimulating encounters as discussed in section 9.3.1.2.1 and 9.3.1.2.2 respectively.

As discussed respectively in sections 9.3.1.2.1 and 9.3.1.2.2, the extension of concepts from activity theory to IMEs (i.e. HABS) provided ways to reason about whether an encounter provides appropriate and/or stimulating experience through firstly, objective outcome coinciding with the motive that stimulates a user to an IME and secondly, encounters so stimulating that they drive interaction. This provides a way to reason about a user's encounter with an IME through experience within the structure of the HABS framework. However, a way to capture user experience was required. This was achieved through the development of a framework of experience and questionnaire.

The purpose of the questionnaire was threefold: first, to capture user's experience from an encounter within the three Vs framework (as shown in chapters 8.2.1.2 and 8.2.2.2), second, to provide indications of and reason about potential breaks to a user's encounter through no experience, reduced or inappropriate experience, and third, informed from HABS/activity theory the questionnaire also incorporated questions to identify interruptions to their focus of attention during an encounter: internal (equipment or content), external (to the IME system) or subjective (e.g. uninterested or attention wanders) so indicating a break in experience during an encounter (for examples see: section 9.1.3).

For copies of the questionnaires that were used in studies in chapter eight with young adults and teenagers (i.e. "point-and-shoot game") and with children (i.e. role-playing game) refer to Appendix IV and V respectively. The results from the questionnaires used in these two studies showed that experience within the three Vs framework is induced/evoked in, and witnessed by users (refer to: chapters 8.2.1.2 and 8.2.2.2). This provided what could be described as an experience profile for all users as well as for the IME application. Therefore, the questionnaire provided a way to capture the three Vs and together with concepts from HABS assess and reason about appropriate and/or stimulating experience. This is achieved by drawing a comparison between users' experience captured through the three Vs questionnaire and the experience the IME application is designed to induce/evoke (i.e. its purpose, requirements). The evaluator has then to reason about the degree to which experiences from interaction (i.e. objective outcome) are appropriate and/or stimulating (e.g. fitting purpose, requirements, motivating, inspiring or interesting, etc.). The degree to which an IME application provides experiences for which it was designed provides a way to reason about its success. Furthermore, inappropriate, low or no experience may suggest an unsuccessful encounter and potentially point to deficiencies in the IME application's design. As argued, this can impact on a user's focus of attention and potentially break or shift their attention from interacting in the mediated environment.

Questionnaire responses also provided a way to reason about user's behaviour in context and whether it adhered to social and cultural constraints and behaviour patterns. For example as mentioned previously in section 9.1.2.2.1, users were observed in studies in chapter eight (8.3) to adhere to social and cultural behavioural patterns that were appropriate to the environment/game (e.g. medieval castle and "first-person shooter" game) and questionnaire responses and attitudes reflected this. So if a user behaves appropriately within constraints determined by context then it has continuity and if not, can be considered as having discontinuity. Another way in which the experience framework can be used comes with an evaluator's familiarity with the three Vs framework and so is able to identify design features of a mediated environment, scenario events and virtual characters that will most likely induce/evoke specific experience in users. The simplicity, portability and unobtrusiveness of administering the questionnaire allows users to experience a mediated encounter in its entirety and in their natural environment (without having to provide "think-aloud" comments or to respond to an evaluator's inquiries) as demonstrated in studies carried out in chapter eight.

The three Vs do not claim to be an all-encompassing method to reason about every kind of user experience from every type, style and genre of mediated environment application. However, they provide a broad framework that allows us to consider a range of experiences. For example, in contrast to the two games used in studies in chapter eight that included interaction with other characters and were designed to provide a range of experiences for users (as captured through the questionnaire), the study of the EISCAT HMD VR training system in chapter three (3.2) had no characters and wasn't designed to induce/evoke experience beyond its training purposes. So, within the three Vs framework many items/questions of the voyeuristic would make sense within the context of the EISCAT VR training system, while many items/questions of the visceral (because of the lack of thrills from movement beyond walking around a laboratory, etc.) and vicarious (because no other characters existed) would not make sense and so ratings would be negligible.

This doesn't imply that the three Vs are ineffective for use with training systems, but EISCAT doesn't provide these experiences because it was not designed to do so. In contrast, consider for example an IME fire training application that may have a carefully constructed and crafted scenario that induces/evokes powerful experiences in users (for example, is atmospheric, has shocking and unexpected images and scenario) and so through interacting in this scenario/environment provoke a range of experiences. Furthermore, even if the objective outcome does not coincide with motive through inappropriate or un-stimulating experience, it is still possible to reason about the success of an IME application through scenarios as discussed in section 9.3.2.1. Finally, while the questionnaire contained voyeuristic items relating to "space", they do not provide the degree of accuracy necessary to assess participants' spatial awareness of the EISCAT mediated environment and so more direct methods are required as shown in chapter three (plan view drawings and pointing to unseen targets).

Since the three Vs framework of experience was proposed in Marsh and Wright (2000b) and Marsh, Wright and Smith (2001), it has received considerable attention in the HCI community as a tool to provide a language of experience and to give leverage to the analysis and design of user/participant experience of products, technology and media (e.g. Norman 2004; McCarthy and Wright 2004). However, the work contained in this thesis aimed to hold true to Boorstin's (1995) analysis from a filmmaking perspective to inform analysis and design of time-based scenarios and experience of IMEs (Marsh 2003b). Section 9.4.4 suggests future research directions for this work.

**9.3.3 The role that functional organs play in informing analysis of IMEs**

This section will discuss the contribution that functional organs made in informing analysis of IMEs in this thesis. Functional organs are the mechanisms underlying tool mediation in activity theory, a notion similar to transparency in HCI. On first sight, they can be considered to be much the same, or at least, "no less relevant" (Kaptelinin 1996a p. 51). However, functional organs not only encapsulate ideas of artefacts that following mastery disappear from the main focus of our attention per se, but because of the unity of internal (i.e. mental) and external (i.e. physical and perhaps virtual) in activity theory (e.g. Nardi 1996c; Zinchenko 1996) as opposed to a Cartesian perspective (where internal and external are considered separately), artefacts are experienced as a property of an individual. Building on Kaptelinin's (1996a) work on functional organs and Bødker's (1989; 1991, 1996) models of activity provided ways to reason about an invisible style for users in staying there interacting with IMEs. While this provided what may be considered a more descriptive role to inform the development of concepts and models for analysis of users engaged in activities in IMEs, to get to a point where functional organs play a more direct role beyond the informing and descriptive requires further work as discussed in section 9.4.2. In this thesis functional organs were used in the analysis of IMEs in three main ways:

i. to reason about the "link" between a user and a mediated environment (see: section 9.3.3.1)

ii. to identify and reason about context of use through "link" to, and objective in, a mediated environment (see: section 9.3.3.2)

iii. contributed to the formation of a model to reason about "staying there": maintaining interaction towards the objective of activity performed in a mediated environment and formation of interactive device/tool/artefact into functional organ (see: section 9.3.3.3)

These worked *towards* providing ways to reason about IMEs as functional organs that enhance natural human abilities to work, play, learn, shop, communicate, create and be entertained.

#### 9.3.3.1 Reason about the "link" between a user and a mediated environment

The mechanisms underlying tool mediation or the "link" between humans, tools/artefacts and their environment in activity theory are encapsulated in the concept of functional organs as introduced in chapter four (and continued in six, seven and used to inform studies in chapter eight). "Functional organs are functionally integrated goal-oriented configurations of internal [mental] and external [physical] resources" (Kaptelinin 1996a p. 50). This means that "external tools integrated into functional organs are experienced as a property of the individual" (p. 51) and following mastery "support and complement natural human abilities in building up a more efficient system that can lead to higher accomplishments" (p. 50). As argued by Kaptelinin (1996a p.51), these issues are "no less relevant" to the notions of transparency in HCI. For work with computers to be effective, many writers in the HCI community advocate the seamless or transparent nature of tools, focusing on the task at hand (goal/objective) rather than on interactive devices to perform/fulfil it. See discussions in 9.1.2.1. Nardi (1996b p. 11) suggests that transparency is used in HCI "to describe a good user interface…one that is supportive and unobtrusive, but which the user need pay little, if any, attention to". As discussed previously, in this thesis, transparency was used to refer to "supportive and unobtrusive" "equipment" (i.e. enabling technology of an IME system) that once mastered disappears from the main focus of a user's attention; or in Norman's (1998) words, becoming "invisible". This is in contrast to the mediated environment or content that during an encounter remains "visible" to the user and considered through the notion of continuity.

However, functional organs provided an informing role and in turn reasoning and descriptive powers to analyse IMEs. This provided a way to reason about the "link" between a user in the real world and the virtual world. Building on the work of Kaptelinin (1996a) it was argued that the formation and integration of physical and virtual artefacts into functional organs sees that it is experienced as a property of the user acting directly within the mediated environment as illustrated schematically in figure 9.2.

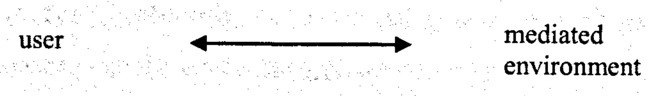


**Figure 9.2 Link: interacting directly within a mediated environment through the formation of functional organs**

Hence, interactive devices to IMEs integrated into functional organs provide a way to reason about the "link" between user's interacting within an IME (in normal transparent use). Conversely, a user reflects on the operation of artefact/tool/device (physical/virtual) if it is not responding correctly, has broken down, interrupts or impedes interaction or presents a learning problem, and so compromises the integration and formation of a "link" between user and mediated environment. This is represented in figure 9.1 by the upward pointing vertical arrow (i.e. "e" - operations to actions). As mentioned, this is referred to herein as *breakdown in interaction.* Functional organs and transparency, and breakdown and shifts in focus (actions to operations, operations to actions) provide ways to consider all configurations of IMEs irrespective of the underlying complexity of supporting and enabling technology/equipment.

**9.3.3.2 Identify and reason about context of use: "link" to, and objective in, a mediated environment**

This thesis extended Bødker's (1989, 1991, 1996) models of activities in order to identify the boundary between the real and mediated environment. This also provided a way to categorize IMEs through their context of use. Identifying where the objective (that categorizes an activity process as a whole) is directed, informs a way to reason about and identify the context of use. Of particular interest to this thesis were IMEs in which the context of use lies *within* (and to a lesser extent *through* e.g. interacting in a remote or hazardous environment – space, deep-sea diving – see chapter 6.2.2) a mediated environment as shown in figure 9.3. This illustrates the objective of an activity to be within the mediated environment performed through an artefact (i.e. interactive) by a user (or many individual users interacting with their own system in a shared mediated environment) without any contribution to, or from sources or resources external to it (i.e. from the real world). Hence, the context of use is the mediated environment. However, exceptions to this were identified in studies with multi-users who interacted in a shared environment and in a shared physical location. This is further discussed later in this chapter and recommendations made for further work (see: section 9.4.1). The interactive tool/artefact as represented by an arrow is the "link" (as described above) between the user and the mediated environment.

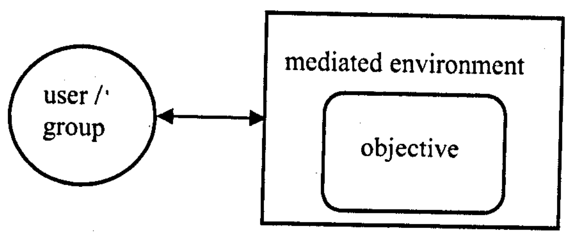


**Figure 9.3 Within a mediated environment: objective present within the mediated environment**

### 9.3.3.3 Staying there: objective in mediated environment and "link" between real and virtual

Building on, and fusing Bødker's (1989; 1991, 1996) models of activity and Kaptelinin's (1996a) work on functional organs, this thesis developed a model to represent users maintaining their interaction in a mediated environment and staying there, continuing to receive mediated experience. For the successful formation of an interactive mediated illusion, it was argued that two things were necessary: first, the formation and integration of interactive devices into functional organs (i.e. transparent interaction providing a "link" between real and virtual); second, the objective of processes of activities is within the mediated environment (see: figure 9.3). In reference to figure 9.4, the consequence of these two situations is that the user performs processes (i.e. actions) of an activity directed towards an objective, and through the formation and integration of interactive devices into functional organs this appears to the user to be unmediated by technology. The amalgamation of underlying individual enabling components of an IME to form one complete system provides a way to consider an IME through a holistic perspective. This works *towards* providing ways to reason about interactive mediated environments as functional organs that enhance natural human abilities to work, play, learn, shop, communicate, create and be entertained, as discussed in future work (9.4.2).

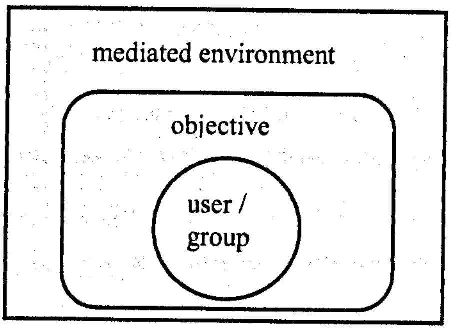


**Figure 9.4 Staying there: maintaining interactive mediated illusion - objective present within mediated environment and formation of functional organs**

For the continuation of user's mediated experience, a user must maintain attention in the mediated environment. Conversely, shifts in focus of attention from the mediated to the real world will potentially disrupt or break the "link" (i.e. formation of functional organs). Likewise, disruptions or breaks in interaction (i.e. to the "link") may potentially break the illusion and mediated experience.

The integration of these concepts is achieved by the addition of a rectangle to the hierarchical model of activity in figure 9.1 to represent the context of use (i.e. "h", the mediated environment). Thus, providing concepts and models in which to reason about: negative mediated environment use (identify potential problems in design through breakdown in interaction - i.e. upward pointing vertical arrow "e" - and shifts in attention from the virtual to the real - i.e. horizontal arrow "g") and positive mediated environment use (maintaining the situation depicted in figure 9.4 through objective and functional organ).

The interest in thesis has been in interactive mediated environments where activities take place within the three-dimensional environment or space. This three-dimensional environment or space provides opportunities for activities and this is the context of use. A shift in focus of attention from activities performed in the virtual world (i.e. context of use) to the real world (denoted in figure 9.1 by the horizontal arrow "g") potentially breaks the flow of activity and may compromise users ability in staying there (figure 9.5). This was referred to herein as *breakdown in illusion.*

### 9.3.4 Guidelines/criteria to inform traditional usability evaluation methods for staying there

This section discusses guidelines/criteria for the detection of *breakdown in interaction* and *breakdown in illusion* with IMEs. These guidelines/criteria as listed in table 9.4 are a shorthand of HABS and activity theory concepts, for use alongside HABS as well as with traditional usability evaluation methods and approaches for the evaluation of IMEs (e.g. as tested in empirical task-based studies of HMD-based VR using "think-aloud" techniques in chapter 6.6.2 and informing studies of desktop-based VEs in chapter 8.2). It is anticipated that the guidelines/criteria may also be used to inform analytical studies of IMEs, though this remains an area for further investigation.

**Table 9.4 Guidelines/criteria for the categorization of usability problems: breakdown in interaction and illusion**

| | break in interaction (remain in illusion) | | break in illusion |
|---|---|---|---|
| *internal* | a. continuity breaks in content: imagery, audio, etc. | *internal* | a. continuity breaks in content: imagery, audio, etc. |
| | b. equipmental breaks in IME mediating technologies | | b. equipmental breaks in IME mediating technologies |
| | | *external* | a. noise/distractions external to IME system |
| | | | b. awareness of activities external to mediated environment |
| | | *subjective* | a. lack of interest in interacting within the mediated environment |
| | | | b. attention wanders from mediated environment |

As identified in studies throughout this thesis (see: section 9.2 and table 9.2), through argument and as echoed in research on usability evaluation of virtual reality/environments (e.g. Kaur 1998; Gabbard, Hix and Swan 1999; Steed and Tromp 1998), limitations with commonly used traditional usability methods and approaches (e.g. empirical and analytical) have been identified. The dearth of appropriate guidelines/criteria meant a reliance on the evaluators' knowledge to capture usability and design problems. To work towards overcoming these limitations it was recommended that appropriate guidelines/criteria were needed to guide evaluators in usability studies of IMEs as discussed in section 9.2 and outlined in table 9.2.

Furthermore, as identified in the role-playing study in chapter eight, breakdowns/disruptions occurring while carrying out an experiential evaluation will disrupt users and most likely have an impact on study results. Therefore, concurring with Steed and Tromp (1998), to ensure the smooth running of an evaluation study and in an attempt to prevent the evaluator's attention from being disrupted (to fix problems), this thesis recommended that an expert/analytical evaluation be carried out to remove causes of disruption prior to going to the expense of conducting empirical experiential studies with users. However the lack of guidelines/criteria to guide evaluators in the identification/capture of potential problems of IME design in use (that will disrupt user's continued encounters) meant this was problematic. Indeed, in reference to section 9.2 and table 9.2, this was the main concern raised, and recommendation made, for the development of appropriate guidelines/criteria to inform traditional usability evaluation methods and approaches.

As argued in this thesis, breakdown in IMEs occurs on two levels. The first is a *breakdown in interaction.* A user may or may not be aware that a breakdown has occurred. In situations in which a user is unaware that a breakdown has occurred they will continue without concern, perhaps until the breakdown disrupts their interactions. On the other hand, situations in which a user is aware that a breakdown has occurred, while this may interrupt or impede their interaction, they may still remain attached in the mediated illusion, that is, staying there. The second type of breakdown occurs when a user's focus of attention shifts from the virtual to the real world. This is referred to as *breakdown in illusion.* This can be either momentary or can be so severe as to shift a user's allocation of attention momentarily or from the virtual to the real world totally (see examples in section 9.1.3). To aid in description, a schematic was developed to illustrate *breakdown in interaction and illusion* along a continuum of "engagement" (refer to: chapter six, figure 6.12). A user's focus of attention can be considered to lie somewhere along this continuum. At one extreme the user is engaged in the illusion of the mediated environment and remains staying there with little awareness or conscious thought for the world external to it (i.e. to the left, the mediated world) and at the other extreme following a disruption or breakdown, the user is aware of the world external to the mediated environment (i.e. to the right, the real world).

Breakdowns in interaction and illusion are identified along this continuum and effective interaction (i.e. the participant remains in the illusion) is identified as being that which is carried out to the left of breakdown in illusion. Although a user may be consciously aware of external activities (e.g. noise or the presence of others around them: see examples and discussions on this and about multiple strands of thought in section 9.1.3), their allocation of attention may be such that, they are able to remain sufficiently attached to the illusion created by the IME system and thus, able to interact effectively in the scenario within a mediated environment. Just how much attention users need to allocate to the illusion for effective interaction in the mediated world is an area for further research and is beyond the scope of this thesis.

The categorization of breakdowns in interaction and illusion was informed from analysis of results from a short study (chapter 5.1.4) to identify disruptions to film spectator's viewing experience. These were identified as: *internal* (e.g. discontinuity of content and awareness of mediating technology), *external* (e.g. awareness of anything external to an IME and supporting technology/equipment) and *subjective* (e.g. contemplation of something other than the IME or lack of interest in the genre). All categories were used for breakdown in illusion whereas only the internal category was used for breakdown in interaction because external and subjective would suggest a shift in focus of attention and hence a breakdown in illusion. As mentioned, these were as tested in empirical studies of HMD-based VR using the "think-aloud" technique in chapter six (for examples see: table 6.4) and desktop-based VEs in chapter eight. The guidelines/criteria are shown in table 9.4. While it has been shown in studies in this thesis (chapters six and eight) that the guidelines can be used to categorize and capture disruptions/breakdowns of desktop and HMD-based VR systems, it is anticipated that these can be used to identify problematic and disruptive features of design of a range of interactive mediated environment configurations. However, investigation of the appropriateness of the guidelines to all types of IME configurations is beyond the scope of this thesis.

Of these categories of breakdowns, some are difficult or impossible for the evaluator or IME designer to control. For example, in debriefing sessions in the study to reduce user disorientation in chapter five (5.1.4), many subjects reported noise external to the study laboratory environment (e.g. people walking close to the study laboratory, the sound of typing in the distance etc.). Additionally, designers and evaluators have no control over what a user is thinking while interacting in an IME (e.g. as mentioned in section 9.1.3: considering "homework" i.e. subjective). As argued in this thesis, one of the goals of an IME is to provide experience that makes users want to remain interacting in the mediated environment and encouraging them in staying there. While there can be little control over external (e.g. ambient noise/disruptions that are external to an IME) and some subjective breakdowns (i.e. contemplation of something other than the mediated environment), there can be considerably more control over the internal (i.e. IME configuration and content). As mentioned, this thesis has been primarily concerned with internal and some aspects of subjective (i.e.

IME design to maintain user's interest) and what we learn from internal (disruptive mediating technology and discontinuity of content e.g. scenario/experience) and subjective can inform redesign for staying there through an invisible style. The three Vs framework of experience and questionnaire was developed (see: section 9.3.2.2) to inform analysis of user experience of IME design in use and this can be used to complement the guidelines/criteria (table 9.4) to reason about users' *subjective* experience attitude, opinion and potential breakdowns.

Finally, the application of the criteria: "low" or "high" (developed in chapter 3.1 and following the work of Hackman and Biers 1992) could be used to distinguish between disruption/breakdown arising from novice, inexperienced users or users that are unfamiliar with an interactive device or system or application and from those arising from potential problems in design. Refer to chapter four (table 4.2) for examples showing breakdowns in interactions from the HMD study and categorized as either low-level problems (i.e. learning difficulties: opportunities for learning) or high-level problems (i.e. potential usability and design problems).

## 9.4 Limitations, recommendations and future research directions for analysis and design of IMEs

Throughout this section, limitations of the work contained in this thesis are identified, and recommendations and potential directions for future work proposed.

### 9.4.1 Enriching HABS through a social and cultural approach

This thesis argued that one approach to consider three-dimensional mediated environments is through (the situations and circumstances of) social and cultural depictions. While this is similar to an approach that has been argued for by Mantovani and Riva (1999) with respect to the concept of a sense of "presence" in mediated environments, this thesis has been concerned not with presence per se, but with user experience from participating in scenarios.

However, chapters four (4.4) and seven (7.1) argued that unlike the real world, the virtual can create imaginary and artificial worlds and so have the potential to be "individualistic" (i.e. single user environments) and "ahistorical" (i.e. without past) (Engeström 1999 p. 23). (It has been acknowledged herein that in time, an IME configuration, application or genre will become part of our history). Therefore, consideration of artefacts that are shaped by successive successful adaptations and that in turn effect activities in environments of this nature considered through a socio-cultural approach can be problematic. Nevertheless, it was argued in chapter seven (7.1) that any attempt to formulate methods to analyse the socio-cultural context of mediated environments would require a sustained research effort that was beyond the scope of this thesis. Therefore, an alternative approach was proposed to consider the idea of *constraints* informed from Norman's (1989, 1999) work linking constraints and affordances (borrowed from J. J. Gibson 1979) and Poortinga's (1992 p.10) definition of culture relating behaviour to constraints. Whereby, in response to interactions, the behaviour of the environment, objects and user/participant, and the induced/evoked user experience (voyeuristic, visceral, vicarious), are considered within the constraints governed by the scenes, settings, circumstances and scenario. So that, something or someone behaving appropriately within constraints determined by context is considered to have continuity and conversely, inappropriate behaviour is considered to have discontinuity.

While this provided some leverage to the analysis of IMEs, limitations of this approach became apparent in studies involving multiple participants in the same environment. For example, in studies in chapter eight, users were observed to break out of the illusion to talk and laugh with other users in the real world, look at colleagues' screen(s) (and in the "point-and-shoot" game, the "enemies" screens) despite being instructed not to do so, or considered to be "cheating" so giving an unfair advantage in the "point-and-shoot" game. While this unanticipated behaviour is a break in illusion and staying there and would seem to suggest a limitation to the model "within" the mediated environment (see: chapters 6.2.1, 9.3.3.2 and figure 9.4), the shifts in focus of attention from the virtual to the real were in many cases voluntary and not caused by the IME. Manninen (2001) reports similar observations in multiplayer games whereby players (in the same real world location) improve their "team-oriented tasks" by communicating with each other outside of the game to overcome limitations of a system.

Future work to inform analyses of IMEs in use in these situations (and also in classroom settings where incidentally, the future versions of the role-playing game are intended to be used) could explore the possibility of extending the context of use to incorporate social aspects in the real world where the IME resides, involving multi-participant mediated environments when users are in the same physical/real environment/location. In doing so, perhaps the concept of "staying there" would also shift to account for this shift in context of use.

Activity theory provides theoretical concepts for future work to move towards considering the social aspects of multi-participant IME use as well as three-dimensional environments by their social and cultural depictions. Moves in this direction could build upon Vygotsky's (1962) sociocultural studies and from the works of Yrjö Engeström and Michael Cole who have extended concepts of activity theory to a wider social and cultural audience, so demonstrating its evolving nature (Cole and Engeström 1993, Engeström 1987). For example, by adapting Engeström's (1987, 1999) expansion to the basic concepts of activity theory (i.e. a *subject* performs processes towards an *object/objective* mediated by a *tool*) to encapsulate the social and cultural aspects of human practice. To do this, he introduces three inter-related components to the basic model to represent activity, including: "social" (i.e. "community", environmental and cultural), "divisions of labour" (i.e. responsibilities and variations in jobs roles) and "rules" (i.e. regulations in which activities are carried out). Building on other work in HCI and CSCW that adopts this approach may provide some leverage to inform future work in this direction (e.g. Bødker 1996; Kuutti 1996; Turner, Turner and Horton 1999; Mwanza 2000).

A related aspect is the modelling of users' collective activities as briefly discussed in chapter six (6.7.3.1). Much of the work in this thesis was restricted to discussions about single activities (single users with single activities and multi-users with shared activities) as discussed in chapter six (6.7). Therefore, future work could address these limitations by shifting towards a sociocultural approach through concepts as described above will provide a way to inform analysis of a "web" and collective activities with IMEs.

### 9.4.2 Future work towards the integration of IMEs into functional organs

It has been argued that the notion of functional organs is very similar to that of transparency in HCI, which, on first sight, can be considered to be much the same or at least "no less relevant" (Kaptelinin 1996a p. 51). However as discussed in this thesis, functional organs go further. As well as encapsulating ideas of artefacts that once mastered disappear from the main focus of our attention, because of the unity of internal and external in activity theory (e.g. Nardi 1996c; Zinchenko 1996), as opposed to a Cartesian perspective (where internal and external are considered separately), artefacts are experienced as a property of an individual. Zinchenko (1996 pp. 295-296) elaborates this through the relationship between the cellist Mstislav Rostropovich and his instrument (see: section 4.1). He goes on to argue that artefacts appear not just to extend or amplify human capabilities per se, but also, "as a continuation of the human soul". While functional organs provided descriptive powers to inform models for reasoning about IME design in use that were used to inform studies carried out in this thesis (see: section 9.3.3), to reach a point where functional organs play a more direct role in the analysis of IMEs beyond the informing and descriptive requires further research.

Therefore future extensions of this work will require answers to a number of research questions. Typical research questions are for example: Can characteristics of IMEs be identified that are conducive for their transformation into functional organs? What is the level of experience of use required for IMEs to become integrated into functional organs? How do we consider that an IME in use has transformed into a functional organ? What are the conditions to continuously maintain a functional organ? What concepts or methods from activity theory, sociocultural studies or other disciplines can be used to provide leverage to these questions? Providing answers to such questions will take us closer towards providing ways to reason about, and design for, interactive mediated environments as functional organs to enhance natural human abilities to work, play, learn, shop, create, communicate and be entertained.

### 9.4.3 Limitations of the three Vs and questionnaire-based approach and directions for future work

Borrowing from film theory and Boorstin's (1995) appraisal of multi-faceted and varying time-based spectators' film viewing experience in response to an unfolding film scenario, this thesis has argued that experience induced/evoked in, and witnessed by participants during an encounter with an IME is likewise multi-faceted and changes in response to interactions performed within an unfolding mediated environment scenario. Adapting Boorstin's (1995) three categorizations of experience, the three Vs framework of experience: voyeuristic, visceral and vicarious, and questionnaire were developed (refer to Appendix IV and V) to capture participants' experience of an encounter with an IME. While this provided a way to capture a participant's multi-faceted experience within the three Vs framework, it was problematic because the post-study questionnaire could not deal with variations or changes in emotions and experience within an unfolding scenario of a mediated environment. For example, as identified in the "point-and-shoot" study in chapter eight, some users selected the neutral option to give throw-away answers by saying things like "don't know" without further explanation, or stated that the neutral option indicated they had experienced "both" the positive and its negative (i.e. opposite adjective/bipolar) during an encounter. In an attempt to overcome this, the neutral option was omitted from the questionnaire in the second study. The intention was to discourage users from giving throw-away answers and encourage them to say things like "both" and hence demonstrate the dynamic nature of experience and emotions during the unfolding story/environment of a mediated encounter. While in some cases users indicated "both", there are two main problems with this. Firstly, where this occurred and users had indicated such by saying for example, "a bit of both", the questionnaire and analysis did not address variations in ratings over time (i.e. in response to the unfolding of the scenario during an encounter). Secondly, omitting the neutral option may force users to choose either the positive or its negative giving an inaccurate indication of a users experience.

Chapters five (5.1.4) and seven (7.5) argued that a continuous assessment technique was required. However, it was argued that techniques from dials used in Gallop's "Opinion Polls" to assess spectators' attitudes of a film presentation (Bouzereau 1994), a sliding potentiometer (IJsselsteijn, Freeman, Avons, Davidoff, de Ridder, Hamberg 1997) or verbalizations (Slater and Steed 2000) to reflect participants' levels of, or "breaks" to a sense of presence respectively, to using a "think-aloud" verbal protocol are problematic because of the requirement of the user/participant to divide their attention between the mediated experience and the operation of the dial, slider, or keep in mind the verbalization, or the verbalising of experience itself respectively. Hence, the data collection methods (i.e. dial, slider, verbalization) may disrupt the actual thing that we are trying to measure (i.e. presence/experience). An advantage of the three Vs questionnaire combined with the HABS approach is that they do not interrupt the user and so are unobtrusive, and as shown in chapter eight, they allow studies to be carried out in users' natural environments rather than in the artificial environment of the laboratory. However as discussed above, using a questionnaire-based approach is neither concurrent nor continuous.

Therefore, future work should look to alternative schemes that are concurrent, continuous and do not require the user to perform any additional operations. For example, previous research has looked at facial analysis and physiological measures. However, Höök, Persson and Sjölinder (2000) report on the problematic use of a facial analysis technique to provide assessment of user experience of animated characters, because as Levenson and Ruef (1992) suggest, there is no one-to-one correspondence between facial expression and feelings/experience and so, what is felt internally (i.e. in the mind) may not necessarily be exteriorised through facial expressions. More accurate data collection techniques may be provided by objective physiological measures such as alpha brain waves, blood pressure, skin resistance/temperature and heart rate. Correlations between physiological data and events with an IME provide a means of assessing presence through for example, users' levels of fear (e.g. Dillon, Keogh, Freeman and Davidoff 2001; Meehan, Insko, Whitton and Brooks 2001). However, with all of the above examples it is difficult to imagine how the many components and variables of experience can be measured. Hence, the problem for future research is how these techniques may be adapted and extended or new techniques developed to capture more accurately the many different kinds of experience without disrupting, overloading or encumbering the user during an encounter with an IME.

Another limitation of the questionnaire is the non-equivalence of items. For example, users' low ratings for something like creative do not have as major an impact on the user as do feelings of nausea. A related and very important limitation is that the questionnaire provides respondents with a universal and limited set of items that may not necessary or ideally reflect adequately a user's experience within the three Vs framework. That is, according to George Kelly (1955), because we all have a different repertory of constructs, it may be more appropriate to let respondents choose their own. To this end, Kelly (1955) developed Personal Construct Psychology to overcome these limitations. As reported in chapter eight (8.3), this has already been applied in a study to capture children's experience of role-playing characters within a computer game. Constructs were elicited from the children by asking simple questions like "what words would you use to describe [insert character's name]" and then obtaining the opposite of the child's response. Using these as bipolars, children were asked to rate each character against each elicited construct while at the same time showing pictures of each character. This may go some way to overcoming children's difficulty of not understanding or misunderstanding some of the items or questions in the questionnaire. However, this was not reported in this thesis.

As mentioned, the limited set of items of the questionnaire imposes limitations that may not reflect adequately a user's experience. For example, only eight items were used in the matrix to capture the vicarious experience and these were selected (following pilot studies) in an attempt to address a broad range of characteristics and feelings: emotions, moods and traits. Furthermore, while the items of the vicarious matrix provided a varied response from users, without a focused and sustained research effort it is impossible to say how effective these items are. Indeed, perhaps a similar argument can be levelled at the voyeuristic and visceral items of the questionnaire. So while the questionnaire did capture varied responses from users within the broad range of the developed three Vs framework of experience, further research is required to explore further the three Vs and identify other sources that can inform it. For example, one potential source to inform the vicarious element of the three Vs framework of experience, may come from Ortony's (2001) work on "believable" characters and in particular, Ortony, Clore and Collins's (1988) framework of emotions to address limitations in the vicarious (i.e. empathy and emotions).

Finally, while the concepts of objective and motive from activity theory provide concepts in which to consider "activity proper" so in turn reason about scenario and experience, studies in chapter eight identified problems of obtaining a user's objective and motive. While a user's objective for interacting with an IME can be imparted to users during briefing sessions, it is left to the study evaluator to reason about a user's (or group's) motive. Future work should aim to increase precision in the analysis of IMEs in activity-based studies by identifying more accurate ways of capturing or determining user's motive. In addition, it is necessary to find more accurate ways beyond a post-study questionnaire to reason about actions that provide experience that is so stimulating that actions transform into activities.

### 9.4.4 Extension of concepts, models and tools to inform design

A valuable direction for future work is the extension of concepts, models and tools to inform design of IMEs. Building on the work herein, two main research paths are identified.

First, future research should work towards integrating more closely HABS and the three Vs framework in order to inform design of IME content and scenarios to induce or evoke appropriate and/or stimulating three Vs experience in users and encourage them in staying there. While chapter five argues that there is a link between the three Vs framework of experience and IME design and in studies chapter eight demonstrates this link, in order to inform the design process we need to identify more precise links between features of IME design and scenarios (e.g. settings, situations and virtual characterization, etc.) and the three Vs experience. As argued in chapter five, it is helpful here to look to film where the relationship between a film spectator's experience of settings, situations and characterization, etc. can be identified through either one or a combination of the voyeuristic, visceral and vicarious. Although limited to a thriller film genre, Boorstin's (1995 pp. 139-142) appraisal of Hitchcock's "Psycho" (1960) as described in chapter five (5.2.1) is a powerful example of the link between film's content and the three Vs experience. Similarly, using a questionnaire, chapter eight demonstrates that the three Vs experience are induced/evoked in users of IMEs so pointing to a link between aspects of IME design and the three Vs experiences (Marsh 2001, 2003b). However, as outlined in the previous section, limitations in using a questionnaire-based approach have been identified and so the process of linking three Vs experience to design should be supported by the development of a continuous three Vs assessment technique.

Next, in response to findings, a table linking design to three Vs user experience could be drawn up and used to subsequently inform three Vs design guidelines. From early phases of design, HABS would then provide a structure to plan and model scenarios using a repertoire of operations (largely dependent on IME configuration) determined by a chain of goal-based actions towards the fulfilment of an objective-based activity. Thus, the guidelines used in conjunction with HABS will inform the design of IME content and scenario to induce/evoke experience in users appropriate to the IME genre and the kinds of three Vs experience required. That is, considered from an engineering development life-cycle perspective, attempting to inform design of an IME so that it meets requirements. As outlined in chapter one, to assess whether design meets requirements it is necessary to evaluate design (using concepts, methods and tools developed in this thesis) and then use any subsequent shortcomings to inform redesign in an iterative manner.

While advocating that the design and development of IMEs should be placed in an engineering development lifecycle, future work should consider the importance of embracing a creative, artistic and craft-based approach as emphasised in chapter one. By injecting the creative and artistic into HABS and the three Vs design guidelines we should aim to create IMEs that are thrilling, emotive and stimulating, etc, and encourage users in staying there.

Extending the main themes of the thesis, the second interesting and potentially valuable direction for future work is to further explore ways to manipulate time and on-screen space in mediated environments. Similar to cinematography and editing techniques (e.g. cuts, fades, 180-degree rule, shot/reverse-shot, flashbacks, flash-forwards) from the invisible style of Hollywood filmmaking, this would work towards developing an invisible style of interactive mediated environments, where every effort is taken to preserve a sense of spatial and temporal continuity for users. Guidelines, techniques or idioms (e.g. phrase, vernacular or dialect) for IMEs should be developed and concurring with Pausch, Snoddy, Taylor, Watson and Haseltine (1998 p. 358), they would form a lexicon (i.e. vocabulary, glossary or common language) between IME developer and user, similar to the lexicon that exists between filmmakers and spectators. The motivation for this, as Laurel, Strickland, and Tow (1998 p. 188) suggest, is to lead to the formation of a language that supports the design of mediated environments of "increasing complexity and power", providing a way to shape character and story and enhance users' experience.

However, the transfer of techniques to manipulate time and space from film to mediated environments is difficult because of the interactive component of IMEs. That is, while film unfolds using many techniques to manipulate both time and space in a linear manner from beginning to end, mediated environments unfold in continuously animated space in real-time but in a non-linear manner in response to user interaction. So the timing and the type of technique to manipulate time and space in mediated environments should be, in part, determined by a user's interaction.

One approach described in chapter five and published in Marsh and Wright 2000a was to develop guidelines to assist in the positioning of design features in mediated environments to imply off-screen space to users, aiding them during navigation, reducing user disorientation and helping user's maintain continuity of mediated experience (Marsh and Smith 2001a; 2001b). Thus demonstrating the significant role that cinematography and editing techniques can play in the development of techniques/idioms in mediated environments. Further support for these guidelines comes from Baudisch and Rosenholtz (2003) who (having been informed by these guidelines) have developed an idiom they call HALO for visualising off-screen locations on the display screens of mobile navigation devices.

Future work should develop similar guidelines to inform the development of techniques to manipulate on-screen space and manipulate time in IMEs. These techniques should be natural, transparent or effortlessly understood by users, either immediately (as demonstrated with off-screen space guidelines mentioned above) or following repeated exposure. Otherwise this can cause difficulties for users. For example, techniques used to manipulate on-screen space from Laurel, Strickland, and Tow's (1998 p. 189) concept of the portal (represented by a spiral) and Pausch, Burnette, Brockway and Weiblen's (1995) "worlds in miniature" used to transport users between different locations, both report problems with user disorientation.

Chapter five further discusses difficulties associated with the manipulation of time in mediated environments and suggests the implementation of a number of ideas from television, film and literature (e.g. Transporter, Wonkavator, Time Machine) to manipulate time and space in mediated environments. Another direction and potential source to inform future work would be to investigate techniques and idioms to manipulate time and space (some informed from film) that are beginning to emerge in computer games, to see if they can be generalised to other interactive mediated environments.

**9.5 Thesis overview**

As discussed in this chapter, a number of concepts, models and tools have been adopted, adapted and developed in this thesis. In particular, two complementary approaches have been discussed that provide ways to consider transparency, continuity and experience: the hierarchical activity-based scenario approach (HABS: Marsh 2003a) and a questionnaire (Marsh 2001) to capture the three Vs framework of experience (i.e. voyeuristic, visceral, vicarious; Marsh 2003b). In reference to table 9.5, the first section consisting of three columns lists concepts that this thesis has argued are positive characteristics of a user's encounter with an IME: from left to right, these are *staying there* through an *invisible style* incorporating *transparency of equipment* and *continuity of content*, and *appropriate* and *stimulating experience*. The fourth column lists what this thesis has argued are negative characteristics of a user's encounter with an IME: *breakdown in illusion, breakdown in interaction, discontinuity* and *inappropriate or un-stimulating experience.* Column five shows how *HABS (providing model of user's interaction),* cross-referenced with figure 9.1, links the *concepts, models and tools* identified in the table. Column six lists the *tools* that were/can be used to complement HABS, or were informed from the HABS approach to analyse a user's encounter with an IME for staying there. Models and ideas informed from concepts from functional organs also provided ways to inform HABS in the analysis of a user's encounter with an IME, however, as discussed in section 9.4.2, this requires further work and so is not included in table 9.5.

**Table 9.5 Concepts, models and tools to inform analysis of a user's encounter with an IME for staying there**

| positive characteristics: concepts | | | negative characteristics: concepts | HABS linking: concepts, models & tools *(cross-referenced with figure 9.1)* | tools |
|---|---|---|---|---|---|
| staying there | invisible style: | transparency | breakdown in illusion | • virtual to real: "g" & "h" | • guidelines for breakdown in illusion<br>• three Vs questionnaire |
| | | | breakdown in interaction | • shift in operations and actions: "e" & "d" | • guidelines for breakdown in interaction<br>• three Vs questionnaire |
| | | continuity of content | discontinuity in: constraints & experience | • dynamic nature of HABS to trace & model scenarios: "a" to "h" | • guidelines for off-screen space<br>• three Vs questionnaire |
| | | appropriate/ stimulating experience | inappropriate un-stimulating experience | • objective outcome & motive: "a"<br>• stimulating experience: "f" | • three Vs questionnaire |

# Chapter Ten Conclusion

Extending ideas from activity theory, film and human-computer interaction, this thesis developed a methodology comprising of concepts, tools and methods appropriate for the evaluation of a range of interactive mediated environments (IME) for usability and user experience. For a précis of the work contained in this thesis refer to chapter nine.

## 10.1 Summary of the thesis

Limitations of usability methods have been identified when applied to IMEs and in particular, they cannot fully address user's experiential encounters. While previous research identified limitations of usability (e.g. Gabbard et al. 1999), and usability guidelines for desktop VR have been developed (Kaur 1998), these works do not address the experiential. The work herein addresses these limitations by developing a methodology to evaluate both usability and user experience appropriate to a range of IME configurations. The term *staying there* was coined to refer to the situation in which users are allowed and encouraged to pursue objectives, free from disruption, and continue to experience the mediated environment (Marsh 2003a; 2003b). To this aim, an *invisible style* was proposed through:

- transparency of mediating technology and equipment, that once mastered, is "supportive and unobtrusive" so disappears from the main focus of user's attention. Unlike other work linking transparency to experiential, this thesis is not concerned with users' sense of presence per se, but with a broad range of user experience.

- continuity (i.e. continuous, coherent and appropriate mediated content) providing ways to reason about firstly, the behaviour of time-based environments that remain in-focus or visible to the user, and secondly, user's behaviour and experience from acting within the constraints imposed by the social and cultural environment depicted virtually.

### 10.2 Summary of Contributions

The thesis contributes a methodology (concepts, methods and tools) to operationalise an invisible style to capture breakdowns and user experience to evaluate IMEs for both usability and user experience. This has been achieved principally through the hierarchical activity-based scenario (HABS) approach together with the three Vs framework of experience (i.e. voyeuristic, visceral, vicarious) and questionnaire to capture the three Vs. In addition, guidelines were developed to identify usability problems through breakdown and to inform design and analysis of off-screen space to reduce user disorientation. This methodology can be used in the laboratory and user's natural environment.

#### 10.2.1 Hierarchical activity-based scenario (HABS) approach

The HABS approach was formulated to evaluate IMEs by extending Leont'ev's (1981) framework from activity theory (operations, actions, activity) and fusing it with concepts from film and HCI (Marsh 2003a). Through staying there, HABS links concepts, models and tools developed in this thesis in logical relation to each other, working *towards* a single framework to analyse IMEs. Studies of a range of IMEs from standard and novel desktop to head-mounted display-based VR show HABS can be used:

- to identify breakdown in interaction through shifts from operations to actions, and breakdown in illusion through shifts in focus from the virtual (context of use) to the real world. While work in HCI has adopted the former, HABS goes a step further by extending activity theory to IMEs as a way to identify breakdown in illusion. The extent to which HABS is successful in identifying breakdown is limited by the evaluation method used (observation, questionnaire or debriefing), the expertise of the evaluator to understand and apply HABS, and the ability and expressiveness of the user in communicating their thoughts.

- to provide a structure to reason about stimulating and/or appropriate mediated encounters with IMEs through firstly, shifts from actions to activity (signifying stimulating experience and new motives) and secondly, the degree to which a user's objective outcome coincides with motive (i.e. "activity proper" see: Leont'ev 1981 pp. 399-400), providing a structure to reason about appropriate and stimulating experience and scenarios. At the time of writing, little if any work in HCI appears to deal with objective and motive separately (Marsh 2003a). The extent to which these concepts are effective is discussed in future work.

- to describe a plethora of genres in a narrative or story-like structure to the level of detail required by the evaluator or evaluation, from operations through actions to activity. Setting scenarios in the hierarchical framework of activity is advantageous for two main reasons: firstly, to provide a means to formally structure activities according to objective and motive, and secondly, because of the flexibility to describe dynamic user behaviour with and within IMEs. This flexibility means a HABS approach can be used to model and trace linear as well as non-linear narrative structures. Furthermore, the flexibility of HABS overcomes the rigidity and problematic use of other modelling techniques (e.g. user interaction model for desktop VR: Kaur 1998; Kaur et al. 1999).

### 10.2.2 Three Vs framework of experience: voyeuristic, visceral and vicarious

The three Vs framework of experience from spectators' film experience (Boorstin 1995) was adapted, and together with a questionnaire to capture the three Vs, provided a language to reason about user's IME experience (Marsh 2001, 2003b). As shown in chapter eight, the questionnaire captures user's experience from an encounter within the three Vs framework and informed by HABS, questions were developed to identify disruptions to user's attention during an encounter through categorizations of internal, external and subjective (see: section 10.2.4). The post-study questionnaire allows users to experience a mediated encounter in its entirety without disrupting the user.

Used together with HABS, the three Vs questionnaire provides the evaluator with a way to capture and reason about appropriate and/or stimulating experience by comparing user's experience with the experience the IME application is designed to induce/evoke. The evaluator can then reason about the degree to which experience from interaction (i.e. objective outcome) is appropriate and/or stimulating and so reason about its success. Questionnaire responses also provided an indication of whether user's behaviour adhered to social and cultural constraints determined by the IME context. If the responses are as expected, the IME scenario has continuity. If not, then the responses suggest a user's behaviour did not adhere to social and cultural constraints and this may indicate either the scenario or the user's encounter has discontinuity and so should be investigated further.

The extent to which the three Vs has been effective in informing analysis in this thesis is largely dependant upon two aspects: its appropriate adaptation from film theory to IMEs and the use of a questionnaire to capture it. While it is acknowledged that the three Vs may not be appropriate to reason about every kind of user experience with every genre of mediated environment application, it is able to describe a broad range of user-encountered experiences with IMEs. Since work began on this thesis, other publications have emerged exploring the three Vs as a framework of user experience applied to new and emerging computer, media, technological devices and products (e.g. e-commerce Wright, McCarthy and Marsh 2001; "Technology as Experience" McCarthy and Wright 2004 and "Emotional Design" Norman 2004). This adds support to the appropriateness of the three Vs framework and it is argued, further investigation of how it can continue to inform analysis as well as design of IMEs would be a valuable direction for future work.

### 10.2.3 Guidelines to aid in user's comprehension of space

Guidelines informed from cinematography and film editing techniques were developed herein and published in Marsh and Wright (2000a). These guidelines inform the implementation of features of virtual environments to aid users in comprehension of off-screen space. Focusing on a subset of the guidelines, a study in chapter five showed they aid users in navigating through a mediated environment, reduce user disorientation and so help maintain continuity of user experience (Marsh and Smith 2001a). Building on these guidelines, Baudisch and Rosenholtz (2003) have developed HALO, a technique for users to visualise off-screen locations on the display screens of mobile navigation devices.

### 10.2.4 Guidelines to identify and categorize usability problems through breakdown

This thesis has worked towards overcoming the lack of appropriate guidelines or criteria for evaluation of IMEs (see: chapter 9.2) by developing a set of guidelines (see: chapter 9.3.4). The guidelines are divided into two main categories: *breakdown in interaction* and *breakdown in illusion.* A further classification reflecting causes of breakdown is: *internal (to an IME), external (to an IME)* and *subjective (to a user).* Used in conjunction with a "think-aloud" verbal protocol these guidelines overcome the problem of users verbalizing routinized operations in activity-based evaluation studies (making them indistinguishable from actions) and the detection of breakdown in interaction more difficult.

## 10.3 Future work

### 10.3.1 Extension of HABS and activity theory to inform analysis and design

Identified below are four directions for future work for HABS and activity theory. Firstly, future research should integrate more closely HABS and the three Vs framework in order to inform design of IME content and scenarios to induce or evoke appropriate and/or stimulating three Vs experience in users and encourage them in staying there. Secondly, it has been argued that IMEs integrated into functional organs (through the unity of internal and external) help users reach higher accomplishments and provide powerful concepts beyond transparency to reason about IMEs in use. However, further research is necessary to directly measure the extent to which artefacts are integrated into functional organs in use and are experienced as a property of the user. Typical research questions to inform the analysis design of IMEs are provided in chapter nine (9.4.2). Thirdly, while objective and motive from activity theory provide concepts in which to consider "activity proper" (so in turn reason about scenario and experience), studies in chapter eight show that there is a limit to the extent to which these are effective. While the IME objective can be imparted to users in briefing sessions, it is left to the study evaluator to reason about a user's (or group's) motive. Future work should identify more accurate ways of capturing and determining user's motive. One approach for future work is to restrict a user's motive to the intended purpose or requirements of the IME. In addition, future work should identify more accurate ways beyond a post-study questionnaire to reason about actions that provide experience that is so stimulating that actions transform into activities. Fourthly, future work should shift away from single users engaged in single activities towards a social and cultural approach of multi-participants engaged in multi-activities, so providing a way to inform analysis of both a "web" and collective activities with IMEs. As discussed in chapter nine (9.4.1), future work could build upon Vygotsky's (1978) sociocultural studies, Cole and Engeström (1993) and Engeström's (1987, 1999) expansion of activity theory's basic concepts, as well as work in HCI that adopts this approach (e.g. Bødker 1996; Kuutti 1996). Furthermore, future work should consider extending the context of use to include multi-participants' interactions and communications outside the IME, so that the social aspects in the real world where the IME resides are incorporated.

### 10.3.2 Beyond a questionnaire-based approach

The limited set of questionnaire items may not necessary reflect a user's IME encounter within the three Vs framework of experience. Therefore, a sustained research effort is needed to identify an appropriate number of items that can adequately capture the three Vs experience. Another approach and source for future work to overcome this limitation is George Kelly's (1955) Personal Construct Psychology that allows respondents to choose their own items. In addition, the post-study questionnaire is unable to deal with variations in emotions and experience in an unfolding scenario. Although continuous assessment methods such as sliders, dials and verbalizations get round this problem, they require users to divide their attention between the mediated experience and the data collection technique being used, thus disrupting what is being measured (i.e. presence/experience). While facial analysis and physiological measures do not require the user to perform any additional operations, some work is still required in order to employ these techniques to accurately measure a range of user experiences. Valuable directions for future work would be to develop these techniques and other continuous methods.

### 10.3.3 Extending the invisible style of IMEs: design of on-screen techniques

Following techniques from the invisible style of filmmaking, one valuable direction for future work is to explore ways to manipulate on-screen space and time in IMEs. Guidelines, techniques or idioms could be developed towards an invisible style of IMEs that preserves a sense of spatial and temporal continuity for users, forming a lexicon between IME developer and user similar to that between filmmakers and spectators. This would provide developers with tools to design mediated environments of "increasing complexity and power" (Laurel, Strickland, and Tow 1998 p. 188), providing a way to shape character, story and enhance user's experience. Emerging techniques to manipulate time and space in computer games could also be explored to see if they can be generalised to other IMEs.

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# Appendix I VPP User Study Material

## Virtual Production Planner (VPP) Desktop Virtual Reality System

### VPP: Briefing

Thank-you for agreeing to help with this study.

We are going to evaluate the usability of a Desktop Virtual Reality system called the Virtual Production Planner (VPP). Virtual Production Planner is a computer-based training system for television camera operators, producers and directors.

It can be used for:

- Storyboarding and camera planning
- Planning virtual productions
- Directing virtual productions

The modelled studios are based on current television sets in use at BBC Television Centre.

The virtual studio set that we are going to evaluate is [at the time of the evaluation] a model of the News and Current Affairs programme Newsnight.

To do this, we will give some standard tasks to do with VPP. The aim is to get some information about how VPP supports these tasks.

To get this information we shall use a question-and-answer technique:

1. when you do each task we want you to think out loud telling us:
    - how you are trying to solve each task
    - what commands you are using
    - and what you think the machine has done in response to your commands and why

In other words: give a running commentary on what you are doing and thinking.

2. if you are unsure about anything, ask for advice.

3. I will ask you questions about what you are trying to do.

I will be noting down any problems with VPP that you mention and a video recording will be made so we don't miss any of the problems. This recording will be anonymous and treated in confidence.

Treat it as a structured discussion about VPP.

Please feel free to say whatever you think about the system and the tasks you're given to solve.

**VPP: Computer Usage Questionnaire 1**

**[*delete as appropriate]**

Subject Number: __________ [evaluator entered]

Name: ________________________________________

Occupation: ________________________________________

University/Company: ________________________________________

Do you use a computer at home Y / N * , at work Y / N * ?

If yes, what kind of operating system/computer do you use?

MS Windows Y / N*, Mac Y / N*,
Unix Y / N*, Other specify ______________________

How many hours per day do you use a computer? at home _____, at work_____

How many years have you been using computers? _______

Have you had experience with any virtual reality products / systems? Y / N*

If yes, was this using:

a Head Mounted Display? Y / N* or Desktop Computer Y / N* ?
Other Specify ________________________________________

which of the following application areas best applies to the virtual reality for which you have had experience of?

Educational Y / N*, Entertainment Y / N*,
Other specify________________________________________

**VPP: Debriefing Questionnaire 2**

1. How did you find the conventional versus the free / flying camera to build up a mental map?

______________________________

______________________________

______________________________

______________________________

______________________________

2. Viewing the studio from the plan view:

   a) Is this what you expected the studio layout to look like?

   ______________________________

   ______________________________

   ______________________________

   b) Do you recognise all the features and objects in the studio from the plan view?

   ______________________________

   ______________________________

3. Indicate in the table below, the key that you would select to operate the following cameras. If unsure, indicate by a question mark (?):

| | Studio Camera 1 | Studio Camera 2 | Studio Camera 3 | Studio Camera 4 | Flying Camera |
|---|---|---|---|---|---|
| Select: | | | | | |
| Move: | | | | | |

## VPP: Plan Sheet 1

**VPP: Plan Sheet 2**

**VPP: Debriefing**

What was the best thing about the Virtual Production Planner?

What was the worst thing about the Virtual Production Planner?

What do you think most needs changing with VPP?

Do you find the video recording intrusive?

How did you find thinking out loud? ...was it easy / difficult / intrusive?

**VPP: Debriefing statement**

The purpose of this study is to find ways to effectively evaluate the usability of VR systems. The study that you have kindly volunteered to take part in, is part of a study designed evaluate an evaluation technique called co-operative evaluation. That is, whilst performing tasks the user (that is, you) used a think-aloud technique (effectively, this is a running commentary). These think-aloud comments, together with any questions and answers that you or the evaluator (myself) asked/gave, may be used as information to evaluate the usability of the EISCAT VR system, and to test the effectiveness of the co-operative evaluation technique.

Thank-you for your time to take part in the study.

If you have any queries relating to the study, please get back to me.

**VPP: Usability Problems**

| User: | Task: | **Verbalisations: Usability Concerns** | Evaluator 1 | | Evaluator 2 | |
|---|---|---|---|---|---|---|
| | | | Low | High | Low | High |
| 1 | Task 1 | 1. User clicks on graphical representation of camera 1; nothing happens. | | √ | | √ |
| | | 2. Evaluator question to user: "have you any idea why there are two sets of numbers?" User reply: "NO" | √ | | √ | |
| | | 3. Evaluator question to user: "have you any idea why there are two views?" User reply: "NO" | √ | | √ | |
| | Task 2 i | 4. User cannot find free/flying camera icon. | √ | | √ | |
| | ii | 5. User goes through the roof/ceiling of the studio. The entire display screen is grey. Evaluator question to user: "have you any idea where you are or what is happening?" User reply "NO". | | √ | | √ |
| | | 6. User: "I think its not very friendly" Evaluator: "why don't you think it is very friendly" User: "the system should show what happens, where I am, and what you need to do to get out of this" | | √ | | √ |
| | iii | 7. In plan view, user tries selecting a camera with the mouse, by clicking and dragging. The camera doesn't appear to be selected. User: "the colour should be changing to let you know that you've clicked it" | | √ | | √ |
| | Task 3 i | 8. User bumps into studio set. Evaluator: "do you know what's happening" User: "its moving" Evaluator: "is the camera moving as you expect it to" User: "NO" | | √ | | √ |
| | ii | 9. User bumps into studio. Evaluator: "what do you think is happening" User: "it's going forward whenever I try to go backward" Evaluator: "why do you think the camera moves like that" User: "I don't know, it shouldn't behave like that" | | √ | | √ |

| User: | Task: | Verbalizations: Usability Concerns | Evaluator 1 | | Evaluator 2 | |
|---|---|---|---|---|---|---|
| | | | Low | High | Low | High |
| 2 | Task 1 | 1. User clicks on graphical representation of camera 1; nothing happens. | | √ | | √ |
| | | 2. User: "I don't know where the free camera is, I can't see it" | | √ | | √ |
| | | 3. Evaluator: "have you any idea why there are two views" Referring to the main and the mini views.<br>User: "I found it confusing at first"<br>Evaluator and user discuss the reason for the mini view. User is eventually told what its purpose is. | √ | | √ | |
| | Task 2 | 4. Seems confused about camera movement.<br>User: "I would have thought that the camera rotates on its base, rather, or maybe its moving on a large circle " "...all the figures have stopped moving"<br>User is referring to the camera co-ordinates along the bottom of the screen. | √ | | √ | |
| | | 5. User bumps into set.<br>User: "its moving left and I'm pulling it backwards"<br>Evaluator explains that the camera is colliding with objects or the studio set. | | √ | √ | |
| | | 6. User thought that the icons directly above each camera, controlled the movement of each camera, and therefore, did not use all the camera movement icons until the evaluator suggested using all controls for more precise movements. | √ | | √ | |
| | | 7. Flying camera goes through the wall of the studio. The entire display turns grey. User looks puzzled.<br>Evaluator: "have you any idea what the grey is"<br>User: "run out of the scope of the programme" | | √ | | √ |
| | | 8. User: " the camera went in the direction the head was pointing. I would have thought it would move in the direction of the camera base" | √ | | √ | |
| | | 9. The user selects the plan view.<br>User : "I don't know what the representation of the flying camera that they use" | | √ | | √ |
| | Task 3 i | 10. User bumps into wall and camera moves left instead of ahead.<br>User: "I don't want to go that way I want to go straight ahead" | | √ | √ | |
| | | 11. Evaluator: "have you any idea why the camera moves in that way in response to your camera movement selection."<br>User: "maybe it's on a lead or cable and I've got to the end of the cable" | | √ | √ | |
| | ii | 12. User: "I would expect one icon to move the wheels and one icon to control the | √ | | √ | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | movement of the head. But the camera moves in the direction the head is pointing in" | | | | |

| User: | Task: | Verbalizations: Usability Concerns | Evaluator 1 | | Evaluator 2 | |
|---|---|---|---|---|---|---|
| | | | Low | High | Low | High |
| **3** | Task 1 | 1. User: "Now, the obvious method is to click on the camera itself. User clicks on graphical representation of camera ; nothing happens. "But we get no reaction, no feedback" | | √ | | √ |
| | Task 2 i | 2. User is moving around the outside of studio set, bumps into studio one wall, then bumps into another wall. User: "I'm struggling" User appears to lose co-ordination and control. | | √ | √ | |
| | | 3. User fails to use zoom in/out. Evaluator:" is there any particular reason why you didn't use those buttons" Evaluator points to zoom. User: "In actual fact, I thought that I could achieve the same effect with the other buttons, referring to track and pan" | | √ | | √ |

| User: | Task: | Verbalizations: Usability Concerns | Evaluator 1 | | Evaluator 2 | |
|---|---|---|---|---|---|---|
| | | | Low | High | Low | High |
| 4 | Task 1 | 1. User clicks on graphical representation of camera 1; nothing happens.<br>User: " trying to click on actual camera, but that doesn't work" | | √ | | √ |
| | | 2. User experiments with zoom and track icons. There appears to be some confusion between the zoom and track icons.<br>Evaluator: "do you know the difference between, or the function of these two icons?"<br>Evaluator points to zoom and track.<br>User: "No, they appear to do the same thing" | | √ | | √ |
| | Task 2 ii | 3.User: "what is a plan view"<br>Evaluator explains what a plan view is. | √ | | √ | |
| | Task 3 i | 4. User: "how come when I select camera 2 there "<br>User points to main view camera 2 icon.<br>User: "it doesn't highlight 2 there?"<br>User points to mini view camera 2 icon.<br>Evaluator: "have you any idea?"<br>User: "No"<br>Evaluator: "try clicking on the buttons"<br>User experiments, becoming familiar with the functions.<br>User: "I suppose this is for previewing and this is what the viewers see". | √ | | √ | |
| | ii | 5. User zooms in to ceiling and the whole screen goes grey for a few seconds.<br>User: "Oh, what happened, disappeared". | | √ | | √ |
| | | 6.User moves camera very close to studio set, is disoriented.<br>User: "I'm entirely lost"<br>Abandoned task | | √ | √ | |

# Appendix II EISCAT User Study Material

## EISCAT (European Incoherent SCATter radar facility) Virtual Reality System

### Recruitment of subjects:

**Wanted: Volunteers for Virtual Reality Study**

Volunteers are required to participate in a virtual reality study that involves the use of a head-mounted display (HMD).

This study is being carried out as part of the INQUISITIVE project, a joint research effort between the Rutherford Appleton Laboratories and the University of York, UK.

Participants will be paid £10 to wear a HMD and complete simple tasks in a 3D virtual environment. No virtual reality experience required.

The duration of the study will be approximately 30 minutes. The study will take place in R18 at the Rutherford Appleton Laboratories on Tuesday 29th June and Wednesday 30th June, 1999.

If interested, please send contact details and availability to *[contact details inserted here]*

**EISCAT: Briefing**

Thank-you for agreeing to help with this study.

We are going to explore the use of a Head Mounted Display / Desktop Virtual Reality system called EISCAT (European Incoherent SCATter radar facility).

EISCAT is a simulation of the real site located in Norway. The purpose of the simulator is to familiarise (with location and layout) and train (using typical experiments) scientists prior to their secondment in Norway.

Your role in this study, is to help in the evaluation of the EISCAT VR system.

To do this, we will give you 3 standard tasks to perform in the EISCAT system. The aim is to collect information about how EISCAT supports these tasks.

To get this information we shall use a question-and-answer technique, involving:

4. when you do each task we want you to give a running commentary (think out loud) as you do each task telling us
   - how you are trying to solve each task
   - what actions, commands you are using
   - and what you think the machine has done in response to your actions and commands and why, highlighting any good points or problems that you may encounter.

In other words: give a running commentary on what you are doing and thinking.

5. if you are unsure about anything, then feel free to ask any questions at any time.

6. I will also ask you questions to gain more information about what you are trying to do.

I will be noting down any problems with EISCAT that you mention and a video recording will be made so we don't miss any of the problems. This recording will be used for analysis only, and will be anonymous and treated in confidence.

(Remember its not you that is being testing, it's EISCAT. I am only interested in what you think so don't treat this as an examination. Treat it as a structured discussion about EISCAT).

Please feel free to say whatever you think about the system and the tasks you're given to solve.

**EISCAT: Computer Usage Questionnaire 1**

**[* delete as appropriate]**

Number: __________ [evaluator entered]
Male/Female *

1. Have you had any experience with 3D computer graphics products / systems? Y / N* If no, please go to next page.

   If yes, was this with:

   3D modelling package Y / N* CAD Y / N*

   Simulation Y /N* Visualisation Y / N*

   Graphics programming Y / N* Virtual Reality Y /N*

   Other, please specify ______________________________

2. Have you had any experience with virtual reality products or systems? Y / N*

   If yes, was this using:

   a Head Mounted Display (HMD) Y / N*

   Desktop Computer Y / N*

   Other, please specify______________________________

   Which of the following application areas best applies to the virtual reality products for which you have had experience of?

   Educational Y / N* Entertainment Y / N*

   Other, please specify____________________________

## EISCAT: Plan View 1

**EISCAT: Debriefing Questionnaire 2**

What was the best thing about the EISCAT VR system?

______________________________________________

______________________________________________

Why?__________________________________________

What was the worst thing about EISCAT?

______________________________________________

______________________________________________

Why?__________________________________________

What do you think most needs changing with EISCAT?

______________________________________________

______________________________________________

Do you find the recording intrusive? Y /N *

Why?__________________________________________

______________________________________________

How did you find thinking-aloud? was it easy / difficult / intrusive?
Why?__________________________________________

______________________________________________

**EISCAT: Debriefing statement**

The purpose of this study is to find ways to effectively evaluate the usability of VR systems. The study that you have kindly volunteered to take part in, is part of a study designed evaluate an evaluation technique called co-operative evaluation. That is, whilst performing tasks the user (that is, you) used a think-aloud technique (effectively, this is a running commentary). These think-aloud comments, together with any questions and answers that you or the evaluator (myself) asked/gave, may be used as information to evaluate the usability of the EISCAT VR system, and to test the effectiveness of the co-operative evaluation technique.

Thank-you for your time to take part in the study.

If you have any queries relating to the study, please get back to me.

## EISCAT: Usability Problems

| User | Task | UP No. | UP Type | User/ Evaluator/ Observed | Usability Concerns: Verbalized and Observed | Evaluator 1 | | Evaluator 2 | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Low | High | Low | High |
| 1 | 1 | 1 | 6 | U | User selects middle mouse button, menu appears:<br>**User:** "I'm not sure what that is, is that a terminal?" | √ | | √ | |
| | | 2 | 2 | U | User goes through wall: screen turns white:<br>**User:** "I've got lost now"<br>User appears disorientated. | | √ | | √ |
| | | 3 | 5 | U | User appears back in the room in a high position:<br>**User:** "oh, I'm up in the air now"<br>User appears startled. | | √ | | √ |
| | | 4 | 2 | E | User moves backwards and goes through a wall - screen turns white. User appears startled:<br>**Evaluator:** "what do you think has happened?"<br>**User:** "going back too far, I'm not to sure why, sort of out of range?" | | √ | | √ |
| | | 5 | 5 | O | **Observed:** The user's position or point of view, becomes closer and closer to the ground. This seems to be because the HMD is slowly weighing the user's head down. | | √ | | √ |
| | 2 | 6 | 8 | U | **User:** "is that a mirror?"<br>User misidentifies window, pointing to the window between the control room and the terminal room. | √ | | √ | |
| | | 7 | 1 | O | **Observed:** HMD cable tangled around chair. Evaluator untangles cables. | | √ | √ | |
| | | 8 | 5 | U | User's perspective is high up in the control room:<br>**User:** " I'm up in the air now"<br>**Evaluator:** "have you any idea why?"<br>**User:** "no, how do I get back down?"<br>Evaluator explains how to move down. | | √ | √ | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 9 | 4 | U | **User:** "I don't know how to get across there…bang"<br>User believes they had collided with the wall gives sound effects.<br>**User:** "how do I navigate myself around there?"<br>Evaluator explains how to navigate through doorway. | √ | | √ | |
| | | 10 | 1 | O | **Observed:** HMD cable tangled around chair.<br>Evaluator untangles cables. | | √ | √ | |
| | | 11 | 4 | U | **User:** "I don't know how to get out"<br>User struggles to find way out back into control room | √ | | √ | |
| | | 12 | 8 | U | **User:** "was that table there before?"<br>**Evaluator:** "did you notice it before?"<br>**User:** "no" | √ | | √ | |
| | 3 | 13 | 2 | U | User goes through instrument racks:<br>**User:** "oops" | √ | | | √ |
| | | 14 | 7 | E | **Evaluator:** "I noticed that you were holding the HMD?"<br>**User:** "its just not on the bone of my eyes, that's all, it wants to stay on my forehead more….tilted"<br>**Evaluator:** "try adjusting the HMD"<br>User adjusts HMD to sit more comfortably on user's head. | | √ | √ | |
| | | 15 | 2 | U | User goes through instrumentation rack:<br>**User:** "that was number 10" | √ | | | √ |
| | | 16 | 4 | U | **User:** " I don't know how to get round that way, my neck won't go round there"<br>User has difficulties navigating: that is, user trying to stretch body and neck/head too far. | √ | | √ | |
| | | 17 | 4 | E | User momentarily forgets functions of 3D mouse buttons whilst moving around the control room:<br>**Evaluator:** "can you remember how to more | √ | | √ | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | around the room?"<br>**User:** "no" | | | | |
| | | 18 | 2 | U | **User:** "can't get in there"<br>**Evaluator:** "can you get closer?"<br>**User:** "I nearly did"<br>User goes through rack<br>**User:** "that's 13" | √ | | | √ |
| | | 19 | 1 | O | **Observed:** 3D-mouse cable twists around back of user.<br>User is caught up and cannot move in the direction in which they intended to move without difficulties. | | √ | √ | |
| | | 20 | 3 | O | **Observed:** numerous due to combination of having to lift the virtual hand high into the air, the jittering of the virtual hand, and fast speed of forward movement. | | √ | | √ |
| | | 21 | 2 | U | User goes through the instrumentation rack:<br>**User:** "I'm useless at this" | √ | | | √ |
| | | 22 | 3 | U | **User:** "finding it difficult to get the hand...need six hands here"<br>User referring to the mouse movement control, its position and orientation, and the trigger selection. | √ | | | √ |
| | | 23 | 3 | U | User appears to be experiencing difficulty with virtual hand:<br>**User:** "I can't remember how to get the buttons green again… …..I'm not very good at this, at all" | √ | | | √ |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 24 | 4 | E | User seems to be having problems moving around the control room:<br>**Evaluator:** "do you think that it is your difficulty with the system?"<br>**User:** "I seem to want to move myself sideways left or right and I can't 'cause you feel you want to be on wheels on a chair so you can zoom yourself along in front of it, and I haven't got to grips with the headset enough to be able to come out or in"<br>**Evaluator:** "when you mean get to grips, what do you mean?"<br>**User:** "I can't manoeuvre myself in the room very easily"<br>**Evaluator:** "do you know what the problem is?"<br>**User:** "yes, I don't know what I'm doing, that's how it feels. I know I can go backwards and forwards, I know I can turn left or right, but I don't seem to get the two acts together very easily" | √ | | √ | |
| | | 25 | 3 | U | User has difficulties viewing virtual hand:<br>**User:** "I can't see my virtual hand above the instrument panel" | | √ | | √ |
| | | 26 | 4 | U | Compounding difficulties trying to find the optimum position in which to select the instrumentation rack's black button:<br>**User:** "I can't move back without pressing…taking this hand off, the right hand, oh, yes, I've got it…no, I'm too far away" | √ | | √ | |
| | | 27 | 4 | U | **User:** "oh, this is hard work isn't it?"<br>**Evaluator:** "what do you find hard work?"<br>**User:** "moving backwards and forwards at the same time. I think if I was more practised in it then I could come in and look round the room and be able to move myself. But I'm not | √ | | √ | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | getting to grips as well as I would of expected to" | | | | |
| | | 28 | 4 | U | **User:** "now I'm at a point where I need to come backwards to look round the room so I can come forwards at it straight on and not sideways at it. This seems to be my problem. If I zoom in here, I'm going to be sideways at it, and I find it difficult as if I want to walk across the room and get in front of it. How would I move from here?" | √ | | | √ |
| | | 29 | 2 | U | User goes through instrumentation rack:<br>**User:** "oops, too far" | √ | | | √ |

| User | Task | UP No. | UP Type | User/ Evaluator/ Observed | Usability Concerns: Verbalized and Observed | Evaluator 1 | | Evaluator 2 | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Low | High | Low | High |
| 2 | 1 | 1 | 1 | O | **Observed:** HMD cable tangled around chair. Evaluator untangles cables. | | √ | √ | |
| | | 2 | 1 | U | HMD cable becomes tangled around chair:<br>**User:** "ah, seems to be snagging on something".<br>Evaluator untangles cables. | | √ | √ | |
| | 2 | 3 | 1 | O | **Observed:** HMD cable tangled around chair. Evaluator untangles cables. | | √ | √ | |
| | | 4 | 1 | U | 3D-mouse cable gets tangled around user:<br>**User:** "again, slightly caught-up" | | √ | √ | |
| | | 5 | 10 | U | **User:** "finding it slightly difficult, there's a slight delay on moving your head, so you have to anticipate where you are OK" | | √ | | √ |
| | | 6 | 1 | O | **Observed:** HMD cable tangled around chair. Evaluator untangles cables. | | √ | √ | |
| | | 7 | 7 | O | **Observed:** User seems to be supporting and adjusting HMD throughout this task. | | √ | | √ |
| | | 8 | 1 | O | **Observed:** HMD cable tangled around chair. Evaluator untangles cables. | | √ | √ | |

| User | Task | UP No. | UP Type | User/ Evaluator/ Observed | Usability Concerns: Verbalized and Observed | Evaluator 1 | | Evaluator 2 | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Low | High | Low | High |
| 3 | 2 | 1 | 1 | O | **Observed:** HMD cable tangled around chair. Evaluator untangles cables. | | √ | √ | |
| | | 2 | 2 | U | User moves too close to the wall, becomes disorientated:<br>**User:** "oh, got lost now".<br>Evaluator guides user back into the control room. | | √ | | √ |
| | | 3 | 2 | U | User walks through door between control and computer rooms, User appears startled:<br>**User:** "there's a door there it says door is fixed open…oh, which I've walked through and I'm back in the control room. …did I walk through the door?". | √ | | | √ |
| | | 4 | 11 | U | **User:** "I thought it might make me feel like travel sick, and it does" | | √ | | √ |
| | | 5 | 11 | E | **Evaluator:** " how do you feel at the moment?"<br>**User:** "its OK when I'm zooming into things but when I move my head round quickly it's a bit sickly" | | √ | | √ |
| | | 6 | 7 | E | **Evaluator:** "I noticed that you've got your hand on the front of the HMD?"<br>**User:** "it just seems that it's slipping down a bit too far. I just need to hold it up"<br>**Evaluator:** "do you think it needs adjusting more?"<br>**User:** "yes, it goes a little bit blurred".<br>HMD is adjusted until the user is satisfied. | | √ | √ | |
| | 3 | 7 | 3 | U | Virtual hand goes through the rack:<br>**User:** "so, I'm putting my hand up so I can touch the button….I just whoops" | √ | | | √ |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 8 | 2 | U | **User:** "there's number 13 second from left, and I'll try to reach out"<br>User goes through rack 13. | √ | | | √ |
| | | 9 | 1 | O | **Observed:** 3D mouse cable tangled around user.<br>Evaluator untangles cables. | | √ | √ | |
| | | 10 | 3 | U | User struggles to reach up far enough to select the black button:<br>**User:** "OK, I'm just going to zoom in a little bit so that I reach the button again…ah, and I still can't reach the it" | √ | | | √ |

| User | Task | UP No. | UP Type | User/ Evaluator/ Observed | Usability Concerns: Verbalized and Observed | Evaluator 1 | | Evaluator 2 | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Low | High | Low | High |
| 4 | 2 | 1 | 4 | U | **User:** "I have a bit of trouble round…I think to face in the opposite direction…"<br>**Evaluator:** "what trouble?"<br>**User:** "if I want to face, ah…behind me it seems you have to turn".<br>Evaluator explains how to swivel on chair. | √ | | √ | |
| | | 2 | 1 | O | **Observed:** 3D-mouse cable gets tangled around user.<br>Evaluator untangles cable. | | √ | √ | |
| | | 3 | 2 | U | **User:** "can't really see what's in front of me, could be a door, can't really tell,…can go through it, going through what's behind what looks like a door"<br>User goes through wall to the outside.<br>**User:** "outside" | √ | | | √ |
| | | 4 | 1 | O | **Observed:** 3D-mouse cable gets tangled around user. | | √ | √ | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 5 | 5 | U | User finds way back into the control room.<br>**User:** "it seems I'm at a different height than I was"<br>User is almost at floor level. | | √ | | √ |
| | | 6 | 2 | U | User goes back through the wall to the outside.<br>**User:** "little bit disorientated"<br>Screen changes pink and white, the colour of the walls.<br>User is lost.<br>Evaluator guides user back into the control room. | | √ | | √ |
| | | 7 | 1 | O | **Observed:** 3D-mouse cable becomes tangled around user.<br>Evaluator untangles cables. | | √ | √ | |
| | | 8 | 1 | O | **Observed:** HMD cable becomes tangled around chair.<br>Evaluator untangles cables. | | √ | √ | |
| | 3 | 9 | 2 | E | User goes through rack.<br>**Evaluator:** "what happened there?"<br>User: "I went too far and went straight through the rack to the other side" | √ | | | √ |
| | | 10 | 1 | U | **User:** "I need to unwind the cable I think"<br>Evaluator unwinds the HMD cable. | | √ | √ | |
| | | 11 | 3 | U | **User:** "its higher so I have to go up higher"<br>Virtual hand goes through the rack 13.<br>**User:** "my hand seems to go through objects as well" | √ | | | √ |

| User | Task | UP No. | UP Type | User/ Evaluator/ Observed | Usability Concerns: Verbalized and Observed | Evaluator 1 | | Evaluator 2 | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Low | High | Low | High |
| 5 | 1 | 1 | 6 | E | User selects middle mouse button, menu appears:<br>**Evaluator:** "have you any idea what that is or how to disable it?"<br>**User:** "no" | √ | | | √ |
| | 2 | 2 | 1 | O | **Observed:** HMD and 3D-mouse cables tangled around the chair.<br>Evaluator untangles cable. | | √ | √ | |
| | | 3 | 1 | O | **Observed:** 3D-mouse cable tangled around the chair.<br>Evaluator untangles cable. | | √ | √ | |
| | | 4 | 9 | U | User reads caution message.<br>**User:** "…caution non-interactive, what does that mean?" | √ | | √ | |
| | | 5 | 8 | U | User cannot identify a section of the virtual model.<br>**User:** "…a little bit like doors in front of me, but I'm not convinced" | √ | | | √ |
| | | 6 | 2 | U | User goes through wall to outside.<br>**User:** "I seem to be outside"<br>**Evaluator**: "can you make your way back inside?" | √ | | √ | |
| | | 7 | 2 | O | User goes through door with 'No Exit' sign placed on it to outside.<br>**Evaluator**: "can you make your way back inside?" | √ | | | √ |
| | | 8 | 1 | O | **Observed:** 3D-mouse cable becomes tangled around user.<br>Evaluator untangles cables. | | √ | √ | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 9 | 5 | U | Returning back into the control room, the user notes that their eye position is now close to the ground.<br>**User:** "I'm not quite sure why my perspective is close to the floor"<br>User has no idea how to return to original eye-level. Evaluator explains how to re-adjust eye position. | | √ | | √ |
| | 3 | 10 | 1 | O | **Observed:** 3D-mouse cable becomes tangled around user.<br>Evaluator untangles cables | | √ | √ | |
| | | 11 | 6 | O | **Observed:** user selects middle mouse button, menu appears.<br>User has difficulty in disabling the menu. | √ | | | √ |
| | | 12 | 2 | E | User goes through rack and wall to the outside.<br>User appears startled.<br>**Evaluator:** "what's happening?"<br>**User:** "I pushed the forward key instead of the backward key" | √ | | | √ |

| User | Task | UP No. | UP Type | User/ Evaluator/ Observed | Usability Concerns: Verbalized and Observed | Evaluator 1 | | Evaluator 2 | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Low | High | Low | High |
| 6 | 1 | 1 | 7 | U | User wearing glasses has problems with HMD focus:<br>**User:** "there's going to be a trade-off between the circle appearing on the outside and a semicircle appearing on the other…."<br>User adjusts on HMD.<br>**User:** "I think that's the optimum" | √ | | | √ |
| | | 2 | 6 | U | User selects middle mouse button, menu appears:<br>**User:** " I've got some tools in front of me"<br>Evaluator explains how to disable menu. | √ | | | √ |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 3 | 8 | U | User incorrectly identifies a section of the virtual model:<br>**User:** "Got some windows here…to another passage?" | √ | | | √ |
| | | 4 | 1 | O | **Observed:** 3D-mouse cable gets tangled around user.<br>Evaluator untangles cables | | √ | √ | |
| | | 5 | 2 | O | **Observed:** user goes through window and instructed to go back into the control room | | √ | | √ |
| | | 6 | 9 | U | User incorrectly believes a caution sign fixed to a window, is the reflection from another caution sign:<br>**User:** "….that's a reflection of that sign" | √ | | | √ |
| | | 7 | 1 | O | **Observed:** HMD cable tangled around chair.<br>Evaluator untangles cables. | | √ | √ | |
| | | 8 | 1 | O | **Observed:** HMD cable tangled around chair.<br>Evaluator untangles cables. | | √ | √ | |
| | | 9 | 5 | E | User's eye-position is at door handle height.<br>**Evaluator:** "have you any idea how to get back to the original height?"<br>**User:** "no" | | √ | | √ |
| | | 10 | 1 | O | **Observed:** 3D mouse cable tangled around chair.<br>Evaluator untangles cables. | | √ | √ | |
| | 3 | 11 | 1 | O | **Observed:** 3D mouse cable tangled around chair.<br>Evaluator untangles cables. | | √ | √ | |
| | | 12 | 1 | O | **Observed:** 3D mouse cable tangled around chair.<br>Evaluator untangles cables. | | √ | √ | |
| | | 13 | 12 | O | **Observed:** Chair moves too far from tracker source.<br>Evaluator repositions chair. | | √ | √ | |

| User | Task | UP No. | UP Type | User/ Evaluator/ Observed | Usability Concerns: Verbalized and Observed | Evaluator 1 | | Evaluator 2 | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Low | High | Low | High |
| 7 | 1 | 1 | 6 | E | User selects middle mouse button, menu appears:<br>**Evaluator:** "have you any idea what that is or how to disable it?"<br>**User:** "no"<br>Evaluator explains how to deselect menu.<br>User cannot deselect menu.<br>Menu left selected. | √ | | | √ |
| | | 2 | 1 | O | **Observed**: 3D-mouse cable tangled around user.<br>Evaluator untangles cable. | | √ | √ | |
| | | 3 | 1 | O | **Observed:** HMD cable tangled around chair.<br>Evaluator untangles cable. | | √ | √ | |
| | 2 | 4 | 1 | O | **Observed:** HMD cable tangled around chair.<br>Evaluator untangles cable. | | √ | √ | |
| | | 5 | 1 | O | **Observed**: 3D-mouse cable tangled around chair.<br>Evaluator untangles cable. | | √ | √ | |
| | | 6 | 5 | E | User's eye position is very close to the floor:<br>**Evaluator:** "do you think you are too close to the floor?"<br>**User:** "yes"<br>**Evaluator:** "have you any idea how to get back to the original height?"<br>**User:** "no"<br>Evaluator explains how to reposition eye-level. | | √ | | √ |
| | 3 | 7 | 1 | O | **Observed:** 3D-mouse cable tangled around user.<br>Evaluator untangles cable. | | √ | √ | |
| | | 8 | 2 | O | **Observed:** User goes through instrumentation rack. | √ | | | √ |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 9 | 3 | O | **Observed:** User's virtual hand goes through instrumentation rack creating difficulties for the user to select rack 7. | √ | | | √ |
| | | 10 | 1 | O | **Observed:** 3D-mouse cable tangled around user.<br>Evaluator untangles cable. | | √ | √ | |
| | | 11 | 3 | O | **Observed:** User's virtual hand goes through instrumentation rack creating difficulties for the user to select rack 13. | √ | | | √ |
| | | 12 | 3 | U | **User:** "its higher so I have to go up higher"<br>Virtual hand goes through the rack 13.<br>**User:** "my hand seems to go through objects as well" | √ | | | √ |

| User | Task | UP No. | UP Type | User/ Evaluator/ Observed | Usability Concerns: Verbalized and Observed | Evaluator 1 | | Evaluator 2 | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Low | High | Low | High |
| 8 | 1 | 1 | 10 | U | **User:** "it's moving slowly....the graphics are not moving as fast as I can move my head" | | √ | | √ |
| | | 2 | 6 | E | User selects middle mouse button, menu appears:<br>**Evaluator:** "have you any idea how to deselect it?"<br>**User:** "no"<br>Evaluator explains how to deselect menu. | √ | | | √ |
| | | 3 | 4 | U | **User:** "not sure if I am moving or zooming in"<br>Evaluator suggests experimenting. | √ | | | √ |
| | 2 | 4 | 1 | U | **User:** "I'm stuck"<br>3D mouse and HMD cable is entangled around chair and user. | | √ | √ | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 5 | 5 | U | **User:** "I seem to be much higher up than I was before…I'm floating"<br>Evaluator describes to user how to reposition eye-level. | | √ | | √ |
| | | 6 | 1 | U | 3D-mouse cable entangled around user.<br>User untangles cable by moving 3D mouse around their back. | | √ | √ | |
| | | 7 | 1 | O | **Observed:** HMD cable tangled around chair.<br>Evaluator untangles cable. | | √ | √ | |
| | | 8 | 1 | O | **Observed:** HMD cable tangled with the tracker source pole.<br>Evaluator untangles cables. | | √ | √ | |
| | 3 | 9 | 2 | U | User goes through instrumentation rack.<br>**User:** "just walked right through rack" | √ | | | √ |
| | | 10 | 2 | O | **Observed:** User goes through instrumentation rack | √ | | | √ |
| | | 11 | 3 | U | Virtual hand goes through instrumentation rack.<br>**User:** "my hand's gone through the rack" | √ | | | √ |
| | | 12 | 2 | O | **Observed:** User goes through rack | √ | | | √ |
| | | 13 | 2 | O | **Observed:** User goes through rack | √ | | | √ |

## Appendix III Navigation Guidelines User Study Material

### Navigation Guidelines: Pre-Study Computer Usage Questionnaire 1

**[* delete as appropriate]**

Number: __________ [evaluator entered]
Male/Female *

1. Have you had any experience with 3D computer graphics products / systems?
   Y / N* If no, please go to next page.

   If yes, was this with:

   3D modelling package Y / N* CAD Y / N*

   Simulation Y / N* Visualisation Y / N*

   Graphics programming Y / N* Virtual Reality Y / N*

   Other, please specify ______________________________

2. Have you had any experience with virtual reality products or systems? Y/N*

   If yes, was this using:

   Head Mounted Display (HMD) Y / N*

   Desktop Computer Y / N*

   Other, please specify______________________________

   Which of the following application areas best applies to the virtual reality products for which you have had experience of?

   Educational Y / N* Entertainment Y / N*

   Other, please specify____________________________

**Navigation Guidelines: Debriefing Questionnaire 2**

**[* delete as appropriate]**

1. please rate the level of difficulty / effectiveness using the cursor keys to move around the corridors?

difficult 1 2 3 4 5 6 7 effective

2. please rate the speed of movement through the corridors?

too slow 1 2 3 4 5 6 7 too fast

3. did you feel disorientated at any time? yes/no

*if yes, please comment on the cause of this disorientation:*

___

4. how attentive/focused did you feel in the task of moving through the corridors?

not focused 1 2 3 4 5 6 7 totally focused

5.when moving through the corridors were you aware of activities external to your task?

*if yes, what things were you aware of:*

___

6. did anything break your attention away from your task of navigating in the corridors, to anything external to your task?

*if yes, what things were you aware of:*

___

## Appendix IV Computer Games User Study - Questionnaire

1. Age: 13-17 ☐ 18-23 ☐ 24-28 ☐ 29-33 ☐ 34-38 ☐ 39-43 ☐ 44-49 ☐ >50 ☐

2. Sex: male: ☐ female: ☐

3. Do you play computer games: at home: ☐ in arcades: ☐

4. On average, how many hours a week do you play computer games?
none ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ more than 5, please specify: ☐ ________

5i. How would you describe the type of game that you have just played?
action / adventure ☐ simulation e.g. driving ☐ role playing game ☐ first-person shooter ☐ sport ☐ other, ☐ please specify: ________

6. What was the overall objective of the game? ________________

7. What were you in the game, that is, what were you controlling? ________________

8i. Did you find the pace/speed of the game:

| | very | quite | a little | about right | a little | quite | very | |
|---|---|---|---|---|---|---|---|---|
| slow | | | | | | | | fast |

ii. The pace/speed of the game reduced its appeal for you?

| strongly disagree | mildly disagree | disagree | about right | agree | mildly agree | strongly agree |
|---|---|---|---|---|---|---|
| | | | | | | |

9i. Was the games response to your interactions

| | very | quite | a little | about right | a little | quite | very | |
|---|---|---|---|---|---|---|---|---|
| predictable | | | | | | | | unpredictable |

ii. The level of predictability of the games response reduced its appeal for you?

| strongly disagree | mildly disagree | disagree | about right | agree | mildly agree | strongly agree |
|---|---|---|---|---|---|---|
| | | | | | | |

10i. You had total control (autonomy) over the games outcome?

| strongly disagree | mildly disagree | disagree | about right | agree | mildly agree | strongly agree |
|---|---|---|---|---|---|---|
| | | | | | | |

ii. The level of control over the games outcome reduced its appeal for you?

| strongly disagree | mildly disagree | disagree | about right | agree | mildly agree | strongly agree |
|---|---|---|---|---|---|---|
| | | | | | | |

11. The game (including the story and plot) made perfect sense?

| strongly disagree | mildly disagree | disagree | about right | agree | mildly agree | strongly agree |
|---|---|---|---|---|---|---|
| | | | | | | |

12. The personality/nature of the person/object that you controlled during the game was:

| | very | quite | a little | neutral | a little | quite | very | |
|---|---|---|---|---|---|---|---|---|
| a. confident | | | | | | | | unconfident |
| b. relaxed | | | | | | | | tense |
| c. calm | | | | | | | | angry |
| d. happy | | | | | | | | sad |
| e. strong | | | | | | | | weak |
| f. courageous | | | | | | | | cowardly |
| g. assertive | | | | | | | | timid |
| h. cheerful | | | | | | | | serious |

13. Did you find the graphics/scenes:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| a. stylish | | | | | | | | drab |
| b. atmospheric | | | | | | | | unimpressive |
| c. creative | | | | | | | | unimaginative |
| d. gave you a sense of depth/space | | | | | | | | felt flat/ one dimensional |

14. Did you find the game:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| a. engaging | | | | | | | | un-engaging |
| b. absorbing | | | | | | | | dull |
| c. interesting | | | | | | | | uninteresting |
| d. stimulating | | | | | | | | tedious |
| e. inspiring | | | | | | | | uninspiring |
| f. unexpected | | | | | | | | predictable |
| g. enjoyable | | | | | | | | un-enjoyable |
| h. exciting | | | | | | | | unexciting |
| i. satisfying | | | | | | | | unsatisfying |
| j. challenging | | | | | | | | unchallenging |
| k. fun | | | | | | | | boring |

15. During the game, did the person or object that you controlled make you feel:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| a. confident | | | | | | | | unconfident |
| b. relaxed | | | | | | | | tense |
| c. calm | | | | | | | | angry |
| d. happy | | | | | | | | sad |
| e. strong | | | | | | | | weak |
| f. courageous | | | | | | | | cowardly |
| g. assertive | | | | | | | | timid |
| h. cheerful | | | | | | | | serious |

16. Rate the sensation of movement that you experienced during the game:

| | no sensation | mild | strong | intense | | no sensation | mild | strong | intense |
|---|---|---|---|---|---|---|---|---|---|
| a. driving | 0 ______ | 1 ______ | 2 ______ | 3 | d. walking | 0 ______ | 1 ______ | 2 ______ | 3 |
| b. flying | 0 ______ | 1 ______ | 2 ______ | 3 | e. running | 0 ______ | 1 ______ | 2 ______ | 3 |
| c. falling | 0 ______ | 1 ______ | 2 ______ | 3 | f. jumping | 0 ______ | 1 ______ | 2 ______ | 3 |

17. Rate the sensations/feelings that you had during the game:

| | no sensation | mild | strong | intense | | no sensation | mild | strong | intense |
|---|---|---|---|---|---|---|---|---|---|
| a. frightened | 0 ______ | 1 ______ | 2 ______ | 3 | c. disgusted | 0 ______ | 1 ______ | 2 ______ | 3 |
| b. nauseated | 0 ______ | 1 ______ | 2 ______ | 3 | d. shocking | 0 ______ | 1 ______ | 2 ______ | 3 |

18. did any of the following interrupt your concentration/attention while playing game?
ambient noise:_____ other people:___ display:___ interactive devices: ___ uncomfortable:___
thinking of other things: ___ other:____

## Appendix V Role-Playing User Study – Questionnaire

1. Age: ________________ 2. Male: ________ Female: ________

3i. do you play computer games: at home: ________ other, specify: ________
ii. how many times a week do you play computer games? ________
iii. how long do you play games for? ________
iv. what are your favourite games? ________________________________________

4i.what was the overall goal of the game you have just played? ____________________
ii. did you enjoy playing the game? yes: ___no: ___

5i. did you think the game was fast or slow or about right?
fast: _______ slow: ________ about right: ________
ii. if slow or fast: did you like it less because it was too fast/slow? yes: ___ no: ___

6. what were you in the game, what was your character, that is, what were you controlling?

________________________________________________________________

7. did you think it was easy or difficult to control and move [Boy/Girl] using the:

| | easy | difficult | why? |
|---|---|---|---|
| arrow keys: | | | |
| mouse: | | | |

8. did you have to think about what keys to press to control/move [Boy/Girl] or didn't you have to think about it, it felt natural and you just did it?
natural: __________ had to think: __________ why? ________________________

9i. did [Boy/Girl] move in the way that you wanted then to?
yes: __________ no: __________ why? ____________________________
ii. did all the objects and the scenery in the game move in the way that you thought they would? yes: __________ no: __________ why?____________________________

10i. did you think you had total, some or no control over what happened in the game?
total: __________ some: __________ no: __________ why?____________________
ii. did your level of control over what happened in the game make you enjoy the game?
more: __________ less: __________ why? ____________________________

11i. do you think the story made sense?
yes: __________ no: __________ why? ____________________________
ii. did you like the story?
yes: __________ no: __________ why? ____________________________

12i. did you think it was easy or difficult speaking during the game?
easy: __________ difficult: __________ why? ____________________________

ii. did you enjoy speaking?
yes: __________ no: __________ why? ____________________________

iii. did you have to think about what you were going to say or didn't you have to think about it, it felt natural and you just did it?
natural: __________ had to think: __________ why?____________________________

13. I'm going to ask you words to describe the [Boy's/Girl's/Witch's] personality. Would you say (s)he was:

| | very | quite | a little | a little | quite | very | |
|---|---|---|---|---|---|---|---|
| a. confident | | | | | | | scared |
| b. relaxed | | | | | | | tense |
| c. calm | | | | | | | angry |
| d. happy | | | | | | | sad |
| e. strong | | | | | | | weak |
| f. brave | | | | | | | cowardly |
| g. cheerful | | | | | | | serious |
| h. kind | | | | | | | evil |
| i. honest | | | | | | | dishonest |

14. did you find the graphics/scenes:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| a. interesting | | | | | | | dull/boring |
| b. made you feel at any time that you were: inside the castle | | | | | | | always in class |
| c. gave you a sense of space/depth | | | | | | | feel flat |

15. did you find the game:

| | very | quite | a little | a little | quite | very | |
|---|---|---|---|---|---|---|---|
| a. engaging | | | | | | | un-focused |
| b. interesting | | | | | | | uninteresting |
| c. surprising/ unexpected | | | | | | | predictable/ could guess what happens next |
| d. enjoyable | | | | | | | un-enjoyable |
| e. exciting | | | | | | | unexciting |
| f. fun | | | | | | | boring |

16. during the game did the [Boy/Girl/Witch] make you feel:

| | very | quite | a little | a little | quite | very | |
|---|---|---|---|---|---|---|---|
| a. confident | | | | | | | scared |
| b. relaxed | | | | | | | tense |
| c. calm | | | | | | | angry |
| d. happy | | | | | | | sad |
| e. strong | | | | | | | weak |
| f. brave | | | | | | | cowardly |
| g. cheerful | | | | | | | serious |
| h. kind | | | | | | | evil |
| i. honest | | | | | | | dishonest |

17. when you played the game did you ever feel that you were:

| | no sensation | mild | strong | intense | | no sensation | mild | strong | intense |
|---|---|---|---|---|---|---|---|---|---|
| a. walking | 0____ | 1 ____ | 2 ____ | 3 | b. running | 0____ | 1 ____ | 2 ____ | 3 |
| c. falling | 0____ | 1 ____ | 2 ____ | 3 | d. jumping | 0____ | 1 ____ | 2 ____ | 3 |

18. when you played the game did you ever feel that you were:

a. frightened 0_____ 1 _____ 2 _____3 b. shocked 0_____ 1 _____ 2 _____3

c. sick 0_____ 1 _____ 2 _____3

19. did any of the following interrupt your concentration/attention while playing game?
ambient noise:___ other people:___ jerky display:___ uncomfortable surroundings:___
thinking of things:__ looking at time: ___ strange sounds ___ interactive device/style __