Sketching and visual perception in conceptual design:

Case studies of novice and expert architecture students

Alexandre Monteiro de Menezes

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Alexandre Monteiro de Menezes

Supervisor: Prof. Bryan Lawson

To Rosana, Theo and Luma

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ABSTRACT

This research is concerned with conceptual sketches, visual perception and verbal description. Firstly, it focuses on the role of sketching in conceptual design and begins to question why conceptual sketches are considered a good medium for reflective conversation with one's own ideas and imagery. Secondly, it focuses exclusively on the mental process involved in the analysis and verbal description of conceptual sketches.

The empirical study examines how novice and expert designers might perceive different things from the same conceptual sketch and thus use different verbal descriptions, and what this might reveal about their different approaches to design. For this reason some experiments on visual perception, conceptual sketches and verbal description were conducted with expert and novice architecture students.

The main objective is to verify to what extent the use of formal references such as line, square or circle and symbolic references such as describing a circle as a sun or a long oval as a sausage, help to understand how designers might think with sketches, while searching for a specific design solution. It also investigates which of the two types of images (non-architectural and architectural sketches) present greater potential for allowing the use of formal and symbolic verbal references, and why.

The results show that, on average, the expert group used more formal and symbolic verbal references per minute than novices while describing the same images. The results also show that the non-architectural sketch was judged as easier to describe than the architectural one and gave rise to the use of more symbolic references. This can be seen to confirm earlier work suggesting that we find symbolic descriptions easier and more powerful than formal ones. The results also suggest that the expert students were more able to employ symbolic references to architectural concepts than novice students.

However, in many other respects there were few differences between the groups. This may in part be due to the limitations of the empirical methodology employed.

CONTENTS

VOLUME 1

LIST OF FIGURES

CHAPTER 2

CHAPTER 3

CHAPTER 4

CHAPTER 5

CHAPTER 6

LIST OF TABLES

CHAPTER 2

CHAPTER 4

CHAPTER 5

Chapter 1

Introduction

CHAPTER 1 – INTRODUCTION

1 – INTRODUCTION

This study is related to conceptual sketches, visual perception and verbal description. As this is a significantly broad subject area, it is not possible to encompass all aspects. However, as will be shown, the interaction between designers and drawings deserves careful attention to gain a better understanding of designers' thoughts.

In the conceptual stage of the design process, it is usual to find the use of some forms of graphic representation as conceptual sketches and abstract diagrams. These conceptual sketches and diagrams are different from any other type of drawings employed by designers, as can be seen in Chapter 2. This thesis starts by questioning why conceptual sketches are considered a good medium for reflective conversation with one's own ideas and imagery. This inquiry constitutes the principal focus of this research.

Some researchers (Schon 1992; Herbert 1993; Goldschmidt 1994; McGown 1998; Verstijnem 1998; Suwa 2000; Dorst 2001) have suggested that designers can see more information in the sketch than was invested in its making. It means that conceptual sketches seem to support the phenomena of emergence and reinterpretation during the early design activity. Emergence refers to new thoughts and ideas that could not be anticipated or planned before sketching. Reinterpretation refers to the ability to transform, develop and generate new images in the mind while sketching.

It appears that designers discover new information and features in sketches as they are being made. This seems to allow designers to look at them from different points of view and this is vital in this early stage. It can be suggested that some sketches provide visual clues for extracting new thoughts for the current design problem and for future use. This is the kind of sketching this work refers to as conceptual sketching.

The purpose of these conceptual sketches is to allow reinterpretation and development of inventive ideas and not for communication with others. Inventive ideas seem to allow architects to revisit their own sketches from new points of view and thus make new unexpected discoveries (Suwa 2000; Dorst 2001).

In order to better understand conceptual sketches and their influence on imagery and creativity, the research focuses on the mental process involved in the interaction with them. For this reason, the study of visual thinking is a highly, influential and relevant reference area. However, as it discussed in Chapter 2, visual thinking is a profoundly complex phenomenon and to provide a single definition is not the intention here.

This research will also show that this interaction between novice and expert architects and conceptual sketches has been the subject of various research investigations (Goldschmidt 1991; Lawson 1994; Goel 1995; Suwa 1997; Verstijnem 1998; Casakin 1999). According to them, sketching appears to be not as helpful for novices as for experts and has helped experts for the purpose of developing new ideas, but failed to do so for novices.

The objective here is to investigate differences in the way novice and expert architects interact with conceptual sketches. One way to approach this problem is by asking what they see and perceive while looking at conceptual images. For this reason, this research intends to invite novice and expert architecture students to describe what they can see while looking at the same images. The question that will be asked is how they use knowledge and memory to create analogies when describing what they are seeing. The outcome may reflect differences in content and meaning of the same images between the two groups.

This research suggests that identifying features in the mental process involved in the interaction and description of conceptual sketches could support future research to gain an insight into the designers' thoughts while sketching, and specially, how they use sketches in order to allow emergence and reinterpretation of new thoughts.

2 – DEFINITION OF THE MAIN PROBLEM

The main problem to investigate is the mental process involved in the interaction and description of conceptual sketches. The research focuses on the process of verbal description, and is concerned with differences between novice and expert designers in the way they use formal and symbolic verbal references, and what this might inform about the way they interact with sketches while designing. Formal references are geometric and physical features in the drawings, such as lines, squares or circles; Symbolic references are analogies to something else that are not in the drawings, such as trees, sausages or sun.

The results of several items of research suggest that it is not the ability of sketching that is the great difference between novice and expert designers, but the ability to interact with sketches (Goldschmidt 1991; Verstijnem 1998; Casakin 1999; Suwa 2000; Dorst 2001; Kavakli 2001). It seems reasonable to expect that novice and expert designers present differences in their process of interaction and description of conceptual sketches. Therefore, it could be suggested that expert architects perceive information from the visual display in freehand sketches and interact with their knowledge and memory, for reinterpretation and description of this information, in a different way to novice architects.

For this reason, this work supports that research into differences between these two groups – novice and expert designers – must be concerned with the reasoning process and its characteristics, and not on questions relating to the physical skill of sketching and use of diagrams. So, the focus is to compare how they use previous knowledge and memory for interpretation description of the same conceptual sketches.

In order to achieve this target, some experiments on visual perception, conceptual sketches and verbal description were conducted with expert and novice architecture students. The experiment intends to investigate differences in the way they describe their thoughts while looking at the same sketch and then compare the groups. This is not a study of sketches made during the actual process of designing, and it is not related to design activity, however, the output seems to mirror the result of a mental synthesis process, an activity thought to occur in the design process.

A high quality in description is not expected, but it is hypothesised that the quality of the description for the expert architecture students would be higher than for novices because of their ability in recognizing features in visual displays. It is also hypothesised that experts use their memory and previous knowledge more effectively to create analogies using more formal and symbolic verbal references to describe what they are thinking.

3 – OBJECTIVE AND IMPLICATIONS OF THE RESEARCH

The main objective of this research is to verify to what extent the use of formal and symbolic verbal references used by designers during the description of conceptual sketches help to understand how they might think with sketches while searching for a specific design solution. This research also would like to investigate whether expertise is related to the use of formal and analogical reasoning, and if so, in what way.

This study suggests that identifying and classifying verbal cognitive actions during the process of interpretation and description of conceptual sketches could enable future research to gain an insight into the designer's reasoning steps. This could probably support the study of how designers interact with their own conceptual sketches and, specially, how sketching could allow unexpected thoughts. Therefore, this research seems to have inevitable implications for design education and practice.

This study intends to contribute to the investigation of how and when to teach drawing skills to design students. There is a lot of evidence from other research (Larkin 1987; Purcell 1998; Verstijnem 1998; Kokotovich 2000; Kavakli 2001) to suggest that designers are able to get benefits from drawings because they were trained to use them in the way required to design, thus facilitating emergence and reinterpretation allowing new design ideas, and those who have not been trained in this way have less benefit from them. These seem to be fundamental issues for teaching drawing skills in architecture schools. For designers it is not just a matter of drawing to represent existing things.

This research supports the idea that if imagery can be amplified by sketching there is no reason to assume that it cannot be further amplified using computers. However, this study agrees with other researchers and also identifies obstacles against the use of current CAD software during the conceptual stage of the design process (Goel 1995; Gross 1996; Lawson 1997a).

According to Gross the precise and structured internal CAD representations and tedious mouse-based interfaces are two big obstacles (Gross 1996). It seems that such computer tools must be intuitive and their use may not require specialized knowledge to facilitate lateral transformations, using Goel's term, that are essential in the early phases of the design process (Goel 1995).

It appears that Lawson agrees with Gross, when suggesting that the computational theory of mind fails to communicate the richness and diversity of thinking implied by freehand sketching activity (Gross 1996; Lawson 1997a). For Lawson, the problem in design is that the situation itself is very fluid and it is often represented by drawings, which may be quite hard to understand. He concludes that for expert computational systems to be really useful to designers they need to be able to read those design sketches in order to approach the design problem.

According to Lawson, the most difficult part of this question is how the computer 'understands' the design but there is significant work going on to enable computers to recognise the kinds of rough sketches and diagrams (Lawson 1997b).

4 - GENERAL STRUCTURE OF THE THESIS

This thesis is divided into six chapters and eight annexes. The whole thesis is divided into two volumes where Volume 1 contains the chapters and Volume 2 contains the annexes.

Volume 1

Chapter 1 provides an introduction to the whole thesis, which is divided into five sections. The first section is a brief introduction to the chapter where general interests are presented. This research starts asking why conceptual sketches are considered a good medium for reflective conversation. The second section explains that the main focus of the investigation is regarding the differences between novice and expert designers related to the mental process involved in the interaction with conceptual sketches. It seems that a key difference between them is the experts' ability to interact with sketches and their reasoning approach to the design problem supported by sketches.

The third section of this chapter presents the objectives and implications of the research. The suggestion is that people need to learn how to draw in order to design, that is, in a way to allow emergence and reinterpretation of new thoughts, and this seems to be a different approach to teaching drawing skills in an architecture school. This also suggests some implications for a computer tool to support early design activities. The fourth section provides a general structure of the thesis. The fifth section presents the bibliographic references related to Chapter 1.

Chapter 2 is related to the different types and uses of drawings during the architectural design process and is divided into five sections. The first section is an introduction to the chapter, where general aims and interests are presented. Section two presents different types of architectural drawings. As can be seen in this section, architectural drawings basically belong to two different projection systems: Cylinder and Conical. All these projection systems result from the way a three-dimensional object is projected onto a two-dimensional plane of projection.

What seems to be relevant is the classification and application of different types of architectural drawings and their different roles during the design process. As will be shown in Chapter 2, no drawing is considered a lesser drawing and all of them contain important information used to help and clarify specific modes of seeing during the design process. This section also explores the influence of words and conversation during the process of generating ideas.

Section three of Chapter 2 approaches the sketching activity during the conceptual design stage. As this section will show, there is evidence that with rapid sketches designers transform images and each sketch allows the generation of new images in the mind. It is demonstrated that many different types of sketch are used even within the conceptual design stage. This section also presents a classification system for sketches and it is suggested that the uncertainty in these sketches appears to be important in the conceptual design activities.

Section four is dedicated to the study of visual thinking and its influence on architectural design process and unexpected discoveries. However as this fourth section will demonstrate, visual thinking has different meanings and connotations for different people, and it seems only to be possible to suggest some approaches. However, as will be shown, even when basic approaches are taken together, there still remains a debate over the nature of visual thinking.

The suggestion is that, in design terms, the nature of visual thinking is seen and understood as a process in which ideas emerge through sketching, rather than the view that ideas originate first in the designer's mind. The fifth section of Chapter 2 presents its bibliographic references.

Chapter 3's main focus is the study of the mental process involved in the designer's interaction with conceptual sketches. The focus is on how the brain and memory work. It suggests that novice and expert architects differ from each other in the way they use knowledge and memory to perceive information from freehand conceptual sketches. This chapter is divided into six sections.

Section one is a brief introduction to the whole chapter, where general areas of interest and some objectives are presented. Section two is concerned with differences between novice and expert designers. It is suggested that some of the important skills of the expert designers seems to be their ability to recognize visual clues and to retrieve large knowledge chunks from memory.

Section three of Chapter 3 is mainly concerned with human cognitive actions of perception, imagery, remembering and creativity. The section starts with a distinction between passive reception and active perception and suggests that the diversity of treatment of visual patterns is due the importance of the second one. The understanding of this difference appears to be crucial for the development of the argument and hypothesis of this research.

Section four examines the use of memory and precedents in a design solution. The focus is on the study of how the human brain works and how memory is used during design activities. The section provides evidence to demonstrate that knowledge and procedures relevant to solving a design problem seems to be retrieved from long-term memory and used in short-term memory.

This section shows that the cortex of the human brain is symmetrically divided into two hemispheres and they seem to process information in different ways. It is recognized that the left-brain controls the right-hand side of the body and right brain the left-hand side. However, in terms of cognitive functions, the left cerebral hemisphere is verbal, analytic, logical, linear and time oriented, whereas the right hemisphere is non-verbal, intuitive, diffuse, spatial, and timeless.

Clearly the design process requires both sides of the brain, involving linear/analytical and intuitive/creative thinking. It is suggested that neither of them is more important than the other, but both seem to be essential components in designing. These findings are supported by Tovey's work related to designing with both halves of the brain and Lawson's view when suggesting that design involves both convergent and divergent productive thinking (Tovey 1984; Lawson 1997).

The fifth section presents and discusses some questions from other researchers related to the same theme. It is suggested that expert architects perceive information from freehand sketches and interact with their knowledge and memory, for interpretation and description of this information, in a different way to novice architects. The investigative hypothesis is presented and can be summarized in this way: The descriptions of expert architects would be higher in quality and richer in symbolic references than the descriptions of novice architects, because of their training in recognizing features in visual displays and their ability to use prior knowledge and memory more effectively to create analogies while describing what they are seeing. The sixth section of this chapter contains the bibliographic references.

Chapter 4 presents the methodology developed and employed in this work, and is divided into seven sections. Section one is a brief introduction to the chapter where the objectives and background theories are presented. A variety of reactions are expected in this type of experiment and these images used – conceptual sketches – can be compared with Rorschach cards, which are interpreted in many different ways by those who perceive them. Therefore the 'Rorschach Test' and its influence in this work are also presented.

Section two is related to the methodology and procedures of the experiment. At the beginning, subjects receive a set of general instructions about tasks. There are two descriptions tasks, one remembering task and one review task. The apparatus, stimuli and instructions to subjects are presented within this section.

The third section of this chapter discusses the images selected for this experiment. The criteria adopted to select the right images are presented. As will be shown, the images belong to two different groups: non-architectural sketches and architectural conceptual sketches. The experiment intends to allow free reinterpretation and to compare subjects while perceiving, recognizing and describing their thoughts. It is expected that a variety of displays emerge in imagery and descriptions may be equally diversified.

Section four describes the two pilot studies developed and conducted during this study. The focus of this section is the identification of problems and mistakes during the pilot studies. From these pilot studies the final images and the final instructions were defined.

The fifth section presents the final experiment, the subjects involved and the tasks. The experiment provided interesting data for further analysis. The results and analysis of data are presented in the next chapter of this research. The sixth section presents the limitations and potential problems of the methodology adopted in this work. They are related to procedure of the experiment, number of images used and specific culture of participants. The seventh and last section of Chapter 4 provides the bibliographic references.

Chapter 5 is dedicated to the results and analysis of the data and is divided into five parts. Part one is a brief introduction that presents an overview of the whole chapter. Part two presents an overview of the lengths of time for all sessions and tasks. This part is divided into three sections: Session times, tasks times and a summary of results. Part three of the chapter is related to the analysis of the protocols. This part is divided into four sections: Previous protocols analysis, the method developed, results and conclusions. Part four is related to the analysis of the drawings. The experiment used two different types of drawing: drawings made during the description task and drawings made during the remembering task. The fifth part presents the bibliographic references.

The protocol analysis method developed in this work was adapted from the analysis method proposed by Suwa and Tversky, and Suwa, Purcell and Gero (Suwa 1997; Suwa 1998). It is based on segments and cognitive actions of designers and intends to inspect their thoughts and behaviour while perceiving, remembering and describing freehand conceptual sketches.

As many previous protocols analysis methods have done (Suwa 1998; Suwa 2000; Kavakli 2001) this study also used retrospective reporting that employed both segmentation and encoded categories of cognitive actions. In relation to the focal interest of this research, the analysis concentrates on verbal cognitive actions and their subclasses. However, in the videotapes it is possible to identify a strong link between verbal and physical cognitive actions, which suggests a very interesting field for further research.

In order to develop its own method of analysis, this work conducted different approaches to the protocol analysis. During the first and second approaches some problems were found camouflaging the results and masking the data interpretation. The different approaches to the protocols can be seen at Annex IV and the final analysis at Annex V.

The results are presented and divided into three groups: the segmentation scheme, verbal cognitive action categories and the indication of which image was easier to describe and why. The suggestion is that the easier image to describe is always the one that is recognizable to the subject and he/she can use knowledge retrieved by memory and create analogies to describe their thoughts. It appears that names were commonly used and occupied a position of great importance during the descriptions. The names, in many cases, determined what was perceived. This seems to be supported by Bartlett's findings (Bartlett 1950; Bartlett 1958).

In order to analyse the drawings, 7 referees ranked them. All referees are architects and staff from the School of Architecture of The University of Sheffield. A statistically high level of concordance between referees was found, therefore all the analysis was based on the results of the average referees ranking (Kendall Coefficient of Concordance for non-architectural sketch w=0.80 and architectural sketch w=0.74).

Chapter 6, the last chapter of Volume 1, presents the conclusions, final considerations and future implications of this research. It is divided into four sections. The first is a brief introduction to the chapter. The second section presents the principal results and some discussions. The third section is concerned with future research and implications of this study. The fourth and last section presents the bibliographic references.

This study focuses on differences between novice and experts designers related to the mental process involved in the descriptions of conceptual sketches. Some statistical significant differences between subjects groups were found and show that the expert group used more segments per minute and more verbal cognitive actions per minute on average for both descriptions than novices. However, a very little statically significant difference between them was actually found. These, according to the author, were surprising, unexpected and interesting results. A number of reasons why these results should be treated with caution will be presented in this chapter.

Volume 2

Annex I present the sketches pre-selected for the experiment as mentioned in Chapter 4. There are two groups of images (non-architectural and architectural) and twelve sketches in each group.

Annex II shows the material used during the final experiment. General information to the subjects and specific information to subjects A and B are presented. This annex also presents the images used in the final experiment and the work paper given to subjects.

Annex III presents all descriptions made by subjects during the experiment. There are sixty different descriptions where thirty are related to the non-architectural sketch and thirty to the architectural one.

Annex IV presents the two different approaches to the protocol analysis.

Annex V presents the final analysis of the protocols. Each description was fragmented into small segments and each segment was analysed in order to identify and quantify verbal cognitive actions.

Annex VI shows the drawings produced during the description tasks. There are sixty drawings where thirty are from the non-architectural description and thirty from the architectural description.

Annex VII shows the drawings produced during the remembering task. Again there are sixty drawings where thirty are non-architectural and thirty architectural images.

Annex VIII presents the summary of the findings and the results of this research.

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Chapter 2

Drawings and design process

CHAPTER 2 - DRAWINGS AND DESIGN PROCESS

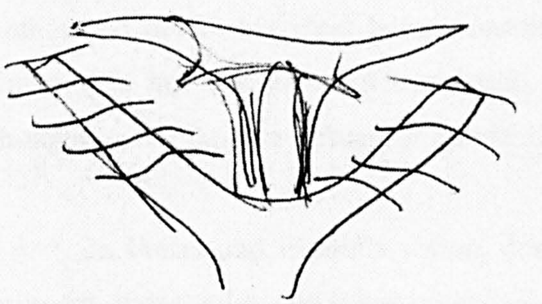
1 – INTRODUCTION

This chapter relates to the use of drawing during the design process. The use of different types of drawings is a characteristic in all areas of design (Herbert 1993; Fraser 1994; Purcell 1998) and different types of drawings are associated with different stages of the design process (Goel 1995; Lawson 1997; Purcell 1998). The aim of this chapter is to examine architectural drawings and their applications, in order to gain a better understanding of the design process.

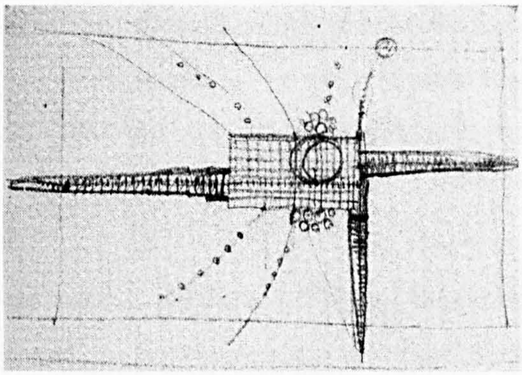
In design it is assumed that different stages of the process are associated with different types of drawings. Visual representations are present in all stages of the design process, from early sketches to CAD-rendered drawings. The focus of this chapter is to study these different types of drawings employed during the design process.

To achieve this, the chapter is divided into five sections. The first section is an introduction to the whole chapter. The second section shows that architectural drawings basically belong to two different projection systems: Cylinder and Conical. What is relevant for this work is the information about various different types of architectural drawings and their roles during different stages in the design process.

The third section of this chapter focuses on sketching activity and its role in creative discovery. This section will solely concentrate on the study of sketching in the early conceptual phase of the architectural design process (Figure 2.01). As it will be shown, these conceptual sketches are different from the any other types of drawings employed by designers. The interest of this section is in understanding why they - conceptual sketches - are considered a good medium for reflective conversation with one's own ideas and imagery.



A



B

Figure 2.01: Different types of conceptual architectural sketches
A – Paolo Soleri - Villages 1961. The sketchbooks of Paolo Soleri 1971: 109
B – Ivan Leonidov – The complete works 1988: 100

The fourth section is concerned with visual thinking and its relation to freehand conceptual sketches. As can be seen, in terms of visual thinking, the sketches that are of interest are mainly those that are being made before it becomes clear what the concept of the design is. It appears that sketches give access to various mental images that allow modification of ideas on the current design problem and it seems that the production of design ideas tends to depend upon the interaction with the concept sketches.

This interaction between architects and sketches has been the subject of a lot of research (Goldschmidt 1991; Lawson 1994; Suwa 1997) and the same basic questions have already been formulated and investigated. This research is also interested in how and what information expert architects see in the conceptual sketches and how they differ from novices. The fifth and last section presents the bibliographic references for the chapter.

2 - DRAWINGS AND DESIGN PROCESS

2.1 – Introduction

The activity of drawing involved in the design process is a highly significant one, because it is an activity conventionalised and personal, shared and private, involving the discovery of forms and their communication (Fraser 1994). For Fraser and Henmi the drawing activity in the design process lies between the imagination of the designer and the design of a product (Fraser 1994). According to them, drawings are more than passive recipients of their authors' action. 'Drawing intervenes between an author and her or his ideas being considered a third presence' (p viii). In this sense, drawing is not a transparent translation of thought but a medium which influences thought just as thought influences drawing.

In Fraser and Henmi's vision, drawings have a lifetime, persisting beyond the moment of execution and initial reception, and influencing those who view them (Fraser 1994). This is supported by Schon when he notes that while drawing can be rapid and spontaneous, its residual traces are stable and can be subsequently examined later by the designer (Schon 1983).

According to Fraser and Henmi once a drawing has been completed, its author is absent, and its influence exists independently, acquiring its own voice and its own history through many acts of viewing and interpreting (Fraser 1994). For Fraser and Henmi, a powerful drawing may last decades, its physical presence continuing to make a vision indelible. Again, this is supported by Schon's work, when suggesting that completed drawings have their own physical presence and materiality independent of their maker (Schon 1983).

This research agrees with Fraser and Henmi when they state that 'drawing's involvement in the process of thoughts and representation is not a simple, linear condition of presentation/ representation or conceptualisation/drawing but rather one of complex, interwoven relationship between presentation/representation, drawing/building/language and thought' (Fraser 1994).

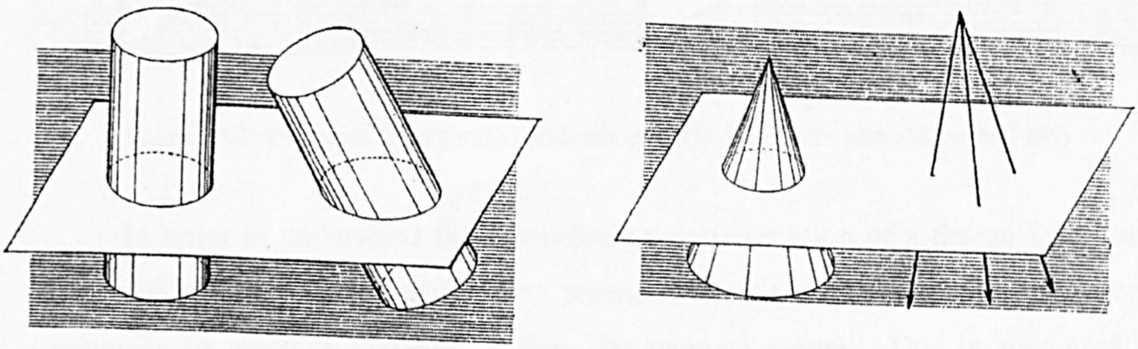
2.2 - Types of architectural drawings

The need for visualisation is recognized in several design fields. That externalisation for visualization fulfils a need and it is suggested by the fact that most artists and designers use some kind of externalisation, such sketching and modelling. They consider this essential for their creative process. Architects also use drawings as a means for speculating, testing ideas through their graphic representation.

Architectural drawings basically belong to two different Projection Systems: Cylinder and Conical (Figure 2.02). What is relevant for this work is the information that depending on the angle of projection, that is conveyed in various different types of architectural drawings.

Architectural drawings have been analysed by several researchers (Herbert 1993; Fraser 1994; Ching 2003; Porter 2003) and it seems to be useful to revisit some of them here. Fraser and Hemni analysed architectural drawings and presented three types grouped according to the projections systems: orthogonal, axonometric and perspective drawings (Fraser 1994). Ching also presents the same three distinct types of drawing systems that he called: multiview, paraline and perspective drawings (Ching 2003). Porter and Goodman's classification system also use these three types of drawings called: orthographic projections, axonometric and perspective (Porter 2003).

All these drawing systems result from the way a three-dimensional object is projected onto a two-dimensional plane of projection. All of them, although sometimes applying different terms, belong to Cylinder and Conic projection systems. For Ching this is the central task of architectural drawing: representing three-dimensional forms and spatial environments on a two dimensional surface (Ching 2003).



Cylinder Projection System　　　　Conic Projection System

Figure 2.02: Projection Systems - Cylinder results from parallel projected lines and Conic results from radiating projected lines (Menezes 1996).

2.2.1 - Orthogonal drawings

Orthogonal drawings are drawings where the projection lines are all parallels and orthogonal to the picture plane (figure 2.03). The results are 2D drawings where only two dimensions are accurately measured in each drawing, as it uses two axes of measurement. In plan, the axes measure length and width, while in section and elevation the axes measure width and height.

Ching points out that ambiguity of depth is inherent in any orthographic projection as the 3rd dimension is flattened onto the picture plane (Ching 2003). For him, one of the greatest advantages of using orthographic projections is to be able to describe facets of form parallel to the picture plane without foreshortening.

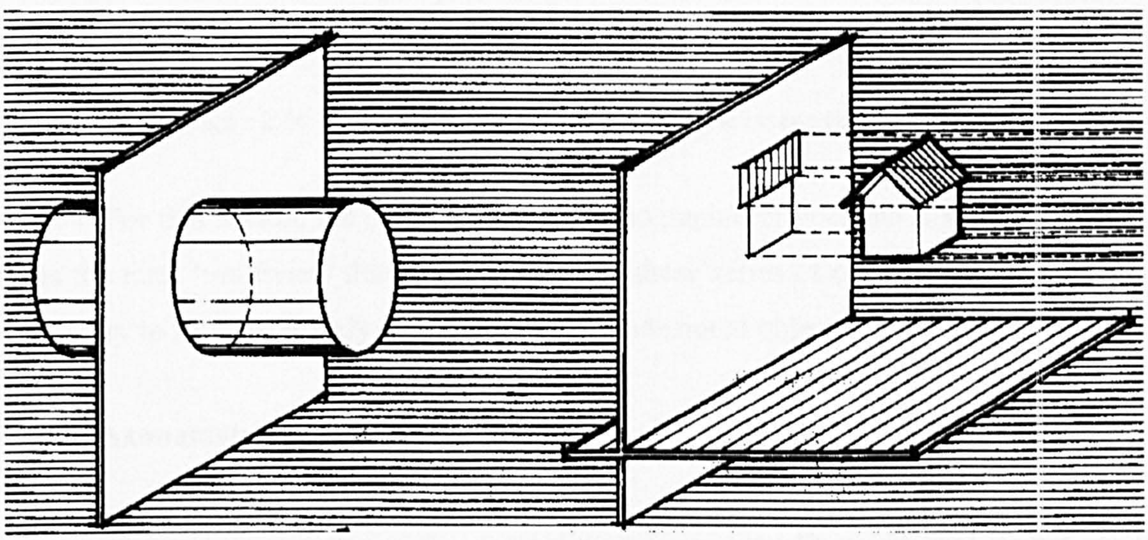


Figure 2.03: Projection lines parallel and orthogonal to the picture plan (Menezes 1996)

In order to understand the three-dimensional condition of a design from these orthographic drawings, it seems to be necessary to view several related orthogonal projections to mentally construct a three-dimensional model. This is supported by Fraser and Hemni when they suggest that the vertical views of elevations or sections and the horizontal views of a plan need to be cross-referenced or synthesized in the mind in order to understand the three dimensionality of a design (Fraser 1994). That is why plans, elevations and sections are often studied and presented together as combined views (Figure 2.04).

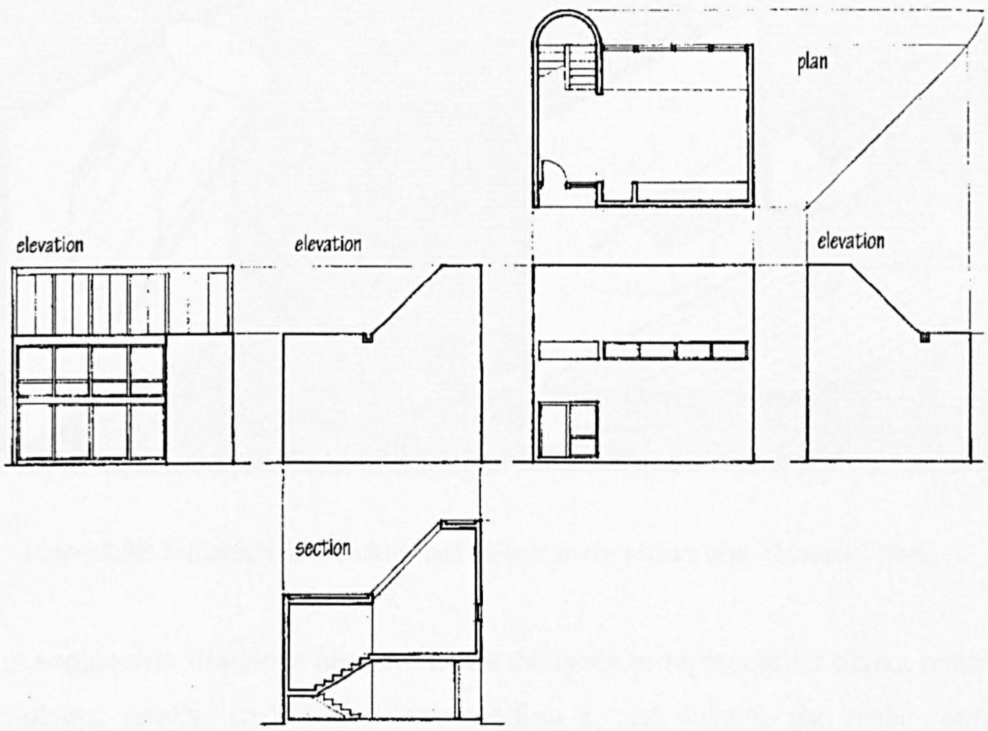


Figure 2.04: Plan, section and elevation as combined views (Ching 1996)

For this reason, the need for several orthographic projections is apparent, Ching uses the term 'multiview drawings' to describe these series of orthographic projections necessary to fully accurately describe a three-dimensional object (Ching 2003).

2.2.2 - Axonometric drawings

These drawings depict the three dimensions – length, width and height -in a single drawing. In contrast with orthogonal drawings that use two dimensions in each construction, they use three axes for measurement. Porter points out that axonometric drawings provide one of the most popular graphic vehicles in design currency (Porter 2003). Porter states that 'it can bring the plan, elevation and section together in a quickly drafted and easily understood illusion of space' (Porter 2003).

It is important to clarify that the images that emerge from oblique projections (Figure 2.05) are distinct from isometric views that are developed from orthographic projections. Oblique drawings have a higher angle of view than isometric drawings (Ching 2003).

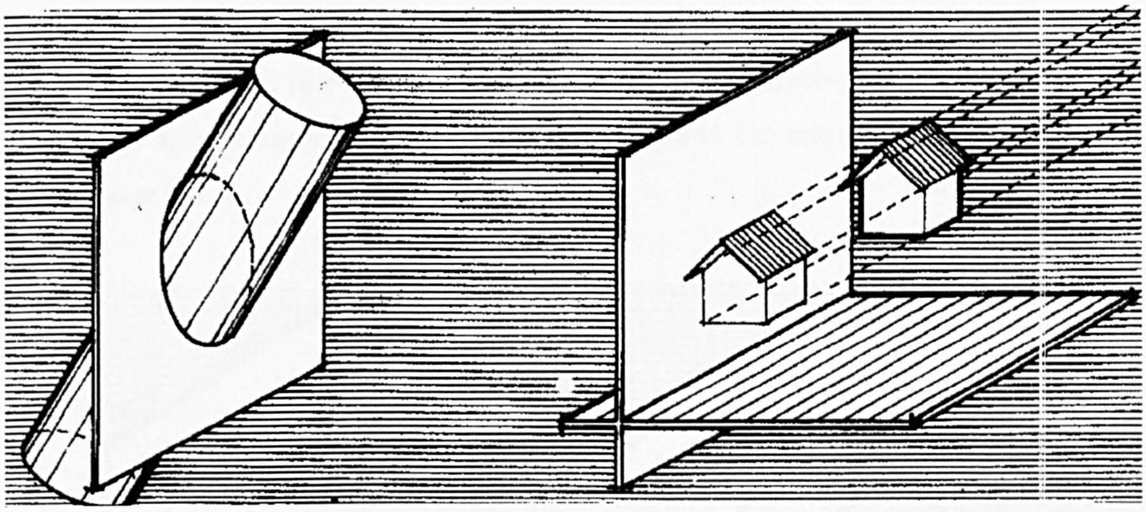


Figure 2.05: Projection lines parallel and oblique to the picture plan. (Menezes 1996)

Axonometric drawings also allow the designer to represent an object relative to another object, relative to the space surrounding it, and even to the space contained within a building (Figure 2.06). For Fraser and Hemni, it is this graphic simultaneity that makes the axonometric construct such a valuable tool for three-dimensional visualization (Fraser 1994). Using their words, 'the facsimile of three-dimensionality combined with the ease of construction and scaling make it a compelling graphic device with which to study developing designs from many viewpoints and with virtually any degree of dissection' (Fraser 1994).

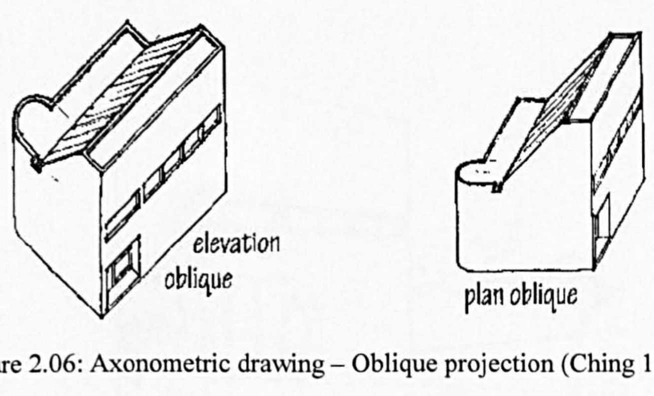


Figure 2.06: Axonometric drawing – Oblique projection (Ching 1996)

2.2.3 - Perspective drawings

Perspective drawings are constructed by projecting lines from a point representing a specific point of view (Figure 2.07). Moving this specific point of view and projecting lines from a different point will alter the result. Every different point of view will produce a different picture and dramatically affect the appearance of the drawing. According to Fraser and Hemni, since its construction is dependent on the location of this presumed viewer, the drawings depict the nature of a view from one spot (Fraser 1994).

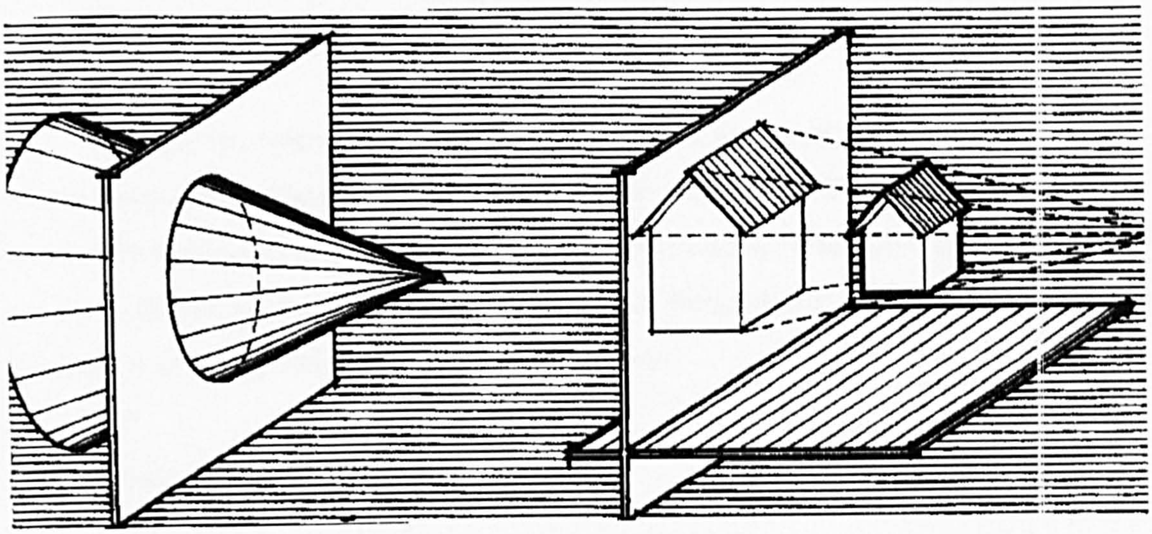


Figure 2.07: projection lines from a pre-established point of view (Menezes 1996)

In the perspective drawings, depth, length and width are all shown, relative to each other and relative to this specific point of view. The drawings give a sense of being there, depicting the quality of experiencing the building from that place (Figure 2.08).

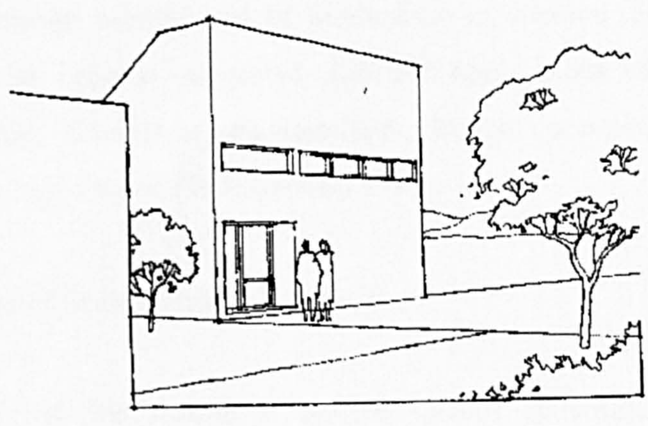


Figure 2.08: Perspective drawing (Ching 1996)

Unlike the orthographic and axonometric projections where the projectors are parallels, in perspective, the projectors converge at this point of view (Ching 2003). These converging projectors in perspective give rise to the two principal pictorial characteristics of perspective drawings: convergence of parallel lines and reduced size with distance.

During the Renaissance, perspective was seen as a symbolic form representative of the humanistic rationalistic ideals of the period (Ching 2003). It was a discovery, a new method of seeing the world. For contemporary users, perspective as a medium has a very different resonance than it did during the Renaissance. Today it is an ordinary method of drawing, which is useful and convenient.

2.2.4 - In summary

It can be concluded that each type of drawing has virtues and advantages. All drawings select information in order to help and clarify specific modes of seeing. No drawing is a lesser drawing. A plan is not less than an axonometric because it concretises only two rather than three dimensions. As this work shall show, each drawing offers specific potentialities for organizing perception and understanding.

It is not the intention here to teach drawing skills, but to study the role of the drawings in the design process and its implication in creative discovery. In this way Fraser, Hemni and Lawson suggested different applications of these architectural drawings, including referential, diagrammatic, design, presentation, visionary and construction drawings (Fraser 1994; Lawson 1997).

2.3 - Applications of architectural drawings

The focus of this section is on the various different ways architects use drawings. For this purpose, Fraser and Hemni's classification system seems to be useful (Fraser 1994). These were called 'referential drawings', 'diagrams', 'design drawings', 'presentation drawings', and 'visionary drawings' and Lawson added 'construction drawings' (Lawson 1997). All of them have different roles to play in the design process.

For Fraser and Hemni, 'whether drawings are referring to an existing environment, diagramming, presenting a design or giving concrete form to a visionary idea, they pull their authors into the imaginary world of envisioning, representing and therefore designing' (Fraser 1994).

2.3.1 - Referential drawings

Referential drawings are not usually considered to be part of the design process. What distinguishes them from the other applications of drawing is their focus on the existing phenomena. That is, they intend to draw that which is seen, to use a drawing as a means of understanding what is, in order to design what might be. They can be orthographic, axonometric or perspective, but not necessarily scaled or measured. Not every referential drawing is of an existing building, and they can be of rivers, landscape, nudes, etc. Normally designers use them to record others designers and the world around them.

For Lawson these referential drawings force the need to pass an idea from eye to mind to hand and it results in a level of understanding not necessary when simply looking at, or photographing, an object or place (Lawson 1997). The process of drawing is one of the best ways to absorb design ideas and perhaps, he affirmed, 'this explains why so many designers keep sketchbooks to record things they see' (Lawson 1997).

Referential drawings are considered to be a valuable tool for insight and inspiration, because turning to a sketchbook invokes memories and impressions. When looking at our own referential drawings (Figure 2.09) we are reminded of the experience of the sounds, of the smell, of the wind and of the light. The architect may refer back to a drawing for information, confirmation and as stimulus for memories of a prior experience.

Figure 2.09 – Alexandre Menezes: Botanical Gardens – Sheffield /UK. 2002

However, according to Lawson it is possible to see evidence of these referential drawings emerging as part of the design process (Lawson 1997). He shows several drawings done by the architect/engineer Santiago Calatrava (Figure 2.10) when working on his design to complete the Cathedral of St John the Divine in New York.

According to Lawson, in this case 'we see a referential drawing used to turn some guiding principles into a primary generator for a particular design' (Lawson 1997).

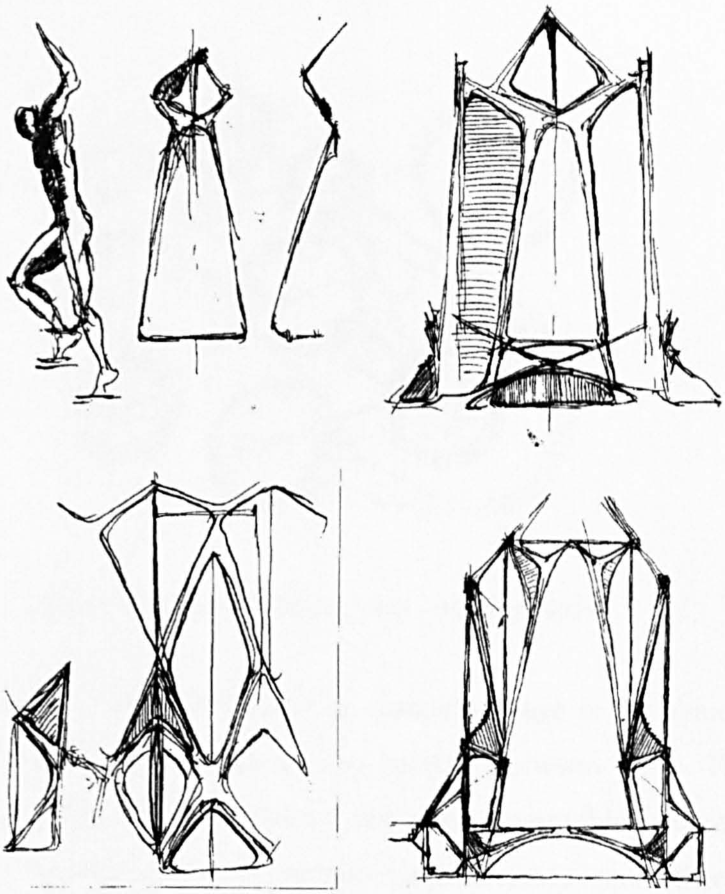


Figure 2.10: Drawings from Santiago Calatrava when working on his design to complete the Cathedral of St John the Divine in New York (Lawson 1997)

2.3.2 - Diagrams

Diagrams offer other applications as architectural drawings. Any drawing type whether orthographic, axonometric or perspective, can be used for diagrams. The characteristic of diagrams is their ability to simplify the consideration of formal or conceptual qualities by minimizing the elements presented. For Fraser and Hemni, diagrams aim for clarity and conciseness, avoiding ambiguity and focusing on one specific issue in isolation (Fraser 1994).

Every drawing can be considered diagrammatic in the sense that it involves a process of abstraction and a corresponding reduction of information. Diagrams are limited in their representation of the real world and they are intended to represent relationships. Architects typically may use bubble diagrams to represent the required relationships between spaces in a building (Figure 2. 11).

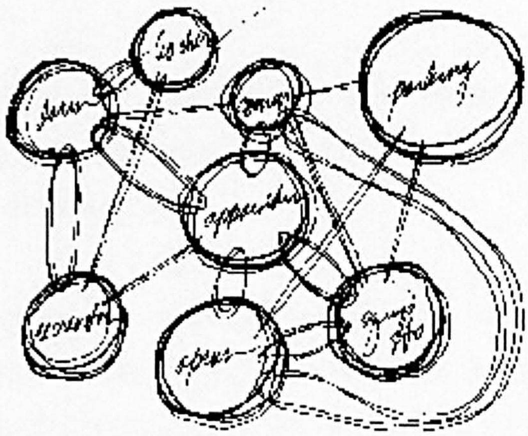


Figure 2.11: Edward T. White, 1986 - (Herbert 1993)

A good example of these diagrams in common usage is the famous London Underground map (Figure 2.12) as suggested by Lawson (Lawson 1997). This diagram represents the relationships between stations not their geographical location. If this diagram were used to calculate distances, certainly unpredictable incorrect results would be attained. This is because it is a topological diagram showing what is connected to what and by which line. In that way, no other information inferred from it can be assumed to be reliable, not even for orientation.

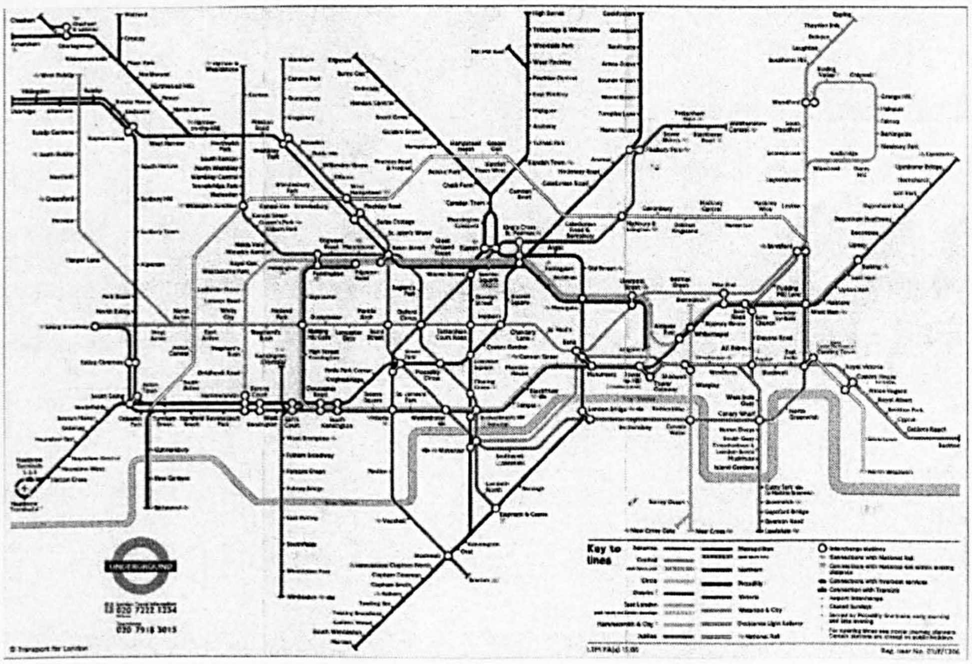


Figure 2.12: London Underground Map

2.3.3 - Design drawings

Design drawings are the focus of this work although referential drawings, diagrams, visionary drawings, presentation drawings and construction drawings also have roles to play in the design process.

According to Lawson one of the most challenging aspects of designing is the need to keep in mind and to consider so many disparate factors and perhaps for this reason, the drawing is such a popular tool with designers (Lawson 1997). For him, the drawing represents a sort of hypothesis or 'what if' tool. According to him design drawings usually display two important characteristics. First, the drawing does not show or suggest answers to questions, which are not being asked at the time. Second, the drawing suggests only a level of precision, which corresponds to the level of certainty in designer's mind at the time.

The sketch plan of the Sainsbury Wing for the National Gallery in London, by Robert Venturi and Denise Scott Brown, can be seen as a good example of these characteristics (Lawson 1997). A series of plan sketches by Robert Venturi (Figure 2.13) shows these two ideas under examination and appear very much as if the designer was having a conversation with the drawing, as described by Schon (Schon 1983).

According to Fraser and Hemni, design drawings are done primarily as a way to study architecture, to find and test ideas, and to develop the process of inspiration, invention and exploration (Fraser 1994). Intended as means for private discovery, design drawings are often less self-conscious about graphic conventions and correctness. In this sense, what is correct is whatever works for the author.

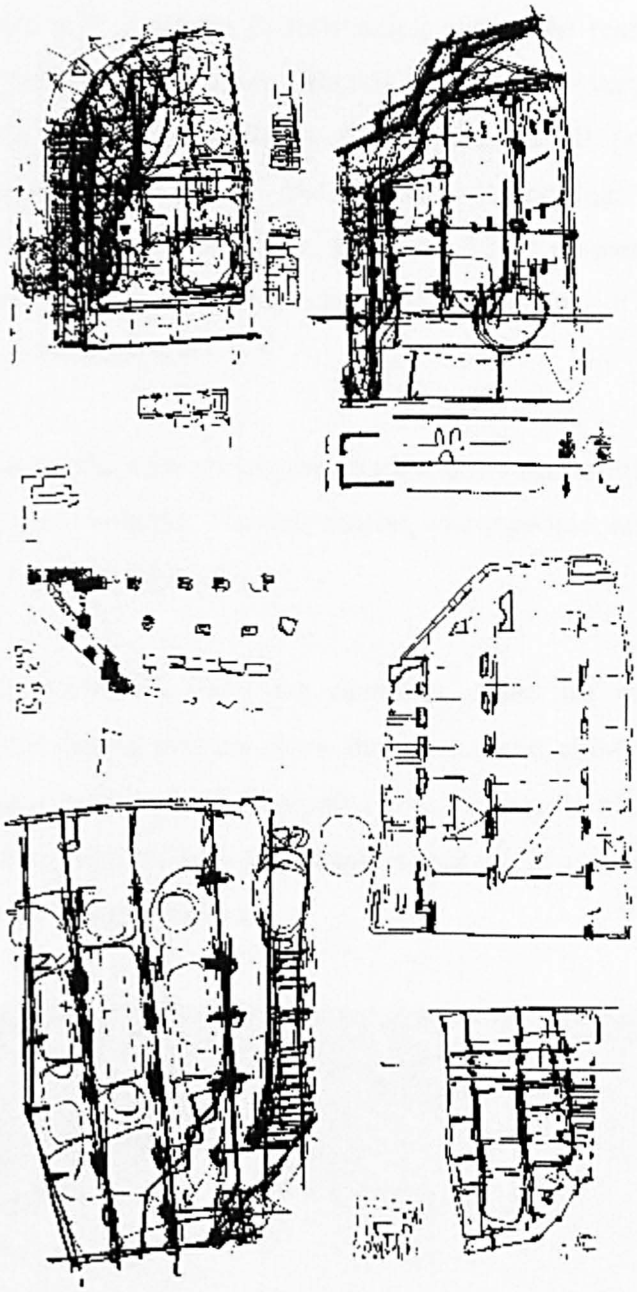


Figure 2.13: Sketches by Robert Venturi – (Lawson 1994)

2.3.4 - Presentation drawings

Presentation drawings are those drawings architects prepare in order to convince an audience of the merits of a design. As they are intended to engage and persuade an outside audience, these graphics are usually the most finished, carefully crafted and artful of drawings (Figure 2. 14).

These presentation drawings are the most public of architectural drawings playing an important role in public understanding before the realization of a project. They are the end results of a graphic process and are thus very different from the incomplete character of design drawings. Fraser and Hemni pointed out that 'the difference in attitudes between design and presentation drawings is evidenced by the fact that architectural offices frequently have the latter prepared by professionals delineators, freelance individuals who specialize in the business of making compelling, persuasive drawings' (Fraser 1994).

It seems that by the time these presentation drawings are produced, the design process is more or less complete. For this reason, many people assume that they have nothing to do with that design process.

However, in Lawson's view the drawings made for clients are often an important part of the design process since they frame the client's perception of the design and consequent reaction to it (Lawson 1997). Clearly, in his opinion, the role of the drawing as communication between designer and client is crucial and potentially problematic within the design process.

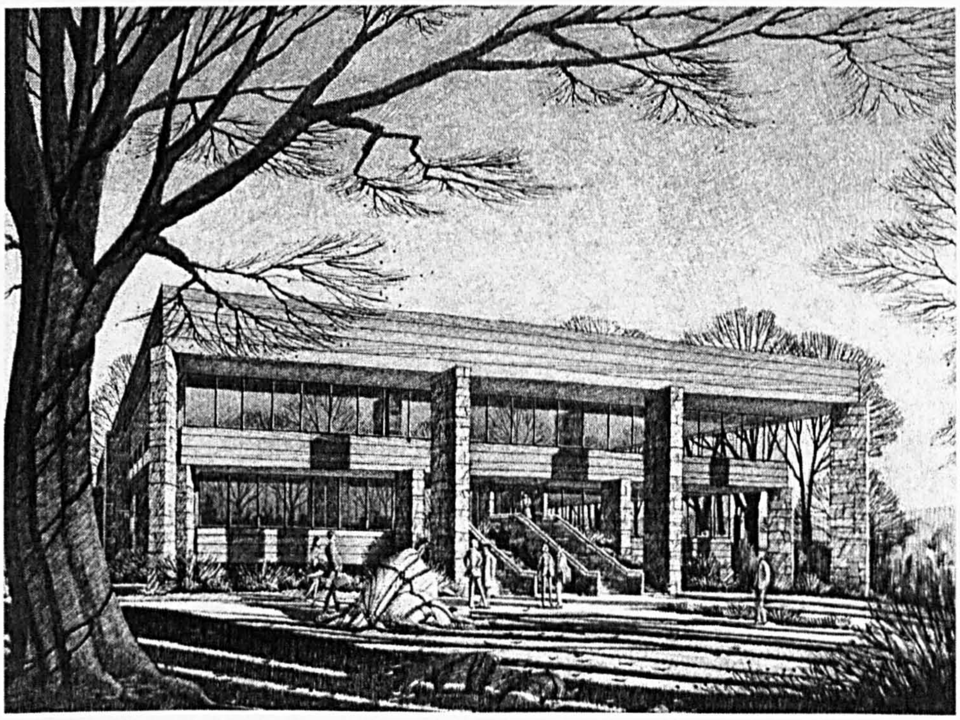


Figure 2.14: Presentation drawing - (Doyle 1981)

2.3.5 - Visionary drawings

Visionary drawings are not only representations of architectural intentions, but also as a presentation of architectural visions, which can only be experienced through drawings. Such drawings represent more than the shapes of an intended object; they evoke a sense of light, atmosphere, monumentality, texture and intent.

According to Fraser and Hemni, the elaborated, constructed nature of visionary drawings manifest imaginary worlds, which cannot exist in any other realm except through drawings (Fraser 1994). In this sense, they conclude, a drawing represents an author's entire virtual world, nascent in the imagination. A good example is the work of the Dutch artist M. C. Escher (Figure 2.15). Escher explores that impossible world and allows people to explore its structure with their eyes and its life with their imaginations.

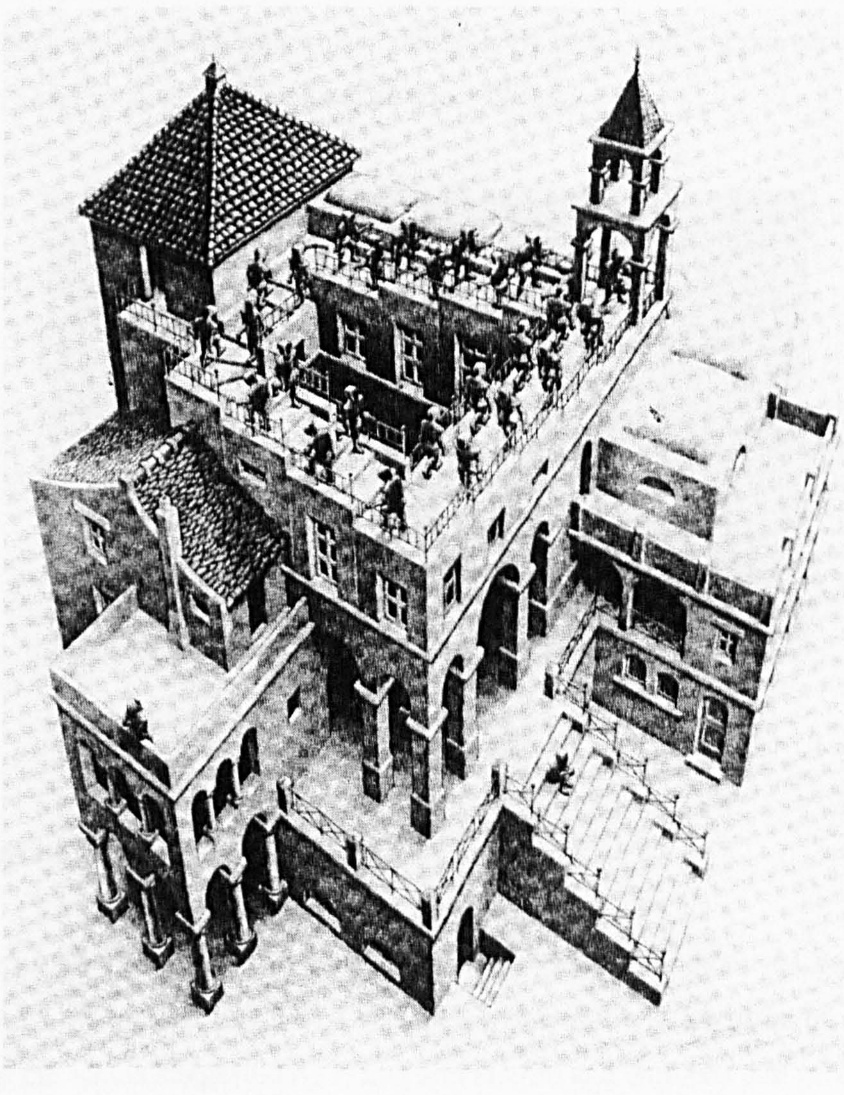


Figure 2.15: Visionary Drawing – Escher 'Ascending and descending' (Coxeter 1986)

Visionary drawings push the boundaries of imagination beyond the normative constraints of physicality. In this sense, the architecture depicted through these drawings is not limited by considerations of gravity, function, scale or materiality. In the drawings there is a sense of spatial ambiguity, complexity and mystery. It is at once real and illusive, a vertiginous domain of uncertainty.

Fraser and Hemni present drawings from Piranesi, Woods, Boullee, Mies and Soleri that illustrate the use of conventional drawing techniques to draw unconventional architecture. In the drawing by Etienne-Louis Boullee (Figure 2.16) light and scale are exaggerated to produce a dramatic, emotional depiction (Fraser 1994).

In Lawson's opinion, visionary drawings are usually thus concerned with the 'what' of design rather than the 'how', and there is little if any technical accuracy (Lawson 1997). For him, designers often deliberately break drafting conventions in such drawings in order to make their point (Lawson 1997).

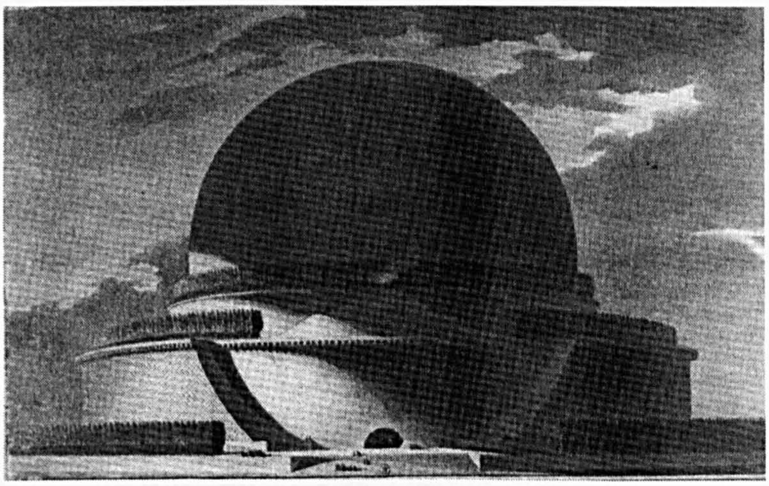


Figure 2. 16: Etienne-Louis Boullee (Fraser 1994)

2.3.6 - Construction drawings

Construction drawings are those drawings done to explain to the builder or manufacturer how to construct a design. Lawson added this application of architectural drawings to the others suggested by Fraser and Hemni and explains that producing these drawings can be seen as an integral part of the design process as the designer imagines the act of making (Fraser 1994; Lawson 1997).

As part of the design, the designer has to imagine the process of construction and consider the problems of construction while designing. In Lawson's view, the extent to which this influences, or even dominates, the designer's mind is clearly variable (Lawson 1997). For him, there is evidence that a good design solution often integrates different kinds of constraints such as the practical and the formal.

Lawson presents an interesting example of reconnection of designing and making (Lawson 1997). The work of Carlo Scarpa when working on the Castelvecchio Museum in Verona can be seen as an example of the use of the drawing to simulate the construction process (Figure 2.17). This is a drawing of Scarpa resolving part of the handrail, the size of rail, which fits comfortably in the hand with the structural depth of the post. In this case, as Lawson points out, the drawing not only represents the built object, but the process of drawing can also represent the process of making the object (Lawson 1997).

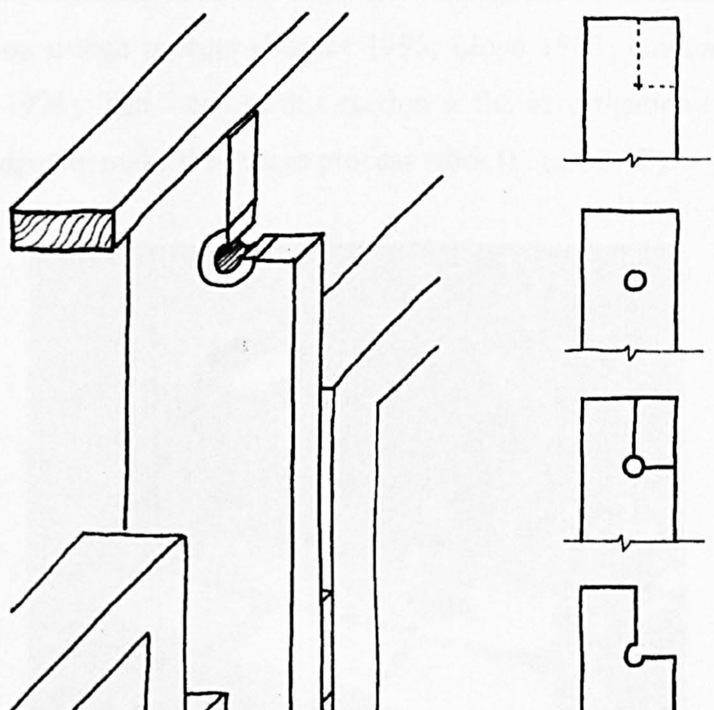


Figure 2.17: Carlo Scarpa handrail detail – (Lawson 1997)

2.3.7 - In summary

It can be concluded that each application of drawing has a focus of intent, concentrating an author's attention on a particular aspect for a specific reason. Architects, for example, approach design drawings in a variety of ways and working methods vary so much that in some situations a definitive drawing for one serves as a initial sketch for another.

According to Fraser and Hemni, each application contributes to a way of speculating about architecture in a particular manner (Fraser 1994). For them, referential drawings represent and structure a way of seeing when studying existent forms; diagrams serve as formats for analysis and clarification; design drawings are involved with project's intention and development; presentation drawings self-consciously persuade through graphic charisma; visionary drawings use the exploratory possibilities of drawing to expand the boundaries of architecture.

2.4 – Drawing and words

A significant amount of recent research in design studies has focused on the role of conversation on design process (Davies 1995; Lloyd 1995; Lawson 1997; Lawson 1997; McGown 1998). The focus of this section is the investigation of how drawings and conversing together make the design process work (Figure 2.18).

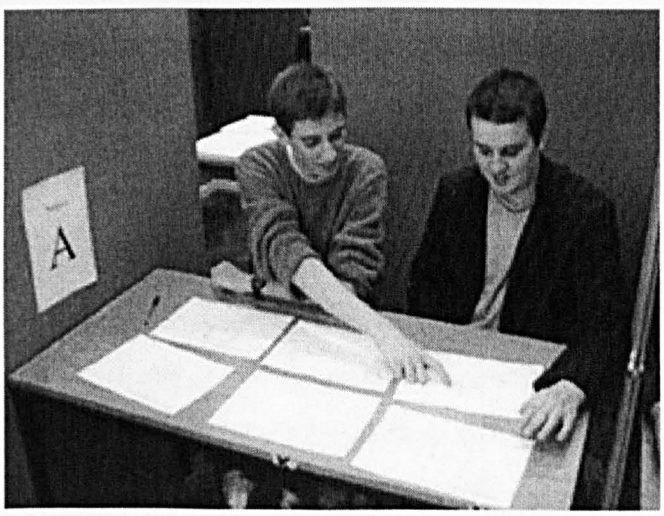


Figure 2.18: Drawings and talking together during the design process

For Lloyd, Lawson and Scott, design is a combination of many types of thinking and the concurrent verbal reports are best at revealing particular types of thinking (Lloyd 1995). In their work, they showed how the design task changes as a result of the designer having to continually think aloud.

Lloyd, Lawson and Scott conclude that although concurrent verbal reports can reveal some aspects of design thinking, there are many types of design thinking that remain impervious to concurrent verbalisation requiring different methodologies for analysis (Lloyd 1995). They argue against design as a unitary concept, and propose a view of designing as consisting of many interlocking and overlapping processes. In their words, 'design is not a unitary thing but a collection and pattern of many things' (Lloyd 1995).

Davies' experimental work suggests that concurrent verbal descriptions of a design activity may not map well onto the behaviour that such descriptions are intended to characterize (Davies 1995). His findings suggest that design descriptions are not only mediated by cognition limitations, but also grounded in the conventions of practice surrounding design activities.

Davies concludes that verbalization appears to give rise to opportunistic events in the design composition, on the other hand, it appears that while designers may say that they design in one way, it is quite possible that their actual design behaviour might be described in an entirely different way (Davies 1995). The conventions of practices surrounding the design activity may also have a significant impact upon the way in which designers present and structure their argumentation about design and their process.

Lawson and Loke suggest that creative design may be as dependent on words as it is on pictures (Lawson 1997). For them, work in this area has tended to concentrate on pictures to the detriment of studying words. They suggest that more investigation needs to be pursued on how we hold conversations about design and conclude that we should concentrate less on pictures and more on words. As ambiguity, uncertainty and parallel lines of thought are central to any creative design process, they conclude that words seem more flexible than pictures in sustaining multiple meanings and are employed by many designers in conceptualising designs (Lawson 1997).

According to Lawson, drawings are tangible recorded evidence of design thinking, but the words used in design process are usually spoken rather than written and are therefore transient, leaving no permanent effect (Lawson 1997). It seems that Cross supports Lawson when suggesting that both words and pictures have their advantages, but combined they offer what he called a very powerful language of design (Cross 1996; Lawson 1997).

Cross concludes that studying both together it is possible to see the development of design ideas not necessarily as creative 'leaps' but as 'bridges' between ideas as the words enable transitions between ideas which look abruptly different if only looking at the drawing (Cross 1996).

McGown, Green and Rodgers' findings further support the idea that design is often more understood when words are added to help explain the drawing's meaning, context or scale (McGown 1998). To demonstrate this, they show two examples of how words may improve the efficiency of communication in the conceptual stage (Figure 2.19). They noted how it is quite difficult to ascertain what is represented in Image A, without the aid of the caption. Image B is easier for an observer to understand since it carries additional text annotations to provide context and also a sense of scale.

All this evidence suggests a twofold need, which may improve the evaluation and communication at the conceptual design stage. It means that to improve evaluation and concept selection at the early stage of design process it is suggested to combine mediums as drawings (visual) and words (textual and oral).

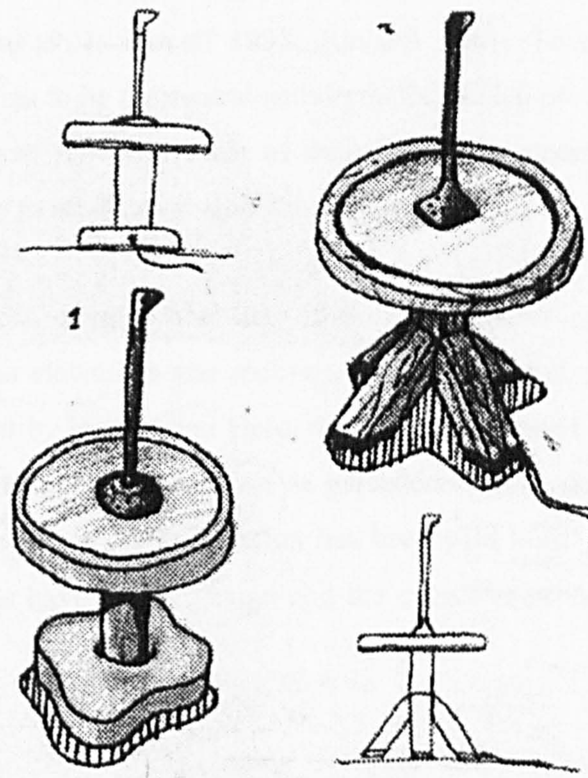


Image A

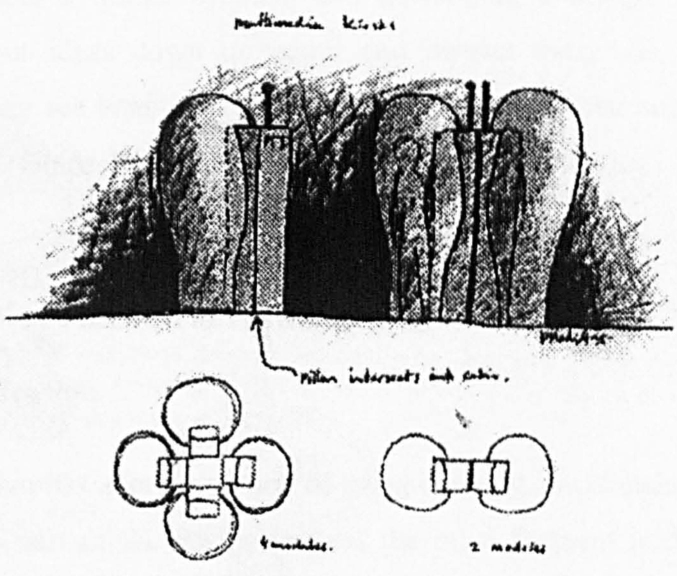


Image B

Figure 2.19: McGown, Green and Rodgers' illustration of the use of drawings and words.

2.5 – Conclusions

There has been a long tradition of using drawings and other pictorial forms as part of the design process, especially in those disciplines concerned with the design of objects and buildings. There is evidence from several researchers (Lawson 1994; Goel 1995; Lawson 1997; Purcell 1998; Kavakli 2001; Tovey 2003) that maintain that drawing remains to be the central activity in the design process, and the drawing itself is one of the most powerful tools of thought and communication. The act of drawing seems actually to mediate creative thought processes.

This can involve the use of quite abstract diagrams, functional diagrams, sketches, plans elevations and sections, perspectives and very detailed representations. As pointed out by Purcell and Gero, designers also spend considerable time looking at conceptual sketches that could act as precedents in the design process (Purcell 1998). They argue, however, little attention has been paid until recently to the function such representations have during design and the cognitive process that are involved in their use.

The process of developing pictorial and diagrammatic representations has traditionally been treated as a skill rather than an essential part of the process of thinking about a design problem and developing a design solution. Architects and designers put ideas down on paper and inspect them. As they inspect their own sketches, they see unanticipated relations and features that suggest ways to refine and revise ideas (Goldschmidt 1991; Herbert 1993; Suwa 1997).

3 – SKETCHING AT THE CONCEPTUAL STAGE

3.1 – Introduction

Design has a long tradition of using drawing and sketches as part of the process. In the early part of the design process the most frequent is the use of quite abstract diagrams together with conceptual sketching (Figure 2.20). On the other hand, in the later part of the process, more structured and detailed representations are used to document a design that has been developed (Figure 2.21).

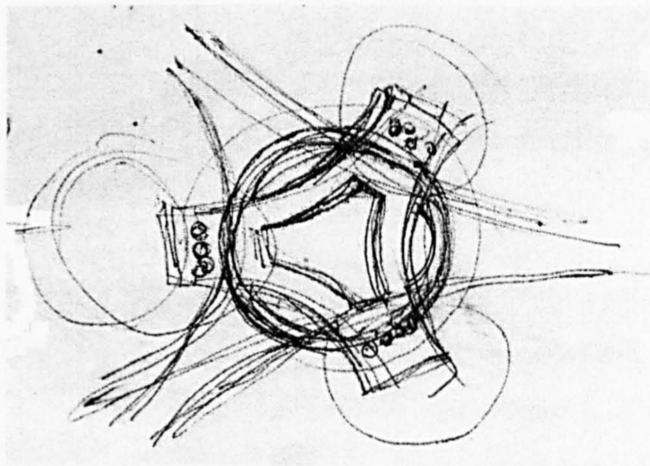


Figure 2.20: Conceptual sketch - Paolo Soleri 1961 – Airport (Soleri 1971:311)

This section is concerned with the early stage of the architectural design process focusing in the conceptual sketches employed by designers. These sketches are for explore more possible reinterpretation and development of new design thought and not for communication with others (Goldschmidt 1991; Goel 1995; Lawson 1997; Purcell 1998; Kavakli 2001).

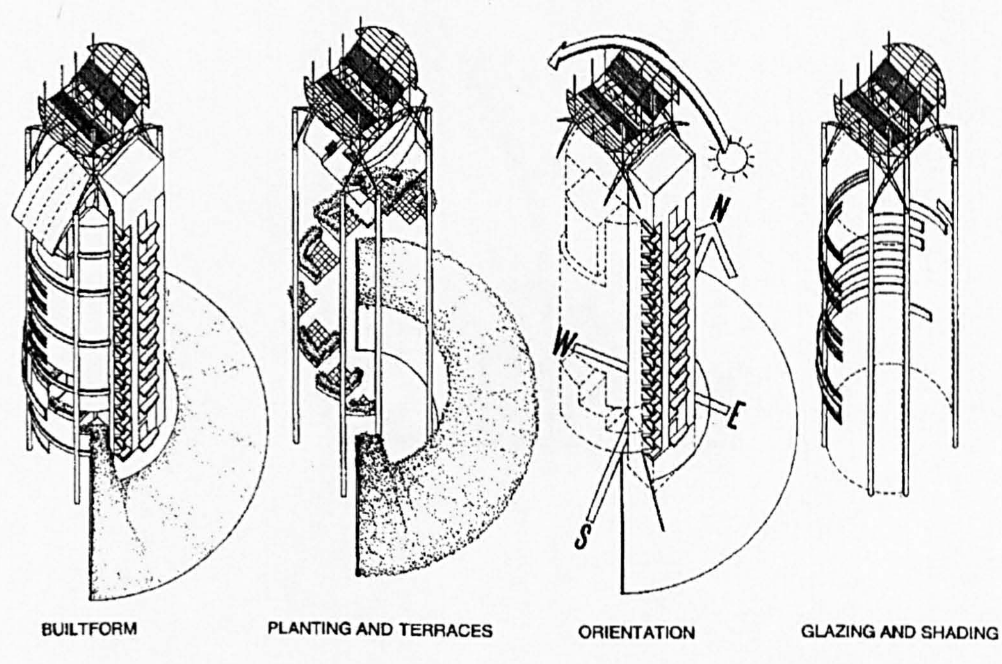


Figure 2.21: More detailed architectural representation by Ken Yeang (Lawson 1994: 127)

Some researchers (Schon 1992; Herbert 1993; Goldschmidt 1994; McGown 1998; Verstijnem 1998) have suggested that the designer reads off the sketches more information that was invested in its making. This becomes possible because when designers put sketches down on paper, new combinations and relationships among them are created that they could not have been anticipated or planned for. It seems that designers discover them in the sketch as it is being made.

There is evidence that with rapid sketches the designer transforms images and each sketch generates new images in the mind (Goldschmidt 1991; Goldschmidt 1994; Verstijnem 1998). These sketches can be brief and vague because speed facilitates transformations, whereas vagueness contributes to more interpretations. The uncertainty of the images seems to allow the designer to approach the sketch from different points of view and this is vital in this early stage.

This seems to be in concordance with McGown, Green and Rodgers' work, when viewing 'sketching as direct action within conceptual design' but, they argue, 'sometimes the drawings produced can be difficult for any observer other than the original 'artist' to understand', as illustrated in Figure 2.22 (McGown 1998).

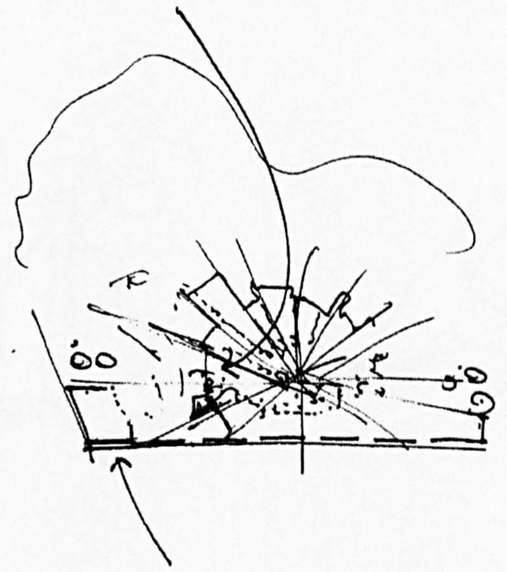


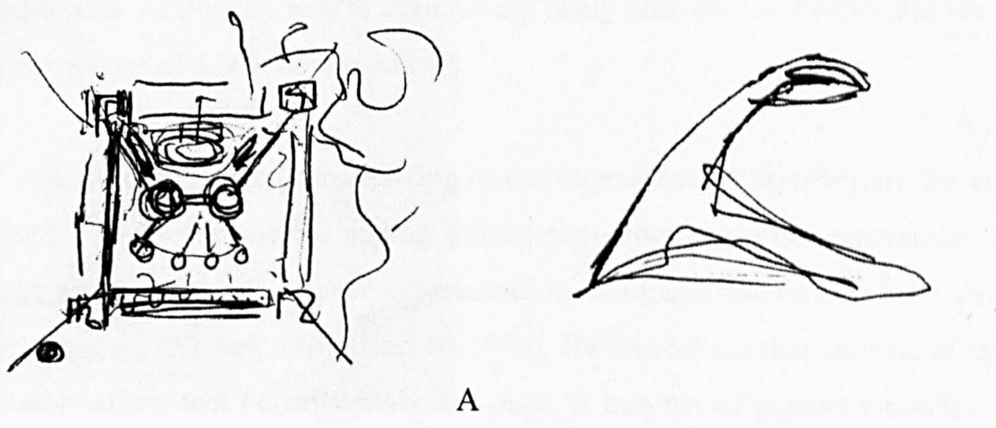
Figure 2.22: Renzo Piano – Banca Popolare di Lodi 1991 (AU Renzo Piano Building: 136)

Recently, some studies (Lawson 1994; Goel 1995; Lawson 1997; Kokotovich 2000; Rodgers 2000; Tovey 2003) have begun to indicate what role sketching may play in design but so far there have been a small number of empirical studies that have focused on the role of these representations in the early stage in design process.

However, despite its importance, it appears that the sketch is perceived to have a low status, its true value hidden by the modesty of the designers (Lawson 1994). Normally, when a project is over, early sketches are often destroyed and cleared away to make space for the next job and perhaps its performance has been overlooked in favour of its spontaneity.

3.2 – Why are sketches considered to be visual thinking?

This research concentrates on the study of sketching in the early conceptual phase of architectural design. However, even within the conceptual phase of design process there are many different types of sketch (Figure 2.23). They can be plans, elevations and simple volumes or even representation of ill-defined thoughts. The focus here is ascertaining why conceptual sketches are considered as a good medium for reflective conversation with one's own ideas and imagery.



A B

Figure 2.23: Different Types of Sketches
A – Louis Khan - Chemistry Building University of Virginia (Laseau 1989: 106)
B – Terry Farrell – Sketchbook of Terry Farrell and others (1998: 6)

Schon has referred to conceptual sketches as the medium of reflection-in-action (Schon 1983). This is due to the unique condition of the design project meaning that the designer cannot apply standard theories or techniques. So, in that way, the sketches create the perfect conditions for reflection-in-action. The conceptual sketches allow the designer to explore a new idea on paper, quickly and cheaply.

To explain and illustrate these concepts of uniqueness and reflection-in-action, Schon presented and discussed examples of practices in two professions usually considered very different from one another – architecture and psychotherapy (Schon 1983). Although the goals of the two professions have almost nothing in common, he demonstrates that there are similarities of process. In both examples the practitioner approaches the practice problem as a unique case. Each one seeks to discover the particular features of the problematic situation and from gradual discovery, design an intervention. These points of similarities, he concludes, create the condition for reflection-in-action.

Following this argument, Gross, Ervin, Anderson and Fleischer argue that sketches are important because they embody ill-defined design ideas, they allow a degree of uncertainty about particular physical attributes to exist and they impose constraints (Gross 1988). They also agree that sketches are more appropriate for the early design stage because it is open to considerable uncertainty. Uncertainty was related to imprecision in placement, dimensioning and shape, as well as to ambiguity and vagueness. Ambiguity results from having many possible resolutions and vagueness is a consequence of a lack of alternatives.

For Herbert, the reasons relating to the importance of sketches are the capacity to provide graphic means for adding information from cognitive experience and for recalling and manipulating visual representation or images relevant to the solution of design problems (Herbert 1988; Herbert 1993). He also agrees that the role of sketches in the early stage, that he calls study drawings, is one not of passive recording but of active participation in formulating design. The ambiguity of these types of drawings, he concludes, enables a designer to see more out of a drawing that she/ he puts into it. For him, the conceptual sketches are always poised between an unresolved past and an unpredictable future and they are part of graphic thinking process.

In Goldschmidt's work, the intention is to point out what seems to be the inherent reasoning patterns in the practice of sketching at the front edge of architectural designing (Goldschmidt 1991). She argues that if architects use the sketching tool so persistently it must be very helpful to their thinking, but what kind of reasoning does sketching represent? She concludes that sketching is not merely an act of representation of a pre-formulated image, but it is a search for such an image. She introduces the concepts of 'seeing as' and 'seeing that'. 'Seeing as', she explains, is when the designer is using figural argumentation while sketching-thinking and 'seeing that' is when the designer advances non-figural arguments pertaining to the entity that is being designed. Goldschmidt perceives the design process as a systematic dialectic between these two reasoning modalities (Goldschmidt 1991).

Based on the results of Goldschmidt's work, it is proposed that design reasoning at the time of sketching is characterized by short sequences of arguments which shift between 'seeing as' and 'seeing that' modalities, which she calls 'the dialectic of sketching' (Goldschmidt 1991). Her conclusions are that sketches introduce this special kind of dialectic into the design process that is indeed unique, by a continuous production of displays pregnant with clues, for the purpose of visually reasoning not about something previously perceived, but about something to be composed, something that is being designed.

According to Goldschmidt, sketching induces a special relationship between these two modalities of visual reasoning - 'seeing as' and 'seeing that' - and allows the creative process of form-producing, at least in architectural designing (Goldschmidt 1991). She argues that it is the ambiguity and unstructured characteristics of sketches that allows reinterpretation.

Schon and Wiggins added to all these 'seeings' the term 'seeing in' and suggest that design is an interaction of making and seeing, doing and discovering (Schon 1992). They also see architectural designing as a kind of experimentation that consists of reflective conversation with the situation and present the concept of 'design move'. The 'move' is considered a 'basic local unit of a design process' and involves several kinds of seeing and discovering (Schon 1992). This 'move' can be seen in different two ways: 'first as an accomplished transformation, a shift from one drawing configuration to another; and second, as the act of drawing by which the transformation is made' (Schon 1992).

For Schon and Wiggins, the early stage of design process can be schematised as seeing-moving-seeing conversational structure, where the second 'seeing' involves recognition of unintended as well as intended features (Schon 1992).

Goel's findings seem to agree with others researchers, since he also supports the idea that free hand sketches work well for exploring design ideas in the early stage of the design process because they are dense and ambiguous (Goel 1995). Ambiguity is important, he maintains, because one does not want to crystallize ideas too early and freeze design development and the density of sketching insures that possibilities are not excluded and helps to transform one idea into another. Density of sketches refers to the different reinterpretations and meanings that are allowed for.

Goel presents two important types of transformation that can be identified in the design process: lateral transformation and vertical transformation (Goel 1995). According to his explanation, 'in a lateral transformation, movement is from one idea to a slightly different idea. In a vertical transformation, movement is from one idea to a more detailed version of the same idea' (Goel 1995). His findings indicate that lateral transformations are generally confined to preliminary design stages, whereas vertical transformations generally occur in the refinement and detailing stages.

To illustrate these concepts of lateral and vertical transformations, Goel provides examples of both transformations that can be seen at Figure 2.24 (Goel 1995).

In Figure 2.24, number 1 is the first proposed floor plan for a post office. It calls for three separated booths under one roof. Number 2 is a lateral transformation and reorganization of the initial idea in number 1. The three booths are still under one roof, but now they protrude from a common core.

Number 3 is a lateral transformation of number 2. The three booths retain their location but they have been internalised into the walls of the main core. Number 4 on the other hand, is a vertical transformation of number 3. There is no modification of the previous idea, only a clarification of lines and an addition of details. Similarly, number

5 is a result of a vertical transformation of number 4. Lines and dimensions are been further articulated and some landscape elements added.

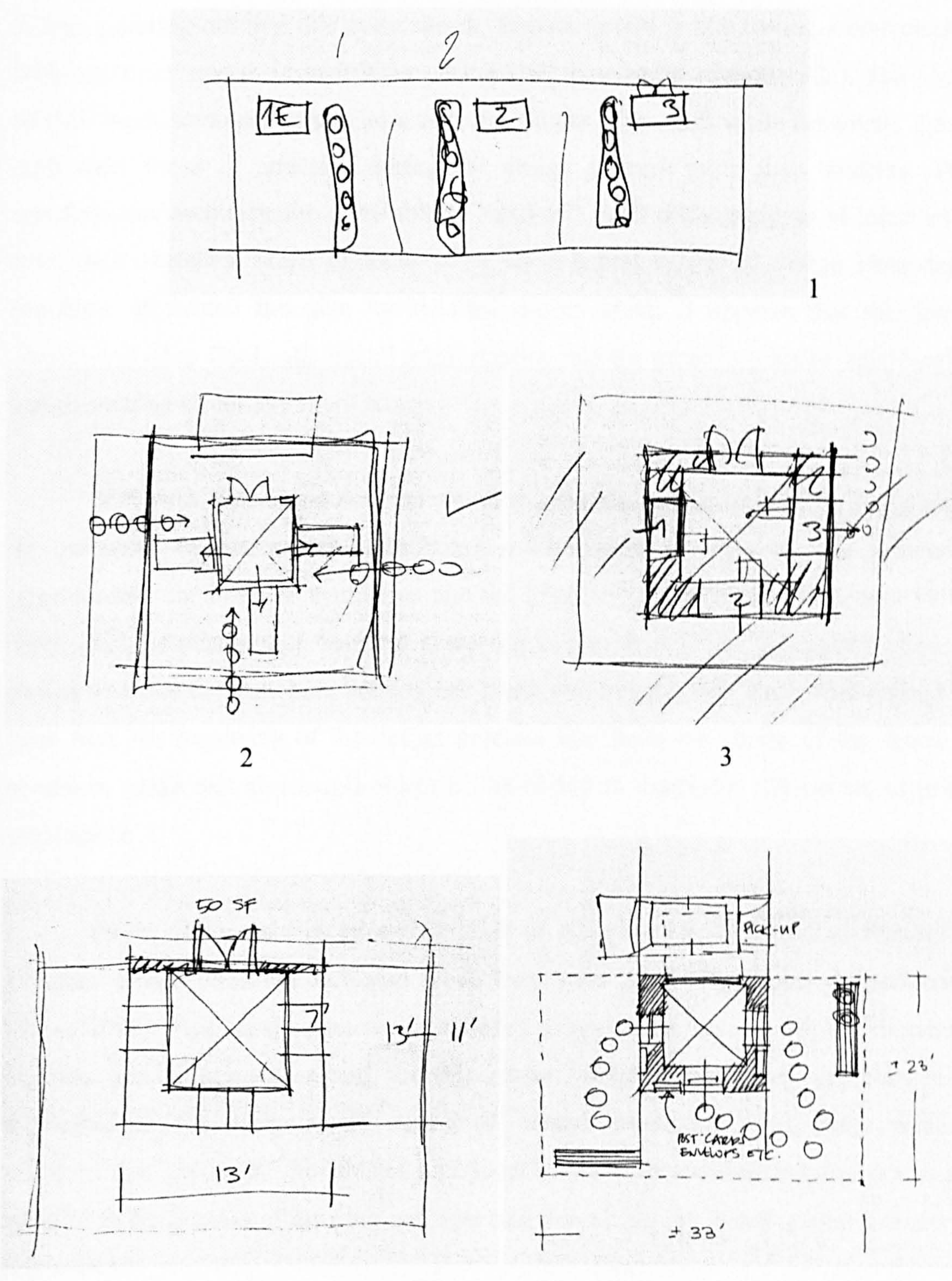


Figure 2.24: Examples of lateral and vertical transformations.
'Sketches of thought' (Goel 1995: 122)

Suwa and Tversky suggest that facilitation by external representation derives from not just its external existence, but from the interaction between the representation and the cognitive process of interpreting it (Suwa 1997). They seem to agree with Schon, pointing out that this cycle sketch, inspect, revise is like having a conversation with one's self and they present the concept of 'focus-shift' (Schon 1983). The results of their work demonstrate that architects have more focus-shift while designing, that is, shift their focus of attention during the design process more than students. They conclude that architects are more able to 'read-off' more different types of information from their sketches. Shifts of focus allow for a lateral variety of design ideas and a sequence of related thoughts for detailed design ideas. It appears that the former correspond what Goel calls lateral tranformation and the latter to what he calls vertical transformation (Goel 1995).

McGown, Green and Rodgers also argue that the conceptual sketch may possess the potential to act as both facilitator and recorder of creative acts presenting opportunities for improve evaluation and the re-starting of problems (McGown 1998). Their study confirms that freehand sketching is prevalent in the conceptual phase of design and that the sketching activity has peaks and troughs over time, with its highest peak near the beginning of the design process. For them, the ability of the sketch to somehow make real an imaged object or the ability to remember objects are of prime importance.

Suwa, Gero and Purcell call this act of attending to visual-spatial features in sketches which were not intended when they were drawn 'unexpected-discoveries' (Suwa 2000). Free-hand sketches are believed to encourage discoveries of unintended features and consequences and for this reason, they explain, they are considered indispensable for designers in conceptual design processes. This study presents evidence that architects' thoughts of functional issues in an architectural design task are born from the process of drawing on paper and perceiving the visual-spatial features of depictions.

From this evidence, Suwa, Gero and Purcell formulated a question that will be basic for the development of this work (Suwa 2000). 'What aspects in the acts of drawing sketches and perceiving features in them enable a designer to invent important design issues and requirements of a given problem?' It is important here to clarify what they mean when using the word 'invent'. By 'invent', they do not mean that the issue or requirement has been generated for the first time in history, or that a designer has generated it for the first time in his/her life. What they mean is that a designer has generated the issue or requirement for the first time in the current design task, in a way situated in the design setting. This is referred to as 'situated-invention'.

Tovey, Porter and Newman's investigation has been influenced by the use of conceptual sketches by designers in the automotive industry (Tovey 2003). They affirm that there are many areas of apparent similarity between the activities of automotive designers and by those of designers in other fields. For them, in all design areas, the conceptual sketches and other form of drawings are languages for handling design ideas and the process of design is one of interactive generation. They conclude that a number of findings by other design researchers, mostly based on architecture and engineering products, can be applied to automotive designers and are thus likely to be generic (Tovey 2003).

3.3 – Types of sketch

Even within the conceptual design stage there are many different types of sketch and a number of researchers appear to be interested in this classification (McGown 1998; Suwa 1998; Rodgers 2000; Tovey 2003). According to McGown and Rodgers, it was Ferguson who identified three kinds of sketch related to three different design actions (Ferguson 1992; McGown 1998). The designer can use the sketches to try out new ideas, to compare alternatives and to capture 'fleeting ideas' on paper.

The three types of sketches according to McGown and Rodgers are (McGown 1998; Rodgers 2000): First, the thinking sketch, that is, the one designers use to focus and guide non-verbal thinking. Second, the prescriptive sketch drawn by a designer to direct a draftsman in creating a finished drawing. This one is used almost exclusively within the latter detailing stages of the design process. Third, the talking sketch, that is produced during exchanges between technical people in order to clarify complex and possible confusing aspects of the drawing.

McGown and Rodgers go further in their analysis and suggest that a sketch is likely to be made for one of these three reasons (McGown 1998; Rodgers 2000): First, to communicate the physical nature of an entity conceived in the imagination. Second, to visually recall the physical nature of objects or environments from memory, and third, to make a quick visual representation of entities or environments exposed to the naked eye.

Although Goel's work recognizes that transformation has taken place in the early design process and the role that sketches play in this transformation, no measure of the degree of transformation is proposed (Goel 1995). Only McGown and Rodgers developed and presented a practical complexity scale to facilitate a measure of sketch's degree of transformation (McGown 1998; Rodgers 2000). The simplest of sketches, typically found in the student's sketchbook, they explain, was rated a 'one' and the most complex a 'five'. Interpolating between the two extremes created the scale. Figure 2.25 shows the classification of each sketch.

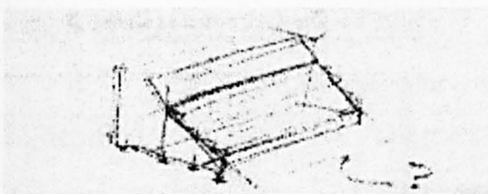
Complexity level 1 (least complex): Monochrome line drawing. No shading to suggest 3D form. No text annotations or numerical dimensions are used. Motion arrows may indicate moving parts. If a single colour is used then this also counts as monochrome (eg. a drawing made in blue biro pen).

Complexity Level 2: Monochrome line drawing. There is shading to suggest 3D form, but there is use of different levels of thickness and line pressure within a single medium. One or two brief annotations may appear, not more than 6 or 7 words each. As in (1) motions arrows may be allowed.

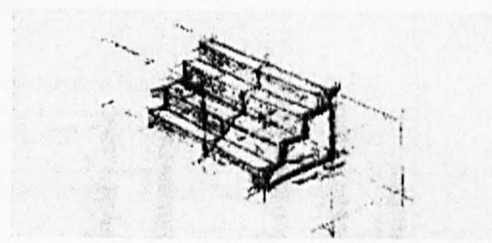
Complexity Level 3: Monochrome, with rough shading used to offer suggestion of 3D form. The drawing may be annotated to describe certain aspects of the concept. May include dimensions.

Complexity Level 4: Subtle shading is heavily suggestive of 3D form. The drawing will almost certainly be annotated. Colour or gradation of monochrome colour may be used to illustrate certain concepts or arrangements, but not to suggest the true colours of parts.

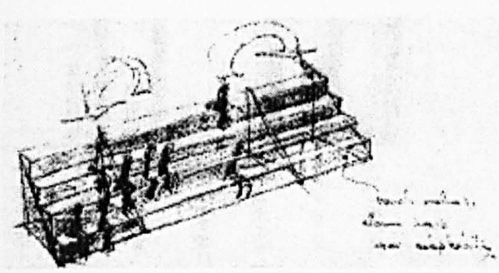
Complexity Level 5: Extensive use of shading to suggest 3D form. Annotations will be used to ask questions relating to the idea or to explain it. Colour will be heavily used to represent the actual colours of the parts of the product. Generally a very busy drawing, many lines will be used in its construction.



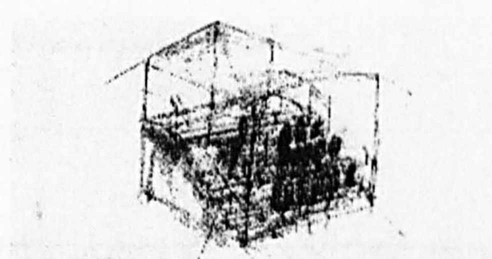
Complexity level 1



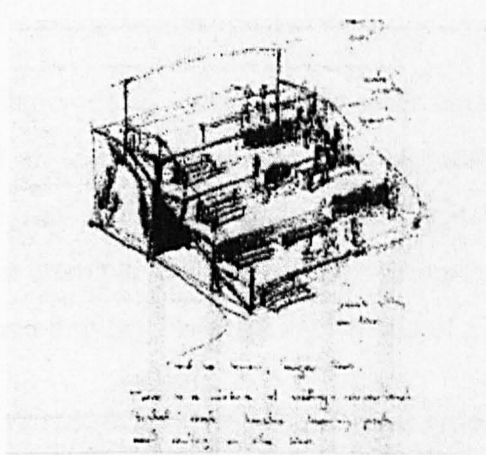
Complexity level 2



Complexity level 3



Complexity level 4



Complexity level 5

Figure 2.25: The sketches' complexity scale as suggested by Rodgers, Green and McGown (Rodgers 2000)

Another codification of sketches is presented by Tovey and related to levels of details in representation of design models (Tovey 1989). According to him, drawings and 3D models are languages to handling design ideas, but the actual process of creating

design ideas goes on in the mind and the drawings and 3D models are attempts to reproduce the designer's mental images. For him, the design process may be regarded as the movement from one model to the next and the models themselves, as representation of the design activity. In his work, all types of design model can be subdivided into a number of types of representation, which can be ranked from un-detailed to detailed, as can be seen on Table 2.01.

Table 2.01: Codification for level of details presented by Tovey (Tovey 1989)

Un-detailed	Diagrammatic drawings	Abstract schematic
	Representational drawings	Ideas sketching
		Concept drawings
Detailed	Measured drawings	General arrangements
		Axonometric
		Parts drawings

Tovey also presented some examples of design drawings (Tovey 1989). Design drawings, he explains, include drawings of various types fulfilling different functions. He presents four different types of design drawings, as follow:

Schematic and diagrammatic drawings are more abstract representations of the underlying principles of an idea. Ideas sketches are representational drawings that are useful for investigating the appearance and visual impact of such ideas. Concept drawing is a drawing that attempts to show what the design proposal will look like as a finished product. Measured drawing is a working version of a technical drawing.

As this research shows, there are many different types of sketch involved in the concept stage of the design process. As many types of sketch are used, it is expected that many different techniques for drawing should be used as well. Some researchers (Rodgers 2000; Tovey 2003) started to investigate the different techniques employed in the early conceptual stage of the design process.

Tovey, Porter and Newman identify the techniques that tend to place an emphasis on lines rather than areas of colours (Tovey 2003). As lines are easy to produce, they conclude, they are almost always the initial mode of expression. The other key components are colour and shading, but both are used less often in concept sketches, which may consist simply of lines. However, there are a number of different ways in which lines can be used and they present three types.

Form lines are the key form descriptors and are assumed to be of primary importance in delineating the shape that the designer intends for the design. Crown lines are not 'real' lines in the design but indicate the crown of a curve or extend of a contour. Area lines are lines, which simply define an area. This may be a physical separate component or a cartoon-like depiction of the edge of a shadow.

Tovey, Porter and Newman suggest that form lines are the major contributor to understanding of the form and such lines are what designers tend to use in their sketching process (Tovey 2003). They also suggest that concept sketches of complexity level 1, that is, the low level of complexity, may have utility in a CAD system. This gives a clear guidelines as to the type of material that any CAD system will have to face.

3.4 – Learning how to draw in order to design

It seems that the process of learning how to draw and use diagrams could be at the heart of design expertise. Recently, some researchers (Larkin 1987; Purcell 1998; Kokotovich 2000; Kavakli 2001) have suggested that the ability to coordinate recognition and inference using sketches and quite abstract diagrams is learnt during the development of expertise and is a critical aspect of expertise.

In order to study the process of forming mental images, it is useful to revisit others researchers (Larkin 1987; Purcell 1998; Kokotovich 2000; Kavakli 2001). Kokotovich and Purcell's work investigates the relationship between sketching and creative mental synthesis (Kokotovich 2000). The focus of their work is the investigation of when and how sketches are important and increase creative mental synthesis. They found that how and when drawing is used is important and suggest that drawings play a central role in the design thinking process. However, it is important to learn how and when to use drawing. Designers are able to get benefits from drawings because they were trained and have developed this skill and those who have not been trained to use drawings in the way required to design have less beneficial effect from drawings.

Kokotovich and Purcell present a series of generic tasks involving novice and expert designers, developed to investigate themes found in both cognitive psychology and design literature (Kokotovich 2000). The tasks of their experiment allow the subjects to use drawing as an aid to solving the problems posed. Their result confirms the mental imagery condition, not the drawing condition, is of greater benefit to designers and is of no aid to non-designers. They found that novice designers often use drawing to focus early on a design solution, in contrast, experts would use drawings to generate ideas and concepts at the early stages of the process. They suggest that people have to be taught to draw in a way to assist in mental synthesis and creativity.

This result seems to be in concordance with Purcell and Gero's work (Purcell 1998). It supports Kokotovich and Purcell's suggestion when affirming that the process of learning how to draw and use diagrams could be at the heart of design expertise (Purcell 1998; Kokotovich 2000). For Purcell and Gero, the emphasis of research into differences between expert and novice designers in solving problems should be incorporated into knowledge that informs the reasoning process and the characteristics of the reasoning process itself, and not on the questions related to drawing and diagram processes (Purcell 1998).

3.5 – Interaction with sketches: clues and emergence

There is a lot of evidence from both cognitive psychology and design literature to support the idea that architects have a strong interaction with their own sketches, especially in the early stages of the design process. But the question this study would like to ask is: what kind of interaction do they have with their own sketches?

This interaction between architects and their own sketches has been the object of much recent research (Goldschmidt 1991; Lawson 1994; Suwa 1997) and some basic questions have been formulated. To investigate some of them, revisiting Suwa and Tversky is important here (Suwa 1997). According to these researchers, this issue can be divided in three separate issues:

How do architects see sketches?

What do they see in sketches?

How and what do they draw?

Goldschmidt's work on 'seeing as' and 'seeing that' appears to pertain to the first category (Goldschmidt 1991). For Goldschmidt the ambiguity and unstructured characteristics of sketches, she concludes, result in reinterpretation. Suwa and Tversky's work pertains to the second group by focusing on information categories that architects 'see' in their own sketches (Suwa 1997). Their results show that architects have more 'focus-shift' while sketching than students, being more able to 'read-off' different types of information from their own sketches.

According to Suwa and Tversky, Van Sommers's work looked at graphic production from a developmental and cognitive perspective, and pertains to the third category (Van Sommers 1984; Suwa 1997).

It appears that the early sketching activity is primarily to avail oneself to potentially meaningful clues. Clues are never universal and they mean something specific to a person in a particular circumstance, while they may signify something different to another person, even under similar circumstances. Clues are useful only if they can be associated with something that is relevant to that which a person is looking for or preoccupied with.

Goldschmidt argues that in the process of making architectural form, displays are useful to the designer only if helpful clues can be read off them (Goldschmidt 1998). Displayed images may provide the designer's capability of using imagery to manipulate them until they suggest something meaningful to the task at hand. However what a designer makes of clues he or she identifies in a visual display depends on many parameters. When reading clues off displays, it seems that designers use pre-existing forms that they then transform and rearrange in new and unexpected ways.

A clue must be able to trigger some relevant information that is stored in the memory but that is difficult or impossible to achieve. To exemplify how visual clues work, Goldschmidt present a similar situation: 'If you are trying to think of someone's name, it may be help if you are told that the name starts with an A, but this clue is useless if you never knew the name in first place' (Goldschmidt 1994). She perceives visual clues as working in a similar way.

For Suwa, Purcell and Gero sketches serve as something more than just a provider of visual clues (Suwa 1998). They serve as a physical setting in which design thoughts are constructed: 'sketches serve as a provider for visual clues for association of functional issues and as a physical setting in which functional thoughts are constructed on the fly in a situated way' (Suwa 1998).

In relation to this evidence, it can be concluded that a basic theme in the design literature about the role of conceptual sketches in the early stages of design process is the reinterpretation and the sketches' properties that allow this reinterpretation. The results of several research investigations indicate that there is a sequence of activities involving thinking, imagery, drawing and reinterpretation and the accessing of different types of knowledge (Goldschmidt 1991; Schon 1992; Goel 1995; Suwa 1997).

From all the work presented, a common premise about emergence and reinterpretation can be identified. Reinterpretation results in further reinterpretations and access to new knowledge. During or following sketching activity, new knowledge becomes part of the problem solving process. The bringing in of new knowledge is a process that progressively reduces the ill-defined nature of design process. It allows the designers to move towards a physical object and develop their design ideas.

4 – VISUAL THINKING

4.1 – Introduction

The aim of this section is the study of visual thinking and its role in the architectural design process. However, visual thinking is not an easy or simple phenomenon and it is not the intention here to suggest a definition for it. A single definition for visual thinking is problematic, what exactly does it mean? The answer, as this research will demonstrate is: visual thinking means different things to different people.

Firstly, visual thinking appears to be simply an externalisation for visualization of the designer's thinking. However, it is significantly more than this in concordance with Suwa and Tversky's findings (Suwa 1997). Their study perceives external representations not only as memory aids but also as facilitating reinterpretation, inference and understanding.

As visual thinking has different meanings and connotations, it is only possible to suggest some approaches. But, even when all basic approaches are taken together, there still is a debate over the nature of visual thinking. This study agrees with other researchers and understands visual thinking as the production of thought via visual imagery (Goldschmidt 1994). So, to begin, it is necessary to study actual thinking.

4.2 – Different ways to understand thinking

Thinking seems to be one of the most problematic fields of cognitive science since it involves investigation of something that cannot be seen, heard or touched. There are different types of thinking and different uses for the word 'think'. Philosophers and psychologists have been written so widely about thinking that this work cannot do justice to the subject and it is not the intention.

Lawson analysed different uses for the word 'thinking' and presented some views (Lawson 1997). For Lawson, there is one type of thinking we do when we are trying to remember where we left something. This is remembering and important to design, but not the central task. There is another form that is indicative of concentrating or paying attention. There is an imaginative 'thinking' related to fantasy that is apart from reality. There is the sort of 'thinking' that reflects 'reasoning'. This is reflective thought and problem solving. Some times people say 'I think' with the real meaning of 'I believe'.

So, as the words 'thinking' and 'design' are used in many different ways, it seems to be useful revisit Bartlett, Gregory, Gilhooly and Lawson's work in order to specify exactly which version this study is concerned with (Bartlett 1958; Gilhooly 1996; Lawson 1997; Gregory 1998).

4.2.1 - Theories about thinking

Historically, a number of theoretical approaches have been applied to the topic of thinking. A brief historical overview seems to be necessary because there are some theories about thinking that this research would like to review. It is useful here, to outline some explanations about the behaviourist theories, the Gestalt school and cognitive science.

4.2.2 - Behaviourist theories

John Broadus (1878-1958) founded Behaviourism with his manifesto of 1913, according to Gregory (Gregory 1998). According to Gregory, the behaviourists assumed that chains of conditioning would explain all learned behaviour. This idea was extremely influential, especially for its experiment on conditioned reflexes. For the behaviourists, perception and behaviour were supposed to be controlled quite directly by stimuli and problem solving was supposed to be by trial-and-error without insight into the nature of the problem.

The behaviourists explain thinking purely in terms of direct associative links between stimuli and responses. Their theories of thinking hardly admitted that thinking was any more than very mechanistic behaviour. According to Lawson, their theories have appeared most successful in explaining behaviour such as learning and the acquisition of physical skills (Lawson 1997).

In Gilhooly's view, the early behaviourists changed the focus of psychology from conscious experience to observable behaviour, with a theoretical notion based in 'stimulus-response link' (Gilhooly 1996). For the behaviourists, notions of insight or understanding were felt to be unnecessary.

4.2.3 – The Gestalt School

Gestalt psychology was a very different school. According to Gregory, founded in 1920 by a group of German scientists (Gregory 1998). The emphasis was on dynamics and holism. Problem solving was supposed to be by insight and visual perception was more than a sum of individual stimuli. Gregory defines Gestalt as a group of elements such that the whole is greater than the sum of its parts (Gregory 1998).

The Gestalt psychologists were more interested in how people solve problems and their theories concentrate more on process and organization rather than mechanisms. They were also interested in perception and focused on the importance of context in thoughts. According to Lawson, their attention was on the way people represent the external world inside their minds (Lawson 1997).

This seems to be similar to the concept of 'schema' - an internalised mental image. According to Lawson, the schema represents an active organisation of past experiences, which is used to structure and interpret future events (Lawson 1997). It means that people must already form the appropriate schemata in advance to interpret and appreciate events.

Gilhooly also points that the Gestalt theory focused specially on perception, rather than on thinking or learning, therefore the importance of perceptual organization was particularly stressed (Gilhooly 1996). Thus, in addressing thinking and problem solving, the Gestalt theorists emphasized the way in which the problem was perceived as a determining factor in task difficulty.

By the contrast with the behaviourists, for the Gestalt theorists problem solving involves insight, which is an appreciation of how the solution was necessitated by the nature of the problem.

4.2.4 - Cognitive science

The cognitive theories draw many parallels between thought and perception and have a great interest in the way people organise perceived information and store it. The emphasis is on the importance of general background knowledge and logical thought process. According to Gregory, the notion of representing by the brain, means that the brain works with existing functional internal models of perceived and imagined objects and situations, is accepted as central to cognitive approaches (Gregory 1969; Gregory 1998).

Lawson also analysed the cognitive science approach to thinking and he seems to agree with Gregory when pointing that its most important feature is the recognition of the existence of some kind of executive controlling function in mind (Gregory 1969; Lawson 1997; Gregory 1998). That is, the recognition that information is actively reorganised and reconstructed in memory rather than passively recorded and recalled and something must control this process.

According to Gilhooly, in the case of problem solving, the focus of cognitive science is on real life, complex, knowledge-rich problem areas, in which extended effort is required for solution (Gilhooly 1996). For Gilhooly, a typical cognitive science study will examine in detail the performance of a small number of subjects on a complex task and will often lead to a computer program model of the processing underlying performance. He concludes that a combination of psychological and computational skills is brought to understanding the task performance. Thus cognitive science is typically an inter-disciplinary enterprise.

For Lawson the new cognitive science approach to human thinking sees human beings as much more adaptable and genuinely intelligent organisms than the earliest behaviourist approach (Lawson 1997). However, it is strongest when dealing with well-ordered problem-solving situations rather than the ill-defined problems, which are so characteristic of design. Lawson focused his study on the exploration of what he called 'creative and imaginative thinking', considered very much as what designers do (Lawson 1997).

This research is particularly interested in productive (rational) and creative (intuitive) thinking and its role in architectural design process. In order to gain a better understanding of this matter, it is necessary to focus this study on rational/logical and intuitive/imaginative thinking.

4.2.5 - Rational/logical and intuitive/imaginative thinking

Throughout much of the literature on productive and creative thinking, it is possible to find a variety of this binary division between rational/logical process and intuitive/imaginative process. There is evidence that design seems to involve both rational and intuitive processes of thinking.

Bartlett called these processes 'thinking in closed systems' and 'adventurous thinking' and accordingly made a distinction between design and art thoughts (Bartlett 1958). According to his definition a 'closed system' has a limited number of units, which may be arranged in a variety of relations. In 'adventurous thinking', the repertoire of elements that can be considered is not prescribed. He identifies two processes in closed systems: interpolation and extrapolation.

However, for Lawson, these two modes of productive thinking presented by Bartlett, 'thinking in close systems' and 'adventurous thinking', lose some of their clarity when we consider real-world design conditions (Lawson 1997). Lawson argues that it is certainly possible to find examples of closed systems in design, but concludes that the ensemble of elements in design problems is usually neither entirely closed nor entirely open (Lawson 1997).

To illustrate his discordance with Bartlett, Lawson uses the example of arranging tables and chairs in a restaurant (Bartlett 1958; Lawson 1997). This problem, he said, certainly requires thinking in closed systems, but if a particular arrangement of tables will not fit, the designer may often be free to try different sizes or shapes of tables, or even alter the shape of the restaurant. Thus that is why many designers see the rigid imposition of closed systems as a threat to their creative role.

Lawson, like Bartlett, also presented a distinction between design and art thinking (Bartlett 1958; Lawson 1997). In his words, 'designers must consciously direct their thoughts processes towards a particular specified end, although they may deliberately use undirected thought at times. Artists, however, are quite at liberty to follow the natural direction of their minds or to control and change the direction of their thinking as they see fit' (Lawson 1997).

For Lawson, these two major categories are called 'convergent' and 'divergent' thoughts (Lawson 1997). For him, the convergent task requires deductive and interpolative skills to arrive to one identifiably correct answer and has been associated with ability in science. On the other hand, the divergent task demands an open-ended approach seeking alternatives where there is no clearly correct answer and has been associated with skill in arts (Figure 2.26). In fact, very few real-work tasks require exclusively convergent or divergent thought, but the distinction is valid and useful.

Lawson concludes that design involves both divergent and convergent productive thinking and affirms that study of designers working have shown that they are able to develop and maintain several lines of thoughts in parallel (Lawson 1997).

The interest here is the study of those thought processes that are required to identify and understand design problems and create design solutions. The conclusion about thinking process seems to be that the mode of thinking employed is very much dependent on the nature of situation and interest.

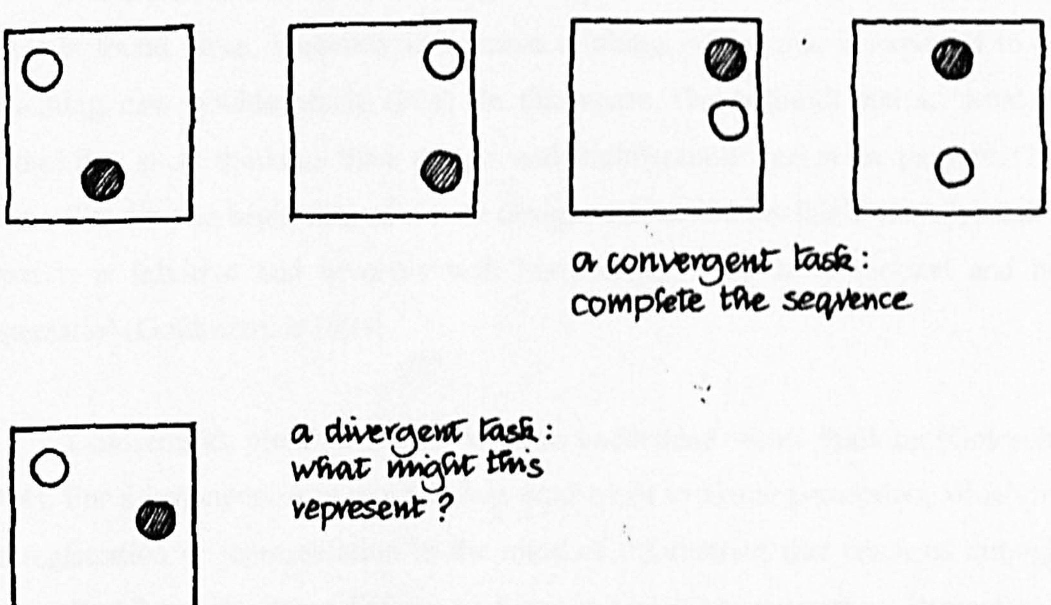


Figure 2.26: Convergent and Divergent thinking (Lawson 1997: 146)

4.3 - Different ways to understand visual thinking

As established previously, a single definition for visual thinking is problematic. Visual thinking means different things to different people. The aim here is the study of its role in architectural design process and understand why sketching is considered to be visual thinking.

According to Arnheim, visual thinking is visual perception, as no thought processes are seen to exist that cannot be found to operate, at least in principle, in perception (Arnheim 1969). For Arnheim, thinking is not the privilege of mental process, but the essential ingredient of perception itself.

However, it appears that for Goldschmidt, those notions of visual thinking to equate it to vision or to perception are incorrect (Goldschmidt 1994). However, both Arnheim and Goldschmidt are following similar principles, since they establish a difference between passive reception and active perception (Arnheim 1969; Goldschmidt 1994).

For Goldschmidt, visual thinking is the production of thought via visual imagery and it is found more frequently in creative thinking, where one is expected to create something new (Goldschmidt 1994). In this sense, Goldschmidt states, 'what better exemplifies such thinking than design and architectural design in particular?' She claims that 'in the beginning of a new design task architects think visually, and even when it is intuitive and involves tacit knowledge, is perfectly rational and highly systematic' (Goldschmidt 1994).

Goldschmidt presents several ways to understand visual thinking (Goldschmidt 1994). For a layperson, it is more or less equivalent to visual perception, which means the registration or representation in the mind of information that reach us through the senses. But she points some differences between vision and perception. Perception is an interpretation of vision: the impressions of the world that the eye delivers to the brain.

For psychologists, the challenge lies in explicating the universal rules that govern perception. They attempt to explain the selectivity that we exercise when taking note of that which we see: what our memory prioritises and what it sends to background; the circumstances under which optical illusions are created.

For computational people, it is how the external world is codified in our brain via retinal impressions. How we recognize shapes and how the process involved can be simulated computationally.

For the cognitive scientist, perception and visual thinking have an ambivalent status. Some think that perception has little to do with cognition and others accept perception as an extension of vision. In cognitive science thinking is identified with language: its acquisition, production and development. For them, thinking in pictures is seen as developmentally rudimentary, a pre-linguistic phase of cognitive functioning, befitting the young and the inexperienced.

Finally, for the designer and specifically for architects, visual thinking represents the need for visualization. Visual thinking is the production of ideas, the reasoning that gives raise to ideas and helps bring about the creation of forms and solutions in design.

Goldschmidt suggests that from all these basic approaches to visual thinking, we can see two modes of thinking, which she codifies as 'analytic-rational' and 'synthetic-nonrational' (Goldschmidt 1994). The former is attributed to scientific thinking and it is typically described as conscious, verbal, systematic and intellectual. The second, on the other hand, is said to be characteristic of art and is considered intuitive, visual (or auditory) and unsystematic, and not necessary conscious. This seems to be in agreement with Bartlett and Lawson's findings (Bartlett 1958; Lawson 1997).

However, Goldschmidt does not consider visual thinking to be a synthetic process or that it is non-rational or unsystematic (Goldschmidt 1994). She claims that architects think visually when addressing a new design task and that visual thinking, even when intuitive, is rational and systematic. She agrees with Lawson when saying that design depends on both types of thinking and concludes that a bridge between the analytic-rational or scientific-artistic dichotomy would provide a major gateway to concepts of design and its practice (Lawson 1997).

4.4 - Visual thinking and sketching

The author is in agreement with other researchers (Fraser 1994; Lawson 1994; Robbins 1994) when they point out that designers appear to have adopted freehand sketching as an invaluable part of the design process. Architects, for example, normally engage in free hand sketching in the early phase of design process for development of their ideas. This is supported by Robbins when it is suggested that visiting an architecture office during its working hours, a group of architects might been seen talking and drawing at the same time and on the same sheet or different sheets of paper while exchanging or developing their ideas (Robbins 1994). It confirms and illustrates how freehand sketches are used to communicate or record ideas as they are brought up in conversation.

However, although the importance of sketches and the need for visualization in the evolution of early design ideas are recognized in several design fields, this research agrees with Fraser and Henmi when they suggest that designers often do not clearly understand how their sketches impact on their ideas (Fraser 1994).

Sometimes these sketches are for representing thoughts that are already in the mind and they do not differ from symbolic representation, like writing. But not all sketches that architects make belong to this category. Some of the sketching does not follow ideas in the mind but instead, precedes them. In other words, architects quite often engage in sketching not to record an idea, but to help generate it. Some sketches provide visual cues for extracting new ideas for the current problem and for future use.

Several researchers (Goldschmidt 1991; Lawson 1994; Robbins 1994; Suwa 1997; Suwa 2000; Kavakli 2001; Tovey 2003) see sketching as an inherently creative process at the front edge of architectural designing. They suggest that the production of design ideas appears to depend upon the interaction with the concept sketches. It seems that sketches give access to various mental images that may trigger ideas for the current design problem. The sketches that are of interest in terms of visual thinking are mainly those that are being made before it becomes clear what the design idea is.

In summary, the nature of visual thinking is seen and understood as a process, in which ideas emerge through sketching, rather than the view that ideas originate in the designer's head. But, as this work will show, even within the conceptual phase of design there are many different types of sketch.

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Chapter 3

Sketching and mental process

CHAPTER 3 – SKETCHING AND MENTAL PROCESS

1 – INTRODUCTION

This chapter addresses some questions that arose from chapter two. These questions are related to differences between novice and expert designers. The interest here is the study of what and how they see conceptual sketches and how they differ from each other.

The aim is the identification of differences in the way novice and expert architects perceive information from freehand conceptual sketches. It has been shown that these sketches are for exploring more possible reinterpretations and the development of inventive ideas. Reinterpretation refers to the ability to transform and generate new images in the mind, and inventive ideas allow architects to revisit their own sketches from new points of view and thus enables them to make new unexpected discoveries (Suwa 2000).

To examine the mental process involved in this interaction with sketches, this chapter is divided in six sections. The first section is this introduction and presents an overview of the chapter. The second section of this chapter compares expert and novice designers. This suggests that practicing architects are more adept at perceiving functional features from visual features than students of architecture or novice architects.

The third section of this chapter is interested in the study of visual perception, creativity and the influence it has on the design process. For this purpose, the relation between visual perception, imagery, remembering and creativity trying to understand the phenomenon of emergence and reinterpretation involved in design process will be explored. As will be shown, it is believed that our thoughts influence what we see, and vice versa, and they may profoundly influence remembering and creativity.

The fourth section is related to memory and the use of precedent in architectural design. A distinction between precedent and referent in architectural design is established and the focus of this section is on human memory. How do the human brain and the human memory work? The aim is understand how the conversation with oneself is established and how our brain and our memory work to allow emergence and reinterpretation in the early stages of the design process.

At the end of this chapter, the fifth section presents some questions, hypotheses and conclusions. The suggestion is that the mental imagery condition, not the drawing condition, is the greater benefit to expert designers related to novice designers. Therefore, in order to study the mental imagery condition involved in the interaction with conceptual sketches, this work intends to do some experiments on visual perception and conceptual sketches with novice and expert architecture students. The aim is identify differences in the way they use memory to create analogies to describe what they are thinking and then compare the groups. The sixth and last section brings the bibliographic references for this chapter.

2 - NOVICE AND EXPERT DESIGNERS

This section is concerned with differences between novice and expert designers. Therefore it revisits several researchers who have considered the issue of expertise (Suwa 1997; Casakin 1999; Kokotovich 2000; Kavakli 2001; Kavakli 2002). A common ground from the literature about design expertise is that experts access different types and amounts of knowledge during the process of reinterpretation. The results of several experiments show that practicing architects are more adept at perceiving functional features from the perception of visual features than students of architecture or non-architects.

Suwa and Tversky's work also looks at these issues related to interaction with sketches (Suwa 1997). They present an analysis based on a method of retrospective protocol, examining a participant's design thoughts in an architectural design task. Their experiment consists of a design task and a report task. Practicing architects and advanced architecture students worked collaboratively on designing an art museum through successive sketches as a tool of designing. Their sketching activity was recorded. Following the design task was the report task. Whilst watching their own videotapes, participants were asked to report what they were thinking while drawing.

The results show that, in the early stages of the process of designing, architects are able to perceive a higher variety of different types of information from their sketches than students (Suwa 1997). What may cause this difference is that architects are more trained to think of shapes, angles and sizes after they shift their attention to a new topic. Again the evidence suggests that the mental process involved in a design task, not the ability of drawing, is the greater benefit for experts.

Casakin and Goldschmidt's work is also interested in differences between expert and novices in terms of their use of prior knowledge to solve ill-defined problems (Casakin 1999). The ability to retrieve large knowledge chunks from memory and the ability to recognize clues are some of the skills of the expert designers. Casakin and Goldschmidt's work suggests that the use of analogy supports these important and basic skills (Casakin 1999). The results of their empirical research indicate that experts' skills in using analogical reasoning differ from novices. For example, they show evidence that novices tend to generate irrelevant analogies, while experts are likely to establish a relevant analogy more spontaneously. They argue that novices frequently fail to recognize how new situations can be understood in terms of prior situations.

Kokotovich and Purcell also compared designers and non-designers by conducting two experiments that examined design issues of creativity, mental synthesis and drawing (Kokotovich 2000). Significant differences were found between groups. The first experiment demonstrated that expert design students do produce more creative forms in a mental synthesis task than non-designers. The results of the second experiment indicate how the methodology adopted can provide insights into design processes. Their work examined two issues considered to be central to design process these are the role of drawing and reinterpretation.

Kavakli and Gero also investigate the possible reasons for differences between the novice and expert designers in the rate of information processing based in the experience in drawing production and sketch recognition (Kavakli 2001). They found that experts are more active and productive in the conceptual design process in terms of cognitive actions and the alternatives produced.

From this evidence, it can be assumed that the difference in cognitive activities may result in the difference in performance. In other words the mental processes employed are the major difference between the groups (Casakin 1999; Kokotovich 2000; Kavakli 2001). This seems to be in agreement with other researchers' findings and reaffirms that the expert's ability to use remembered information is one of the great differences between them and novice designers.

In a later work, Kavakli and Gero start questioning why the expert is more active and productive than the novice in the conceptual design process (Kavakli 2002). They present evidence and suggest that the difference in performance in the design process may be attributed to the difference in structure of concurrent cognitive actions. Their results indicate that the expert's cognition actions are more structured and organized in comparison with the novice's cognitive actions.

This research is also concerned with differences between novice and expert designers. The aim is to investigate how expert architects differ from novices in the way they perceive information freehand conceptual sketches and how they interact with their knowledge and memory for verbal description of these sketches, and specially, what this can inform about the way they might use sketch while designing.

3 - PERCEPTION AND CREATIVITY

This section is related to visual perception and its influence on the design process. Perception, imagery, remembering and creativity although studied and presented here separately for the purpose of intellectual understanding, interact in practice and are considered, in a psychological sense, complex human cognitive actions.

However, as this research will show, perception, imagery and creativity mean different things to different people. However there is a common sense within the cognitive literature (Bartlett 1950; Bartlett 1958; Arnheim 1969; Goldschmidt 1994; Kosslyn 1995; Lawson 1997): it is our thoughts that influence what we see, and vice versa, and they may profoundly influence remembering and creativity.

3.1 - Perception

There are differences in how people use the term 'perception' and perception seems to have different meanings for different people. Arnheim, for example, points to some different ways of utilising it (Arnheim 1969). Some, he claims, take the term 'perception' to describe only what is received by the senses when the outer environment stimulates them. But, for him, this definition is too narrow because it excludes the imagery present when a person whose eyes are closed thinks of what is or could be. Others include any kind of knowledge obtainable about the outer world, not only what he/she sees, hears or smell but also what he/she finds out about the people's principles, habits, possessions and actions.

So, listening, observing, smelling or touching, are all considered to be general perceptual situations. It seems to be necessary to clarify that the interest of this study is visual perception and its role in early architectural design process. Therefore, it seems to be necessary to start with the study of visual perception

3.1.1 – Visual perception

When studying visual perception it is necessary make a distinction between seeing and noticing, that is, between passive reception and active perception. There is evidence from other researchers that the diversity of treatment of visual patterns is due the importance of the second factor (Bartlett 1950; Bartlett 1958; Arnheim 1969; Goldschmidt 1994; Kosslyn 1995; Lawson 1997; Gregory 1998).

This appears to be in accordance with Gregory's findings, when he suggests that retinal images are open to an infinity of interpretations (Gregory 1998). The brain's task, he stated, is not to see retinal images (passive reception), but to relate signals from the eyes to objects of the external world (active perception). The brain representation is far more than pictures, since it includes information of what various kinds of objects may do or be used for.

In some way, even with all different views and definitions for visual perception, this difference between passive reception and active perception seems to be a common ground in the cognitive science literature. This is considered to be an important concept to understand imagery, since it is strongly related to perception. The understanding of passive reception and active perception is fundamental to the development of the argument and hypothesis of this research.

3.1.2 – Experiments on visual perception

In order to investigate empirical data about visual perception, this work revisited other researchers (Bartlett 1950; Verstijnem 1998). Bartlett conducted a series of experiments on perception that repeatedly demonstrate that temperament, interest and attitudes often direct the course and determine the content of perceiving (Bartlett 1950). His work shows that a great amount of what subjects claim they perceived, has in fact been inferred.

According to Bartlett, the best point of departure for an experimental investigation of visual perception is a close study of the ways in which people perceive common objects and the immediate recall of perceptual data (Bartlett 1950). The material used in his experiments was graded in character and passed from simple shapes and patterns through designs, the complexity of which was considerably greater representational picture material. The types of experiments on perceiving presented by Bartlett (Bartlett 1950) are:

1. Perception of Simple Design and Patterns
2. Perceiving Progressive Designs
3. Perceiving Simple Concrete Representations
4. Perceiving the Complex Picture Material

The experiments show that the common method of an observer is to respond to whatever is presented as unitary. When the material to be observed is a very simple construction, often the first reaction is the assignment of a name. According to his conclusions, the name given may determine what is perceived. When the material is a more complex object, especially when unfamiliar, there is often a search for analogical material. Finally, when the material is a highly complex representational one, there may be hesitation and then, the emergence of a definitive sensory image, which constitutes the necessary ground. This findings and conclusions were of importance and helpful for the understanding of the argument, hypothesis and main questions of this work.

3.2 - Imagery

Imagery is frequently associated with perception. The concept of imagery covers a wider field and the interest here is the study of mental imagery and its influence on conceptual activity of architectural design process.

3.2.1 – Mental imagery

According to Liddament, mental imagery is generally thought of as a conjuring up of various impressions in the mind, which may be visual, although this need not be the case (Liddament 2000). Mental images might be auditory, olfactory, verbal, textual or even musical. Certainly only one definition for mental imagery is not the purpose here, however Finke presents what he calls 'a convenient working definition for the scientific investigations' (Finke 1989). He defined mental imagery as 'the mental invention or recreation of an experience that in at least some respects resembles in experiences of actually perceiving an object or an event, either in conjunction with, or in absence of, direct sensory stimulation' (Finke 1989).

This suggests that mental images may have many visual characteristics in common with perceived objects and events. There is evidence from other researchers (Bartlett 1950; Finke 1989; Kosslyn 1992; Kosslyn 1995) that they exhibit constraints on resolution that correspond to those in visual perception and they can provide visual contexts that influence perception in much the same way as actual visual contexts.

Finke's work has lead to the investigation of what he calls five major principles of imagery: the principle of implicit encoding, the principle of perceptual equivalence, the principle of spatial equivalence, the principle of transformation equivalence and the principle of structural equivalence (Finke 1989). He explains that, taken together, these five principles provide a general description of the fundamental characteristics of mental images.

Kosslyn also associates perception with imagery and argues that all imagery characterization rests on its resemblance to perception (Kosslyn 1995). Kosslyn also asserts that one way to consider the purpose of imagery is to explore the parallels between imagery and perception (Kosslyn 1995). This appears to be in agreement with Kavakli and Gero's concept, that perception and imagery can be considered functionally equivalent processes (Kavakli 2001).

Kosslyn and Koenig separate visual imagery from visual memory and conclude that visual images are often built on the basis of visual memories (Kosslyn 1992). However it does not mean that visual images are replays of material stored in visual memory. According to Kosslyn and Koenig, people mentally draw, making scribbles that they have never actually seen (Kosslyn 1992). So, in order to gain a better understanding of how mental imagery can be used and its purpose, this study revisited Bartlett, Kosslyn and Koenig, Kosslyn and Kavakli and Gero's researches (Bartlett 1950; Kosslyn 1992; Kosslyn 1995; Kavakli 2001).

Kosslyn and Koenig's investigation points to some ways people can use visual imagery (Kosslyn 1992). The results of their study suggested that imagery could be used in four ways: to access information in memory, to help one reason, to learn new skills and to aid comprehension of verbal descriptions.

In relation to the purpose of visual imagery, in a later work Kosslyn asserts that it has two purposes (Kosslyn 1995). One is to identify properties of imaged objects, which allow people to retrieve information from memory. A second purpose of imagery parallels the role of vision in allowing people to navigate, track and reach.

In order to investigate visual imagery, Kosslyn conducted an experiment where he asked people to record the kinds of images they formed and the purpose of each one (Kosslyn 1995). The results show evidence that memory can be improved if one visualizes the material and then encodes the images into memory. He concludes that imagery is used to retrieve information from memory in a variety of circumstances. According to him, people store the information necessary to form images in long-term memory and that means that people do not have a given image all the time.

It seems that images only come to mind when people are faced with a specific situation. This argument finds support in Bartlett's work (Bartlett 1950). For Bartlett, when people try to discover how imagery is used, they find that it is by an effort to connect what is given with something else (Bartlett 1950).

To study imagination, Bartlett suggested the technique of using inkblots (Bartlett 1950). He prepared a series of 13 inkblots (Figure 3.01) and laid them face downwards in front of the subjects. In his experiment, the subjects turned over the cards for themselves and the reaction times were recorded. The instructions were: 'here are a number of inkblots. They represent nothing in particular, but might recall almost anything. See what you can make of them, as you sometimes find shapes for clouds, or see faces in a fire' (Bartlett 1950). The most immediate feature of the results was their enormous variety. Bartlett concludes that what is imaged and when images occur are both strongly determined by the nature of interest (Bartlett 1950).

Figure 3.01: Bartlett inkblots to study imagination (Bartlett 1950: 47)

All this evidence indicates that mental imagery really shares some of the same processing mechanisms used in visual perception and recognition, and that imagined objects could be interpreted in the same way as physical objects. This seems to be an important and valuable issue for the study of architectural design process.

3.2.2 - Mental image generation

The process of forming mental images is called image generation. Currently, a considerable amount is known about how the brain generates, inspects, maintains and transforms objects in images. In order to gain a better understanding of the generation of mental images, Kosslyn and Koenig, Kosslyn, Gregory, Kavakli and Gero's work provides a useful framework (Kosslyn 1992; Kosslyn 1995; Nakayama 1995; Gregory 1998; Kavakli 2001). Their work considers each one of these mental abilities: image generation, image inspection, image maintenance and image transformation.

Kosslyn points out that there are several mechanisms working together to generate images and these mechanisms may have other roles as well, since there is not a single mechanism dedicated to generating images (Kosslyn 1995). He illustrates this by the following analogy: a car can slow down if one simply takes one's foot off the accelerator, which does not activate a separate slowing-down system.

Kosslyn also presented evidence in his work that the brain processes information about location separately from information about shape (Kosslyn 1995). He concluded that if the two types of information are entered into memory separately, it is reasonable to assume that separated subsystems use each type of information when the system is running in the other direction, that is, forming an image rather than encoding one (Kosslyn 1995).

Gregory's work seems to confirm and support Kosslyn's findings (Kosslyn 1995; Gregory 1998). According to Gregory, experiments using scanning to detect brain activity have made it possible to see which regions of the brain are particularly active under various conditions, such as while reading, seeing or imaging (Gregory 1998). In general, he affirms, the same regions of brain are active for seeing things and for imaging things visually.

In summary, it can be concluded that activating visual memories can form images. Actually it is apparent that activating visual memories of total patterns or single parts and then arranging them, or by selectively allocating attention can form images. But, as the brain is a complicated mechanism, it would not be surprising that these are few of the several possible methods to generating mental images.

3.2.3 - Mental image inspection

Kosslyn and Koenig's work suggests that image inspection can be accomplished in the same way as perceptual identification (Kosslyn 1992). This means that in their view, if we were not able to inspect patterns in mental images, for all intents and purposes they would not exist and imagery would be useless for recalling information. They present some ways mental images can be inspected, including zooming, image overflow, detecting parts and scanning.

Kosslyn's work confirms that image inspection is accomplished by the same mechanisms used in perceptual recognition (Kosslyn 1995). This means that objects seem to be inspected in imagery in the same way they are in perception. His work demonstrates that many of the brain areas that are activated when we recognize and identify objects that are also activated during visual mental imagery.

Kavakli and Gero's work also provides evidence that mental image inspection and an associative interpretation allows creative thinking (Kavakli 2001). They define the creative thinking process as the 'forming of associative elements into new combinations, which either meet specified requirements or are in some way useful' (Kavakli 2001).

3.2.4 – Mental image maintenance

There is evidence from the cognitive literature to support the idea that we can retain relatively little information at one time (Kosslyn 1992; Kosslyn 1995; Gregory 1998; Kavakli 2001; Kavakli 2002; Robertson 2002). This indicates that retaining a mental image requires effort and a limited amount of information can be held in an image for a limited period of time.

Kosslyn presents what he calls the two most important aspects about image maintenance (Kosslyn 1995). First, we can retain relatively little information in an image at once, and second, the critical measure is the number of chunks, or perceptual units that are present. Kosslyn concludes that, presumably, the total amount that can be kept in the mind at one time depends on the speed with which the parts can be refreshed and the speed with which they fade (Kosslyn 1995).

This appears to be in agreement with Kavakli and Gero's findings when they assert that images can be retained only with effort and apparently often cannot be retained long enough to recognize them (Kavakli 2001).

3.2.5 - Mental image transformation

Related to image transformation, Kosslyn affirms that we can mentally rotate imaged objects and demonstrates that motor areas of the brain are active when subjects mentally rotate objects (Kosslyn 1995). He shows that mental images are not real objects that must obey the law of physics. In addition to being rotated, imaged objects can expand or be reduced in size.

Kavakli and Gero categorized the factors affecting mental image transformations as representational richness, pattern goodness, representational mismatch, image size and image rotation (Kavakli 2001). They suggest that these might affect the speed of imagery processing and conclude that the expert's ability to use visual mental imagery is one of the major differences between expert and novice designers (Kavakli 2001).

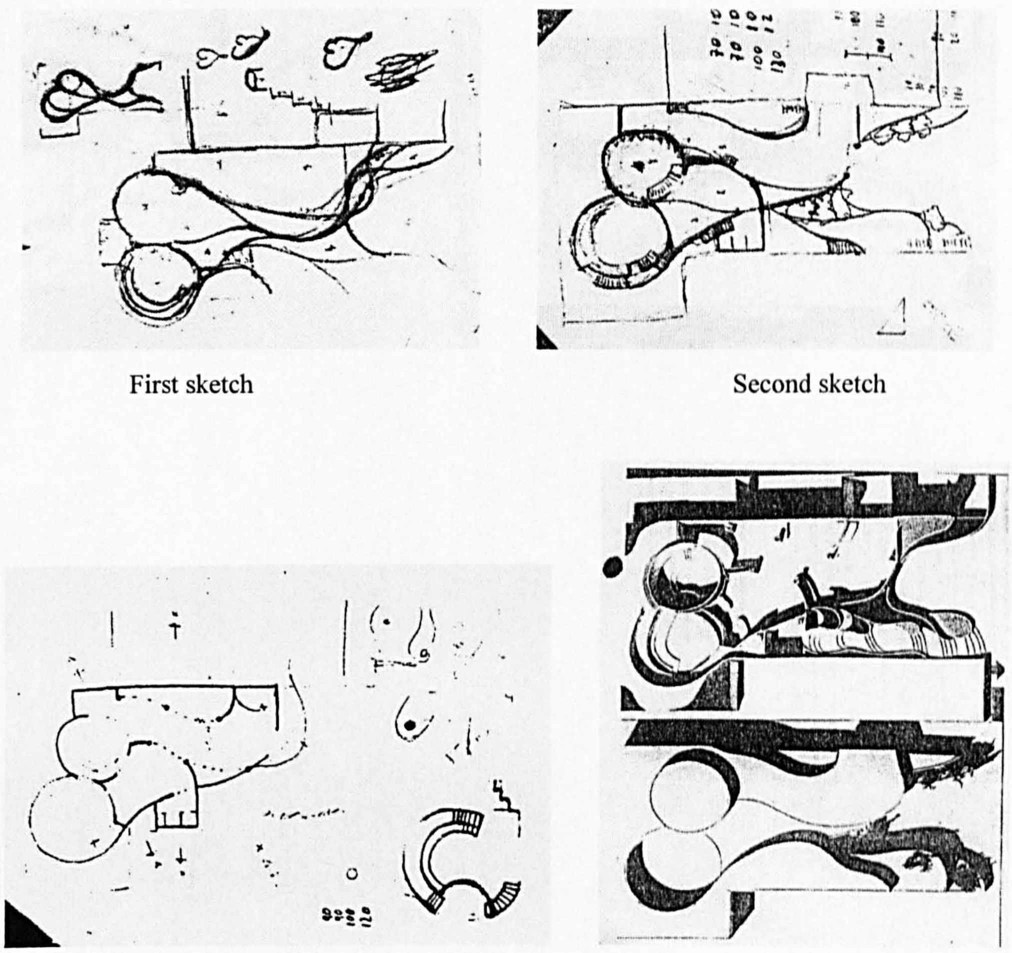
3.2.6 - Interactive mental imagery

In this section, the Goldschmidt's definition of interactive imagery will be revisited and explored as an important concept for the development of the argument of this research (Goldschmidt 1994). For Goldschmidt, seeing something as something else is the essence of the imagery and when imaging is brought through sketching this is referred to as 'interactive imagery' (Goldschmidt 1994). She explains that the difference between normal imagery and interactive imagery is that in the case of the latter, in the process of designing, images are not retrieved from memory.

To demonstrate the conceptual and figural qualities of interactive imagery in designing, Goldschmidt presented an empirical case of designing and sketching (Goldschmidt 1994). She chooses an example from an exercise by a novice designer, Larry, a young architecture student (Goldschmidt 1994). Larry's task was to design a kindergarten on a given urban lot. He sits in front of a blank sheet of paper, not knowing where to start and what he wants to do. The urge to make marks on paper is irresistible and he produces his signature. He repeats the signature, and he did it again and again until his sheet of paper was so full of graphic marks that it became a graphic display.

Larry looked at the display in search for a clue. The search for a clue is largely unselfconscious. He crossed out the seventh signature, and proceeded to sign once more. On this occasion something catches his eye, and he contemplates the figure for many minutes. He selected a heavier pencil and marked over the signature with a heavy line. The enclosed space was clearly visible and this comes as a revelation. Could that space, so randomly generated, possibly be interpreted as the embryo of a plan? Or is this an insignificant anecdote? Larry transformed the signature figure into something that had more plan-like qualities (Figure 3.02). Larry arrived at something that was very nearly a plan. When the basic design was almost finished, he stopped sketching and drawing. The finished project was submitted for review, in the form of a model and presentation drawings.

During the review, no mention was made of the signature. Larry himself did not think it was relevant; for him the process started at a later phase. Goldschimdt said that he remembered the signature as something he had jotted down after he had already worked out the initial plan (Goldschmidt 1994). She stated that in a posterior explanation we always start with a concept and then match a figure to it. During the process things are not as orderly. Incomplete concepts come to mind and partial forms are generated, both randomly and intentionally. There is no predetermined temporal sequence: a concept may lead to a figure as a figure might lead to a concept (Goldschmidt 1994).



First sketch

Second sketch

Third sketch

Aerial view of the model, with and without roof

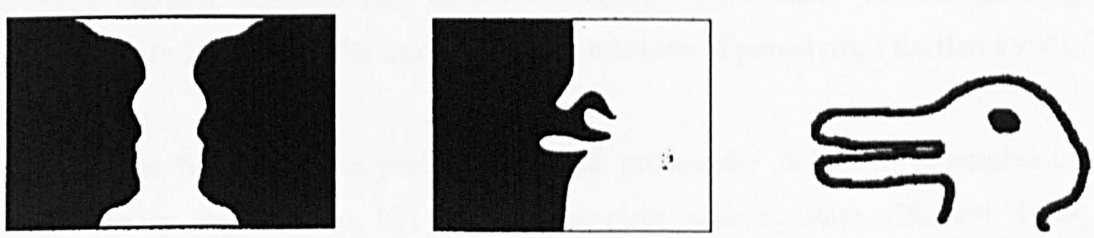
Figure 3.02: Interactive imagery – Larry's case (Goldschmidt 1994)

3.2.7 – Mental image and ambiguity

Ambiguities can be extremely useful for perceptual research and this work is particularly interested in visual ambiguities and its relation to mental imagery. In order to investigate this relation between visual ambiguities and mental imagery and its influence in architectural design process, it seems useful revisit Nakayama and Shimojo, Gregory, and Verstijnen (Nakayama 1995; Gregory 1998; Verstijnem 1998).

This work agrees with Gregory when he said that the retinal image is infinitely ambiguous, this means that it could correspond to, or represent several interpretations (Gregory 1998). There are well known figures (Figure 3.03), generally known as ambiguous figures, which flip between multiple possibilities. According to Gregory, there are three kinds: those which alternate as objects or space between objects (figure-ground); those which spontaneously switch in depth; and those which change from one object into a different object or kind of object (Gregory 1998).

Nakayama and Shimojo also investigate the phenomenon of ambiguous figures (Nakayama 1995). They worked with some famous demonstrations like the face-vase figure (Figure 3.03) where sometimes people see a pair of faces and sometimes a single vase. They arrive at three important conclusions about this phenomenon (Nakayama 1995): First, the perception is bi-stable, that is, people see either the vase as a figure or the faces as figures. Second, when one portion of the picture becomes the figure, the other portion degenerates. Third, with each perceptual reversal, there is also a reordering of depth, that is, whichever portion is seen, as the figure always appears to be closer.



A) Face-vase ambiguous figure B) Ambiguous figure without familiar objects C) Rabbit-duck ambiguous figure

Figure 3.03: Ambiguous figures - Nakayama and Shimojo (Nakayama 1995) pag 8

This seems to be in agreement with Verstijnen, Hennessey, Van Leeuwen, Hamel and Goldschmidt's findings. They also show evidence in their experiments that subjects were unable to reverse the interpretation of an ambiguous figure in mental imagery (Verstijnem 1998).

Using the famous example of dog-chief figure (Figure 3.04) Verstijnen, Hennessey, Van Leeuwen, Hamel and Goldschmidt explain that when the figure was presented to a subject as representing a dog, for example, they were unable to discover the alternative interpretation of a chief before their mental eye (Verstijnem 1998). On the other hand, this discovery took place easily when subjects were allowed to visually inspect the figure. Their conclusion is that reversal involves the discovery of an unanticipated structure.

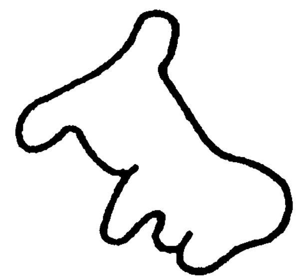


Figure 3.04: The ambiguous figure 'Chief/dog' - (Verstijnem 1998)

3.3 – Remembering

In this section, this study follows Bartlett's suggestions and procedures (Bartlett 1950). Bartlett suggests that in the beginning of the study of remembering, it is necessary to investigate the character and conditions of perceiving (Bartlett 1950).

For Bartlett, since perceiving might profoundly influence remembering, it is legitimately regarded to be the psychological starting-point (Bartlett 1950). For example, there are some features of the perceptual situation, which take lead over the others and these dominant details are a kind of nucleus about which the rest cluster.

Bartlett also presents a distinction between perceiving, imaging and remembering and affirms that a great amount of what goes under the name of perception is actually recall (Bartlett 1950). For him, perception is the direct response to some cluster, or combination, of sensory stimuli immediately presented. Remembering is a way of making use of such combinations of stimuli, though the observer knows that they are not now present to any of his senses and also that they were at one time so present. In imaging, the details of what is imagined may be changed and recombined to form structures, which do not correspond with anything that has been presented to the observer.

For Bartlett, passing from perceiving and imaging to remembering is not a field of new psychological problems (Bartlett 1950). He demonstrated that perceiving is much more than passive reception of stimuli and remembering much more than the simple reduplication of the patterns. For Bartlett, in perceiving the data presented, the stimuli has to be actively connected with something else before they can be assimilated. He explains this factor by stating that every human cognitive reaction is an effort after meaning.

Bartlett also explores the concepts of perceiving, recognising and recalling (Bartlett 1950). These are psychological functions, which belong to the same general group. He asserts that it is obvious 'that nothing could be recognized or recalled which has not first been perceived, that is, nothing can be reacted to in a familiar manner, which has not already been presented and reacted to in some other way' (Bartlett 1950). But he maintains, not everything that has been perceived is recognized or recalled.

3.3.1 – Experiments on remembering

In order to investigate empirical data about remembering, this study revisited other researchers (Bartlett 1950; Verstijnem 1998). Bartlett conducted a series of experiments on remembering and concluded that remembering is not the re-excitation of innumerable fixed, lifeless and fragmentary traces (Bartlett 1950). It is an imaginative reconstruction, or construction and images have fundamentally important parts to play in mental life.

Remembering is considered to be one special form of the general problem of meaning and occurs when the setting of a particular group of stimuli is treated and described as belonging to the past life of the remembering object.

The types of experiments on remembering presented by Bartlett are as follows (Bartlett 1950).

3.3.2 – The method of description

His conclusion in this experiment is that remembering is rapidly affected by unwitting transformations; therefore accurate recall is the exception and not the rule. The transforming agencies fall into two groups: first, the methods of recall adopted and second, individual or common interests and feelings.

Those elements of dominance of special features in a perceptual pattern, similarly affect recall. The transformation of material occurs most frequently in connection with the details which individual interest tends to make salient, or psychologically clear.

3.3.3 – The method of repeated reproduction

Again, the conclusion here is that accuracy of reproduction is the rare exception and not the rule. In this experiment, the most interesting result was the confirmation that the names, phrases and events are changed and appear in forms current within the social group to which the subject belongs.

According to Bartlett, the given material is initially connected with something else and treated as a symbol of that other material and eventually it tends to be unwitting replaced by that which it has symbolised (Bartlett 1950).

3.3.4 – The method of picture writing

According to the results, subjects could be classed broadly into 'visualisers' and 'vocalisers' although no person used one method only. The typical visualiser, he explains, relied more upon direct memorisation, treated the different signs of a series more definitely as individuals and was generally rapid and confident in his method of work. The typical vocaliser used descriptions, names, secondary associations and analogies as aids to recall.

These methods help to show what occurs when a person makes use of some new material, assimilating it and later reproducing it in a personally characteristic manner. Elements of culture, or cultural complexes, pass from person to person within a group, or from group to group, and, eventually reaching a thoroughly conventionalised form, may take an established place in the general mass of culture possessed by a specific group.

3.3.5 – The method of serial reproductions

In order to investigate the effects of the combination of changes brought about by many different individuals, Bartlett designed what he called the method of serial reproductions (Bartlett 1950). He presents two methods of serial reproduction, using written and picture materials. The second one, using pictorial material, is of great interest here.

In this method, subject A's reproduction is itself reproduced by subject B, whose version is subsequently dealt with by subject C, and so on.

3.3.5.1 – The method of serial reproduction 1: written material

In case of written material, each subject read it twice through, to himself, at his normal pace. This material is folk-stories or descriptive and argumentative prose passages. Reproducing was an effected after a interval of 15 to 30 minutes.

The experiment demonstrates that all serial reproductions tend to be absent of their individualising features, the descriptive passages lost most of the peculiarities of style and matter and the arguments tend to be reduced to an expression of conventional opinion. It was found that all serial reproductions produce much abbreviation and commonly exaggeration does occur as well.

Bartlett's work demonstrates that written serial reproduction normally brings radical transformation in the material dealt with (Bartlett 1950). At the same time, as demonstrated in his experiments, the subjects may be very well satisfied with their efforts, believing themselves to have passed on all important features with little or no change and to have omitted only unessential features.

3.3.5.2 – The method of serial reproduction 2: picture material

This method is of particular interest to this research. In case of picture material, a subject was allowed adequate time for observation. He effects his reproduction after an interval of 15 to 30 minutes. The results show that whenever material used certain visual features, which are unfamiliar in the community to which it is introduced, these features invariably suffer transformation in the direction of what is familiar to the group of subjects.

Related to these transformations there were two different types of what Bartlett called elaboration (Bartlett 1950). In the first, as a whole figure was gradually being transformed, certain disconnected material was elaborated into some characteristic belonging to the new setting. In the second, details or motives were simply reduplicated.

Illustrating the first type, Bartlett presented an interesting experiment using a drawing that was a representation of the Egyptian 'mulak', a conventionalised reproduction of an owl, which may have been the basis of the form of the letter 'M' as shown in Figure 3.05 (Bartlett 1950).

The results show that the apparently disconnected lines in the original drawing are all worked into the figure and the original unusual figure becomes greatly elaborated into a familiar whole. The results also show that once this end is achieved, simplification tends to set in again and the whole progresses towards a truly conventionalised form.

The conclusion is that the picture material far more frequently induced a subject to use visual imagery and this strongly favours invention. It seems to be necessary and very important here the study of inventions and creativity and their role in architectural design process.

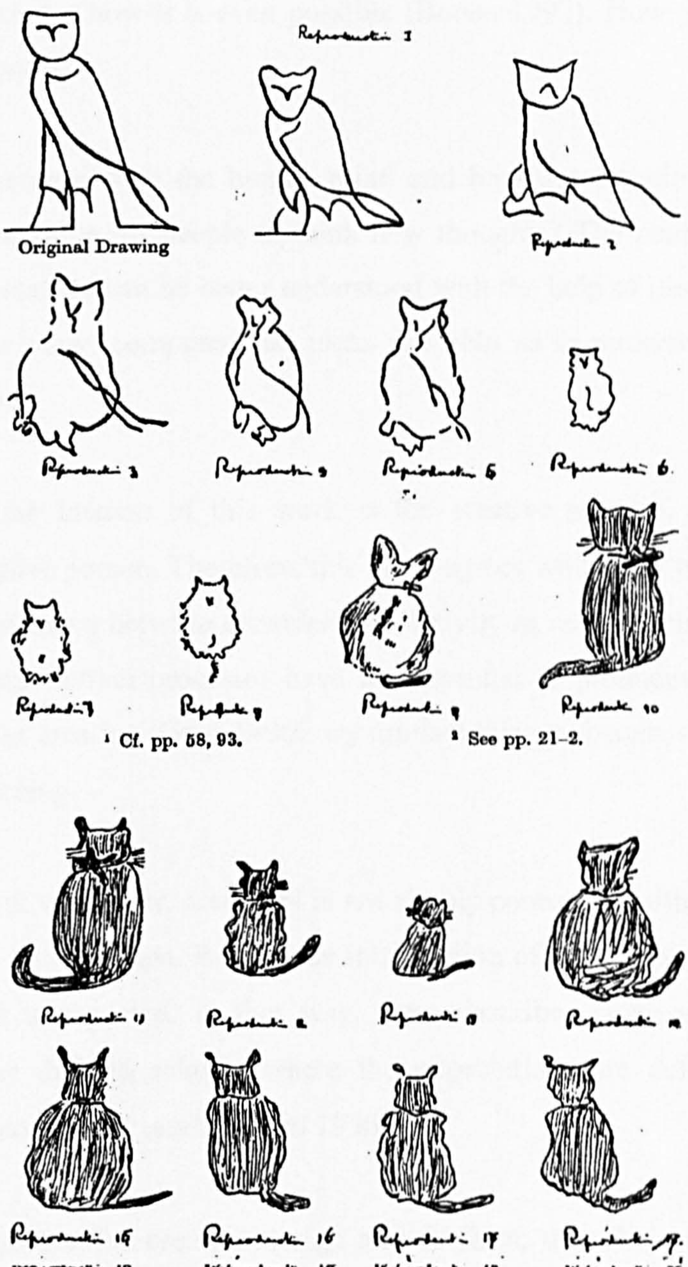


Figure 3.05: The method of serial reproduction using picture material – Bartlett (Bartlett 1950)

3.4 – Creativity

Creativity and particularly creativity in design has many interpretations (Boden 1992; Gero 1996; Lawson 1997; Verstijnem 1998; Kokotovich 2000; Van der Lugt 2000; Dorst 2001; Oxman 2002). According to Boden, there can be disagreement about whether some idea, or person, is creative (Boden 1992). For Boden creativity itself is seemingly a mystery, for there is something paradoxical about it, something which makes it difficult to see how it is even possible (Boden 1992). How, then, can human creativity be understood?

Boden is concerned with the human mind and how our intuition works (Boden 1992). How is it possible for people to think new thoughts? The central theme of her work is that these matters can be better understood with the help of ideas from artificial intelligence. In her view, computational ideas can help us to understand how human creativity is possible.

However, the interest of this work is the creative process, not the creative product or the creative person. Therefore, this work agrees with Gero who suggests that there is a clear distinction between considering creativity as residing only in the artefact and considering that certain processes have the potential to produces artefacts which may be evaluated as creative (Gero 1996). By artefact this work means an object that is made by a human being.

As this work will show, creativity is not simply concerned with the introduction of something new into a design. Rather, the introduction of something new should lead to a result that is unexpected. In that way, Gero describes creative designing as a perturbation of the defined schema where the expectations are defined to produce unexpected and incongruous results (Gero 1996).

Lawson also studied creative design and for him, the whole point of creative design is to create something which other people will experience and which is in some way or other original and new (Lawson 1997). Lawson, based on Poincare's work, describes a creative process divided into phases of different thoughts (Poincare 1942; Lawson 1997).

First, he said, a period of initial investigation of the problem in hand, followed by a more relaxed period of apparent mental rest. Next, an idea for the solution appears almost unbidden by the thinker probably at the most unexpected time and the most unlikely place. Finally, he concludes, the solution needs verification and development (Poincare 1942; Lawson 1997). However, it does not mean that great ideas come to us without effort, that is, simply sitting in the bath or dozing in front of the fire is unlikely to be enough.

Based on Kneller's work, Lawson suggests that the general consensus is that people may identify up to five phases in the creative process (Figure 3.06), which he calls 'first insight', 'preparation', 'incubation', illumination' and 'verification' (Kneller 1965; Lawson 1997).

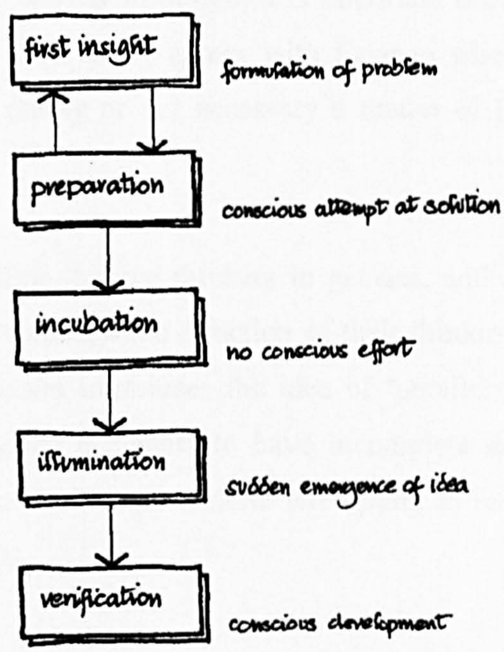


Figure 3.06: The five stage model of the creative process (Lawson 1997)

The period of first insight simply involves recognising that a problem or problems exist and making a commitment to solve them; the problem situation is formulated and expressed in the mind. The preparation phase involves considerable conscious effort in the search of a solution to the problem. This period of intense and deliberated hard work is frequently followed by the more relaxed period of incubation. Then comes what Lawson calls the 'magical moment of illumination' (Lawson 1997).

According to Lawson quite how and why the human mind works in this way is not certain (Lawson 1997). Finally comes the period of verification in which the ideas are tested, elaborated and developed. Frequently the verification period will reveal the inadequacy of an idea. However, he asserts that in design these phases are not as separated as this analysis suggests.

3.4.1 – Creativity in design

Creativity often seems to be defined as new combinations of known entities. As said earlier, there is a distinction between creative behaviour, the creative person and the creative process; the interest here is the study of the creative design process. However when studying creativity in design, it is important draw a distinction between originality and creativity. This study agrees with Lawson when he argues that being creative in design is not purely or not necessary a matter of being original (Lawson 1997).

Lawson suggests that creative thinkers in general, and designers in particular, seem to have the ability to change the direction of their thinking thus generating more ideas (Lawson 1997). Lawson introduces the idea of 'parallel lines of thought'. This represents the ability of good designers to have incomplete and possible conflicting ideas and allow these ideas to coexist without attempting to resolve them too early in the process (Lawson 1997).

Lawson also studied education for creativity (Lawson 1997). He presents some evidence that people cannot expect to be truly creative without a reservoir of experience. To support this affirmation, Lawson uses examples from past literature based on Laxton's work of design education in schools (Laxton 1969). Laxton developed an elegant model of design learning using the metaphor of a hydroelectric plant as can be seen in Figure 3.07 (Laxton 1969; Lawson 1997). According to this model, the ability of initiate or express ideas is dependent on having a reservoir of knowledge from which to draw these ideas. The second skill is the ability to evaluate and discriminate between ideas. Finally, the transformation or interpretative skill is needed to translate ideas into the appropriate and relevant context.

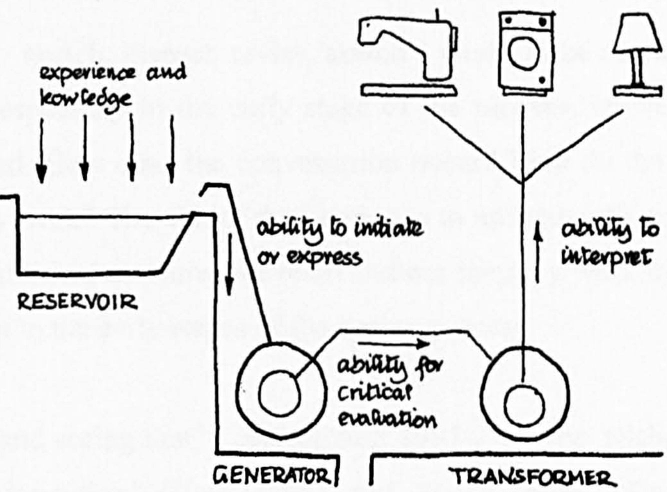


Figure 3.07: Hydroelectric model of design learning based on Laxton's work (Lawson 1997)

Dorst and Cross are also interested in creativity in the design process (Dorst 2001). They show that designers are able to identify points during the design process at which, what they called 'key concepts', began to emerge. However for Dorst and Cross, the study of creative design seems problematic because there can be no guarantee that a creative event will occur during a design process and because of the difficulty of identifying a solution idea as creative (Dorst 2001).

Dorst and Cross conclude that in every design project creativity can be found, if not in the apparent form of a creative event, then as the evolution of a unique solution possessing some degree of creativity (Dorst 2001). This research concurs in suggesting that more studies in creativity in design are necessary in order to develop a better understanding of how creative design occurs.

4 – MEMORY AND PRECEDENT IN ARCHITECTURAL DESIGN

The results of recent research (Goldschmidt 1991; Purcell 1998; Suwa 1998; Lawson 2001) on the role of memory and conceptual sketches in the early stages of the design process seems to indicate that there is a sequence of activities involving thinking, imagery, drawing, reinterpretation and a strong use of memory. Therefore, the interest of this section is the role of memory during the phenomenon of emergence and reinterpretation that occur in the early stage of the design process.

This cycle – sketch, inspect, revise, sketch - seems to be central to development of a design ideas especially in the early stage of the process. However, one question remains unanswered. How does the conversation occur? How do the human brain and the human memory work? The aim of this section is to understand how the conversation with oneself is established and how our brain and our memory work to allow emergence and reinterpretation in the early stages of the design process.

'Seeing as and seeing that' (Goldschmidt 1991), 'moves' (Schon 1992), 'Lateral and vertical transformation' (Goel 1995) and 'focus shifts' (Suwa 1997) are all evidences of the phenomena of emergence and reinterpretation during the early stage of the design process. They are looking for an understanding of how a 'conversation with one self' is established, using Schon's terms (Schon 1988).

In order to study emergence and reinterpretation, this study revisited other research on how the brain operates during the design process (Gregory 1969; Edwards 1981; Tovey 1984; Pinker 1997; Gregory 1998), about memory and design (Klatzky 1980; Potter 1990; Lawson 2001), and about design referents and precedents (Goldschmidt 1998; Lawson 2001). This study also investigates the role of visual analogy and the use of references in the development of design solutions (Casakin 1999).

4.1 – How does the human brain work?

According some researchers (Gregory 1969; Gregory 1998; Robertson 2002), the vital role of the brain became clear from the effects of accidents, that is, when the brain was damaged. Robertson suggests that the study of people who have suffered damage to parts of the brain that control imagery is the clearest way of seeing how the brain builds images (Robertson 2002).

However, there are other studies suggesting different approaches. Another way of approaching this question is to investigate the effects of drugs or chemicals on the brain. Recently it has become possible to see which regions of the brain are active without doing damage or causing undue distress. PET (positron emission tomography) and NMR (nuclear magnetic resonance) scans have revolutionized brain research and are invaluable tools for the clinician (Gregory 1998). A computer builds a map of the activity as three-dimensional thin slices through the brain and makes it possible to see which regions of the brain are active under varying conditions.

Tovey also studied different approaches to this question of how the human brain works (Tovey 1984). According to him, some controlled experiments demonstrate that subjects appear to possess two independent minds within one head. These experiments showed that tumours and excisions within the left hemisphere produced quite different effects from those in the right. The former produced loss of language function, and the latter produced difficulties regarding spatial orientation and recognition of faces.

These approaches have made it clear that different parts of the brain are engaged in different functions. There is evidence that the same regions of the brain are active for seeing things and for imagining things. This suggests that specific mechanisms in the brain select certain features of objects, and probably, perception is built up from combinations of these selected features.

The human brain is symmetrically divided into two hemispheres (Figure 3.08), where it displays different functions and process information in different ways. Although each hemisphere is capable of performing many tasks in the same way as the other, there are certain functions which one or the other is dominant. Nowadays, it is realized that left-brain controlling the right-hand side of the body and right brain the left-hand side in terms of motor functions (Edwards 1981; Tovey 1984).

One half is verbal and analytical and the other is visuo-spatial and holistic. The right half seems to be the more creative part of the brain and right brain superiority is fairly evident in visual tasks. Right hemisphere dominance has been identified in many areas of visual thinking and visual thinking is an important part of design problem solving. However both sorts of rational and intuitive thinking are essential in design problems. The author is in agreement with Tovey when affirming that understanding these differences may assist in design problem solving and strategy selection (Tovey 1984).

Brain

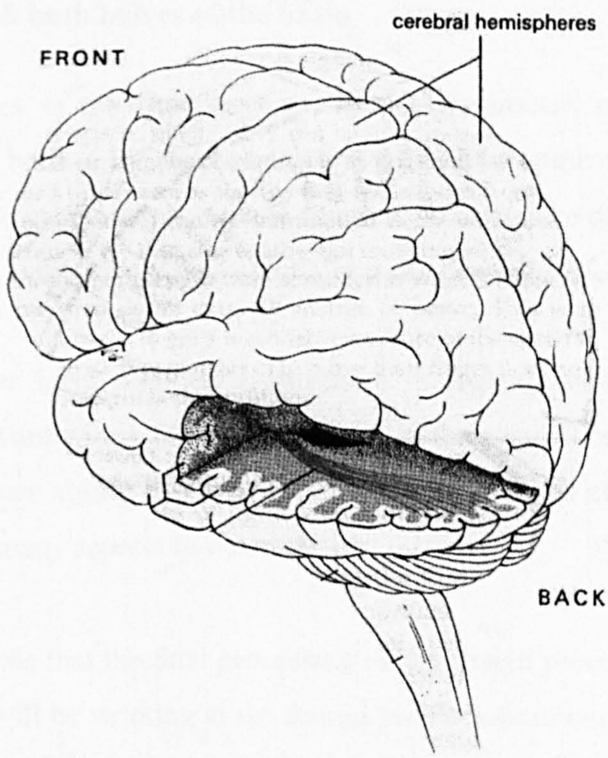


Figure 3.08: Human brain with the two hemispheres –(Gregory 1998)

Broadly the two hemispheres of the brain are: Left hemisphere: verbal, analytic, symbolic, abstract, logical, linear, digital and time oriented. Right hemisphere: non-verbal, synthetic, concrete, analogical, intuitive, holistic, spatial, timeless and diffuse.

Edwards covers a number of techniques to inhibiting the left hemisphere control mechanism and allowing more direct access to the right brain for drawing (Edwards 1981). This includes different ways of looking at the object being represented, by drawing it concentrating on the spaces rather than the contours. So the objects are perceived in terms of abstract symbols, rather than their being appreciated directly.

It seems that Tovey agrees with Edwards, since he also considers that designers, artists, architects and musicians are people who need intact right hemispheres (Edwards 1981; Tovey 1984). Tovey supports the view that the right hemisphere's thinking mode may be of particular importance in several areas of design thinking, creative thinking and appearance design (Tovey 1984).

4.2 – Designing with both halves of the brain

The emphasis in the first stage of the design process seems to be on right hemisphere activity both in the perception and in the development of the conjecture. It requires the ability to synthesize and make concrete what may be defined in the abstract. It demands from the right brain what essentially it can do more effectively than the left.

On the other hand, the left hemisphere is logical, analytical and symbolic thinking is also relevant within the design process in the acquisition and comprehension of the data. Its greater ability to focus on and separate out the components parts will give it control over many aspects of detail design.

Tovey suggests that the dual processing of the design process assumes that both halves of the brain will be working at the design problem simultaneously (Tovey 1984). Each will be processing information in its own way. According to Tovey's analysis, after processing information each hemisphere will then present it to the other (Tovey 1984). Where visual thinking is required then the right will have to work harder. Where the emphasis is on data generation then the left will tend to do more processing.

According to Tovey, the design process will be concluded when there is an agreement between the two hemispheres over a solution (Tovey 1984). The moment when they do suddenly come into alignment might be the classic 'eureka' point. Tovey's final conclusion is that the design process requires both linear analytical thinking and intuitive creative thinking (Tovey 1984). Neither of them is necessarily more important than the other, but both are essential components in designing. It appears to be similar to Lawson's view when suggesting that design involves both convergent and divergent productive thinking (Lawson 1997).

4.3 – How does the human memory work?

Nowadays it is commonly held that human memory is not a single and simple phenomenon but a multiple and complex one. One of its purposes seems to be store information for later use and has different types and phases.

Potter suggests three main phases of memory: registering or encoding information, retrieving or remembering it and forgetting it (Potter 1990). Encoding, she explains, means that the information to be remembered should be put into an appropriate form for later use. Encoding should reduce and transform information, retaining the important material and eliminating the trivial. In order to be used later, the information must be capable to being retrieved and this ability to retrieve information depends on how it was encoded.

According to Potter, forgetting unneeded information seems to be an important component of the memory system (Potter 1990). She suggests that forgetting has the effect of merging information about similar events, resulting in a more abstract and general representation of experience.

This seems to be similar to Klatzky's suggestion that in order for information to be remembered, three things must occur (Klatzky 1980): First the information is encoded, that is, prepared for memory. Second, the encoded information is held in storage. Finally the information is retrieved from the memory store. According to Klatzky, although they are studied separately, these three components of remembering are interdependent (Klatzky 1980). This means that the nature of encoding affects the information in storage and its retrievability.

As a result of this evidence, it can be suggested that the type of memory in use influences our perception and the way we think. The interest here is the study of short and long-term-memory and its role in the design process. It appears to be also important to study semantic and episodic memory, or as defined by Lawson, theoretical and experiential memory and their influence on the design solutions (Lawson 2001b).

It seems appropriate to begin with the study of short and long-term memory. With this purpose, this research agrees and starts with Lawson's suggestion that people are probably all familiar with this distinction, but even so, it is necessary to provide clarity (Lawson 2001).

4.3.1 – Short-term memory

Short-term memory has a very limited capacity and rapid fade. The majority of research on short-term memory has been conducted with verbal material. However, there is evidence that short-term memory can hold information as sounds, visually and meaningfully as well (Klatzky 1980; Potter 1990).

According to past literature, Miller demonstrated that the capacity of short-term memory was limited to seven plus or minus two chunks of information (Miller 1956; Purcell 1998; Lawson 2001b). For example, you can remember a telephone number that you look up in the directory for long enough to dial it, so long as it is not more than about seven digits.

4.3.2 - Long-term memory

Long-term memory appears to have infinite capacity and up to a lifetime of persistence. Research has been conducted regarding to long-term memory and especially in how information can be transferred to it.

Potter suggests that the dominant form of information in long-term memory is conceptual, because that is ordinarily the most important information about events and therefore receives more attention than sounds and appearances (Potter 1990). This seems to be correct but needs to be carefully examined, because it does not mean that people do not remember familiar things and sounds. The conclusion seems to be that any information capable of being experienced can also be stored.

Similarly Lawson suggested that is easy to move something into long-term memory if it has meaning rather than being abstract (Lawson 2001b). For example, memory for names: A well-known device for forcing someone's name into long-term memory is to find some features about them that you associate with the name in some way.

There is also some work done (Schon 1992; Suwa 1997; Casakin 1999) on how expert and novice designers access their memory during the design process. According to Schon and Wiggins, and Suwa and Tversky, expert designers access different types and amount of knowledge in long term memory in a different way as novice designers

(Schon 1992; Suwa 1997). They concluded that experts also make more extensive use of this knowledge and information during the process of reinterpretation, so it is usual in the early stages of the design process.

According to their experiments (Schon 1992; Suwa 1997), expert knowledge is considered to vary not only in terms of type and amount but also in terms of its interconnectedness in comparison to novices and, this interconnectedness facilitates the experts' access to long-term memory.

4.3.3 - Semantic (theoretical) and episodic (experiential) memories

The names 'semantic' and 'episodic' are more commonly applied in cognitive psychology, but Lawson suggests that the terms 'theoretical' and 'experiential' are more appropriate for the study of design process since they relate better to the argument about design (Lawson 2001b). Lawson presents concepts about theoretical and experiential memory and it seems to be important understand the distinction between them (Lawson 2001b).

There is evidence to assume that theoretical or semantic memory is stored and recalled in a different way from experiential or episodic memory. According to Lawson, the two systems seem remarkably independent and, experiential knowledge tends to be much more solution focussed whereas theoretical knowledge tends to be more problem focussed (Lawson 2001b).

To illustrate these concepts, Lawson presents some everyday examples (Lawson 2001b). According to Lawson, a good example of experiential memory is when you meet an old friend for the first time for many years. Your conversation is quite likely to feature a considerable amount of reminiscence. Your friend might say something like 'do you remember when we went to such and such a place…' You might indeed recall this and reply 'yes of course and there was a storm in the afternoon'. You may however struggle to recall it sometimes, but it never the less remained stored (Lawson 2001b).

By contrast to this experiential memory, Lawson presents a theoretical memory example: 'when I was student of architecture, we are expected to be able to draw from memory most of the famous buildings from history. We got up to all sorts of devices for remembering particular building plans and elevations. Since I have not used this knowledge for many years I have largely forgotten it, however I can very clearly remember the pain of study. The formulae for generating plans, which were theoretical, have faded even though I studied them very hard. The experiences of studying them I still recall even though I made no attempt whatsoever to store or remember them' (Lawson 2001b).

4.4 - Memory and design

Related to memory and design, Purcell and Gero suggest that design problem solving consists of a set of cognitive processes, which occur in short-term memory (Purcell 1998). Knowledge and procedures relevant to solving the problem are retrieved from long-term memory and used in short-term memory.

Purcell and Gero argue that design problem solving should exhibit decomposition, and the use of external memory aids, such as sketches (Purcell 1998). For example, when the complexity or size of the problem is such that is exceeds the limits of memory, as in the design problems, the problem is broken and decomposed into sub problems. In addition, external memory aids, such as written material, drawings and diagrams, are used.

4.5 – Design precedent

Several researchers (Lawson 1997; Goldschmidt 1998; Casakin 1999; Lawson 2001) have suggested that the acquisition of experience in the form of precedent seems to be one of the most important things for a designer. This means that the use of precedents to solve design problems is considered central to the development of a design process.

Design precedents might be previous solutions seen on visits or holiday and they are usually considered either whole or partial pieces of design. In modern society, it is also frequently presented through images in magazines, journals, books, the Internet and television. The suggestion is that the more people have seen, experienced and absorbed, the more the frame of precedent expands. It seems that this availability of precedent knowledge is likely to promote design creativity and appears to be motivating research in this area.

It is well known that conversation cannot take place unless there are some shared and known ideas involved. Lawson suggests that this view of design as conversation enables experience to take a more central role in the process (Lawson 2001b). Conversation is often centred on the recalling of previous events that somehow connect with the current topic. For Lawson, the common description of such a feature of design processes is the use of 'precedent' (Lawson 2001b).

According to some researchers (Goldschmidt 1998; Lawson 2001b) precedent can also be understood in relation to the practice of law where it is commonly used for debate and argument. Lawyers will use their knowledge to analyse legal situations to search for aspects of previous cases that might be similar enough to count as precedents. If appropriate, it is cited as an argument for taking a similar legal decision at present, regardless of whether the original decision dates back one year or five hundreds years.

As shown in this section, there is evidence from previous research (Lawson 1997; Goldschmidt 1998; Casakin 1999; Lawson 2001b) to suggest that acquisition of precedent knowledge is central to the development of a design process. In spite of its importance, more research is needed to better understand how precedent knowledge helps the development of the design ideas and design solutions.

4.6 – Precedents versus referents

Goldschmidt establishes a difference between precedent and referent and suggests that learning on precedents in architecture may not be such a good idea (Goldschmidt 1998). To explain this argument, Goldschmidt returns to some basic distinctions between architectural and judicial practices (Goldschmidt 1998).

Law, she argues, relies on a well-formulated body of knowledge, embedded in important past legal decisions. Such decisions are authoritative and alluding to them is not optional, but mandatory. In the legal system, people are obliged to make similar decisions under similar circumstances. This is not the case in architectural design. The same circumstances may give rise to a range of different design solutions. In the legal system, deciding by authority on the basis of precedents is the rule, while deciding by reasoning is the exception. In architecture, the opposite is true.

Goldschmidt argues that the concept of 'referent' is more suitable than 'precedent' for design activity (Goldschmidt 1998). For her, this concept is not a new one and its use neither contradicts nor replaces the use of precedents. In fact, reference as a general class, is inclusive of sub-classes such as precedents. According to Goldschmidt's view reference must carry meaning that a designer can use as arguments in design reasoning (Goldschmidt 1998). In this way, she indicates that a system of referents is better than a system of precedents because its wider scope, its less authoritative nature and its high level of personal adaptability are better for the support of creative design processes.

Even though they use different words, Goldschmidt and Lawson seem to be talking about the same phenomenon (Goldschmidt 1998; Lawson 2001b). Goldschmidt's concept of 'referent' and the Lawson's concept of 'precedent' are absolutely the same. That is, for the first, the architectural referent can be any building or building's system and its components, and for the second, design precedents may be previously solutions seen on study visits or holiday and they are either whole or partial pieces of the design. This work will adopt the name precedent as it is largely used in the design literature, but with the same meaning pointed by the researchers above.

4.7 – Precedent and expertise in design

In order to investigate how designers can be taught to use precedent in design problem solving, it is relevant to revisit Casakin and Goldschmidt's work (Casakin 1999). They present the results of an empirical study in which the objective was to discover the extent of the use of analogy that helps novice and expert designers to improve design problem solving. Casakin and Goldschmidt would like to know whether all designers use analogical reasoning and whether this strategy, if used, contributes to the quality of their work (Casakin 1999). In addition, they also wanted to know whether expertise is related to the use of analogical reasoning, and if so, in what way.

Their results indicate that the use of analogy improves the quality of design and also indicates that experts' skills in using analogical reasoning differs from those of novices and that experts are likely to establish a relevant analogy more spontaneously than novices. It suggests that novices frequently fail to realize how new situations can be understood in terms of prior situations.

According to Casakin and Goldschmidt, in the early stages of design process, analogies are seen as a helpful cognitive strategy for enhancing design problems (Casakin 1999). Their conclusion is that designers are in the habit of availing themselves to a rich assortment of visual displays during the process of designing. They argue the there are a number of examples in the design literature of master architects using analogies to illustrate this claim.

For Casakin and Goldschmidt, the use of analogy requires the identification of abstract knowledge structures that correspond to the similarities between known and unknown situations (Casakin 1999). The generation of new relevant structures through the use of analogy can provide a basic mechanism to develop skills in design problem solving. Casakin and Goldschmidt concluded that novice designers do not need to be taught how to use analogy, since they already have this capacity (Casakin 1999). However, they do need to be shown how and why it can be helpful for supporting design problem solving.

5 – QUESTIONS AND HYPOTHESIS

This thesis intends to contribute to the study of visual perception and memory, and how they influence the process of interaction and description of conceptual sketches. It focuses on what information novice and expert architects perceive from visual displays (conceptual sketches) and how they interact with their knowledge and memory for interpretation and description of these images. The interest is to examine what this might inform about designers' reasoning process while sketching and how they use sketches to allow unexpected thoughts.

In order to investigate these issues, it is appropriate to revisit other researchers who made similar inquiries. The last section of this chapter selects and presents a number of questions.

- **Conceptual Design Process:** Why is the expert more active and productive than the novice in the conceptual design process? (Kavakli 2001)

- **Sketches:** What aspects in the act of drawing sketches and perceiving features in them enable a designer to 'invent' important design issues and recognise the requirements of a given problem? (Suwa 2000)

- **Visual displays:** Displayed images may provide the designer's capability of using imagery to manipulate them until they suggest something meaningful to the task at hand. What is it that the display does for designers while engaged in a design search? (Goldschmidt 1998)

- **Novices and experts:** Why is sketching not as helpful for novices as it is for experts? Why sketching has helped experts in the purpose of developing new ideas, but has failed to do so for novices? (Verstijnem 1998)

- **Prior knowledge:** How can designers be taught to use relevant prior knowledge in design problem solving? (Casakin 1999)

- **Experience:** What does experience mean? What is claimed regarding what the designer has accumulated and acquired through his activities in, and exposure to, the field for many years? (Suwa 2000)

- **Imagery:** One of the major differences between expert and novice designers is the expert's ability to use remembered information. Why does an expert designer use his imagery more efficiently than the novice in the conceptual design process? (Kavakli 2001)

- **Learning how to draw:** Why do people have to be taught how to draw in a way that assists in mental synthesis and creativity? Kokotovich and Purcell found that novice designers often use drawings to focus on a design solution early. By contrast, the expert would use drawing to generate ideas and concepts, not form, at this stage of the process, opening up the possibility of innovative and creative outcomes. (Kokotovich 2000)

This research differs from the previous investigations because it focuses exclusively on the process of interaction and verbal description of sketches and not on the actual design process itself. It is not a study of sketches made during the process of designing, but examines what novice and expert designers can see when looking at conceptual images and, especially, what are the differences between them while describing their thoughts.

This study suggests that identifying features in sketches' interpretation and description between novice and expert architects could enable future research to learn more about how to access remembered information and how architects might use them in a design solution of a given problem.

5.1 – Hypotheses for investigation

All the evidence suggests that research into differences between novice and expert designers in solving design problems must be concerned with the reasoning process and its characteristics. This work is also interested in differences in visual display interpretation and description between novices and experts designers.

It seems reasonable to expect that novice and expert designers would present differences in their process of perception, interaction and description of conceptual sketches. In order to investigate these issues, this research intends to conduct an experiment with novice and expert architecture students related to visual perception, interaction and description of conceptual sketches. The experiment intends to identify differences in the way they describe the same sketch.

Although this is not a study of the sketches made during the actual process of designing, the output of this experiment seems to be clearly the result of a mental synthesis process, an important activity in the design process. This study does not predict a high quality of description and the hypothesis for investigation can be summarized as follows.

The descriptions of expert architecture students will be higher in quality and richer in formal and symbolic references than the descriptions of novice students, because of their training in recognizing features in visual displays and their ability to use prior knowledge and memory more effectively to create analogies while describing what they are seeing.

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Chapter 4

Methodology

CHAPTER 4 – METHODOLOGY

1 – INTRODUCTION

In concordance with the previous chapter, there is evidence to suggest that the use of precedents to solve design problems seems to be central to the development of the design process, and one of the most important things for a designer. The use of precedents and analogical reasoning turn out to be strategies of which skilled designers make heavy use (Goldschmidt 1998; Casakin 1999; Suwa 200; kavakli 2001; Lawson 2001b).

Reasoning by analogy and using precedents have been recognized as cognitive mechanisms that have the potential to bring forth prior knowledge that can support the acquisition of new information (Casakin 1999). This suggests that the use of analogy can improve the quality of design and, in the early design stage, it seems to be a helpful cognitive strategy to approach design problems. The use of precedents and analogies are likely to allow the phenomena of emergence and reinterpretation of new thoughts and to promote design creativity.

In fact, it seems that a number of mechanisms of visual perception and memory can all allow and contribute to the phenomena of emergence and reinterpretation. As Chapter 3 showed, visual perception is a very active process and not a passive one and different types of memories may store different information.

This research is interested in the way designers organize, store and recall perceived information, and how this might be related to emergence and reinterpretation of new thoughts while designing. There is evidence that knowledge and procedures relevant to solving a design problem seems to be retrieved from long-term memory and used in short-term memory. The long-term memory appears to work using symbols, meaning and concepts rather than images.

The study of the designer's mental interaction with conceptual sketches is appropriate to investigate these issues. Conceptual sketches appear to support the use of precedent and analogical reasoning, allowing emergence and reinterpretation during early design activity. As defined earlier, emergence refers to new thoughts and ideas that could not be anticipated or planned before sketching. Reinterpretation refers to the ability to transform, generate and develop new images in the mind while sketching.

Perhaps the first step in understanding the designer's mental interaction with conceptual sketches is examining what he/she can perceive while looking and describing sketches, and specially, how novices differ from experts on this. The interest here is exclusively on the mental activity involved in the process of interpretation and description of conceptual sketches and not on the actual design process itself.

The focus of this research is to investigate how and when designers use formal and symbolic verbal references to describe conceptual sketches, and to what extent this helps to understand how they might think while sketching. As stated earlier, formal references are geometric and physical features in the drawing, such as lines, squares and circles. Symbolic references are pointless to external meanings rather then internal organization. Examples may be describing a circle as a sun or a long oval as a sausage.

In addition, this research will also examine if expertise is related to the use of analogical reasoning and, especially, to the use of formal and symbolic verbal references while describing, and if so, in what way. If experts use their prior experience and knowledge in approaching drawings, they should be both better at analysis and description of conceptual sketches than novices. They should also be able to use more formal verbal references to describe general composition and physical features of drawings, as well as more symbolic verbal references such as precedents and analogies to something else external of the drawings. We might also expect them to rely upon symbolic references to specifically design based schemata such as "having a 'Miesian' quality".

Symbolic references appear to be compact and easier compared with the formal or geometrical references. It is supported by Lawson that suggested that symbolic references such as 'it look likes a squashed sun' are more economic in time than formal geometric references such as 'it is a long flat ellipse with some lines going radically from it all round and extending out about as far as the vertical diameter' (Lawson 2003).

According to Lawson, designers recognize images for which they have schemata to which are attached symbolic references (Lawson 2003). To illustrate his argument, he compared the difference by trying to say 'tartan grid' and trying to describe such a formation through geometrical formal language (Lawson 2003). According to Lawson, there is evidence from the psychology of perception for this tendency to prefer to use symbolic rather than formal references when storing information in long-term memory (Lawson 2003).

The use of formal and symbolic verbal references during the description process might reflect the way they think and the way new thoughts emergence. The hypothesis is that expert designers are able to use previous knowledge, precedents and memory more effectively during descriptions, resulting in a greater use of formal and symbolic verbal references than novices. If this proves to be correct, this could enable future research to gain an insight into the designer's reasoning process.

The mode of thinking employed is obviously very much dependent on the nature of the situation. Therefore, thoughts used during the description process may be different from thoughts used during the design process. However it is suggested that identifying and classifying verbal cognitive actions and creating a list of repertoire used during the process of description of conceptual sketches could inform how designers might use sketches to develop new thoughts while designing.

In order to investigate these issues, this research has developed an experiment with novice and expert architecture students related to interaction and description of conceptual sketches. The experiment requires architecture students to describe conceptual sketches to another student who cannot see the images, but must reproduce them from the verbal description.

The subjects are invited to describe what they are seeing and the focus is to investigate differences in the way the two groups of students think with drawings, or at least, about drawings. The question that might be asked is how they perceive and describe the same image, and especially, how they use formal and symbolic verbal references to complete the tasks. The answer to this question seems to reflect differences in content and meaning of the same sketch between the two groups of students.

Although this is not a study of sketching during the actual process of designing, the output of this experiment is clearly the result of a mental synthesis process, an important activity in the design process. In order to simplify the description tasks the experiment decided to use only black/white line sketches, following the Rodgers, Green and McGown's sketch complexity scale (complexity level 1 – see Chapter 2) therefore, images with texture, grey scale, colour or shadows were rejected (Rodgers 2000).

The images belong to two different groups: non-architectural sketches and architectural conceptual sketches. Architectural conceptual sketches refer to sketches made by architects during the process of designing and developing new design thoughts. Non-architectural sketches refer to sketches made by artists and not in a design context. The reason for this is to investigate which image might allow for more formal geometrical references or more symbolic references and analogies to something else. This research further hypothesizes that experts' use of formal and symbolic verbal references will be greater when describing the conceptual architectural sketch than the non-architectural sketch, because of their area of expertise.

In order to facilitate the interpretation of the data and allow comparisons between groups, this work decided that all subjects must describe the same images. There is a very general agreement that abstract representations seem to facilitate the use of analogy (Arnheim 1969; Arnheim 1986; Gregory 1998; Robertson 2002); therefore both images must be abstract and not formal representations of known things.

These images can be compared with Rorschach cards, which, due to the complexity of their shapes, are interpreted in many different ways by those who contemplate them. It is applicable and relevant to refer to the study of 'Rorschach Test'.

This chapter is divided into seven sections. The first section provides a short introduction focusing on the intentions of the experiment. The second section is related to tasks, apparatus, stimuli and general instructions to the subjects. The third section is concerned with images used during the experiment and how the right images were selected. The fourth section of this chapter offers details regarding the pilot studies focusing on the problems and mistakes encountered. The fifth section is related to the final experiment. The sixth section presents the limitations of this methodology. The seven and last section provides the bibliographic references for the chapter.

1.1 – The Rorschach Test

This work investigates the methodological aspect of the 'Rorschach Test' in order to develop its own methodology. It is important to make clear that this work has no interest on psycho diagnosis and the interest is only on the methodological aspects of the test. In order to better understand this test, revisit in other researchers is necessary (Beck 1944; Klopfer 1946; Allen 1953; Alcock 1963).

This test is known briefly as 'The Rorschach' after its designer Hermann Rorschach (1921) utilized ink blots as a deliberately designed and organized personality probing technique. The 'Rorschach Test' is a method of psycho diagnosis through analysis of perceptual samples given in response jointly to his series of inkblots. Rorschach's aim in the development of his method was to help the psychiatrist to a better understanding of his patients on a more objective basis than the routine clinical observation afforded.

The method offers a procedure through which the individual is induced to reveal his/her 'private world' by telling what he/she 'sees' in the several cards upon which he may project his meanings, significance and feelings, just because they are not socially standardized objects or situations to which he/she must give culturally prescribed responses (Klopfer 1946).

There are ten cards in the standard set and these ten inkblots figures that constitute Rorschach's test are presumably well know, so description of the test material and all exposition of technical detail concerning its composition are omitted in this work. However some examples are provided in Figure 4.01.

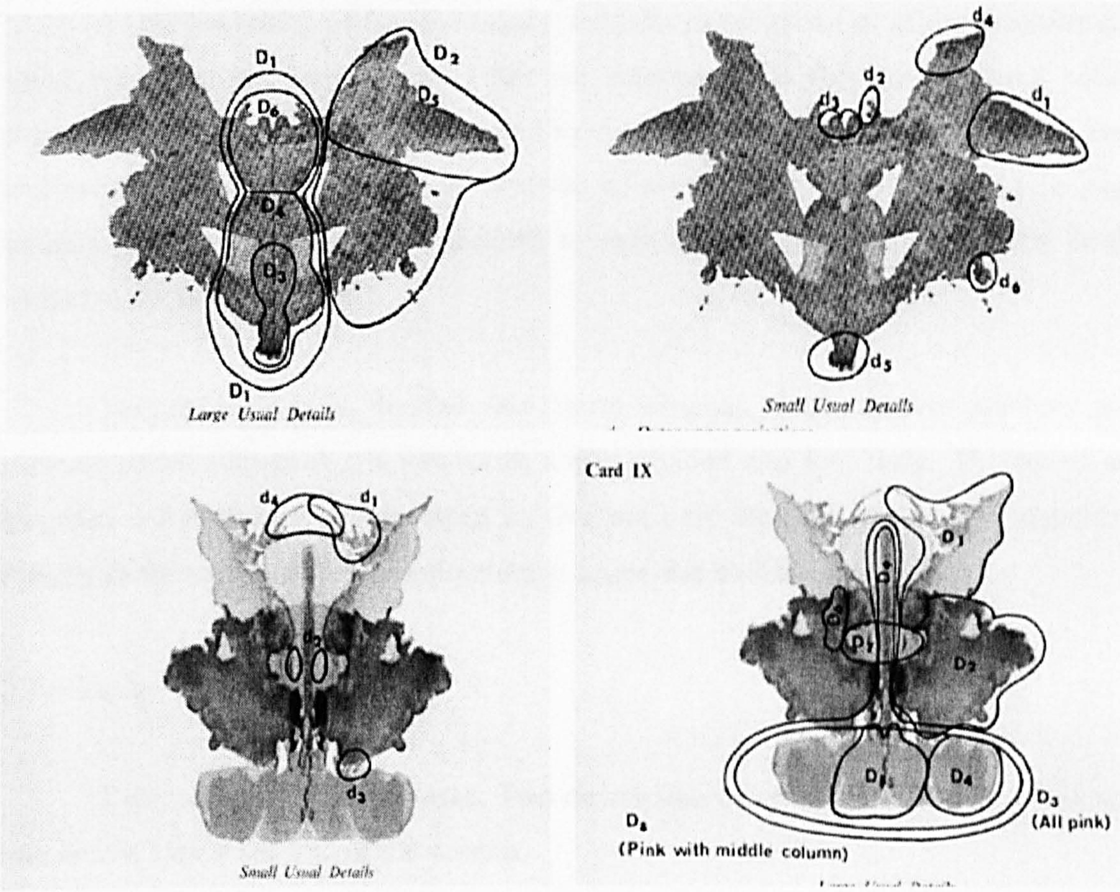


Figure 4.01: Some examples of inkblots figures used in 'Rorschach Test'.

In Rorschach's original technique the subject looks at the cards and has to describe what he/she can see on them. As indicated under the instructions to be given to subject, he/she looks at each card one at a time. The cards are always presented to the subject in the same orientation. Nothing is stated in the instructions about turning the card, but if subject asks about turning, he/she is informed that he/she is free to do so. The subject needs to start producing associations. Therefore, it is important to have the subject in a condition that represents his usual state of relaxation, since the essence of Rorschach test procedure is to leave subject entirely free.

2 – METHODOLOGY OF THE EXPERIMENT

This work intends to exploit some features of Rorschach's methodology. All participants of the experiment are from the School of Architecture of The University of Sheffield.

At the beginning of the experiment, subjects receive a set of general instructions about the tasks and procedures. They are informed that they cannot have visual communication and cannot be interrupted by the experimenter. They have no time limit to conclude the tasks and they are allowed to proceed until they are ready to stop. Initially they can talk and ask questions to each other in order to clarify any doubt related to the description.

The experiment is divided into thirty sessions. Each session involves two students called subject A and subject B, and is divided into four tasks. The voices are recorded and their action videotaped so that not only their description and sketching activity in the task, but also their pointing gestures and doubts can be visible.

2.1 – Tasks

There are four different tasks: Two description tasks, one remembering task and one review task at the end of the session.

During the description tasks subject A is shown the two different images separately (non-architectural and architectural sketches) and has to observe them for later verbal description to subject B. Subject A can look at the image while describing, since the experiment's interest was not on how he/she memorizes the image but how he/she interacts with knowledge and memory to create analogies for interpretation and description of thoughts. Therefore subject A does not need to memorize the images but does need to describe them in his/her own way.

Subject B has to listen to the description and draw what he/she understood from that. Subject B can ask questions to subject A to better understand the descriptions and draw the image, but subject A cannot see what subject B is drawing. This is achieved with both subjects in the same room, separated by a screen and sitting back to back without visual communication.

After the description tasks, there is a remembering task, where subject A is asked to draw from memory what he/she described to subject B. The duration of this task depends of each subject and there is no time limit. They are allowed to proceed until they are ready to stop and there is no interference between the two tasks.

The review task is the last one. At the end of each session, subjects A and B are asked to view all the images and drawings produced and comment on the experience. Whilst watching their own videotape, subjects are asked to review the experience focusing on what, why and any doubts experienced while describing or drawing each portion of the sketches. The focus of this review stage is to identify the easiest and hardest sketch to describe and the reasons for this.

2.2 - Apparatus and stimuli

The study is designed for a specially prepared room divided into three parts, as shown in Figure 4.02. In one part, there is a table where subject A sees the two images (sketches). Camera 1 records subject A examining and describing the sketch. A workspace (desk and chair) with drawing material (paper A4-size, black pencil and eraser) is provided for the subject B's use in another part of the same room. There is also a workspace (desk, chair and control panel) for the experimenter's use. The experimenter controls the video and sound through monitors.

The sketch to be drawn is concealed from view in the workspace by a screen dividing the viewing and working areas. While subject B is sketching what he/she is hearing, two cameras are recording from different angles. Camera 2 focuses on the sketching area and subject B's hands while Camera 3 is placed in front of subject B to register his/her movements and gestures.

The general preparation of the subjects is also based on 'Rorschach Test'. According to this test, the preparatory phase of the experiment, exposing the subject to the stimulus material is of great importance because of the necessity of inducing an atmosphere of relaxation. The subject must not feel the experiment is a test, but more or less like an interesting game with no concern for right or wrong responses. At the beginning of the experiment, participants receive a set of general instructions about the tasks and specifics instructions to each subject.

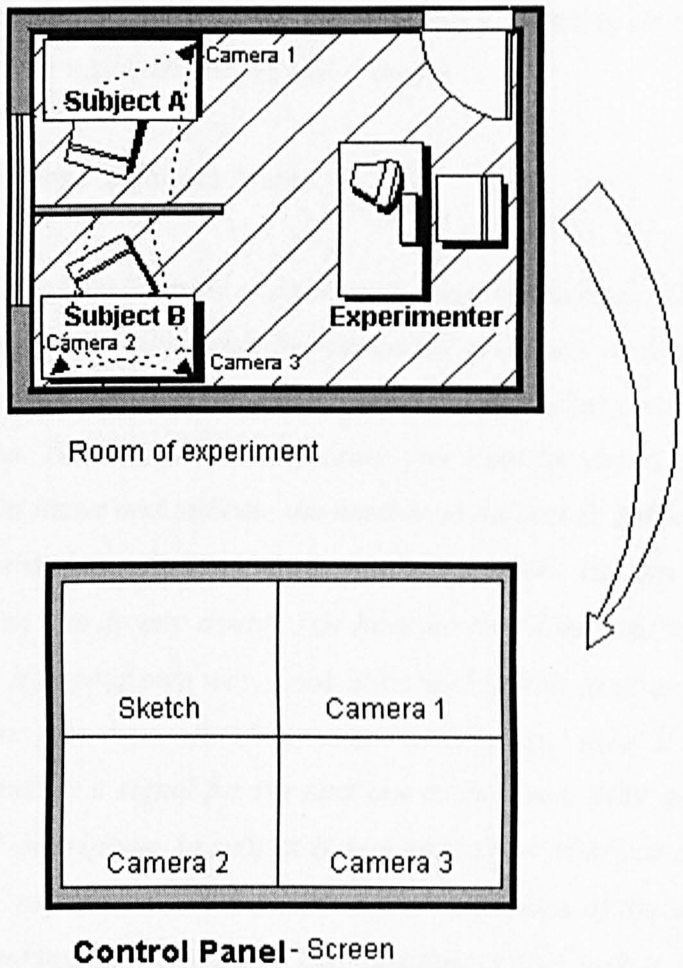


Figure 4.02: The special prepared room for the experiment

2.3 - General instructions to subjects

The general instructions to subjects are:

'This is an experiment on Perceiving, Remembering and Describing. It will involve two subjects (Subject A and Subject B) and one experimenter. It is not a test and has no concern for right or wrong answers. You will be asked to use memory, creativity and analogies to describe (Subject A) and draw (Subject B) some images. You cannot have visual communication during the task and cannot be interrupted by the experimenter. You have no time limit to conclude the task and you are allowed to proceed until you are ready to stop. The

experiment will be recorded and at the end of the session you will be asked to review and talk about the experience, focusing on what you were thinking while describing and drawing.'

The instructions to subject A are:

'You will be given a series of cards with these instructions. The cards have sketches on them, made by recognized architects and/or artists. Look at each sketch and describe to the Subject B what you see on it, one by one. You can choose any order you want for description and you have to insert and indicate the number to Subject B. Subject B has to draw what he understood from your description. He can ask you questions to clarify any doubt. You have no time limit and must feel free to do it in your own way. Look at each sketch as long as you like and when you have finished your description, give it to the experimenter as a signal for the next one to be given. After giving all the verbal descriptions to subject B, you must draw what you mentally perceived, recognized and memorized from each one of the sketches, without looking at the images. The duration of this task is not pre-established and depends on each subject.'

The instructions to subject B are:

'You will listen the description from Subject A and must draw what you understood from it. You can ask questions to Subject A to better understand the description and clarify any doubt in order to draw the image. You have no time limit and must feel free to do it in your own way. Draw each image for as long as you like and when you have finished the drawing, give it to the experimenter as a signal for the next one to be given. Please, be sure to write the experiment's number and the order of descriptions in your drawing.'

3 – IMAGES

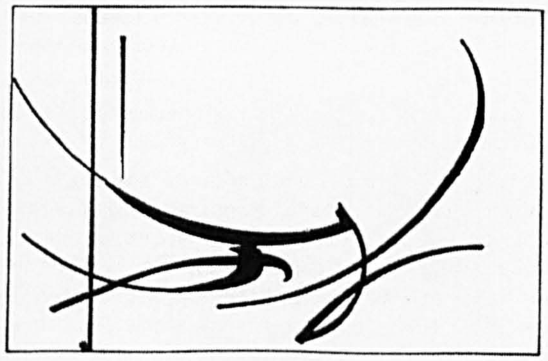
All images are abstract, ambiguous, black/white line sketches. The experiment intends to use sketches from other authors than the participants. That means, the sketches are from recognized architects and artists, and must allow for formal (features) and symbolic (analogies) verbal references. The reason for this is to allow participation of non-architects in the same conditions as architects and compare the groups.

The images are described separately and subjects have some time to observe them to create analogies before verbal description. It is expected that a variety of displays will emerge in imagery and its description may be equally diversified. Again, in order to achieve the same conditions between subjects, it was decided that who is in the position of subject A can not occupy the position of subject B and vice-versa.

After searching through a wide range of art books and architect's sketchbooks 12 sketches were selected in each category, as can be seen on Annex I. From these 12 images, 3 in each group were selected, focusing on the interest of the experiment, that is, memory access, analogy and description. It is important that the images selected allow the subjects to use their imagination and creativity to describe them.

Figure 4.03 shows the three non-architectural pre-selected images and Figure 4.04 shows the three architectural pre-selected images. These six sketches were selected from several drawings, because they seem to give each individual an opportunity to say what they might be, in his/her own way. This personal way of responding to the task is exactly what this experiment is investigating.

The three non-architectural images pre-selected are:



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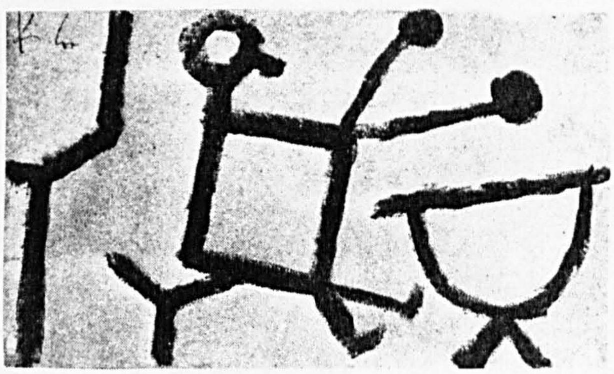
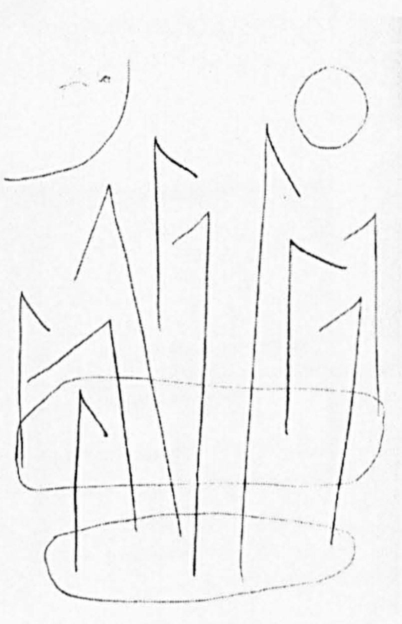
Universos da Arte -1983/3ed
pag. 36 n. 8



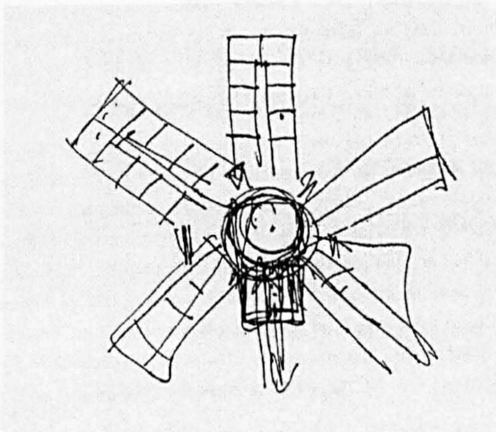
Paul Klee – Amateur Drummer -1940
Klee: A study of his life and work
Di San Lazzaro -1957
pag. 191



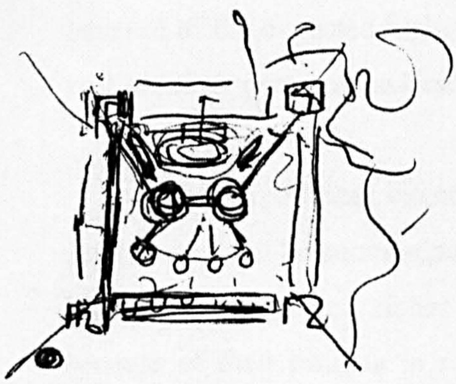
Paul Klee - Double Island -1939
Klee: A study of his life and work
Di San Lazzaro - 1957
pag. 2

Figure 4.03: Non-Architectural pre-selected images

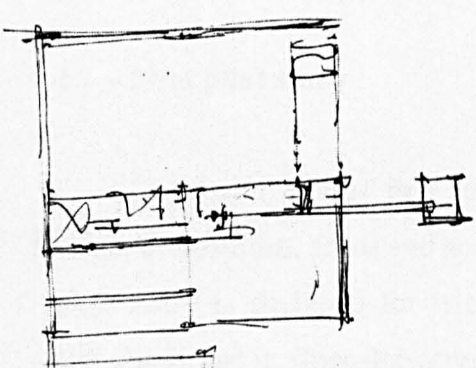
The three Architectural images pre-selected are:



Casakin and Goldschmidt
Expertise and the use of visual analogy: implications for design education.
Design Studies Vol 20 (2) -1999
pag.167



Louis Kahn - Concept Study-University of Virginia - Chemistry Building.
Paul Laseau - Graphic Thinking for Architects and Designers -1989
pag. 106



Mies van der Rohe
Hubbe House Studies - Floor plan 1935
The Mies van der Rohe Archive
Arthur Drexler - 1986 - Vol 4
pag. 45

Figure 4.04: Architectural pre-selected images

4 – PILOT STUDIES

In order to confirm the effectiveness of this methodology and verify expectations, two pilot studies were conducted focusing on the analysis of the descriptions employed by subjects during the tasks. It is expected that novices differ from experts in their process of interaction with conceptual sketches and, consequently, in their verbal descriptions and drawings produced.

This study does not predict a high quality of description and sketch reproduction, but it is expected that the complexity of the images that have to be synthesized and described affect performance for each of the subject groups. It is also expected and the expert's final drawing will be more accurate than the novices' drawing because of the expected higher quality of the description. It is also expected that experts will use their own professional vocabulary during descriptions.

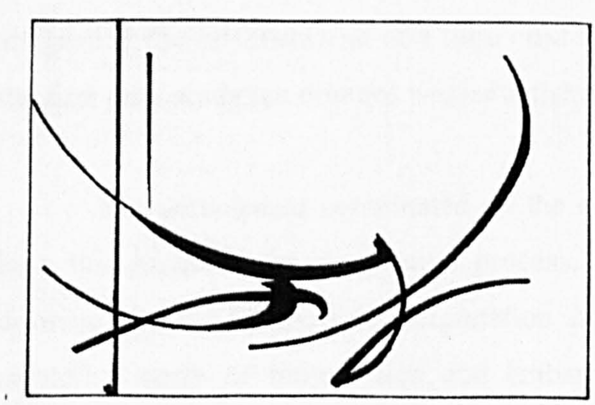
This experiment intends to investigate the hypotheses presented in the previous chapter that can be summarized in this way: The expert students' descriptions would be higher in quality and richer in symbolic references than the novices' descriptions, because of their training in recognizing features in visual displays and their ability to use prior knowledge and memory more effectively to create analogies while describing what they are seeing.

4.1 – First pilot study

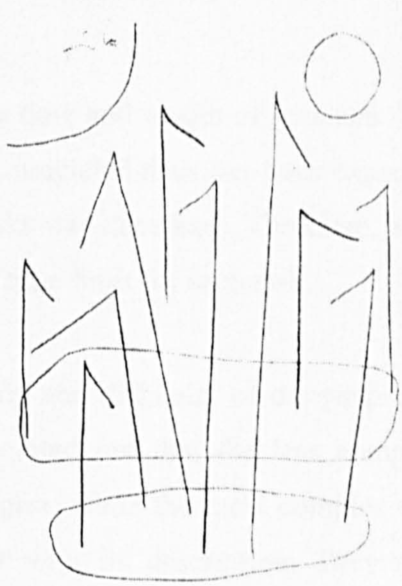
The aim of this first pilot study is check technical problems (adjustment of cameras, positions, focus and sound) as well as to test the images pre-selected. This first pilot study is designed for two sessions of descriptions using the images presented previously that is, three drawings in each group.

The subjects are technicians from the School of Architecture at The University of Sheffield and non-architects. Copies are provided to all participants and the images are showed to them one by one without any identification on them. All subjects need to describe the same images, but in different sequences to avoid the learning effect camouflaging the results. It is expected that each session will take around twenty minutes and each description between five and seven minutes.

However, the pilot experiment took longer than expected and several problems were identified. It comprised of two sessions using only two drawings from the non-architectural group, as all participants considered the third image too much for description and very stressful task. All participants involved considered one image more complicated for description than the other. They preferred image 2 and identified image 1 as the most complicated, as shown in Figure 4.05. Therefore, image 2 was selected and the other rejected.



1



2

Figure 4.05: Sketches employed in the first pilot study – non-architectural group.

4.1.1 – Problems and mistakes during the first pilot study

Some problems were identified which allowed for a better understanding of the complexity of the tasks and gave support for the preparation of a second pilot study. There were problems related to video and audio, time limit, complexity of images, conversation between subjects, materials used for drawings and visibility on the tape.

Related to camera position and focus, this study concluded that all cameras should be better adjusted and positioned, focusing on their objective and main interest. Therefore, it seems to be necessary here to clarify their objectives and interest.

The objective of camera 1 is to record subject A examining and describing the sketch. The focus must be on his/her facial expressions and hand movements. The best position would be in front of the subject A, focusing on his/her movements and gestures. The objective of camera 2 is similar to that of camera 1, but focusing on subject B's expressions and gestures. The best position for this camera would be in front of subject B. The interest of camera 3 is on the sketch construction and not on the hand movements. The best position for this camera would be above the subject and looking down at the paper.

There were also some problems related to the time and length of sessions. The sessions and descriptions took much more time to be completed than was been expected suggesting the establishment of a time limit to the tasks was necessary. Therefore, after the first pilot study ten minutes was established as the time limit for each task.

The participants commented on the complexity and difficulty of drawings and how this hindered the description process. They pointed out that the less complex drawing allowed for more reinterpretation and analogies, while the most complex one created a sense of intimidation and embarrassment with its description. They also considered more than two images inadequate for descriptions and a problematic task. It was apparent that two images were adequate and a comfortable task for future experiments. Therefore, based on this evidence, this research decided to use only two images, that is, one from each group.

During this first pilot study, the subjects were allowed to converse and ask questions to clarify doubts. Analysing the tapes later, this research concluded that this conversation was not beneficial for description, because it did not allow a fluent and free description from subject A. The conversation and questions between subjects seemed to influence the descriptions, creating a strong focus on the formal and geometric aspects of the image and a type of inhibition for external references or analogies. Therefore, this study decided that conversations between subjects are not allowed and they cannot ask questions. The descriptions should be free and spontaneous.

During this pilot study, subject B used a pencil and eraser to draw the image and this proved to be unclear. There was not enough contrast between line and paper and the videotapes became useless for the purpose of further analysis. Therefore, it was decided to use only black pen instead of pencil in all tasks.

4.2 – Second pilot study

The second pilot study was designed using one image from each group - non-architectural and architectural sketches. The drawings were selected based on the previous pilot study and copies provided to all subjects. The images selected for this pilot are shown in Figure 4.06. Ten minutes was fixed as the time limit for each description and participants were not allowed to have visual communication and subject B could not ask questions.

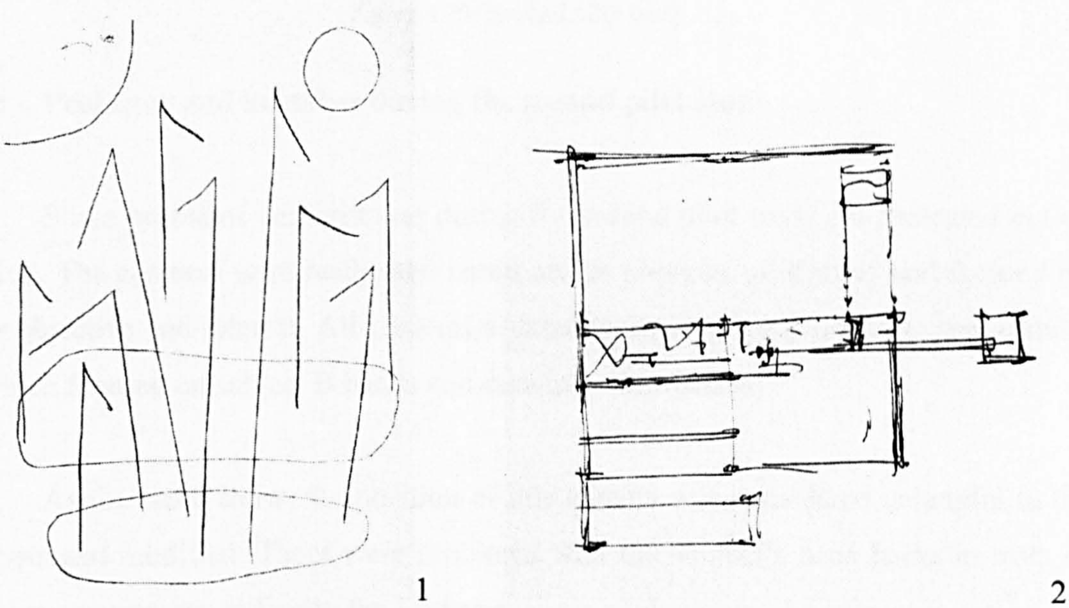


Figure 4.06: Sketches employed in the second pilot study.

The second pilot study was conducted in four sections using the two images pre-selected. The time limit of ten minutes was observed and seemed to be positive, but a few descriptions took longer and the subjects were allowed to continue until they were ready to stop. All subjects described the same images, but in a different sequence, trying to avoid the learning effect and possible camouflaging of the results. Figure 4.07 shows the second pilot study.

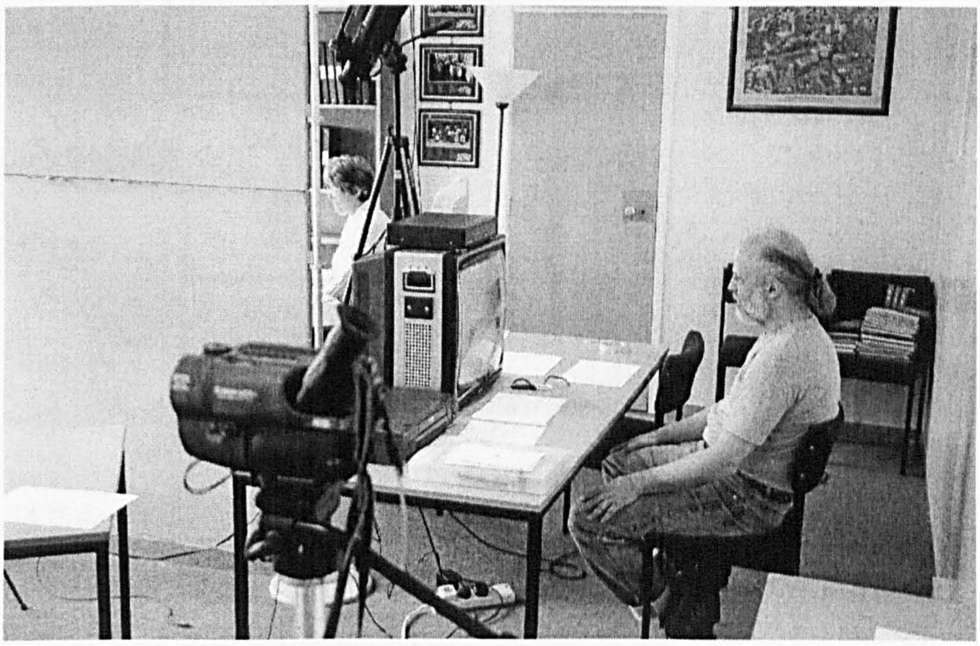


Figure 4.07: Second pilot study

4.2.1 – Problems and mistakes during the second pilot study

Some problems and mistakes during the second pilot study are presented in this section. The cameras were readjusted based on the previous pilot study and focused on their objective and interest. All cameras seemed to be working properly except camera 3, which focused on subject B hands and drawing construction.

As the tapes show, the position of this camera was considered unhelpful to the analysis and modified. There were problems with the subject's head being in front of the camera, creating difficulty for further analysis of drawings. As subject B can be left or right handed, this research decided that the best position for the camera should be above the subject and looking down at the paper. As established previously, the purpose of this camera is to capture the sketch construction and not the subject's hand movements.

This problem related to the position of subject's head between the camera and the drawing needs to be avoided to allow a better interpretation of the data. Figure 4.08 shows the ideal position for recording the desired image.

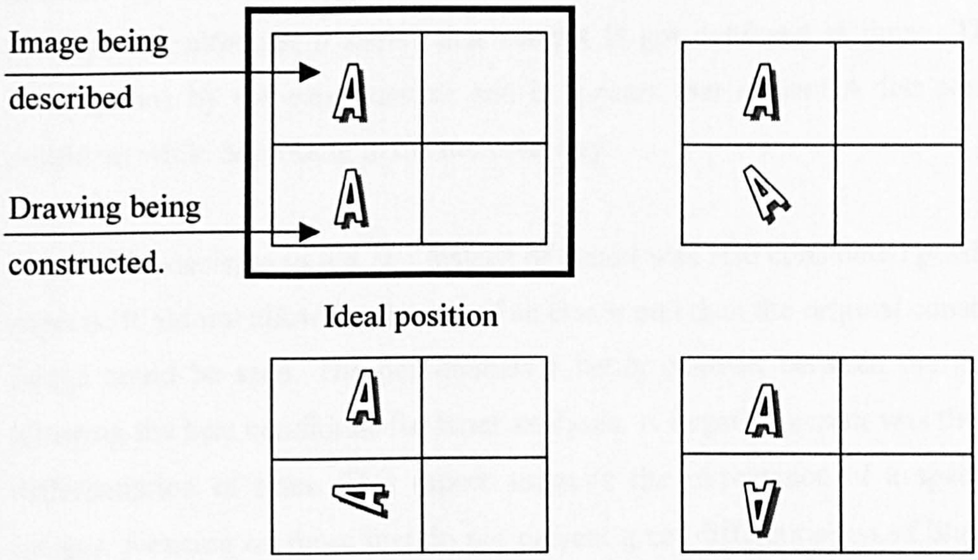


Figure 4.08: The ideal position of images in the screen.

In order to achieve this ideal position, the construction of a special structure to support camera 3 was necessary. Therefore, this research designed and constructed a structure that can be seen in Figure 4.09.

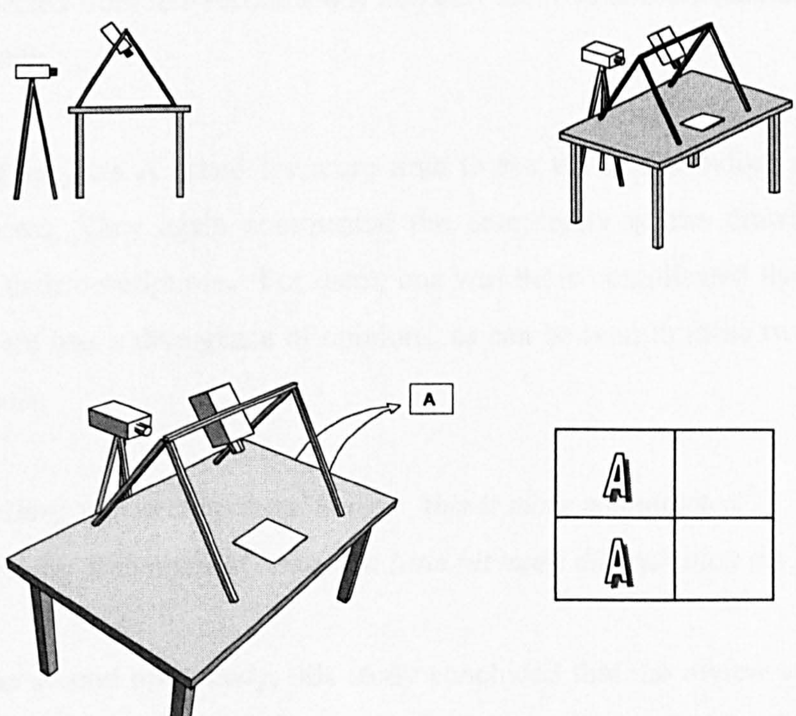


Figure 4.09: Structure for Camera 3

According to the first pilot study, conversation between subjects was not positive, creating a type of inhibition for use of references and symbolic analogies allowed by memory. The non-conversation aspect was considered very positive for descriptions, although it seems that subject B got confused at times. There were no interruptions by the experimenter and it appears that subject A felt comfortable and confident while describing in his/her own way.

The decision to use pen instead of pencil was also considered positive in several aspects. It did not allow for the use of an eraser and then the original construction of the image could be seen. The pen enables a better contrast between the line and paper, allowing the best conditions for latter analyses. A negative aspect was the deficiency in differentiation of lines. This aspect suggests the importance of a specific choice of images, focusing on those that do not present great differentiation of lines. The images selected seemed to be satisfactory.

The use of just two drawings for description was fully confirmed to be good for the purpose of the experiment, because subjects did not feel intimidated by the task. Therefore, this work decided to use only two sketches on the final experiment. The two images were selected from this second study and they are: one non-architectural and one architectural sketch.

Some of subjects A asked for more time to see the image before starting the description process. They again commented the complexity of the drawing and its interference on their descriptions. For them, one was more complicated than the other but this time there was a divergence of opinions, as can be seen in these two examples from the protocols.

2ª session describing non-architectural image: 'this is more complicated'.
3ª session describing architectural image: 'a little bit more difficult than the first one'.

After the second pilot study, this study concluded that the review session must take place on subject A's desk and not in front of the monitor, as planned before. For participants it does not seem to be necessary look at the tape and they only showed interest to see the original drawings and those made through description. Therefore, using subject A desk during the review session allowed for a better recording of conversations between participants while looking and commenting the experience.

During the review session the experimenter asked the subjects questions in order to provoke a more interesting debate. Participants were asked to identify which image was easier to describe, which part was difficult and the reasons. Some foreign students mentioned difficulty with language and not with images. It was hard for them to find the right words for accurate description. One of the subjects said: 'If I can describe in my own language it will be better'. It was suggested that, to get a better result, only people who have English as their first language should participate in this experiment.

5 – Final experiment

After two pilot studies, the final experiment was conducted and comprised of fifteen sessions per group, in a total of thirty sessions. Each session involved two students and one experimenter. A total of sixty architecture students were involved in this experiment. They were all from the School of Architecture at The University of Sheffield and they were divided into two equal groups - First Year and Diploma Year students.

All students were approached in the studio and the intention was find them in their own work place. Looking for the most spontaneous descriptions, this research decided not to inform the students about the experiment in advance. This might prevent them for preparing themselves to describe images in a specific way, which would probably camouflage the results.

5.1 – Final instructions to subjects

The final instructions and all the material given to the subjects during the experiment can be seen in the Annex II of this work.

> ***General Instructions:*** *This is an experiment on Perceiving, Remembering and Describing. It will involve two subjects (Subject A*

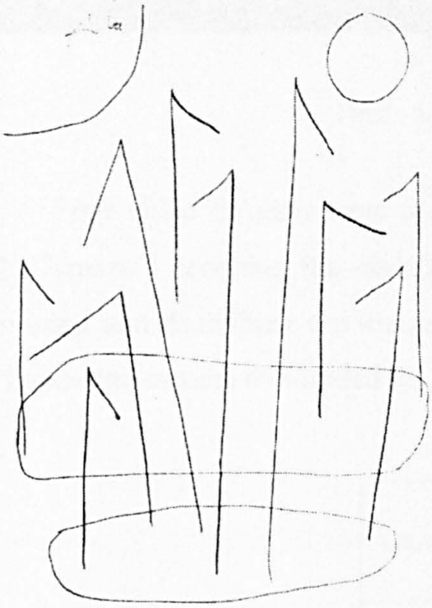
and Subject B) and one experimenter. It is not a test and has no concern for right or wrong answers. You will be asked to use memory, creativity and analogies to describe (Subject A) and draw (Subject B) some abstract images. You cannot have visual communication during the task and cannot be interrupted by the experimenter. You have 10 minutes to complete the task. The experiment will be recorded and at the end of the session you will be asked to review and talk about the experience, focusing on what you were thinking while describing and drawing.

Instructions to Subject A: *You will be given a series of two cards attached with these instructions. The cards have sketches on them, made by recognized architects and/or artists. Look at each sketch and describe to the Subject B what you see on it. Subject B has to draw what he understands from your description. He cannot ask you questions to clarify any doubt. You have 10 minutes to complete each description and must feel free to do it in your own way. When you have finished your description, give it to the experimenter as a signal for the next one. After all verbal descriptions have been given to subject B, please draw what you remember from each of the sketches, without looking at the images. Please, be sure to write the number of the experiment and the order of the descriptions in your drawing.*

Instructions to Subject B: *You will listen Subject A describing a sketch and you must draw what you understand from it. You cannot ask questions to Subject A, at any time, to draw the image. You have 10 minutes to complete each drawing and must feel free to do it in your own way. When you have finished the drawing, give it to the experimenter as a signal for the next one. Please, be sure to write the number of the experiment and the order of the descriptions in your drawing.*

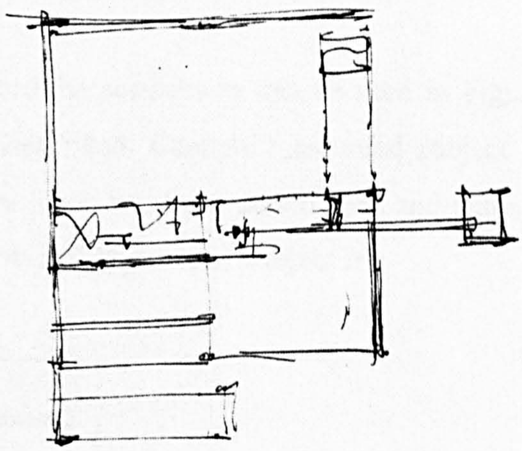
5.2 – Images selected

From previous pilot studies two images were selected for this experiment as can be seen in Figure 4.10. The images belong to two different groups: non-architectural sketch and architectural conceptual sketch. The reason for this is to identify which image must allow the use of more formal geometrical references (features, shapes and positions) or the use of more symbolic references and analogies to something else (precedents).



Non-Architectural sketch

Paul Klee - Double Island 1939



Architectural sketch

Mies van der Rohe –Floor plan 1935

Figure 4.10: Images selected for the final experiment

5.3 – The apparatus

As designed, the experiment was conducted in a specially prepared room divided into three parts as shown in Figure 4.11. In one part of the room, there was a table where subject A saw the sketches and described them to subject B. A workspace with desk, chair and drawing material (paper A4 size and black pen) was provided to subject B in another part of the room. There was also a workspace with desk, chair and panel control for the experimenter's use.

Figure 4.11: Special prepared room

Four video cameras were used to record the sessions as can be seen in Figure 4.12. Camera 1 recorded the sketches to be described. Camera 2 recorded subject A examining and describing the images. Camera 3 recorded the sketch area and subject B's hands and camera 4 recorded the movements and gestures of subject B.

Camera 1	Camera 2
Camera 3	Camera 4

Figure 4.12: Four cameras recorded the experiment for further analysis

Figure 4.13 shows the final position of the cameras and how images were recorded for latter analysis of the protocol.

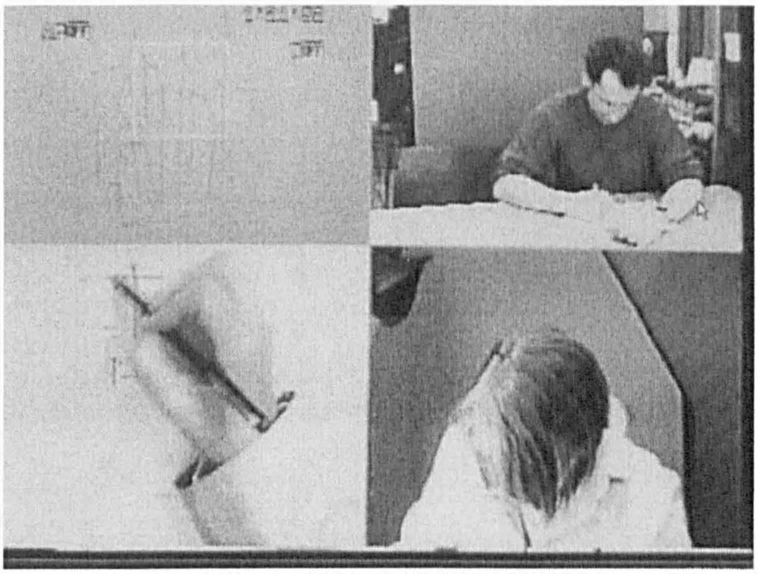


Figure 4.13: Images in the screen.

As demonstrated in the pilot studies a special structure to support camera 3 was necessary. The structure was designed and constructed primarily concerned with finding the ideal position of camera 3 and archived successfully the expectations, as can be seen on Figure 4.14.

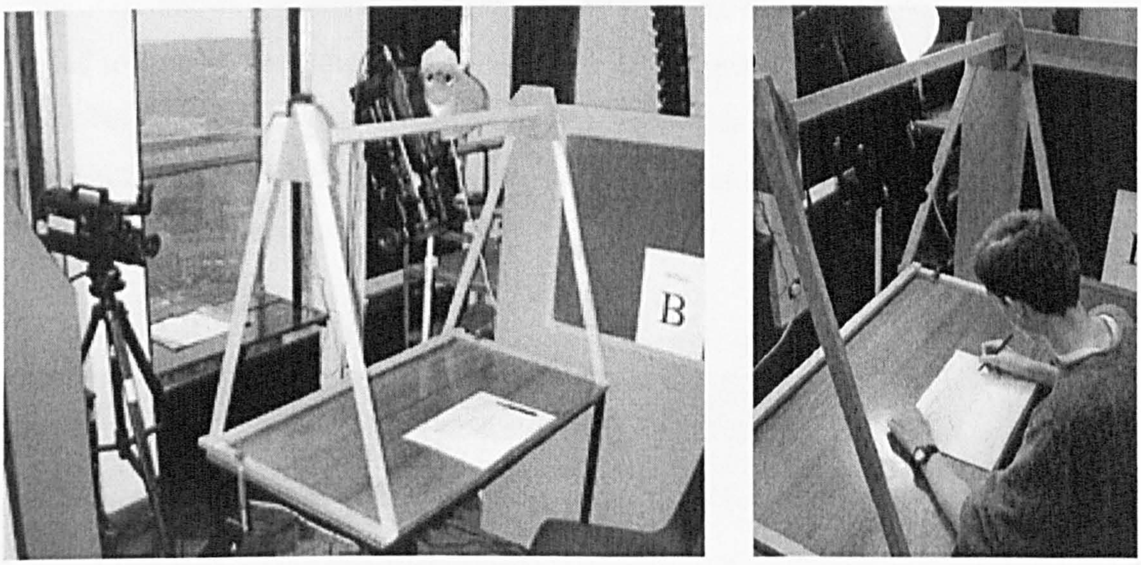


Figure 4.14: Special structure to support Camera 3

This ideal position of camera 3 is to record the drawing being described by subject A and the drawing being made by subject B, while listening to the description, in the same position in the screen, as shown in Figure 4.15 shows.

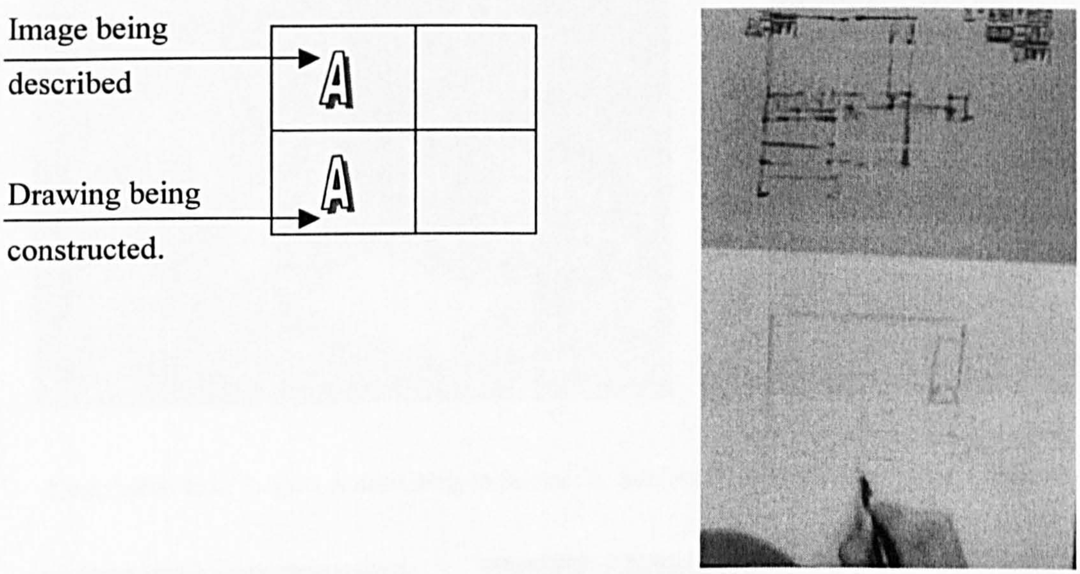


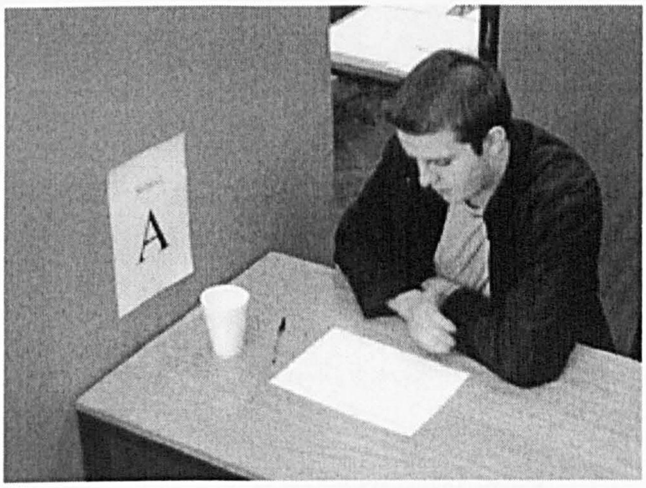
Figure 4.15: The position of the images in the computer screen

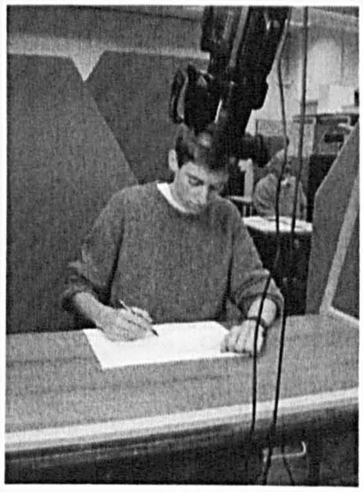
The four tasks previously established were applied and shown in Figure 4.16. Table 4.01 shows the summary of the experiment. In the review task subjects were invited to discuss the experience and identify which image was easier to describe and remember and explain the reasons. As decided early, this review session was conducted in subject A area and the experimenter asked questions to encourage participants to explain their performance.

Table 4.01: The summary of the tasks of the experiment

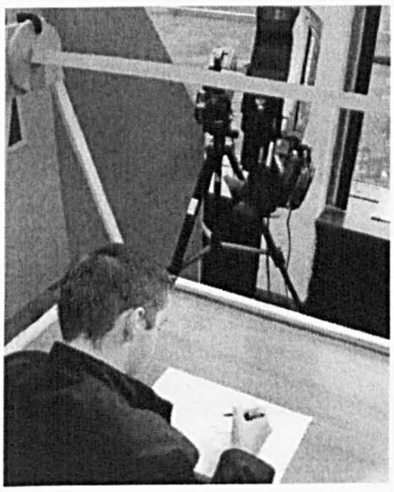
Experiment on perceiving, remembering and describing		
Tasks	**Subject A**	**Subject B**
Description tasks	Subject A describe sketch 1	Subject B draw sketch 1 from description
	Subject A describe sketch 2	Subject B draw sketch 2 from description
Remembering task	Subject A draw sketches 1 and 2 from memory	
Review task	Subjects A and B review and comment the experience	

The experiment produced an interesting and rich data for further analysis. The results and analysis of the data are shown in the next chapter of this work.





Description task: Subject A describing to Subject B. Subject B listen the description and drawing



Memory task:
Subject A drawing by memory

Review task:
Both subjects talking about the experience

Figure 4.16: The four tasks of the final experiment

All data were organized, digitalized and recorded into CDs in order to facilitate the access, analysis and development of this work. Figure 4.17 shows some examples of CDs used during this work.

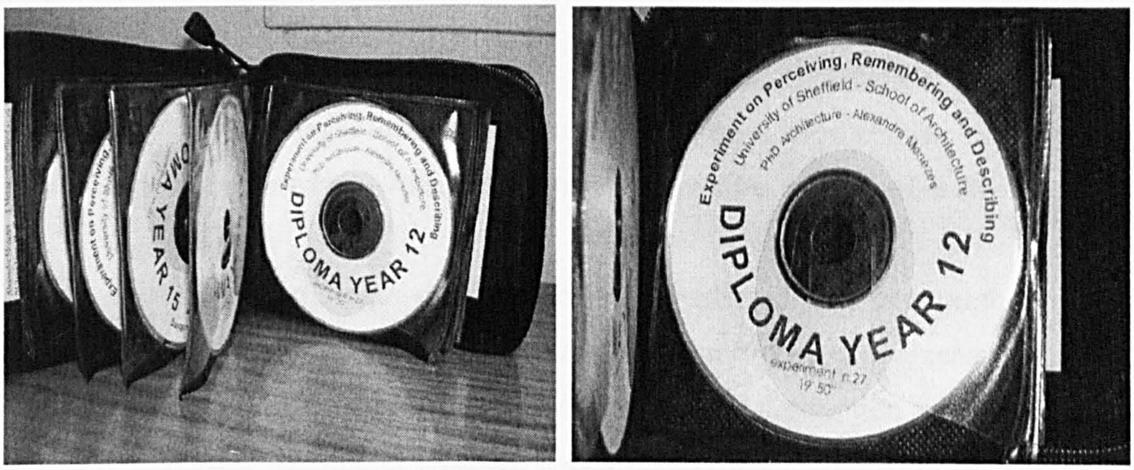


Figure 4.17: some examples of CDs used during this work.

6 – LIMITS OF THE METHODOLOGY

This section is concerned with the limits of the methodology developed and presented in this study. Some limits represent potential problems that can influence the results and conclusions. For this reason, some of them are identified here for further analysis and possible future corrections.

The first important limitation is related to the procedures of the experiment. Such procedures - inviting people to describe what they are seeing - need to be applied and analysed with care. They tend to confuse the process of discovery with that of expression or communication of ideas. For example, a person might be skilled at generating ideas, but poor at reporting or describing them.

The experiment was designed to study the thoughts involved in the interaction and description of conceptual sketches, and not to examine the sketching activity during the design process. As stated earlier, thoughts used during the design process may be different from thoughts used during the description process, and this can represent a mistake in the methodology. However, as established, if it is possible to identify and classify verbal cognitive actions used during the process of interpretation and description of conceptual sketches, this could support future research on designer's reasoning process.

Another limitation seems to be the use of only two images in the experiment. It seems to be questionable as to whether the results and conclusions can be reached against just two drawings. Ideally we would like to use a large number of images, but the decision to be only two was based on the evidence from the two pilot studies.

According to the pilot studies, two images seem to be a comfortable limit for description in one session. All subjects involved in the pilot experiments pointed out that more than two images were considered too much for description and proved to be a very stressful task. Therefore, although it can represent limitations for the results and conclusions, it was decided to use only two images, in order to facilitate the task and gain a better description from participants.

The specific culture of the students certainly represents other limits for this research. The different cultures of the students can influence the descriptions and the use of formal and symbolic references. Some foreign students mentioned difficulties with the language and not with the analysis of the images. As the focus of this research is concerned with the description and verbal references used, this clearly represents a problem and a limitation for the findings.

The non-conversation between students can also influence the results. However, again this decision was based on evidence from the pilot studies. According to these pilot studies, the conversation between subjects did not allow for a spontaneous and free description from the subject A, creating a strong tendency for formal and geometric verbal references and an inhibition for symbolic references and analogies. Therefore, again in order to get a better description, it was decided that subjects could not converse.

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Chapter 5

Results and analysis

CHAPTER 5 – RESULTS AND ANALYSIS

1 –INTRODUCTION

This Chapter is dedicated to the results of the experiment and analysis of the protocols. It is divided into five parts. The first part provides this short introduction to the whole chapter.

The second part presents the times for the lengths of all the sessions and tasks. Each session consists of description, remembering and review tasks. The times for each of those are analysed first per subject group on average, next per individual subject separately and then the results are compared.

The third part of this chapter presents the analysis of the protocols. This work revisits previous protocol analysis in order to develop its own method of analysis. It focuses on the number of segments, number of verbal cognitive actions and the indication of the easiest sketch to describe. The results are compared in order to identify differences and similarities between subject groups and sketches.

The fourth part presents the analysis of the drawings produced during the experiment. It includes those drawings made during the description tasks and those made during the remembering task. Because of the interest of this research, only those drawings made by description are analysed. The results are presented per group and per sketch and compared.

The fifth part, in the end of the chapter, presents the bibliographic references. Some conclusions and implications for further work are embodied in each part of this chapter, but they are all presented together in the next chapter in order to provide a concise summary of the outcomes of this project. All descriptions can be seen in Annex III and all drawings in the Annexes VI and VII of this work.

2 – SESSION AND TASK TIMES

Each session of the experiment involves two subjects, two sketches and different tasks (describing, remembering and reviewing). In this section the times required for a whole session and for each task separately are compared. Using the audio and videotapes of the experiment the beginning and the end of each session and each task were defined and marked.

2.1 – Session times

Firstly the overall times for the subject groups for the session as a whole are compared. The time was recorded and the average of the two groups compared, as shown in Table 5.01.

Table5. 01: Session times per group in minutes.

	First Year - Minutes	Diploma Year - Minutes
Session 01	15.7	17.6
Session 02	16.3	15.4
Session 03	21.7	18.0
Session 04	15.5	15.4
Session 05	11.3	12.3
Session 06	09.6	15.3
Session 07	16.4	12.1
Session 08	09.3	09.2
Session 09	21.0	10.7
Session 10	31.2	8.9
Session 11	18.5	17.2
Session 12	17.6	19.8
Session 13	20.7	09.5
Session 14	20.9	34.9
Session 15	13.7	11.8
Average	**17.29**	**15.21**
Standard Deviation	**5.55**	**6.46**

Figure 5.01 shows the times of each complete session on average.

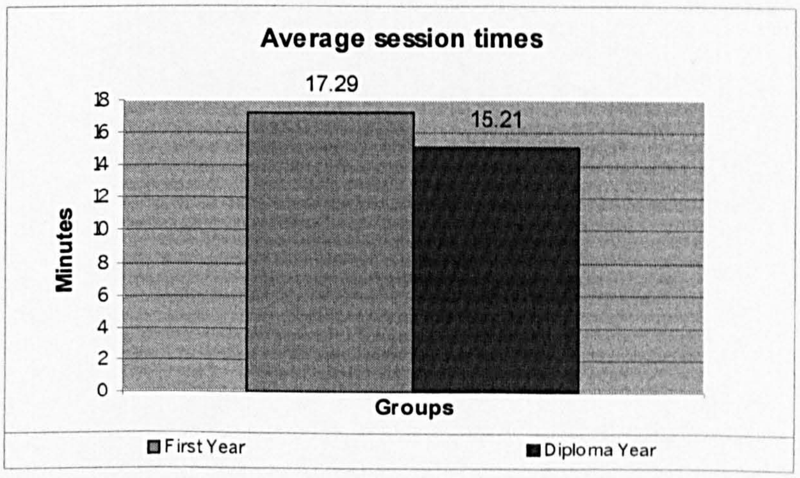


Figure 5.01: Average session times per subject groups in minutes.

The results show that, on average, the First Year group spent more time than the Diploma Year group to complete the same tasks. It might reasonably be expected for tasks to be more difficult for the less experienced First Year group and therefore for them to take longer. However the differences actually found, on average and standard deviation, are narrow and not statistically significant (Ttest $p=0.35$).

2. 2 – Task times

In this section the times taken for each of the tasks in a session (description, remembering and review) are compared.

2.2.1 - Description task

In this section the times for the two descriptions tasks - non-architectural and architectural sketches - are compared separately. In order to avoid the learning effect, the order of these was randomised. All descriptions can be seen in Annex III of this work.

First the times of the first and the second descriptions were examined. Is it likely that the first or second description will be significantly longer overall? On the one hand it is thought that practice makes the subject quicker and able to complete the second description in a shorter time. On the other hand it might be expected that the second description would be longer because subjects can learn how to do the tasks and be more precise and careful.

Therefore, the first question that might be asked is which description took significantly longer on average independently of the type of the image.

2.2.1.1 - First v Second description times per group on average

In order to answer these questions the first and second description times on average for the whole group of students were examined. Table 5.02 shows the results and Figure 5.02 shows the average of these results for the same group of students.

Table 5.02: First and second description times.

	First description (Minutes)	Second description (Minutes)
First Year 01	3.1	6.8
First Year 02	8.6	2.4
First Year 03	9.2	7.4
First Year 04	3.4	7.1
First Year 05	1.9	5.0
First Year 06	2.5	3.4
First Year 07	5.5	7.2
First Year 08	2.0	2.7
First Year 09	3.2	4.4
First Year 10	11.2	11.6
First Year 11	6.0	7.2
First Year 12	6.8	6.6
First Year 13	7.7	6.6
First Year 14	7.0	9.8
First Year 15	3.3	4.1
Diploma Year 01	4.4	6.0
Diploma Year 02	3.8	4.1
Diploma Year 03	3.3	6.6
Diploma Year 04	4.2	7.0
Diploma Year 05	2.4	4.1
Diploma Year 06	4.5	5.4
Diploma Year 07	3.7	5.2
Diploma Year 08	1.6	2.0
Diploma Year 09	2.9	2.5
Diploma Year 10	2.1	2.1
Diploma Year 11	5.2	6.7
Diploma Year 12	5.3	7.5
Diploma Year 13	1.7	3.1
Diploma Year 14	17.2	11.9
Diploma Year 15	2.6	4.4
Average	**4.87**	**5.67**
Standard Deviation	**3.35**	**2.56**

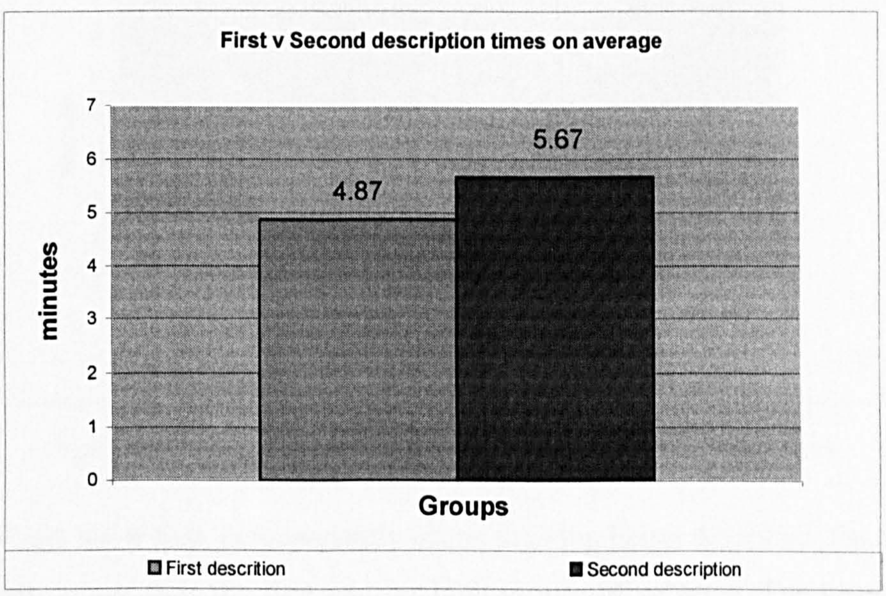


Figure 5.02: First and second description times on average.

The results show that on average the second description took longer than the first one for the whole group of students. However, again the differences found on average and standard deviation are too small and not statistically significant (Ttest p=0.29). This finding was also true for each subject group separately as Table 5.03 shows.

Table 5.03: First x Second description times for each subject group

First Year Group	First description (Minutes)	Second description (Minutes)
Session 01	3.1	6.8
Session 02	8.6	2.4
Session 03	9.2	7.4
Session 04	3.4	7.1
Session 05	1.9	5.0
Session 06	2.5	3.4
Session 07	5.5	7.2
Session 08	2.0	2.7
Session 09	3.2	4.4
Session 10	11.2	11.6
Session 11	6.0	7.2
Session 12	6.8	6.6
Session 13	7.7	6.6
Session 14	7.0	9.8
Session 15	3.3	4.1
Average	**5.43**	**6.15**
Std.Deviation	**2.92**	**2.54**

Diploma Year Group	First description (Minutes)	Second description (Minutes)
Session 01	4.4	6.0
Session 02	3.8	4.1
Session 03	3.3	6.6
Session 04	4.2	7.0
Session 05	2.4	4.1
Session 06	4.5	5.4
Session 07	3.7	5.2
Session 08	1.6	2.0
Session 09	2.9	2.5
Session 10	2.1	2.1
Session 11	5.2	6.7
Session 12	5.3	7.5
Session 13	1.7	3.1
Session 14	17.2	11.9
Session 15	2.6	4.4
Average	**4.32**	**5.24**
Std.Deviation	**3.75**	**2.58**

Figure 5.03 shows the average of these results for both subject groups.

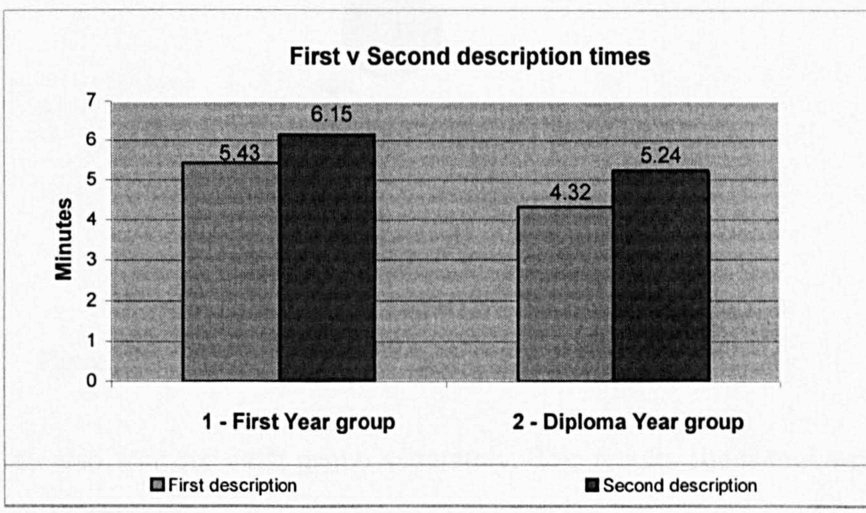


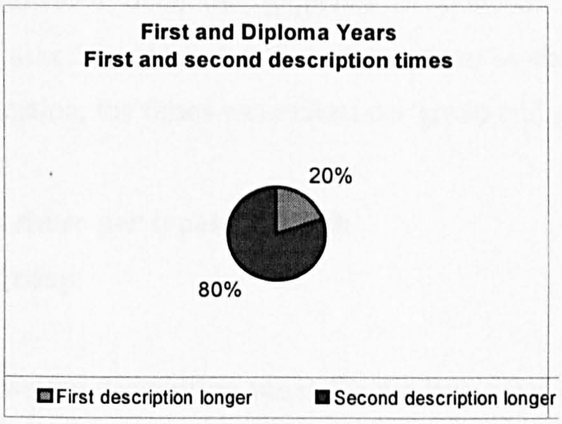
Figure 5.03: Average of first and second description times for both groups.

The results show that, independently of the drawing being described, the second description took longer than the first one for both groups of subjects. The results also show that the novice group took longer that the expert group in both descriptions. However, here again the differences found are not statistically significant (First Year group Ttest p=0.47 and Diploma Year group Ttest p=0.44).

2.2.1.2 - First v Second description times per individual subject

These average differences between the description times are not statistically significant when looking at the subject group. However there are very large variations in times of individual participants. They vary from a minimum of 1.6 min. to a maximum of 17.2 min. for the first description and a minimum of 2.0 min. to a maximum of 11.9 min. for the second description.

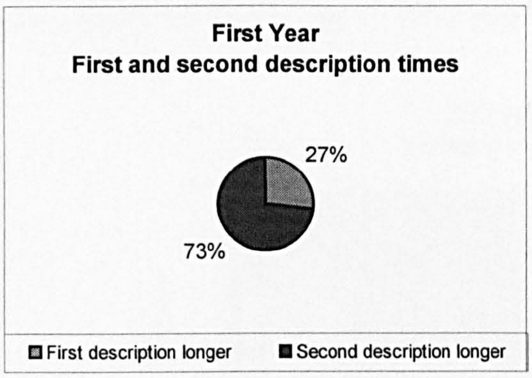
For this reason it is considered to be more sensible to compare the first and the second times for each subject separately. The results show that for the whole group of 30 subjects, only 06 of them (20%) took longer on the first and 24 of them (80%) took longer on the second description one as can be seen on Figure 5.04



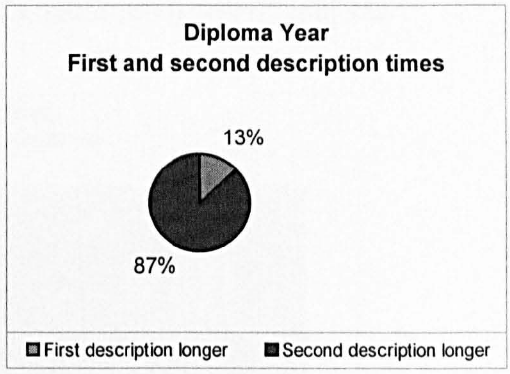
Total of 30 subjects
06 subjects - First description longer (20%)
24 subjects - Second description longer (80%)

Figure 5.04: First and second description times for all participants

This was also true for each group separately. The results show that within the First Year group 11 students (73%) took longer on the second description and within the Diploma Year group 13 students (87%) also took longer on the second description than on the first. As Figure 5.05 shows, the difference in times for the first and second description was greater for Diploma students than for First Year students



First Year group: 15 students
04 first description longer - 27%
11 second description longer - 73%



Diploma Year group: 15 students
02 first description longer - 13%
13 second description longer - 87%

Figure 5.05: First and second description times per subject group

2.2.1.3 - Description times per types of sketch

As shown in the previous sections, the second description was generally longer within both groups, however once the sequence of sketches was randomised, the question that might be asked is which sketch took longer to be described on average. In order to answer this question, the times were taken per group and compared.

2.2.1.3.1 - Description times per types of sketch
First Year group

Table 5.04 shows the description times for the two types of sketch for the First Year subjects.

Table 5.04: First Year group - Description times per sketch

	Non-Architectural - Minutes	Architectural - Minutes
First Year 01	3.1	6.8
First Year 02	2.4	8.6
First Year 03	9.2	7.4
First Year 04	7.1	3.4
First Year 05	1.9	5.0
First Year 06	2.5	3.4
First Year 07	7.2	5.5
First Year 08	2.0	2.7
First Year 09	4.4	3.2
First Year 10	11.2	11.6
First Year 11	7.2	6.0
First Year 12	6.8	6.6
First Year 13	6.6	7.7
First Year 14	7.0	9.8
First Year 15	4.1	3.3
Average	**5.51**	**6.07**
Standard Deviation	**2.83**	**2.66**

Figure 5.06 shows the average of these results for the same group of subjects.

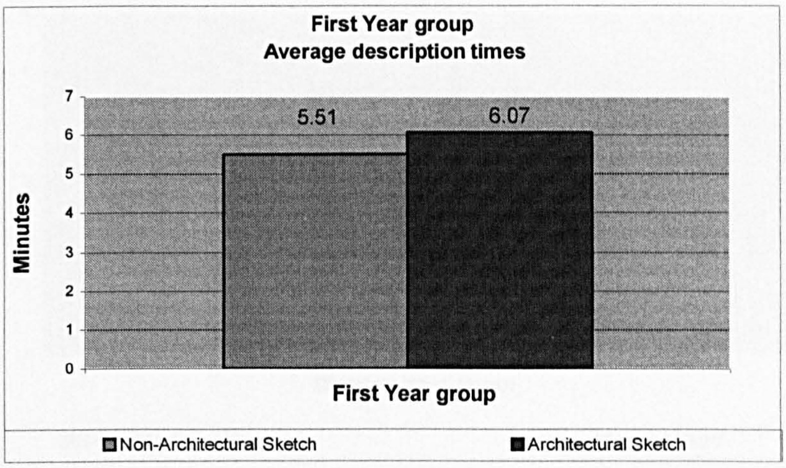


Figure 5.06: Description times for the First Year group on average

The results show that, on average, the First Year group took longer to describe the architectural image than the non-architectural one. However, the differences found are slight and not statistically significant (Ttest p=0.58).

2.2.1.3.2 - Description times per types of sketch

Diploma Year group

The description times for the two types of sketch for the Diploma Year group are shown in Table 5.05.

Table 5.05: Diploma Year group - Description times per sketch

	Non-Architectural - Minutes	Architectural - Minutes
Diploma Year 01	4.4	6.0
Diploma Year 02	4.1	3.8
Diploma Year 03	3.3	6.6
Diploma Year 04	7.0	4.2
Diploma Year 05	2.4	4.1
Diploma Year 06	5.4	4.5
Diploma Year 07	3.7	5.2
Diploma Year 08	2.0	1.6
Diploma Year 09	2.5	2.9
Diploma Year 10	2.1	2.1
Diploma Year 11	5.2	6.7
Diploma Year 12	7.5	5.3
Diploma Year 13	1.7	3.1
Diploma Year 14	11.9	17.2
Diploma Year 15	2.6	4.4
Average	**4.39**	**5.18**
Standard Deviation	**2.74**	**3.65**

Figure 5.07 shows the average of these results for the same group.

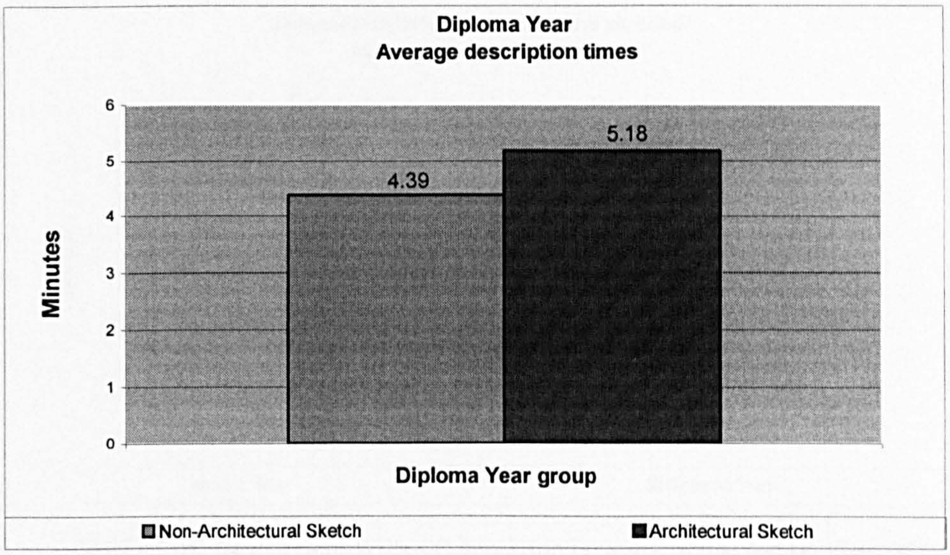


Figure 5.07: Average of description times for the Diploma Year group

The results show that, on average, the Diploma Year group also took longer to describe the architectural image than the non-architectural one. However, the differences found on average and standard deviation, are not statistically significant (Ttest p=0.50).

2.2.1.3.3 - Description times per types of sketch
Comparison between groups and sketches

From all these findings it is possible to compare the groups and sketches. The results are shown on Table 5.06.

Table 5.06: Description times per group and per sketch on average

	Non-architectural sketch Minutes	Architectural sketch Minutes
First Year group	5.51	6.06
Diploma Year group	4.39	5.18

Figure 5.08 presents the description times per group and per sketch on average.

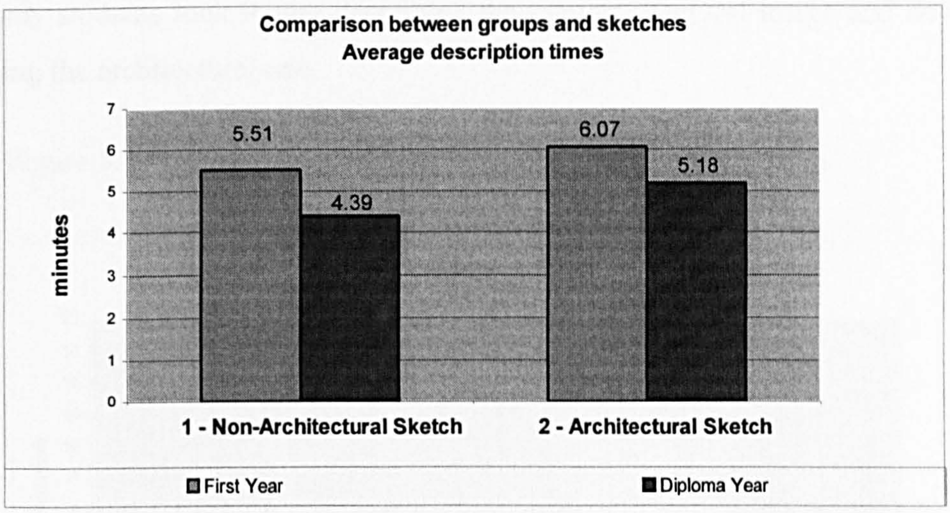


Figure 5.08: Descriptions times - Comparison between groups and sketches.

The results show that, on average, the First Year group took longer to describe both images than the Diploma Year group. However these differences found are not statistically significant (non-architectural Ttest p=0.28 and architectural Ttest p=0.45).

Although not statistically significant when analysed separately, these results when taken together seem to present a picture about differences and similarities between these groups and sketches. They show that, on average, the expert group required less time than the novice group to complete both tasks. They also show that both groups spent more time describing the architectural image than the non-architectural one.

2.2.1.3.4 - Description times per types of sketch
Individual subject

Although the differences found were not statistically significant when looking at the group of students, again a huge variation in times of individual subjects within both groups was found. It varies from a minimum of 1.7 min. to a maximum of 11.9 min. for non-architectural sketch and from a minimum of 2.1 min. to a maximum of 17.2 min. for the architectural one. These differences seem to be masked by simply comparing the mean time for a group as a whole.

Therefore, again an alternative analysis is presented with the comparative length of time for each subject between the two sketches. The question that might be asked is how many students took longer describing the non-architectural image and how many describing the architectural one.

Figure 5.09 shows the description times for whole subject group.

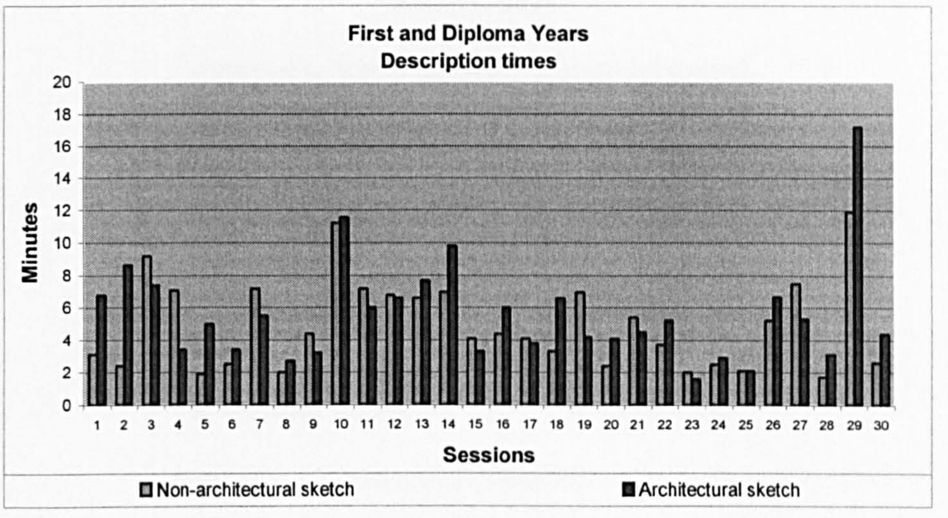
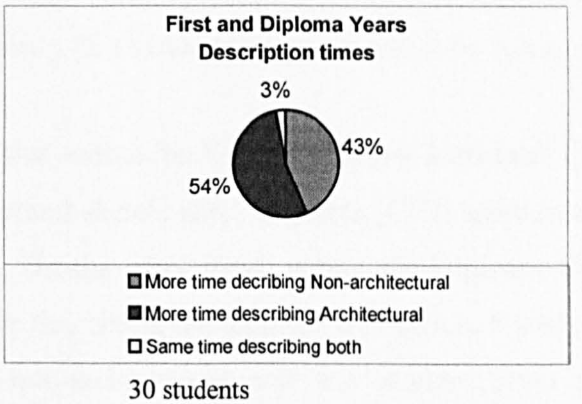


Figure 5.09: Description times for both subject groups.

When this analysis per individual subject is completed the results indicate that the majority of students within both groups took longer describing the architectural image than the non-architectural one. As can be seen on Figure 5.10, within the whole group of 30 students, 16 of them (54%) took longer in the architectural description, 13 of them (43%) took longer during the non-architectural sketch and only 1 (3%) spent the same time describing both images.



30 students
13 took longer for non-architectural sketch
16 took longer for the architectural sketch
1 same time both sketches

Figure 5.10: Description times for the whole group of subjects

This was also true for each group separately. Figure 5.11 shows the description times per each subject for First Year group and Figure 5.12 shows the results for Diploma year group.

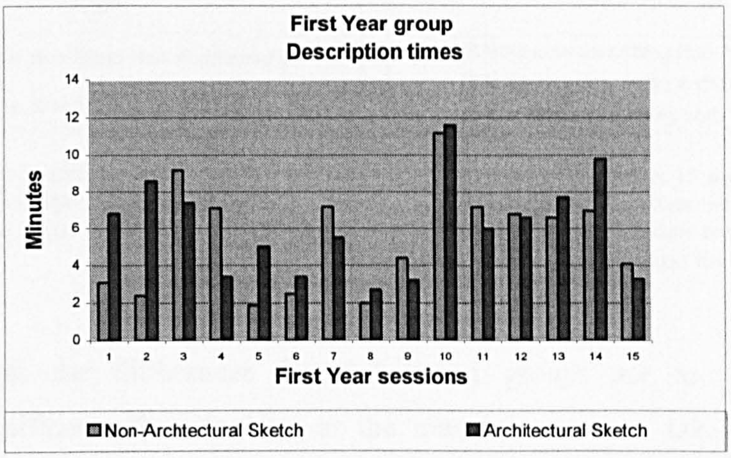


Figure 5.11: The description times for First Year group

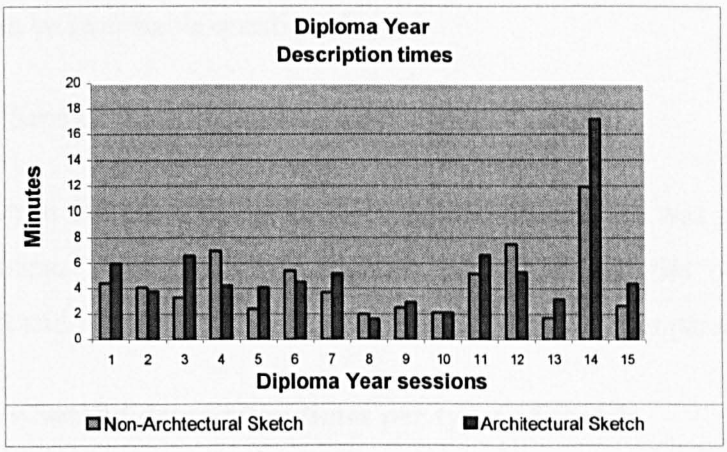
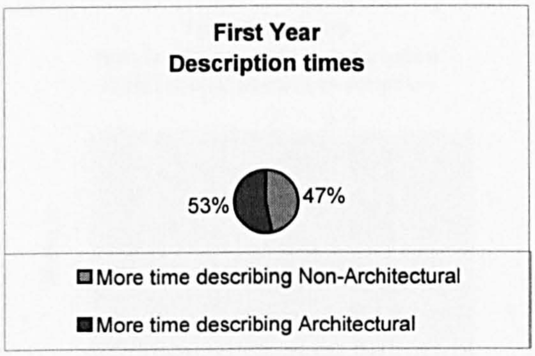
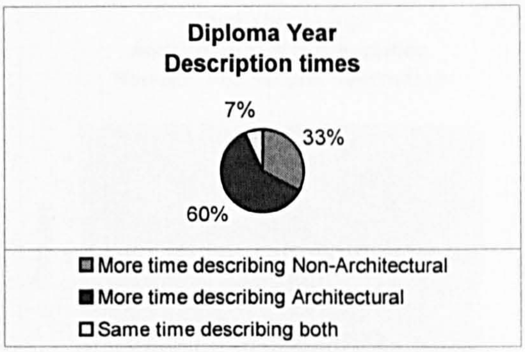


Figure 5.12: The description times for Diploma Year group

It can be seen that within the First Year group 8 students (53%) spent more time describing the architectural sketch, and 7 students (47%) spent more time describing the non-architectural one. On the other hand, within the Diploma Year group, 9 students (60%) spent more time describing the architectural sketch, 5 students (33%) spent more time describing the non-architectural and one student (7%) spent the same time describing both sketches. Again this difference in description times for type of sketches was even greater for Diploma than First Year group, as can be seen on Figure 5.13.





First year group: 15 students
07 students took longer the non-archit.(47%)
08 students took longer the architect. (53%)

Diploma Year group: 15 students
09 students took longer the non-archit.(60%)
05 students took longer the architect. (33%)
01 student took longer the architect. (07%)

Figure 5.13: Description times per participant

Although the differences found between groups are too small and not statistically significant when looking at the mean time, when taken the individual performance they indicate that the architectural sketch appears to require more time to be described from both groups. However, this assertion based only in the analysis of two drawings can be reasonable questioned.

2.2.1.4 - First v Second description times per types of sketch

As shown in the previous sections the second description was generally longer within both groups. Therefore, those students who described the non-architectural image in the first and in the second order within each group are compared.

2.2.1.4.1 - First v Second description times per types of sketch

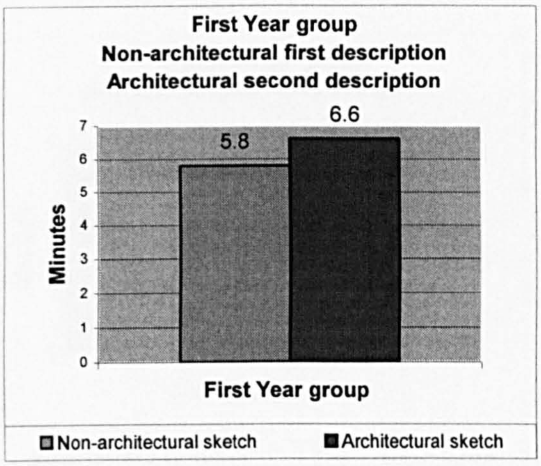
First Year group

Table 5.07 shows the results for the First Year group and Figure 5.14 shows the average of these results for the same subject group.

Table 5.07: First x second description times per sketch - First Year group

First Year Sessions	NON-ARCH 1°description times (min.)	ARCHITECT 2°description times (min.)
F1	3.1	6.8
F3	9.2	7.4
F5	1.9	5.0
F6	2.5	3.4
F8	2.0	2.7
F10	11.2	11.6
F12	6.8	6.6
F14	7.0	9.8
Average	**5.8**	**6.6**
StdDeviation	**3.6**	**3.0**

First Year Sessions	ARCHITECT 1°description times (min.)	NON-ARCH 2°description times (min.)
F2	8.6	2.4
F4	3.4	7.1
F7	5.5	7.2
F9	3.2	4.4
F11	6.0	7.2
F13	7.7	6.6
F15	3.3	4.1
Average	**5.4**	**5.6**
StdDeviation	**2.2**	**1.9**



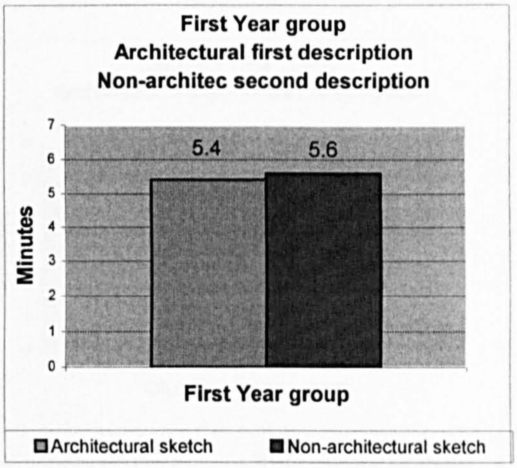


Figure 5.14: First v second description per sketch on average

The results show that on average the First Year group took longer in the second description independent of the sketch being described. However, here again the differences found are not statistically significant (Ttest non-architectural first p=0.63 and architectural first p=0.86).

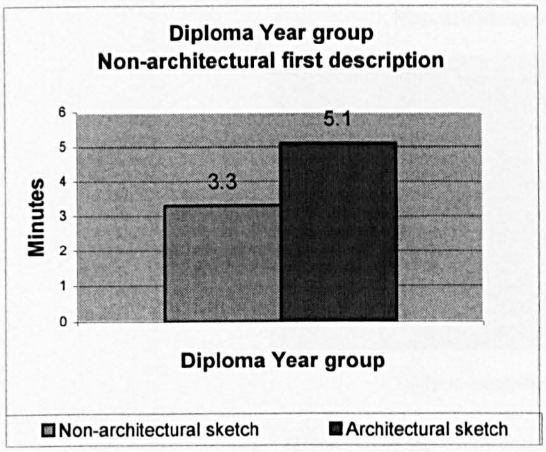
2.2.1.4.2 - First v Second description times per types of sketch Diploma Year group

Table 5.08 shows the results for the Diploma Year group and Figure 5.15 shows the average of these results for the same subject group.

Table 5.08: First v second description times per sketch - Diploma Year group

Diploma Year Sessions	NON-ARCH 1°description times (min.)	ARCHITECT 2°description times (min.)
D1	4.4	6.0
D3	3.3	6.6
D5	2.4	4.1
D7	3.7	5.2
D11	5.2	6.7
D13	1.7	3.1
D15	2.6	4.4
Average	**3.3**	**5.1**
StdDeviation	**1.2**	**1.3**

Diploma Year Sessions	ARCHITECT 1°description times (min.)	NON-ARCH 2°description times (min.)
D2	3.8	4.1
D4	4.2	7.0
D6	4.5	5.4
D8	1.6	2.0
D9	2.9	2.5
D10	2.1	2.1
D12	5.3	7.5
D14	17.2	11.9
Average	**5.2**	**5.3**
StdDeviation	**5.0**	**3.4**



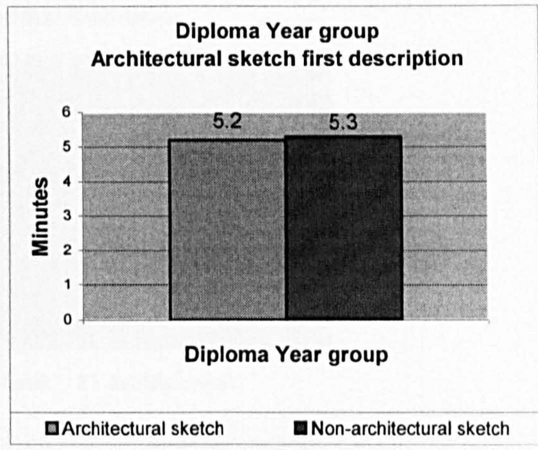


Figure 5.15: First v second description per sketch on average

The results show that on average the Diploma Year group present a slightly statistically significant difference in description times when describing the architectural image later (Ttest p=0.02) and no significant difference when describing the architectural image first (Ttest p=0.95).

2.2.1.4.3 - First v Second description times per types of sketches Comparison between groups and sketches

From all these results the groups can be compared. The results are presented, first, for the non-architectural sketch in the first description, and then for the architectural sketch in the first description.

Non-architectural sketch first description

Table 5.09 shows the results for the non-architectural sketch in the first description for both groups. Figure 5.16 shows the average of these results.

Table 5.09: Non-architectural sketch in the first description for both groups

	NON-ARCHIT1°descrip. (min.)	ARCHITECTURAL- 2°descrip. (min.)
First Year group	5.8	6.6
Diploma Year group	3.3	5.1

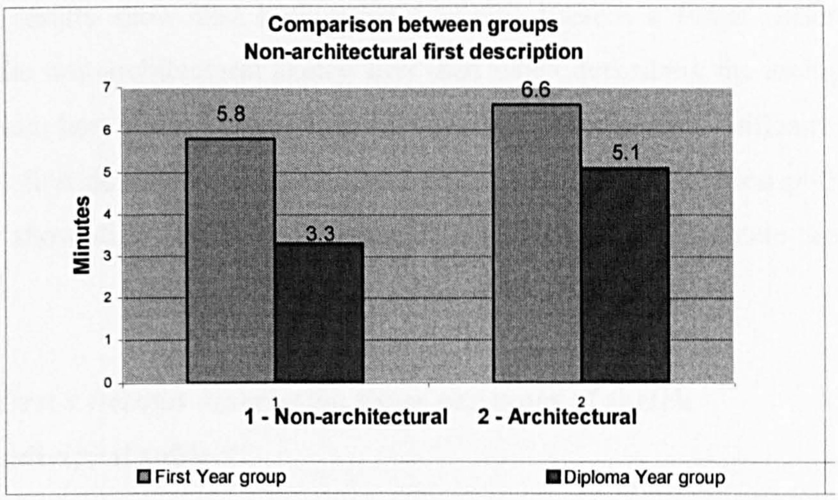


Figure 5.16: Average non-architectural sketch in the first description.

Architectural sketch first description

Table 5.08 shows the results for architectural sketch in the first description for both groups. Figure 5.17 shows the average of these results.

Table 5.10: Architectural sketch in the first description for both groups

	ARCHITECTURAL1°descrip. (min.)	NON-ARCHITEC2°descrip.(min.)
First Year group	5.4	5.6
Diploma Year group	5.2	5.3

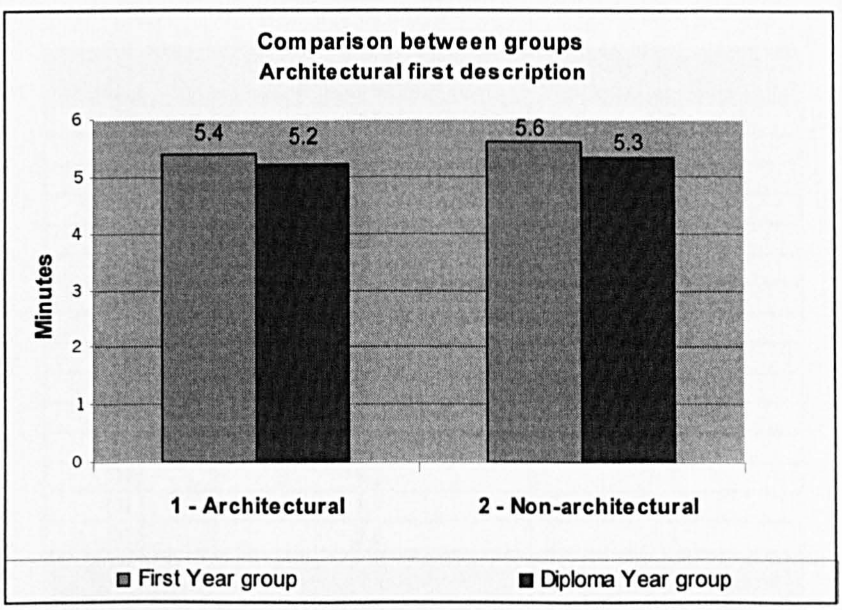


Figure 5.17: Average architectural sketch in the first description.

The results show that both subject groups present a larger difference when describing the non-architectural sketch first than when describing the architectural one first. However, here again these differences are not statistically significant (Ttest non-architectural first description $p=0.14$ and architectural first description $p=0.92$). These results also show that the expert group required less time to complete the tasks than novices.

2.2.1.4.4 - First v Second description times per types of sketch Individual subject

Although the mean time does not show significant difference between groups, it was found that a great variation between times per individual subject within both groups. It varies from a minimum of 1.7 min. to a maximum of 11.2 min. for the non-architectural sketch in the first description and a minimum of 1.6 min. to a maximum of 17.2 min. for the architectural sketch in the first description.

For this reason it seems to be reasonable to provide the alternative analysis per individual subject. Table 5.11 shows the times for those students describing non-architectural image first and Figure 5.18 shows the same results.

Table 5.11: The times for those students describing non-architectural image first

Sessions	NON-ARCHITECTURAL 1°description (min.)	ARCHITECTURAL 2°description (min.)
F1	3.1	6.8
F3	9.2	7.4
F5	1.9	5.0
F6	2.5	3.4
F8	2.0	2.7
F10	11.2	11.6
F12	6.8	6.6
F14	7.0	9.8
D1	4.4	6.0
D3	3.3	6.6
D5	2.4	4.1
D7	3.7	5.2
D11	5.2	6.7
D13	1.7	3.1
D15	2.6	4.4
Average	**4.46**	**5.96**
StdDeviation	**2.87**	**2.44**

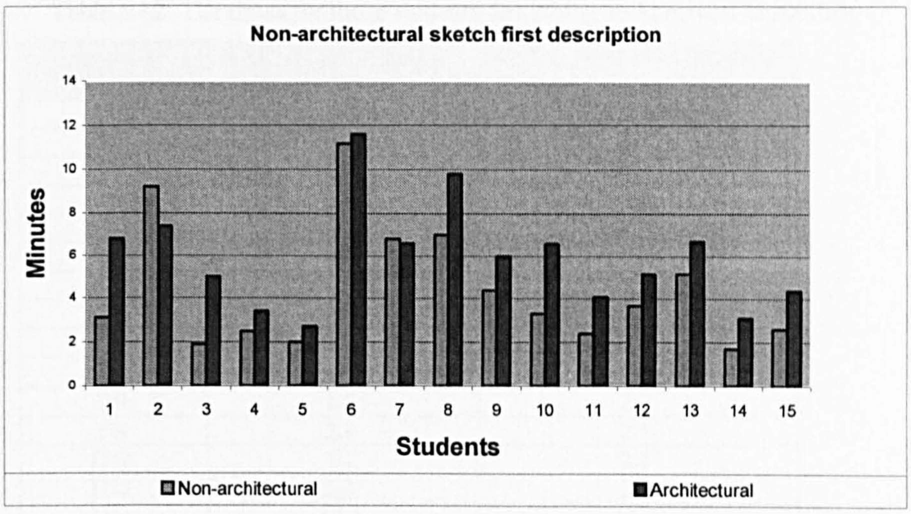
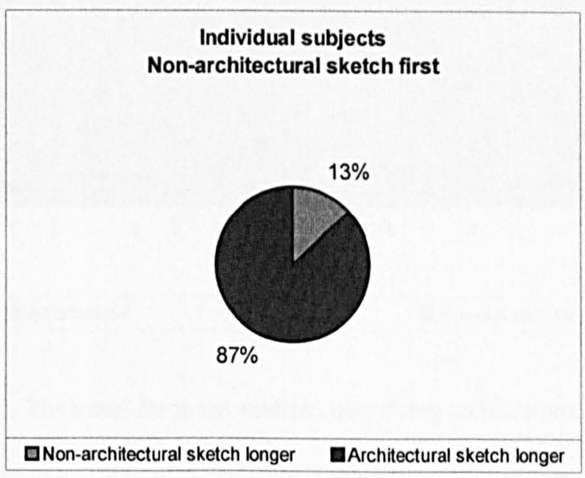


Figure 5.18: The times for those students describing non-architectural image first

Figure 5.19 shows that within a group of 15 students, 13 of them (87%) took longer to describe the architectural sketch and only 2 of them (13%) took longer to describe the non-architectural one.



15 students
13 longer architectural sketch (2ª description)
02 longer non-architectural sketch (1ª description)

Figure 5.19: Non-architectural sketch first description

Table 5.12 shows the times for those students describing the architectural image first and Figure 5.20 shows the same results.

Table 5.12: The times for those students describing architectural image first

Sessions	ARCHITECTURAL 1°descrip (min.)	NON-ARCH ITECTURAL 2°descrip (min.)
F2	8.6	2.4
F4	3.4	7.1
F7	5.5	7.2
F9	3.2	4.4
F11	6.0	7.2
F13	7.7	6.6
F15	3.3	4.1
D2	3.8	4.1
D4	4.2	7.0
D6	4.5	5.4
D8	1.6	2.0
D9	2.9	2.5
D10	2.1	2.1
D12	5.3	7.5
D14	17.2	11.9
Average	**5.4**	**5.6**
StdDeviation	**3.8**	**2.7**

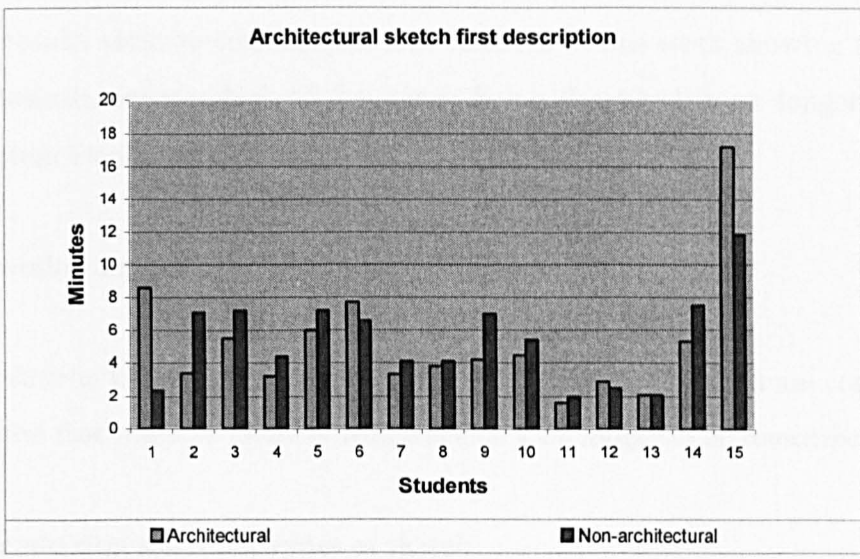
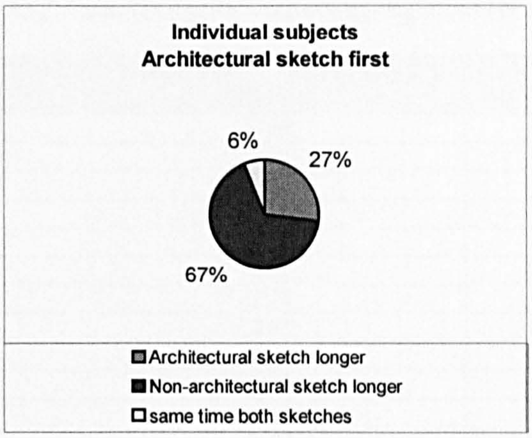


Figure 5.20: The times for those students describing architectural image first

Figure 5.21 shows that within a group of 15 students, 04 of them (27%) took longer to describe the architectural sketch and 10 of them (67%) took longer to describe the non-architectural one and only 01 student (6%) spent the same time describing both images.



15 students
04 longer architectural sketch (1ª description)
10 longer non-architectural sketch (2ª description)
01 student same time both sketches

Figure 5.21: Architectural sketch first description

These results seem to confirm previous findings of this work showing that the majority of students, independent of the image being described, took longer in the second description than in the first one.

2.2.2 – Remembering task

In this section the remembering times for the two types of sketch are compared. The first question that could be asked is which sketch took longer to be remembered.

2.2.2.1 - Remembering times per types of sketch

In this section the remembering times for both images are examined. First the times per group on average are compared, next per individual subject.

2.2.2.1.1 - Remembering times per types of sketch
First Year group

Table 5.13 shows the remembering times for the two types of sketch for the First Year subjects.

Table 5.13: First Year group - Remembering times per sketch

	Non-Architectural Sketch Minutes	Architectural Sketch Minutes
First Year 01	0.68	1.75
First Year 02	0.61	1.43
First Year 03	0.87	0.73
First Year 04	1.06	0.77
First Year 05	0.37	0.53
First Year 06	0.67	0.73
First Year 07	1.28	0.91
First Year 08	0.65	0.70
First Year 09	0.91	0.70
First Year 10	2.22	2.27
First Year 11	1.03	0.77
First Year 12	0.72	1.38
First Year 13	1.27	2.05
First Year 14	0.95	1.60
First Year 15	1.68	1.30
Average time	**1.00**	**1.17**
Standard Deviation	**0.47**	**0.55**

Figure 5.22 shows the average of these results for the same group of subjects.

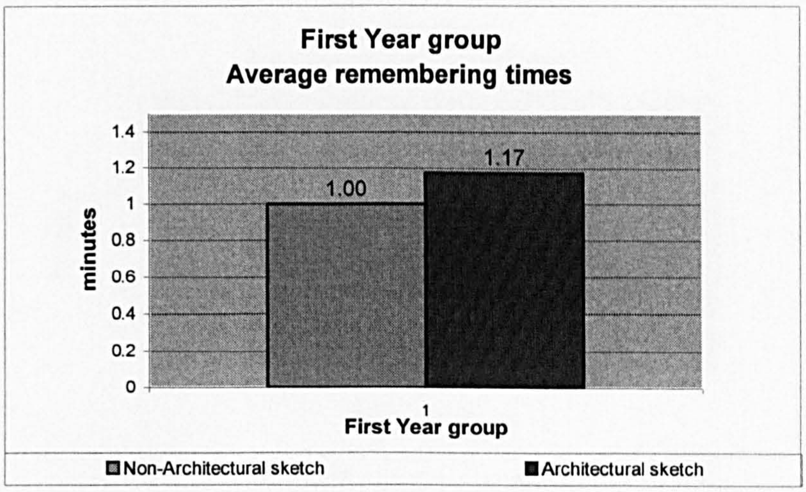


Figure 5.22: The average of remembering times for First Year group

The results show that, on average, the First Year group took longer to remember the architectural image than the non-architectural one. However, here again, the differences found are not statically significant (Ttest p=0.35).

2.2.2.1.2 - Remembering times per types of sketch Diploma Year group

The remembering times for the two types of sketch for the Diploma Year group are shown in Table 5.14.

Table 5.14: Diploma Year group - Remembering times per sketch

	Non-Architectural Sketch Minutes	Architectural Sketch Minutes
Diploma Year 01	0.73	1.12
Diploma Year 02	0.73	1.32
Diploma Year 03	1.47	1.88
Diploma Year 04	0.83	1.01
Diploma Year 05	0.52	0.77
Diploma Year 06	1.03	0.68
Diploma Year 07	0.53	0.47
Diploma Year 08	0.55	0.60
Diploma Year 09	0.77	0.95
Diploma Year 10	0.32	0.65
Diploma Year 11	1.15	0.90
Diploma Year 12	1.05	0.80
Diploma Year 13	0.91	1.33
Diploma Year 14	1.65	1.82
Diploma Year 15	0.55	0.85
Average	**0.85**	**1.01**
Standard Deviation	**0.37**	**0.42**

Figure 5.23 shows the average of these results for the same group of subjects.

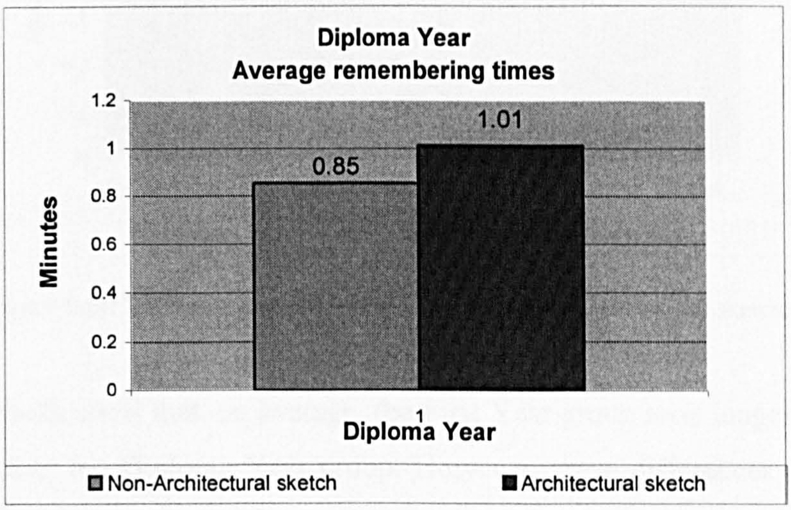


Figure 5.23: The average of remembering times for Diploma Year group.

The results show that, on average, the Diploma Year group also took longer to remember the architectural image than the non-architectural one. However the differences found are not statistically significant (Ttest p= 0.28).

2.2.2.1.3 - Remembering times per type of sketch

Comparison between groups and sketches

From all these findings it is possible to compare the groups and sketches. The results are shown on Table 5.15.

Table 5.15: Remembering times per group and sketch on average

	Non-architectural sketch Minutes	Architectural sketch Minutes
First Year group	1.0	1.17
Diploma Year group	0.85	1.01

Figure 5.24 presents the remembering times per group and per sketch on average

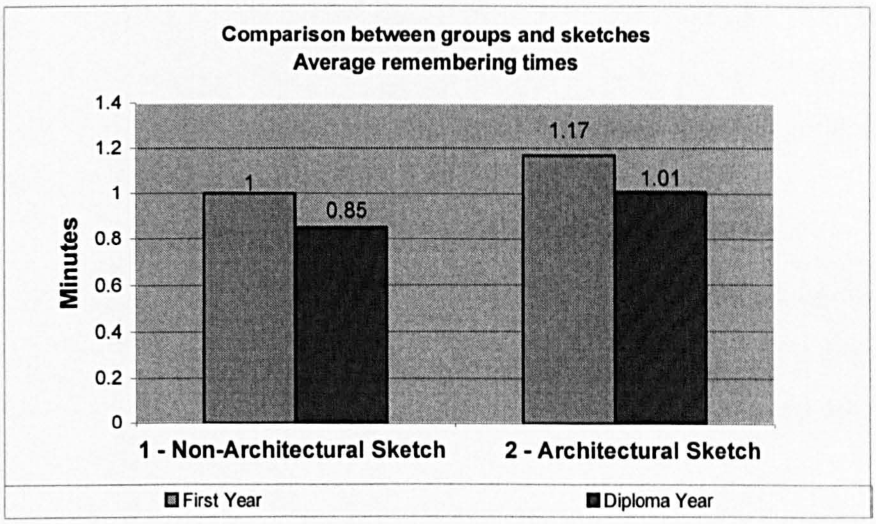


Figure 5.24: Remembering times - Comparison between groups and sketches

The results show that, on average, the First Year group took longer to remember both images than the Diploma Year group. However, these differences found are not statistically significant (non-architectural Ttest $p=0.35$ and architectural Ttest $p=0.36$). Although not statistically significant these results show similarities and differences between groups. They show that, on average, both groups spent more time remembering the architectural image than the non-architectural one. They also show that the expert group required less time than the novice group to complete the task.

Here again these results, taken together, seem to contribute and support early findings of this work. These findings show that the architectural image appears to require more time to be described and remembered from both groups. They also suggest that the expert students are able to complete the tasks – describe and remember – in less time than novices. However, again these assertions based only in the analysis of two drawings can be reasonable questioned.

2.2.2.1.4 - Remembering times per types of sketch Individual subject

This section analyses the remembering times related to individual subject. Here again, although the differences were not statistically significant when looking at the group of students, there is a huge variation in times of individual subjects within both groups. They vary from a minimum of 0.32 min. to a maximum of 2.22 min. for the non-architectural sketch and from a minimum of 0.47 min. to a maximum of 2.27 min. for the architectural sketch. Again, simply comparing the mean time could not identify these differences.

For this reason, it seems to be reasonable again to use an alternative analysis with the comparative length of time for each subject between the two sketches. The question here is how many students took longer to remember the non-architectural and the architectural image.

Figure 5.25 shows the remembering times for both subject groups.

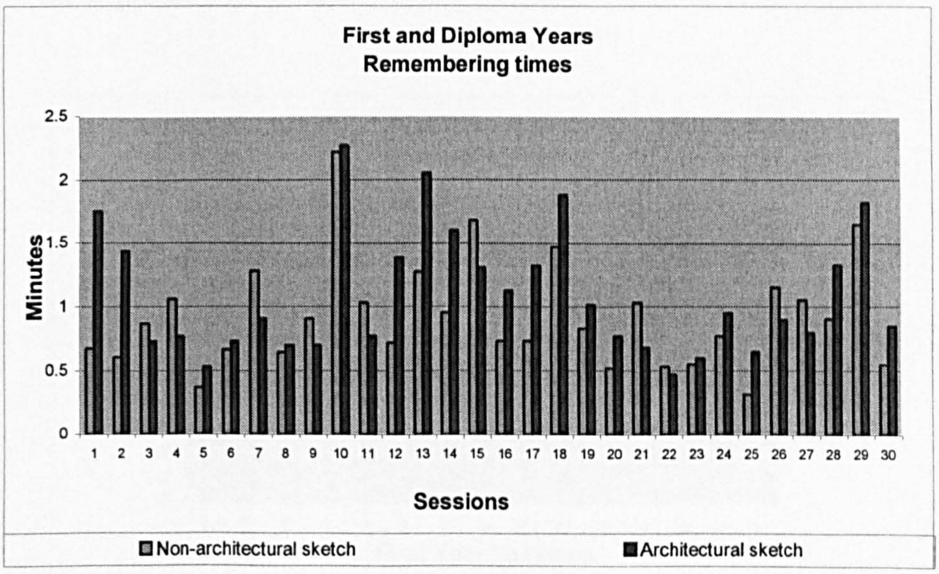
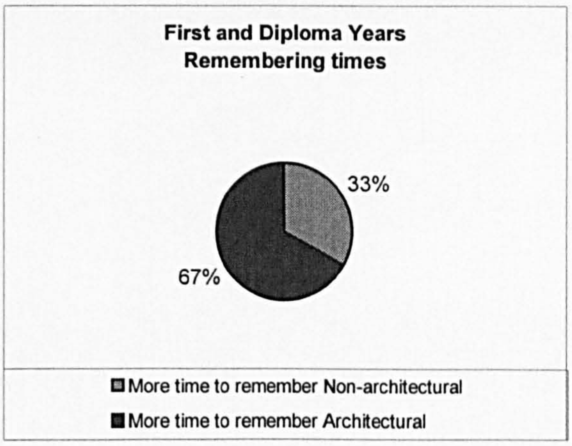


Figure 5.25: Remembering times for both subject groups.

When this analysis is performed the results indicate that the majority of students within both groups took longer remembering the architectural image than the non-architectural one. As Figure 5.26 shows, within the whole group of 30 students, 20 of them (67%) took longer to remember the architectural sketch and 10 of them (33%) took longer to remember the non-architectural one.



30 students
10 took longer to remember non-architectural sketch
20 took longer to remember architectural sketch

Figure 5.26: Remembering tomes for the whole group of subjects

This was also true for each group separately. Figure 5.27 shows the remembering times per each subject for First Year group and Figure 5.28 shows the results for the Diploma year group.

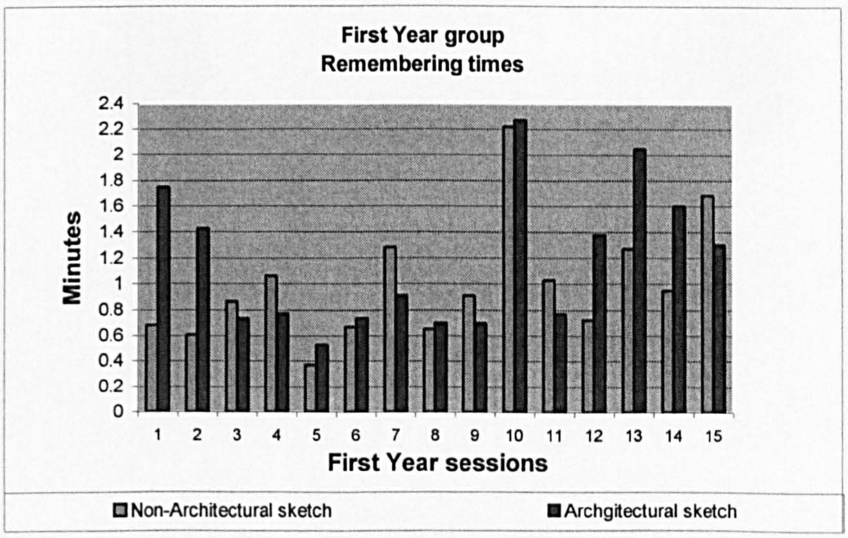


Figure 5.27: The remembering times for the First Year group

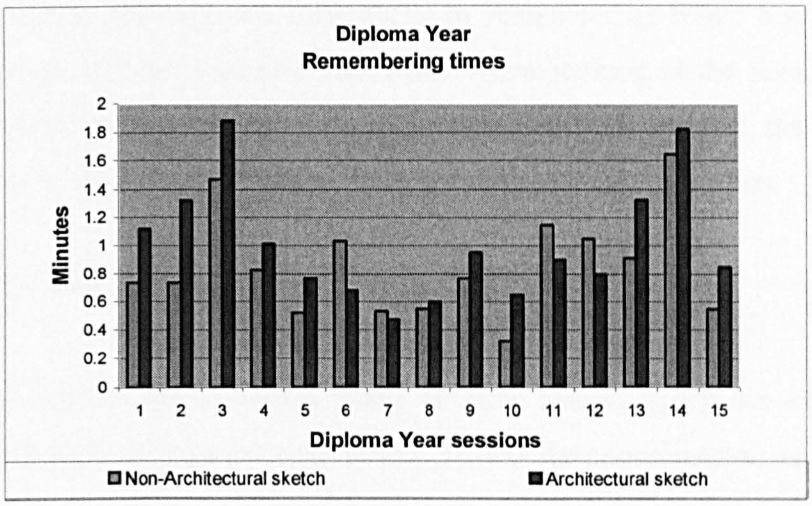
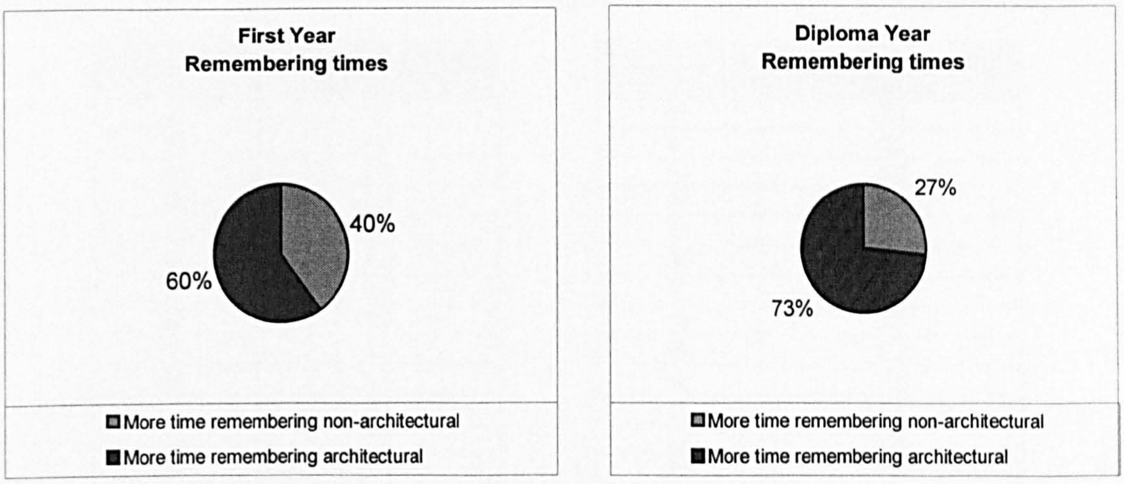


Figure 5.28: The remembering times for the Diploma Year group

It can be seen that within the First Year group 9 students (60%) took longer remembering the architectural sketch, and 6 students (40%) took longer remembering the non-architectural one. On the other hand, within the Diploma Year group, 11 students (73%) took longer remembering the architectural sketch, and only 4 students (27%) took longer remembering the non-architectural. Again this difference in remembering times for different type of sketches was even greater for Diploma than First Year group, as can be seen on Figure 5.29.



First year group: 15 students
09 students took longer the non-archit.(60%)
06 students took longer the architect. (40%)

Diploma Year group: 15 students
11 students took longer the non-archit.(73%)
04 students took longer the architect. (27%)

Figure 5.29: Remembering times per participant

Here again, although the differences in remembering times between the two groups are slight and not statically significant when looking at the mean time, when taking individual performance into consideration they indicate that the architectural sketch appears to require more time to be remembered from both groups.

2.2.3 – Review task

In this section the reviewing times for each subject group are examined. The question is which group required more time to review the experience on average.

2.2.3.1 - Reviewing times

The reviewing times per group on average are examined first, next per individual subject and then the results are compared.

2.2.3.2 - Reviewing times per group on average

Table 5.16 presents the reviewing times for both groups separately.

Table 5.16: Reviewing times per subject groups

	First Year group Minutes
01	2.0
02	1.8
03	2.1
04	1.4
05	2.2
06	1.1
07	1.4
08	1.2
09	1.6
10	3.2
11	2.8
12	1.5
13	2.1
14	0.7
15	1.8
Average	**1.79**
StdDeviation	**0.64**

	Diploma Year group Minutes
01	2.8
02	4.6
03	4.0
04	1.2
05	2.4
06	2.9
07	1.2
08	2.7
09	1.3
10	2.1
11	2.6
12	4.2
13	1.4
14	2.7
15	2.3
Average	**2.56**
StdDeviation	**1.07**

Figure 5.30 presents average of reviewing times for both groups.

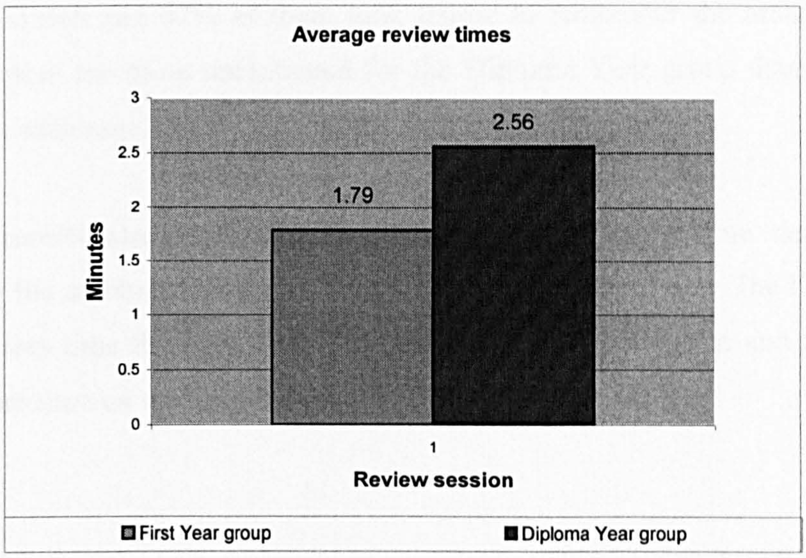


Figure 5.30: Average review times for both groups.

The results show that, on average, the Diploma Year group took longer to review the experiment than the First Year group on average. In this case, the difference found between groups is slightly statistically significant (Ttest p=0.03).

2.3 – Summary of results related to task times

The times were first measured per whole session involving the different tasks (describing, remembering and reviewing). Next they were taken separately per each task. The results were presented per group, per individual subject and compared in order to identify differences and similarities between groups and sketches.

The data show no statistical significant difference between groups on average and between sketches (Figure 5.31). It is an unexpected and surprising result, as this research was expecting to find some significant differences. These results will be further analysed in the next chapter related to conclusions. However, in each case a large variation between individual subjects was found. For this reason an alternative comparison between individual subjects related to the times they taken in each different task is presented.

Although the results are not statistically significant, a general pattern emerges showing 80% of students within both groups took longer during the second description than the first one. It also shows that 54% of all subjects took longer to describe the architectural sketch and 67% of them took longer to remember the architectural one. These differences are more accentuated for the Diploma Year group than for the First Year group in each case.

The results also show that both groups spent more time describing and remembering the architectural sketch than the non-architectural one. The Diploma Year group spent less time than the First Year group in both description and remembering tasks and more time on the review task.

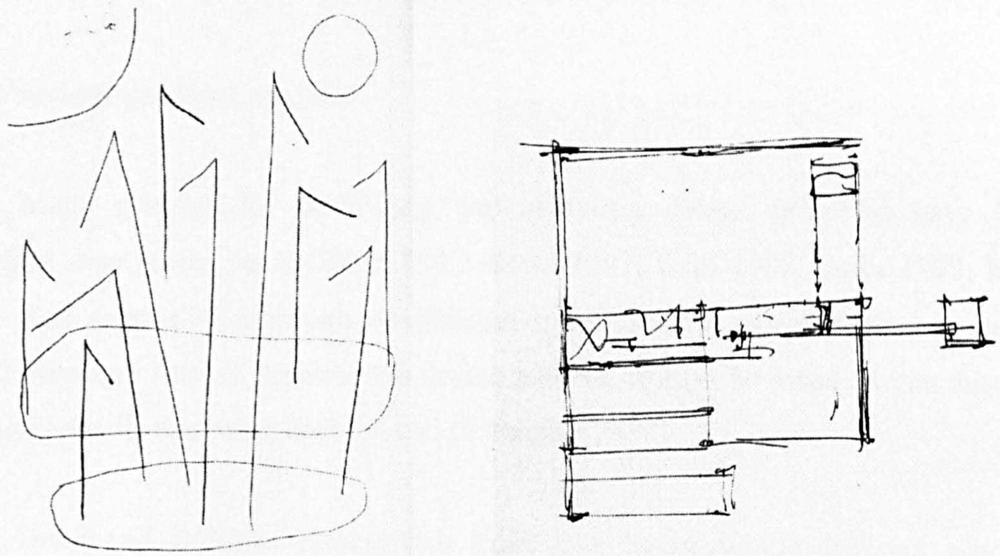


Figure 5.31: Non-Architectural sketch (Paul Klee-1939). Architectural sketch (Mies van der Rohe-1935)

3 – THE ANALYSIS OF THE PROTOCOLS

This third part of the chapter presents the analysis of the protocols. It is divided into four sections. In the first section this study revisits other researchers (Dorst 1995; Suwa 1997; Suwa 1998) in order to develop a protocol analysis method. The second section presents the method developed. The third section shows the results and the fourth presents some conclusions.

The verbal data were the main target of this analysis. They were collected from video and audiotapes of the experiment and are composed of thirty sessions and sixty descriptions. All sessions and descriptions were analysed separately.

Clearly, to make sense of these protocols they need to be broken down into segments, which can be categorized and compared. This will also enable an analysis of sequence and proportion of events in the protocol as a whole. However, a key problem here is exactly how to subdivide the protocols into segments.

This research believes that identifying verbal cognitive actions and creating a list of the repertoire used during the process of interaction and description of sketches can form a representation of the designer's performance and probably can enable people to gain an insight into the designer's reasoning steps.

3.1 – Previous protocol analysis

Many systems for describing and analysing design protocols have been developed over recent years (Dorst 1995; Suwa 1997; Gero 1998; Suwa 1998; Bilda 2003). Any system of protocols subdivision must to some extent depend upon the overall paradigm used to describe the design process. It must be assumed that this will also apply here in analysing descriptions of images.

Dorst and Dijkhuis present two basic and fundamentally different ways of approaching the design process: Rational problem solving and reflection in action (Dorst 1995). It is useful to start with an overview of this distinction.

According to past literature, the first methods of design methodology in the early 1960s were influenced by the theories of technical systems. These theories see design as a rational problem solving process and allowed the study of design problems within the paradigm of technical rationality. Logical analysis and contemplation of design are considered to be the main ways of producing knowledge about the design process.

Some years later, in the early 1980s, Schon proposed a different approach describing design as a process of reflection-in-action (Schon 1983). For him, any design problem is unique and a basic skill of designers lies in determining how every single problem should be tackled. He proposed an alternative epistemology of practice, based on a view of human perception and thought processes. For Schon, design is a reflective conversation with the situation (Schon 1983). This constructivist theory can be seen as a reaction to the rational problem solving approach.

It appears that Dorst and Dijkhuis agree with Schon, because in their opinion, describing design as a process of reflections in action is apt in the conceptual stage of the design process, where the designer has no strategies to follow and is proposing and trying out problem/ solution structure (Schon 1983; Dorst 1995). For them, describing design as a rational problem solving process works well in situations where the problem is clear-cut and the designer has strategies that can be followed

Suwa and Tversky also studied protocol analysis for the design process and they seem to agree with Dorst and Dijkhuis when identifying the same two approaches, that is, rational problem solving and reflection in action (Dorst 1995; Suwa 1997). However, Suwa and Tversky called these different approaches formal and informal protocol analysis. Formal protocol analysis is seeing as a rational problem solving process and informal protocol analysis is viewed as a process in which each design constructs his/her own reality by his/her own actions that are reflective, responsive and opportunistic to the design situation (Suwa 1997).

Figure 5.32 shows a summary of the two paradigms as presented by Dorst and Dijkhuis (Dorst 1995).

	Rational Problem Solving	Reflection in Action
Designer	Information processor (in an objective reality)	Person constructing his / her reality
Design Problem	ill defined, unstructured	essentially unique
Design Process	a rational search process	a reflective conversation
Design Knowledge	Knowledge of design procedures and 'scientific' laws	Artistry of design: when to apply which procedure/ piece of knowledge
Example / Model	Optimisation theory, the natural sciences	Art/ the social sciences

Figure 5.32: The rational problem solving and the reflection-in-action paradigms summarized (Dorst 1995).

It seems that Schon's work on the designer as reflective practitioner and Goldschmidt's work on 'seeing as' and 'seeing that' are typical examples of the latter category (Schon 1983; Goldschmidt 1991). This work does not aim to solve that disagreement between these two models of design, but hopes to shed some light on their properties and limitations revising previous studies.

3.1.1 - Segmentation scheme

It appears that a fruitful way of analysing a design process is to decompose an entire process into its smallest components and to focus in the links among these components (Goldschmidt 1991; Suwa 1997; Gero 1998; Suwa 1998; Bilda 2003).

According to Gero and McNeill, the designer's activity can be considered as consisting of a sequence of actions, what they called micro strategies (Gero 1998). These micro strategies seem to be similar to the concept of segment, presented by Suwa and Tversky (Suwa 1997). It appears that the number of different segments that can be identified in a design process is dependent on both the designers experience and on the complexity of the problem.

Bilda and Demirkan also agree with others and argue that each designer's section has a different number of segments, depending on variables like the designer's way to problem solving, procedure of decision making, learning effects and so on (Bilda 2003).

3.1.1.1 - Two ways to segment the protocol

This study considers two basic ways to segment design protocols. The first is to divide protocols based on verbalization events such as pauses, intonations as well as syntactic markers for complete phrases and sentences. Therefore, pauses or syntactic markers flag the start of a new segment. In this case sentences or phrases or even fragments of phrases will be the segment (Ericsson 1983). Table 5.17 shows an example of this model of segmentation.

Table 5.17: Subdivision of the protocol based on phases and sentences

Segments
1. Draw a sheet of A4,
2. rectangular paper portrait format.
3. Towards the bottom
4. are two sausages,
5. longs ovals.
6. One on top of each other
7. with a gap between them.
8. Top right corner
9. is a circle
10. top left corner
11. a sort of a quarter of the circle,
12. cutting the corner of the page.
13. That's all.
14. with the left hand side of the arrows.
15. It looks likes a face,
16. two eyes, two lips.
17. I think, I hope.
18. Like a flag or something,
19. golf flag.

Another way is to divide protocols based on the subject's intention. A change of subject's intention or the contents of their thoughts or their action flags the start of a new segment. Consequently, a single segment sometimes consists of one sentence, and sometimes of many (Goldschmidt 1991; Suwa 1997). Table 5.18 shows an example of this model of segmentation.

In the second way, a segment whether consisting of one sentence or many, is defined as one coherent statement about a single item. According to Goldschmidt a segment, a 'design move', is an act of reasoning which presents a coherent proposition pertaining to an entity that is being designed (Goldschmidt 1991). Therefore, an entire protocol for a subject could consist of several sentences or segments.

Table 5.18: Subdivision of the protocol based on subject's intention

	Segments
1	Draw a sheet of A4 rectangular paper; portrait format
2	Towards the bottom are two sausages, longs ovals. One on top of each other with a gap between them. Top right corner is a circle, top left corner a sort of quarter of the circle, cutting the corner of the page. That's all
3	It looks likes a face, two eyes, two lips with strange thing poking out of it. I think, I hope. Like a flag or something, golf flag.

Initially the second, intention based, model is explored. So a segment, whether consisting of one sentence or many, is defined as one coherent statement about a single topic. This approach to the protocols is presented in the next section of this chapter and can be seen in the Annex IV.

3.1.1.2 - Types of segments

According to past literature a segment has basically three conceptual dependences with a past segment (Goldschmidt 1991; Goel 1995; Suwa 1997; Gero 1998; Suwa 1998; Bilda 2003). The first dependence is when a topic in the current segment derives from its relationship with another topic, which the past segment was concerned with. The second is when a current segment explores the same topic, which the past segment was concerned with. The third dependence is when an idea or a constraint established in the past segment has been generalized and is applied to the current segment.

The segments are classified into several groups: dependency chunk, isolated segments, focus-shift segment and continuing segment. From past literature the two most important constituents of design activity seems to be the architects' acts of shifting the focus of attention in an opportunistic way and their aspects of exploring related topics consecutively. The former appears to correspond to what Goel calls 'lateral transformation' and the latter to what he calls 'vertical transformation' (Goel 1995).

3.1.2 - Cognitive action categories

A segment could include several cognitive action categories. In order to better understand this matter, revisiting Suwa and Tversky (Suwa 1997) and Suwa, Purcell and Gero (Suwa 1998) is useful here. Suwa and Tversky initially suggest that segments can be categorized based on many cognitive actions that depend on the types of information they utilise (Suwa 1997). However Suwa, Purcell and Gero suggest a richer epistemology of these categories classifying them into four subcategories: Physical; Perceptual; Functional and Conceptual.

Physical cognitive actions are those that have direct relevance to physical depictions or movements. There are two sub-types of actions: One is to make depictions on paper, such as diagrams, figures, symbols, annotations, memos, and even sentences. The second is the motion of a pencil or hands that do not end up with physical depictions.

Perceptual cognitive actions are those that involve analysis or contemplation of visual-spatial features in sketches (think, take a break, etc). This category consists of three subclasses: The first is visual features of elements, such as their shapes, sizes and textures. The second is spatial relations among elements, such as proximity, remoteness, alignment, intersection, connectedness and so on. The third is the organization and comparison among more than one element, such as grouping of elements, and their similarity/uniformity and the difference/contrast of the visual features of elements.

Functional cognitive actions are something with which participants associate visual information. This class corresponds to how people see or interact with the designed image and the psychological reactions of people when they interact with designed images.

There are three types of conceptual cognitive actions: The first is the subject's preference (like-dislike) or aesthetic (beautiful-ugly) or difficulty level (easy-complicated). The second type is to establish goals. Once a goal is established it gives birth to other actions and it may contribute to the birth of other goals or motivate new actions. The third type is retrieval of knowledge from memory. Knowledge is retrieved and then used for reasoning.

Literature in cognitive science (Kosslyn 1992; Kosslyn 1995; Gregory 1998) supports the proposition that information coming into human cognitive processes is processed first at sensory level, then perceptually and semantically. Physical actions correspond to the sensory level, perceptual actions to the perceptual, and both functional and conceptual to the semantic.

This categorization seems to be general enough to be applicable to different activities, especially as it was derived from the perspective of cognitive science, from general insights about how people see, think and perform, perceptually and conceptually.

3.1.2.1 - Cognitive action categories adopted in this study

Based on this previous research, this study intends to determine a set of cognitive action categories into which the segments could be cast. It is not claimed that the cognitive action categories studied here cover all the cognitive actions of the participants, but it was possible to analyse all the sessions in terms of these cognitive action categories proposed. Therefore, two groups of cognitive actions were established: Physical and Verbal.

Physical cognitive actions are all the gestures or movements of the participants and have two sub-classes. The first is not related to the sketch and not used for description. It involves relaxed movements such as drumming with fingers or playing with a pen, scratching or moving the heard or even laughter. The second physical action sub-class is related to the drawing and used for descriptions. It involves drawing with fingers in the air, on the table or over the drawing; showing directions (left, right, up, down), or making shapes with the hands; taking measurements or pointing to something in the sketch.

The verbal cognitive action category considers that the subject solves the problem in terms of formal, symbolic and reflective language. Formal language involves descriptions related to geometric characteristics like paper references (A4, portrait or landscape), shape (square, circle, triangle), size (big, small, high) and texture. It also includes description about spatial relations like left, right, above, below, half or general view about quantity or grouping.

Symbolic language involves the use of exterior references that are not in the sketch, like 'it looks like a' or 'imagine a'. Reflective language is an expression of the reflection on the task and involves judgement like difficult, easy, hard, tricky or simple. Remembering and re-using some previous expressions or even saying 'I think', 'I hope' or 'that is the best I can', 'that is all' can characterize it.

Because of the objective of this research, it concentrates only on the analysis of verbal cognitive actions used by the participants during the task. The objective is the identification of differences in the way subjects use their knowledge and memory to create analogies and references to describe what they are seeing and thinking.

However, in the videotapes it is possible to see a strong link between verbal and physical cognitive actions, which suggests a very interesting field for new research.

Figure 5.33 shows a summary of the cognitive action categories.

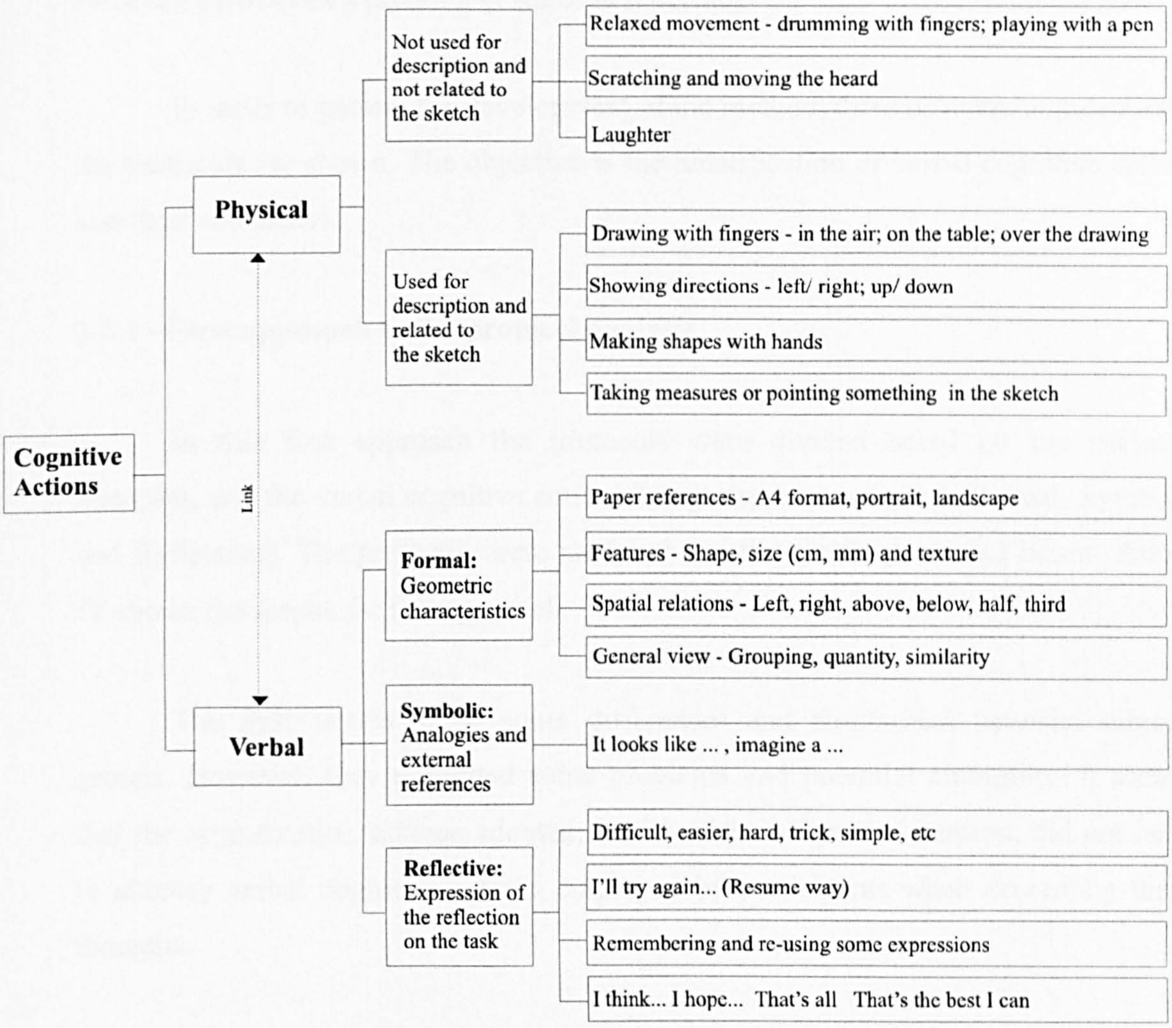


Figure 5.33: A summary of the cognitive action categories.

3.2 – The method developed

The method developed was adapted from the analysis method proposed by Suwa and Tversky, and Suwa, Purcell and Gero (Suwa 1997; Suwa 1998). It is based on the cognitive actions of subjects and intends to inspect their thoughts and behaviour on perceiving, remembering and describing conceptual sketches.

As many previous protocols analysis methods have done (Suwa 1998; Suwa 2000; Kavakli 2001) this study used retrospective reporting that employed both segmentation and encoded categories of cognitive actions. To support and supplement the verbal protocols, the analysis adopted the visual data from videotapes, which had recorded participant's pointing gestures in reporting.

In order to present the development of the method, three different approaches to the protocols are shown. The objective is the identification of verbal cognitive actions and their subclasses.

3.2.1 - First approach to the protocol analysis

In this first approach the protocols were divided based on the subject's intention, and the verbal cognitive actions categories were adopted (Formal, Symbolic and Reflective). The protocols were analysed and the results presented below. Annex IV shows the results for this approach.

The first results show some differences and similarities between subject groups. However, they presented some problems and potential ambiguity. It seems that the segmentation scheme adopted, based on the subject's intention, did not help to identify verbal cognitive actions employed by participants when describing their thoughts.

It was found a great number of symbolic references within these two examples from the first session of each group. However, the analysis tables (Annex IV) just show one tick marked in the symbolic column for each segment, which is not correct for the purpose of this analysis scheme.

> *Example 1 - First Year, session 01: Description 01, Non-architectural sketch, segment nº 4: 'It looks likes a face, two eyes, two lips with strange thing poking out of it. I think, I hope. Like a flag or something, golf flag.'*

> *Example 2 - Diploma Year, session 01: Description 01, Non-architectural sketch, segment nº 3: 'Go to the top right hand corner of that page. Draw a circle like a sun. Sun is shining down on the little vase of ticks.'*

It seems that these results could mask the data interpretation. In order to identify and quantify verbal cognitive actions, it was necessary to revise the segmentation scheme adopted.

3.2.2 - Second approach to the protocol analysis

The new segmentation scheme is based on verbalization events as phrases, sentences and even their fragments. The main objective consists of identifying and quantifying verbal cognitive actions (formal, symbolic or reflective). The focus is to verify differences in the way subjects describe what they are seeing and thinking. This work supports Lawson when asserting that there is evidence from the psychology of perception of our tendency to prefer to use symbolic rather formal references when storing information in long-term memory (Lawson 2003).

The results of this second approach to the protocols can be seen on Annex IV of this thesis. However, before this study investigated this analysis further, some problems will be discussed. The segmentation scheme does not change, but the verbal cognitive action categories do.

Two examples using the verbal references 'long oval' and 'sausage' and the verbal references 'big box' and 'big square' are shown in Tables 5.07 and 5.08.

In the previous analysis scheme, the reference 'long oval' was counted as two formal verbal actions - long and oval - and the reference sausage as just one symbolic verbal action. But both references are related to the same element in the sketch and need to be counted in the same way. This means that references related to the same element in the sketch needed to be counted as just one verbal cognitive action each one, independent of the number of words they use.

Table 5.19 shows the results from previous analysis and Table 5.20 shows the results from new analysis

Table 5.19: Previous analysis scheme

Verbal Cognitive Action	Formal	Symbolic
Long oval	FF	
Sausage		S
Big box	F	S
Big square	FF	
Total	**05**	**02**

Table 5.20: New analysis scheme

Verbal Cognitive Action	Formal	Symbolic
Long oval	F	
Sausage		S
Big box		S
Big square	F	
Total	**02**	**02**

As shown in the tables, the way verbal cognitive actions were being counted appears to be camouflaging the results. Therefore, new verbal cognitive action categories are proposed.

3.2.3 - Final approach to the protocol analysis

The new verbal cognitive action categories are divided into three groups: general references, feature references and reflective references as Figure 5.34 shows.

General references are related to paper information (A4, portrait or landscape), to size (big, small, cm, mm), to spatial relations (left, right, above, below), to general view (quantity or grouping) and to conclusive comments ('that's all'; 'that's the best I can').

Feature references are divided in two groups: Formal and Symbolic. Formal references are related to physical and geometrical characteristics. They include descriptions as square, oval or line. Symbolic references are related to analogies and elements that are not represented in the drawings. They include descriptions as box, sausage or wall.

Reflective references involve judgement as difficult, easy, hard or simple. They also involve remembering ('that I told earlier', 'remember that', or 'you just drew'), reflecting ('I think', 'I hope', 'that's the best I can', 'that's all') and recapitulating ('I'll try again', 'you should have' or 'it's basically composed').

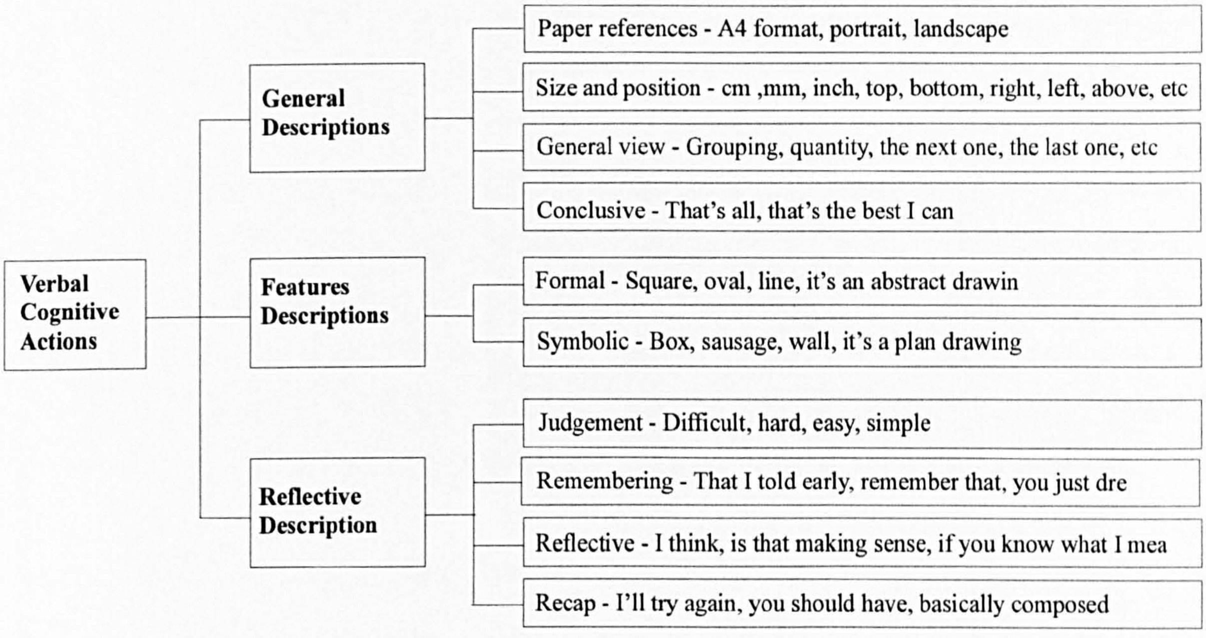


Figure 5.34: A summary of verbal cognitive action categories.

The results from this final approach seemed to be appropriate to the objective of this study. Therefore, all protocols were analysed. Each description was completely segmented and analysed using the same coding scheme developed during this study. All tables with the protocols segmentation and their analysis can be seen in the Annex V of this work.

3.2.4 – Handicap and limitations of this analysis

Protocol studies are seen as worthwhile, although the value of the results is constantly under criticism. As said earlier, such procedures (forcing people to describe what they are thinking) need to be applied with care, as they tend to confuse the process of discovery with that of expression or communication of ideas. A person might be skilled at generating ideas, but poor at reporting or describing them. This is the main handicap of protocol analysis studies in design.

However, it seems to be a useful method to investigate the design process and, as this study shows, is largely used by several researchers with the purpose of the study of designer's thoughts. This research intends to develop its own method of protocol analysis based on previous research. Therefore, the next section presents the results related to the protocol analysis. However, before present the results, it is important to point out some limitations and problems in this analysis method, as they can influence and affect the results and conclusions.

Another limitation appears to be regarded to the number of referees that coded the data. It seems to be questionable the reliability of the analysis and results based on just one coder. It certainly represents a disadvantage and a limit in the data interpretation, since other results can be found if other person analyse the same data, especially related to 'symbolic' references. For this reason, in order to avoid mistakes and allow future double checks, all data is presented in the annexes of this research.

3.3 - Results related to verbal data

In this section the results of the protocols analysis are presented. They are divided into three groups: Segmentation scheme, verbal cognitive action categories and the indication of the easiest image to describe and why.

Some conclusions and discussions are embodied in each section, but they are all presented together at the end of the chapter to give a concise summary of the outcomes.

3.3.1 – Results of the segmentation scheme

In this section the results related to number of segments are presented. They are divided into number of segments per type of sketch and number of segments per minute. The results are shown first per subject group on average and second per individual subject separately.

3.3.1.1 – Number of segments per type of sketch

In this section, the number of segments used for the two types of sketch, are examined. Initially the question that might be asked is which sketch required more segments to be described. Was it the same as the sketch that took longer to be described? Are there significant differences between subject groups?

In order to answer these questions all descriptions were examined separately. The results are presented first per group on average and then per individual subject.

3.3.1.1.1 - Number of segments per type of sketch

First Year group

Table 5.21 presents the results related to the number of segments per type of sketch for the First Year group.

Table 5.21: Number of segments per sketch - First Year group.

	Non-Architectural Number of segments	Architectural Number of segments
First Year 01	43	74
First Year 02	26	88
First Year 03	57	60
First Year 04	88	17
First Year 05	31	70
First Year 06	29	35
First Year 07	150	102
First Year 08	31	37
First Year 09	60	40
First Year 10	163	153
First Year 11	123	86
First Year 12	112	116
First Year 13	89	96
First Year 14	112	129
First Year 15	68	47
Average	**78.80**	**76.67**
Standard Deviation	**45.17**	**38.50**

Figure 5.35 shows the average of these results for the First Year group.

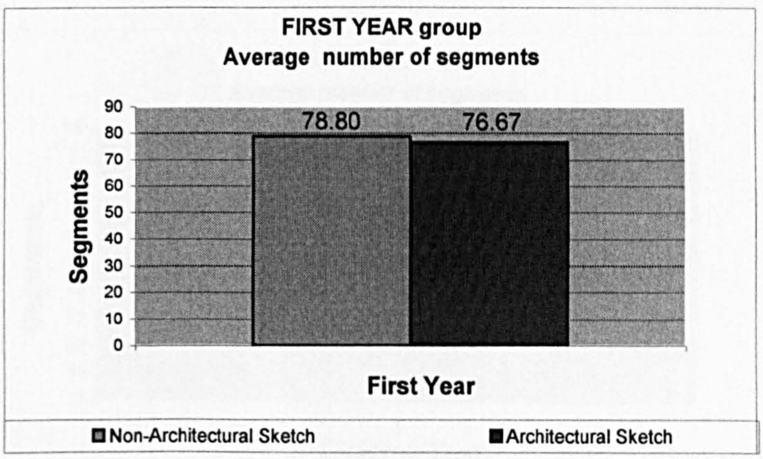


Figure 5.35: Average number of segments - First Year group

The results show that, on average, the First Year group used more segments describing the non-architectural image than the architectural one. However the differences found are slight and not statistically significant (Ttest p=0.89).

3.3.1.1.2 – Number of segments per type of sketch
Diploma Year group

Table 5.22 shows the results related to the number of segments per sketch for the Diploma Year group.

Table 5.22: Number of segments per sketch – Diploma Year group.

	Non-Architectural Number of segments	Architectural Number of segments
Diploma Year 01	66	80
Diploma Year 02	62	70
Diploma Year 03	45	90
Diploma Year 04	130	58
Diploma Year 05	39	81
Diploma Year 06	141	97
Diploma Year 07	53	100
Diploma Year 08	30	23
Diploma Year 09	36	52
Diploma Year 10	33	43
Diploma Year 11	108	139
Diploma Year 12	136	82
Diploma Year 13	25	54
Diploma Year 14	177	295
Diploma Year 15	31	62
Average Segmentation	**74.1**	**88.4**
Standard Deviation	**50.2**	**63.4**

Figure 5.36 shows the average of these results for the same subject group.

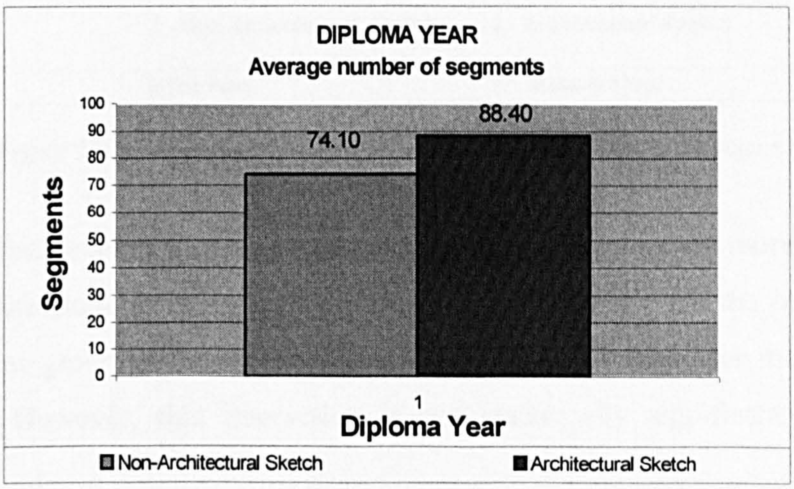


Figure 5.36: Average number of segments - Diploma Year group

The results show that on average the Diploma Year group used more segments describing the architectural image than the non-architectural one. However the differences are not statistically significant (Ttest p=0.50).

3.3.1.1.3 - Number of segments per type of sketch

Comparison between groups and sketches

These results allowed a comparison between groups and sketches. Table 5.23 shows the results for both subject groups.

Table 5.23 – Number of segments on average comparison between groups and sketches

	Non-architectural sketch Number of segments	Architectural sketch Number of segments
First Year group	78.8	76.6
Diploma Year group	74.1	88.4

Figure 5.37 shows the number of segments on average per type of sketch for both subject groups.

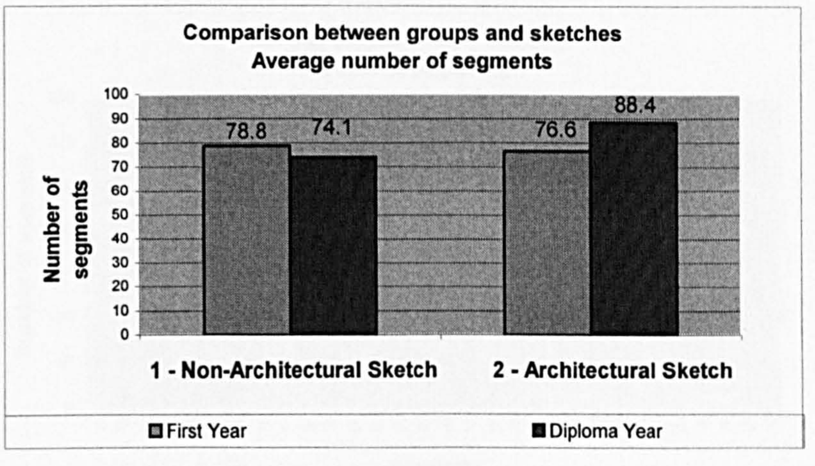


Figure 5.37: Comparison between groups - Average of number the segments

The results show that, on average, the First Year group used more segments for the non-architectural description than Diploma Year students. On the other hand, the Diploma Year group used more segments than First Year group for the architectural description. However, this interaction is not statistically significant (Chi-squared p=0.50)

3.3.1.1.4 - Number of segments per type of sketch
Individual subject

This section analyses the number of segments for individual subjects. Here again, although the differences between subject groups on average are not statistically significant, there is a great variation on number of segments required by individual subjects within both groups. This varies from a minimum of 25 segments to maximum of 177 segments for the non-architectural sketch and from a minimum of 17 to a maximum of 295 segments for the architectural sketch.

For this reason again, it appears to be sensible to use an alternative analysis with the comparative number of segments for each subject between the two sketches. The question that might be asked here is how many students used more segments for non-architectural description and how many for architectural one.

Figure 5.38 presents the number of segments for the whole subject group.

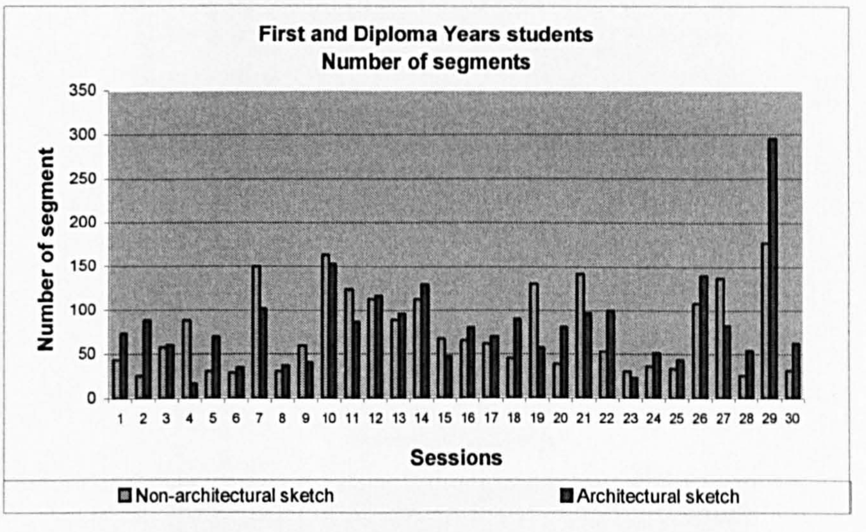


Figure 5.38: The number of segments for the whole subject group.

The results show that the majority of students within the whole group used more segments for architectural description than for non-architectural one. As Figure 5.39 shows within the whole group of 30 students, 20 of them (67%) used more segments for the architectural sketch and 10 students (33%) used more segments for the non-architectural sketch.

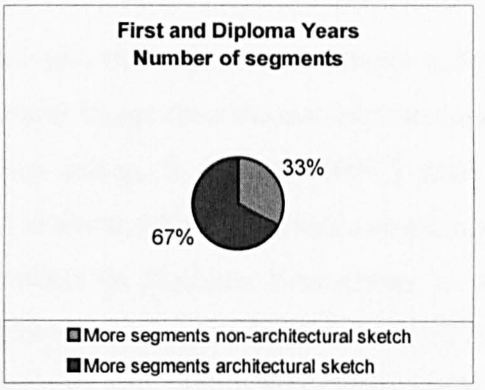


Figure 5.39: Number of segments for the whole subject group

These results are also true for the each group separately. Figure 5.40 presents the number of segments for each subject for the First Year group and Figure 5.41 shows the results for the Diploma group.

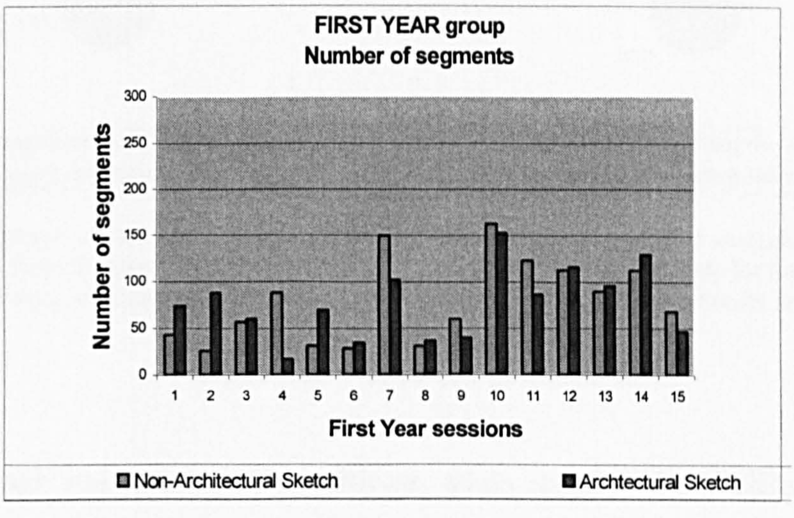


Figure 5.40: First Year group - Number of segments

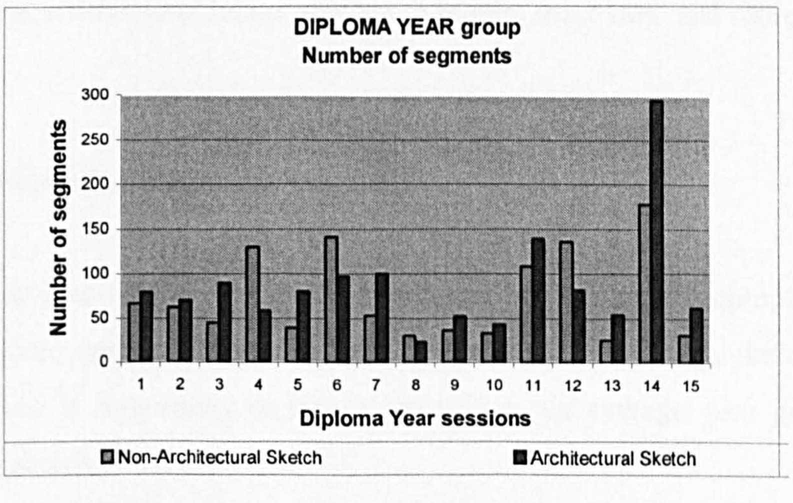
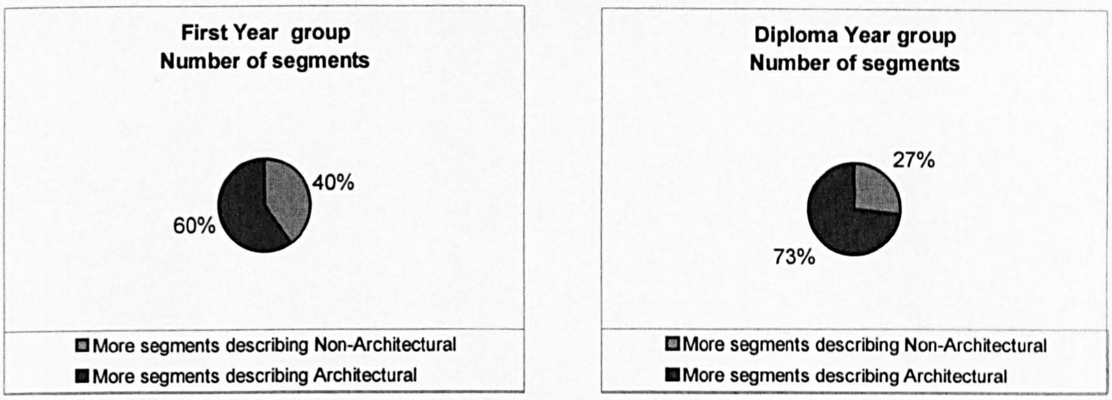


Figure 5.41: Diploma Year group - Number of segments

The results indicate that the majority of students within both groups used more segments for the architectural image than the non-architectural one. Figure 5.42 shows that within the First Year group, 9 students (60%) used more segments for the architectural sketch and 6 students (40%) used more segments for the non-architectural one. On the other hand, within the Diploma Year group, 11 students (73%) used more segments for the architectural sketch and 4 students (27%) used more segments describing the non-architectural one. Again this difference in the number of segments was wider for Diploma students than for First Year students.



First Year group: 15 students
06 students more segments for non-archit (40%)
09 students more segments for archit (60%)

Diploma Year group: 15 students
04 students more segments for non-archit (27%)
11 students more segments for archit (73%)

Figure 5.42: Number of segments per subject

Although not statistically significant, taken together these differences again seem to contribute and support the earliest findings of this work. The early findings suggest that the architectural image appears to require more time and more segments to be described.

3.3.1.2 - Number of segments per minute

The previous sections show that expert students are able to complete the same tasks in less time and use more segments than novices. Therefore, the question that should be asked is how many segments per minute on average each group used to describe each sketch.

The results are presented first per subject group on average and then per individual subject within each group.

3.3.1.2.1 - Number of segments per minute

First Year group

Table 5.24 presents the results for the number of segments per minute for the First Year group.

Table 5.24: First Year group -Number of segments per minute

	Non-Architectural Number of segments per minute	Architectural Number of segments per minute
First Year 01	13.87	10.88
First Year 02	10.83	10.23
First Year 03	6.19	8.10
First Year 04	12.39	5.00
First Year 05	16.31	14.00
First Year 06	11.60	10.29
First Year 07	20.83	18.54
First Year 08	15.50	13.70
First Year 09	13.63	12.50
First Year 10	14.55	13.18
First Year 11	17.08	14.33
First Year 12	16.47	17.57
First Year 13	13.48	12.46
First Year 14	16.00	13.16
First Year 15	16.58	14.24
Average	**14.30**	**12.63**
Standard Deviation	**3.36**	**3.39**

Figure 5.43 shows the average of these results for the same subject group.

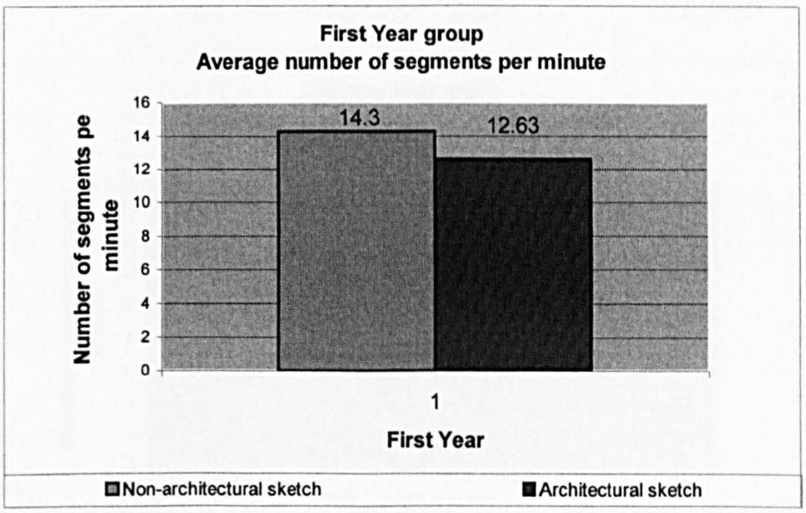


Figure 5.43: Number of segments per minute for First Year group on average.

The results show that on average the First Year group used more segments per minute for the non-architectural description. However, again the differences are not statistically significant (Ttest p=0.15).

3.3.1.2.2 - Number of segments per minute
Diploma Year group

Table 5.25 shows the number of segments per minute for the Diploma Year group.

Table 5.25: Diploma Year group -Number of segments per minute

	Non-Architectural Number of segments per minute	Architectural Number of segments per minute
Diploma Year 01	15.00	13.33
Diploma Year 02	15.12	18.42
Diploma Year 03	13.63	13.63
Diploma Year 04	18.57	13.80
Diploma Year 05	16.25	19.75
Diploma Year 06	26.11	21.55
Diploma Year 07	14.32	19.23
Diploma Year 08	15.00	14.37
Diploma Year 09	14.40	17.93
Diploma Year 10	15.71	20.47
Diploma Year 11	20.76	20.74
Diploma Year 12	18.13	15.47
Diploma Year 13	14.70	17.41
Diploma Year 14	14.87	17.15
Diploma Year 15	11.92	14.09
Average	**16.87**	**17.06**
Standard Deviation	**3.46**	**2.86**

Figure 5.44 shows the average of these results for the same subject group.

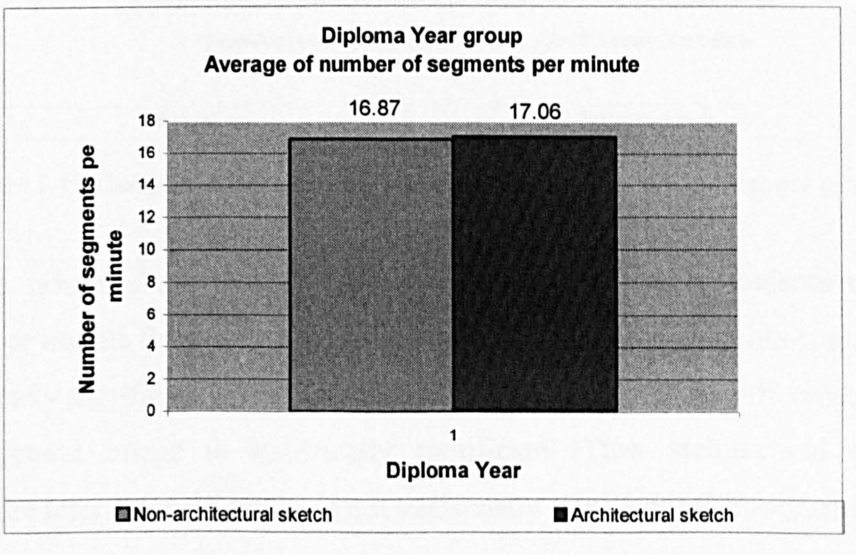


Figure 5.44: Number of segments per minute for First Year group on average.

The results show that on average the Diploma Year group used more segments per minute for the architectural description. However, the differences are not statistically significant (Ttest p=0.46).

3.3.1.2.3 - Number of segments per minute
Comparison between groups and sketches

From all these findings it is possible to compare both groups. Table 5.26 shows the results for number of segments per minute on average for both groups.

Table 5.26 – Number of segments per minute on average: comparison between groups and sketches

	Non-architectural sketch Number of segments per minute	Architectural sketch Number of segments per minute
First Year group	14.3	12.63
Diploma Year group	16.87	17.06

Figure 5.45 shows the average of these results for both subject groups.

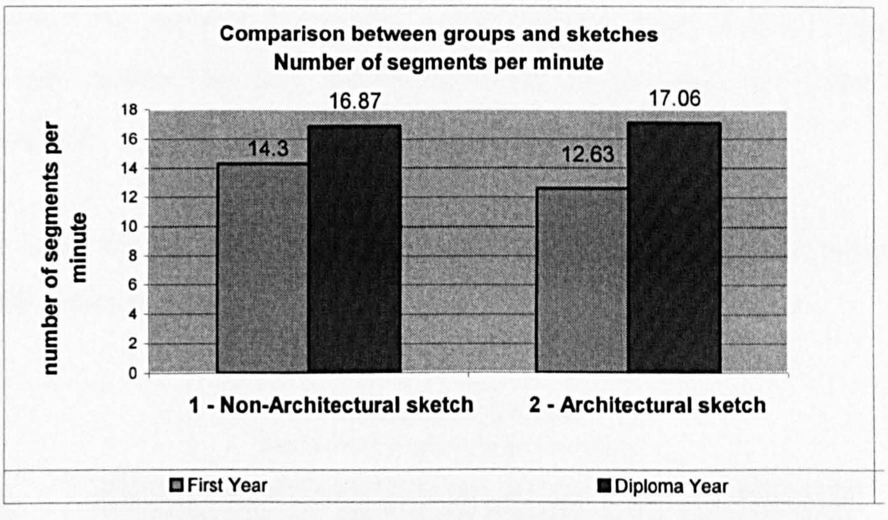


Figure 5.45: Comparison between groups – Average of number of segments per minute

The results show that in both descriptions the expert students used more segments per minute than novices. The difference found for non-architectural sketch is not statistically significant (Ttest non-architectural p=0.13) but the difference found for the architectural image is statistically significant (Ttest architectural p=0.0004). However, the interaction of results is not statistically significant (Chi-squared p=0.20).

These results show that expert architecture students used more segments per minute and completed the tasks in a shorter time than novice students. This might suggests that the expert group seems to be more fluent and quicker in their verbal descriptions.

3.3.1.2.4 - Number of segments per minute Individual subject

A great variation in number of segments per minute of individual subject within both groups was found. It varies from a minimum of 6.19 segments per minute to a maximum of 26.11 segments per minute for the non-architectural sketch and from a minimum of 5.0 segments per minute to a maximum of 21.55 segments per minute for the architectural sketch.

This suggests again that the use of an alternative analysis with the comparative number per segments per minute for each subject between the two sketches seems to be reasonable. The question that might be asked is how many students required more segments per minute for the non-architectural image and how many for the architectural one.

In order to answer this question each subject was examined separately and Figure 5.46 shows the results.

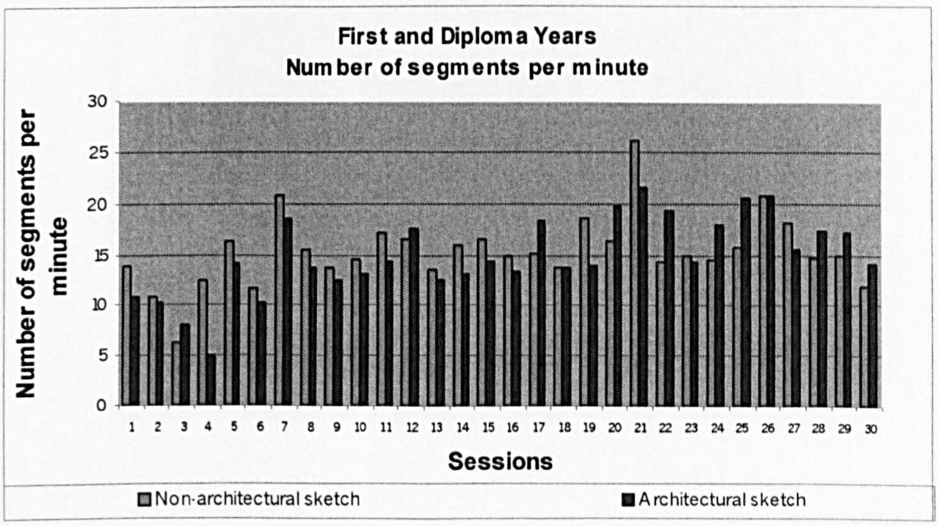


Figure 5.46: Number of segments per minute for both subject groups

The results show that in the whole group the majority of subjects used more segments per minute for the non-architectural sketch. As Figure 5.47 shows, within the whole group of 30 students, 19 of them (64%) used more segments per minute for the non-architectural image, 10 of them (33%) used more segments per minute for the architectural one and just one student (3%) used the same number of segments per minute for both images.

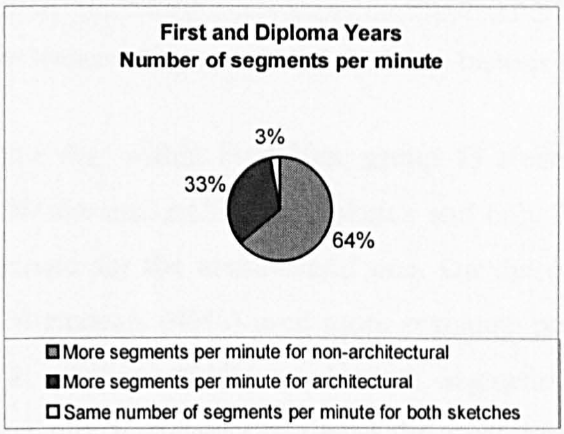


Figure 5.47: Number of segments per minute for the whole group of subjects

These results are different for each of the subject groups separately. Figure 5.48 shows the number of segments per minute for each subject for First Year group and Figure 5.49 show the results for the Diploma Year group.

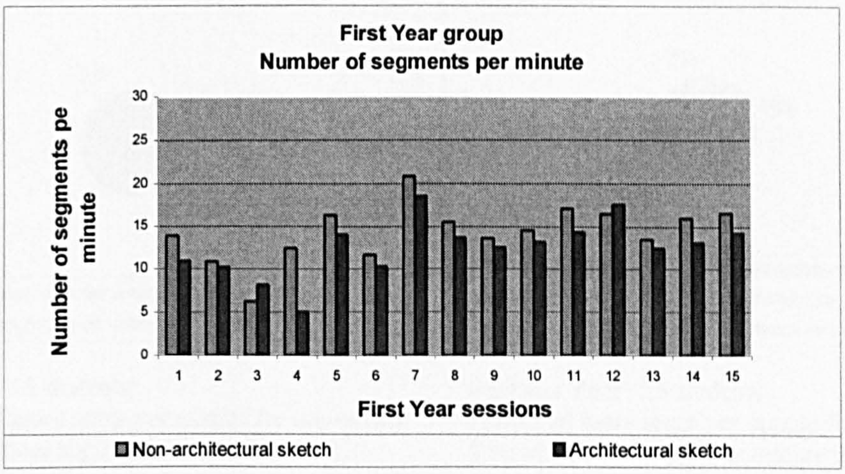


Figure 5.48: Number of segments per minute for the First Year group

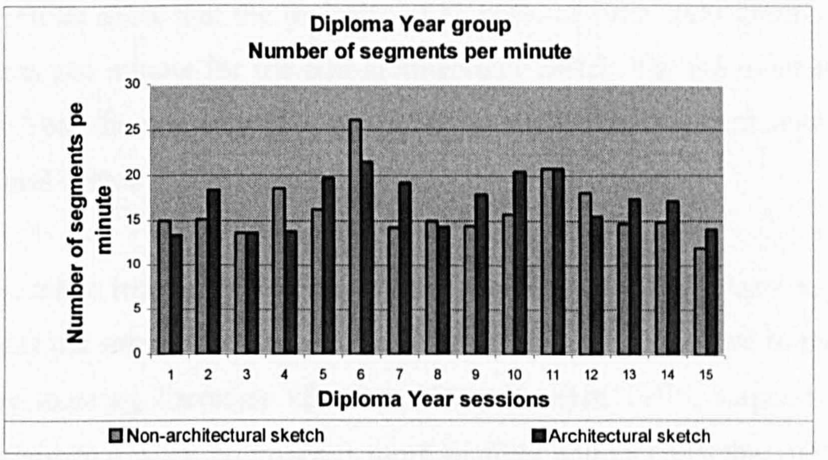
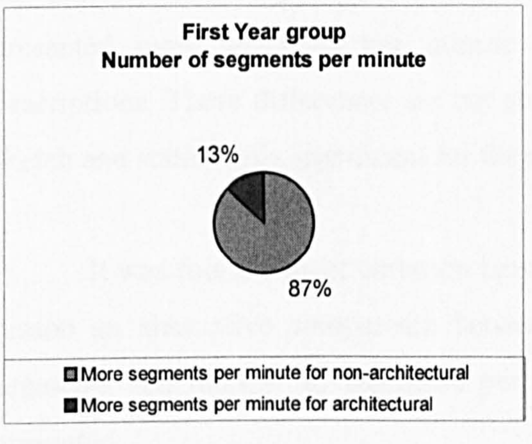
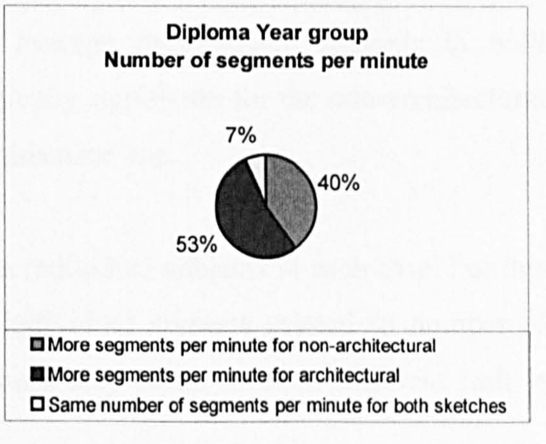


Figure 5.49: Number of segments per minute for the Diploma Year group

The results show that within First Year group 13 students (87%) used more segments per minute for the non-architectural sketch and only 2 students (13%) used more segments per minute for the architectural one. On the other hand, within the Diploma Year group, 6 students (40%) used more segments per minute for the non-architectural image, 8 of them (53%) used more segments per minute for the architectural sketch and just 1 student (7%) used the same number of segments per minute for both sketches.

Figure 5.50 presents the results for both groups of subjects





First Year : 15 students
13 required more segm per minute for non-archit
2 required more segm per minute for archit

Diploma Year : 15 students
6 required more segm per minute for non-archit
8 required more segm per minute for archit
1 required same number of segm per minute

Figure 5.50: Number of segments per minute for both groups of subjects

The results show that the majority of subjects of First Year group (87%) used more segments per minute for the non-architectural sketch. On the other hand within the Diploma Year the majority of subjects (53%) used more segments per minute for the architectural sketch.

When taken together these results seem to suggest that subjects appear to use more segments per minute to describe the image that is more familiar to them. This is supported by existing literature (Bartlett 1950; Kosslyn 1995; Lawson 2003) and seems to suggest that when an image is more familiar and recognisable, people tend to explore their thoughts and descriptions more.

3.3.1.3 - Summary of results for number of segments

The results for number of segments were presented per subject groups on average and per individual subject separately. They were compared in order to identify differences and similarities between groups and sketches.

The data show no statistical significant difference between groups on average related to the number of segments. Again, it is a surprising result as this research was expecting to find some significant differences between them. The number of segments per minute on average was also examined. The results show that expert students presented more segments per minute on average than novice students in both descriptions. These differences are not statistically significant for the non-architectural sketch and statistically significant for the architectural one.

It was found a great variation between individual subjects in each case. For this reason an alternative comparison between individual subjects related to number of segments and number of segments per minute they taken in each different task is presented.

It was found that the majority of students in both groups (67%) used more segments for the architectural sketch than for the non-architectural one. This difference was also true for each subject group separately and greater for the Diploma students (73%) than for First Year students (60%).

It was also found that the majority of students in both groups (64%) used more segments per minute for the non-architectural sketch than for the architectural one. However this difference was not true for each subject group separately. The majority of novice students (87%) used more segments per minute for the non-architectural sketch and the majority of expert students (53%) for the architectural one. This seems to suggest that when the image is more familiar and recognisable, subjects seem to use more segments per minute to describe it. This is supported by existing literature (Bartlett 1950; Lawson 2003).

3.3.2 – Results for verbal cognitive actions

In this section the results for verbal cognitive action categories are presented. All segments were examined using the verbal cognitive action categories developed within this work.

The results are again presented first per subject group on average and then per individual subject separately.

3.3.2.1 - Number of verbal cognitive actions per type of sketch

Here the number of verbal cognitive actions per each different sketch is going to be analysed. The question that might be asked is which sketch required more verbal cognitive actions to be described. Was it the same sketch that took longer and required more number of segments? Are there significant differences between subject groups? In order to answer of these questions each description was examined separately.

3.3.2.1.1 - Number of verbal cognitive actions per type of sketch First Year group

The results for the number of verbal cognitive actions per type of sketch for the First Year group are shown in Table 5.27.

Table 5.27: Number of verbal cognitive actions per sketch - First Year group

	Non-Architectural Number of verbal cognitive actions	Architectural Number of verbal cognitive actions
First Year 01	51	90
First Year 02	37	107
First Year 03	64	80
First Year 04	108	19
First Year 05	37	84
First Year 06	30	43
First Year 07	168	117
First Year 08	41	41
First Year 09	69	44
First Year 10	183	180
First Year 11	139	108
First Year 12	125	136
First Year 13	98	117
First Year 14	117	154
First Year 15	74	64
Average	**89.4**	**92.27**
Standard Deviation	**49.26**	**45.42**

Figure 5.51 presents the average of these results for the same subject group.

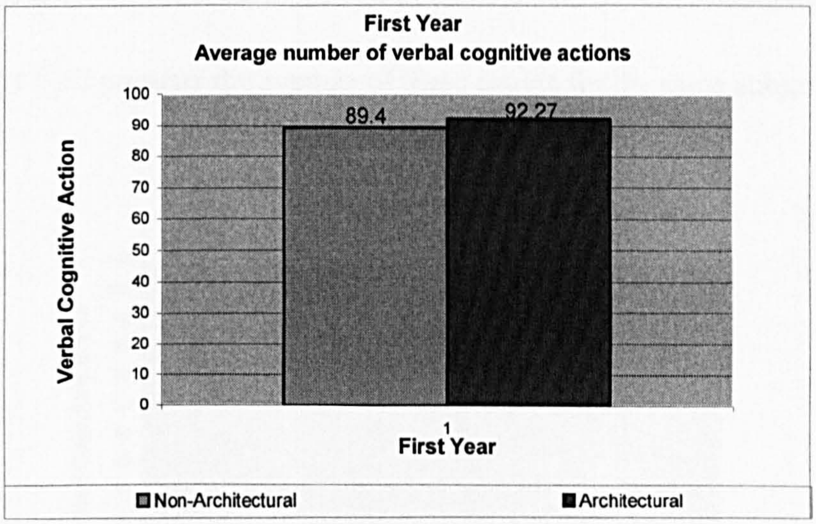


Figure 5.51: Average verbal cognitive actions – First Year group

The results show that, on average, the First Year group used more verbal cognitive actions to describe the architectural image than the non-architectural one. However the difference are slight and again not statistically significant (Ttest p=0.87)

3.3.2.1.2 - Number of verbal cognitive actions per type of sketch Diploma Year group

Table 5.28 shows the results for the number of verbal cognitive actions per sketch for the Diploma Year group.

Table 5.28: Number of verbal cognitive actions - Diploma Year group

	Non-Architectural Number of verbal cognitive actions	Architectural Number of verbal cognitive action
Diploma 01	84	101
Diploma 02	72	82
Diploma 03	48	103
Diploma 04	145	62
Diploma 05	51	97
Diploma 06	151	117
Diploma 07	55	126
Diploma 08	35	26
Diploma 09	38	56
Diploma 10	36	44
Diploma 11	130	166
Diploma 12	153	92
Diploma 13	25	60
Diploma 14	182	302
Diploma 15	33	56
Average	**82.53**	**99.33**
Standard Deviation	**54.07**	**66.57**

Figure 5.52 presents the average of these results for the same subject group.

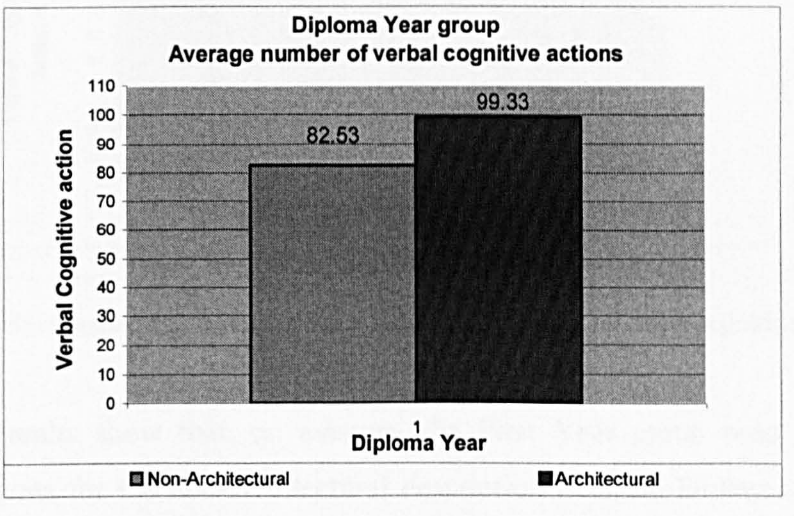


Figure 5.52: Average Verbal cognitive actions – Diploma Year group

The results show that, on average, the Diploma Year group used more verbal cognitive actions to describe the architectural image than the non-architectural one. However, again the differences are not statistically significant (Ttest p=0.45)

3.3.2.1.3 - Number of verbal cognitive actions per type of sketch

Comparison between groups and sketches

The results for the number of verbal cognitive actions allowed for a comparison between groups and sketches. Similarly the differences found are not statistically significant when analysed separately, together they suggest differences between groups and sketches. Table 5.29 shows the results.

Table 5.29 – Number of verbal cognitive actions on average comparison between groups and sketches

	Non-architectural sketch Number of verbal cognitive actions	Architectural sketch Number of verbal cognitive actions
First Year group	89.4	92.27
Diploma Year group	82.53	99.33

The results for the number of verbal cognitive actions on average employed per both groups are shown on Figure 5.53.

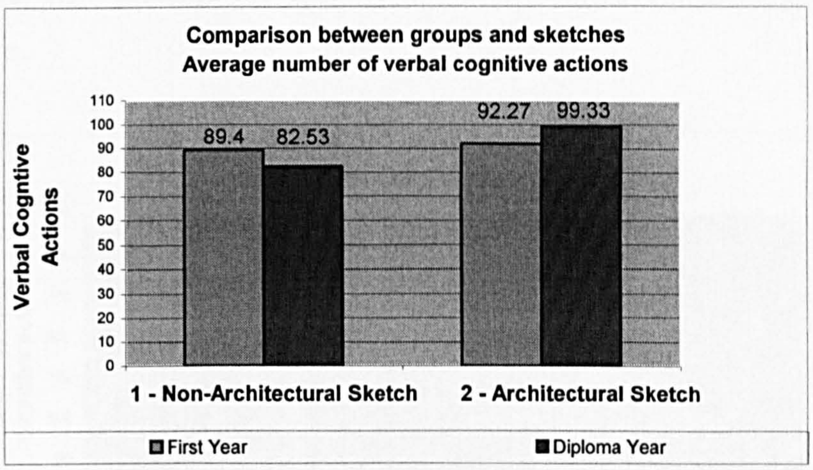


Figure 5.53: Comparison between groups – Average of number of verbal cognitive actions

The results show that, on average, the First Year group used more verbal cognitive actions for the non-architectural description than the Diploma Year group. On the other hand, the expert group used more verbal cognitive actions for the architectural description than the novice group. However, again, this interaction is not statistically significant (Chi-squared p=0.50).

3.3.2.1.4 - Number of verbal cognitive actions per type of sketch

Individual subject

This section examines the number of verbal cognitive actions for individual subjects. Again, although the differences between subject groups on average are not statistically significant, there is a great variation regarding the number of verbal cognitive actions required by individual subjects within both groups. This varies from a minimum of 25 verbal cognitive actions to maximum of 183 verbal cognitive actions for the non-architectural sketch and from a minimum of 26 verbal cognitive actions to a maximum of 302 verbal cognitive actions for the architectural sketch.

Therefore, for this reason again, an alternative analysis with the comparative number of verbal cognitive actions for each subject between the two sketches is used. The question that might be asked is how many students employed more verbal cognitive actions for the non-architectural description and how many for the architectural one.

Figure 5.54 presents the number of verbal cognitive actions for the whole subject group.

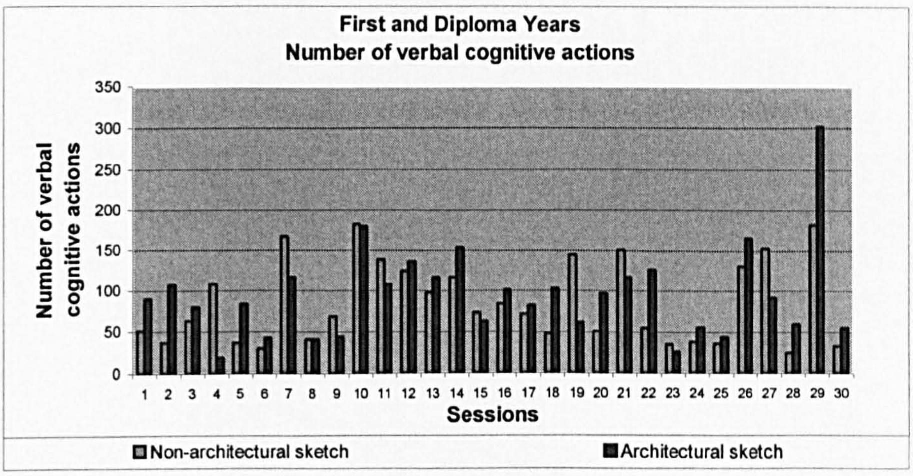


Figure 5.54: The number of verbal cognitive actions for the whole subject group.

The results show that the majority of students within the whole group used more verbal cognitive actions for the architectural description than for the non-architectural one. As Figure 5.55 shows, within the whole group of 30 students, 19 of them (64%) used more verbal cognitive actions for the architectural sketch, 10 students (33%) used more verbal cognitive actions for the non-architectural sketch and only 1 student (3%) used the same number of verbal cognitive actions for both sketches.

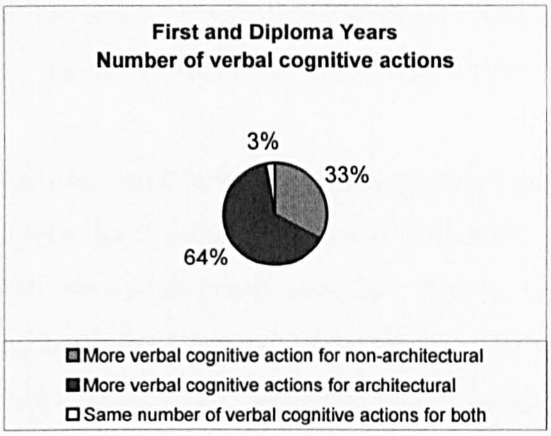


Figure 5.55: Number of verbal cognitive actions for the whole subject group

These results are also true for each group separately. Figure 5.56 presents the number of verbal cognitive actions for each subject for the First Year group and Figure 5.57 shows the results for the Diploma group.

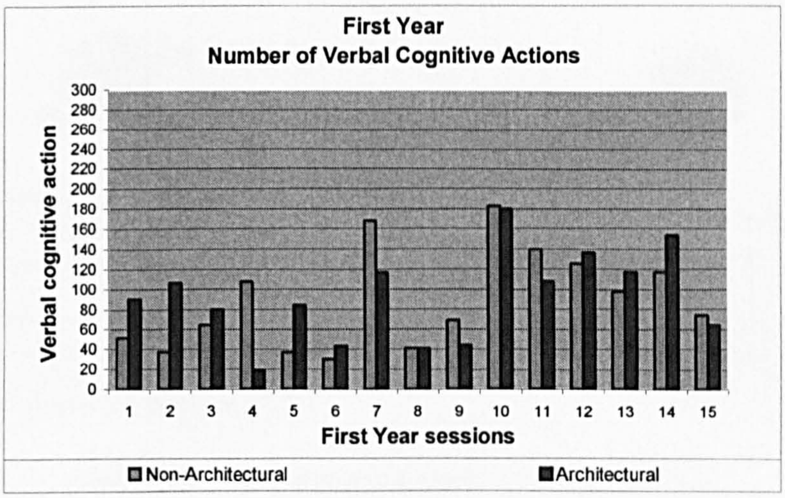


Figure 5.56: Number of verbal cognitive actions – First Year group

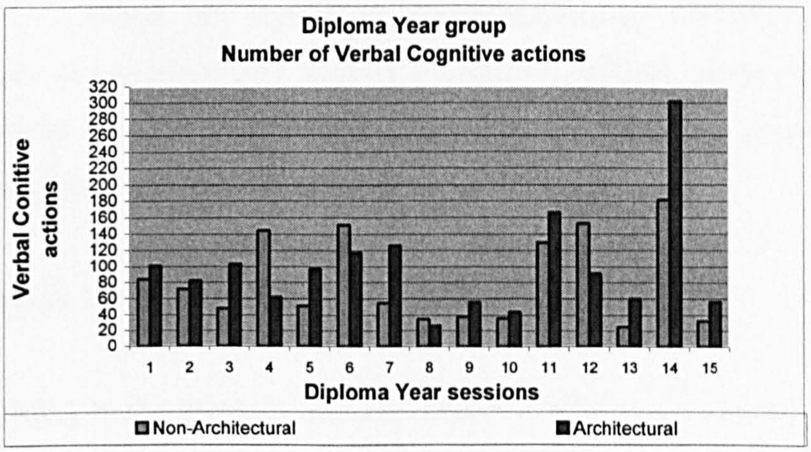
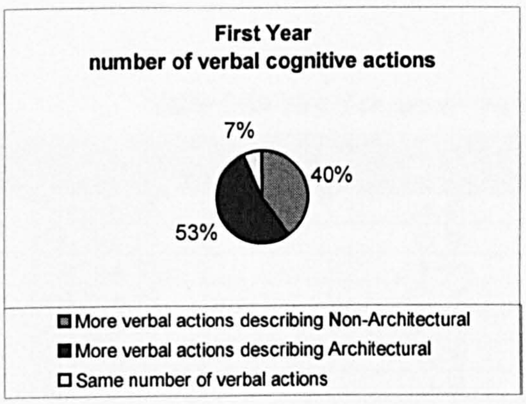
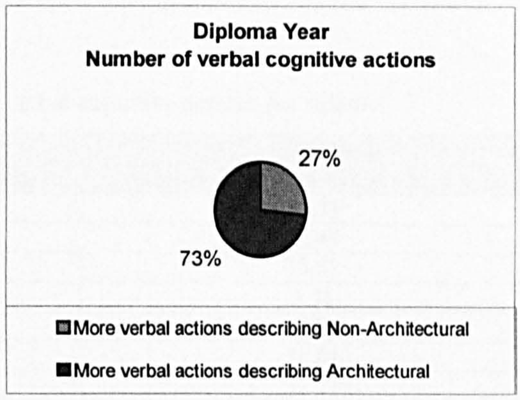


Figure 5.57: Number of verbal cognitive actions– Diploma Year group

The results indicate that the majority of students within both groups used more verbal cognitive actions for the architectural image than for the non-architectural one.

Figure 5.58 shows that within the First Year group, 8 students (53%) used more verbal cognitive actions for the architectural sketch, 6 students (40%) used more verbal cognitive actions for the non-architectural one and 1 student used the same number of verbal cognitive actions for both sketches. On the other hand, within the Diploma Year group, 11 students (73%) used more verbal cognitive actions for the architectural sketch and 4 students (27%) used more verbal cognitive actions describing the non-architectural one. Again, this difference in number of verbal cognitive actions was again wider for Diploma students than for First Year students.





First Year group: 15 students
06 more verbal actions for non-archit (40%)
08 more verbal actions for archit (53%)
01 same number of verbal actions (7%)

Diploma Year group: 15 students
04 more verbal actions for non-archit (27%)
11 more verbal actions for archit (73%)

Figure 5.58: Number of verbal cognitive actions per subject.

Again, although not significant, these differences between groups taken together seem to contribute and support the earlier findings of this research. The findings suggest that the architectural image appears to require more time, more segments and more verbal cognitive actions to be described.

3.3.2.2 - Number of verbal cognitive actions per minute

According to the previous sections, expert students were able to complete the same tasks in less time than novices. Therefore, the question that might be asked is how many verbal cognitive actions per minute on average each group used to describe each sketch.

In order to answer this question, the number of verbal cognitive actions per minute is examined and the results are shown first per subject group on average and then per individual subject separately.

3.3.2.2.1 - Number of verbal cognitive actions per minute

First Year group

Table 5.30 presents the results for the number of verbal cognitive actions per minute for the First Year group.

Table 5.30: First Year group -Number of verbal cognitive actions per minute

	Non-Architectural Number of verbal actions per minute	**Architectural Number of verbal actions per minute**
First Year 01	16.45	13.23
First Year 02	15.41	12.44
First Year 03	6.95	10.81
First Year 04	15.21	5.58
First Year 05	19.47	16.80
First Year 06	12.00	12.64
First Year 07	23.33	21.27
First Year 08	20.50	15.18
First Year 09	15.68	13.75
First Year 10	16.33	15.51
First Year 11	19.30	18.00
First Year 12	18.38	20.60
First Year 13	14.84	15.19
First Year 14	16.71	15.71
First Year 15	18.04	19.39
Average	**16.22**	**15.20**
Standard Deviation	**3.80**	**4.01**

Figure 5.59 shows the average of these results for the same subject group.

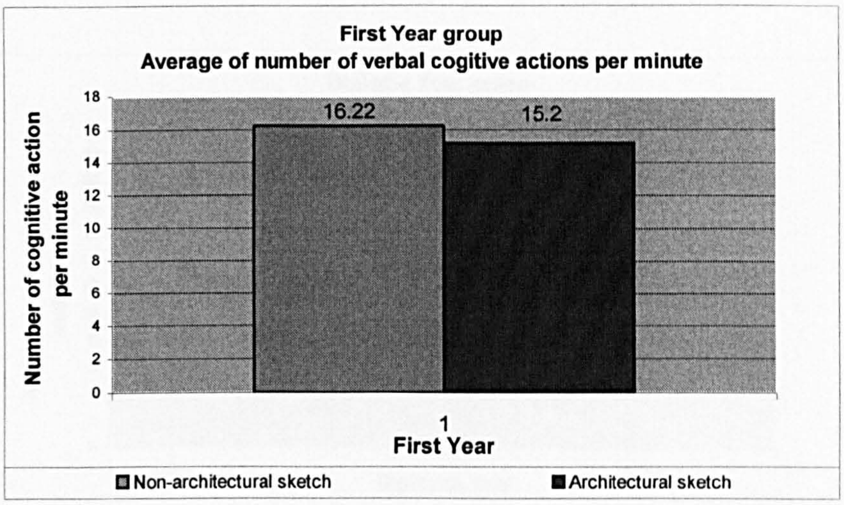


Figure 5.59: Number of verbal cognitive actions per minute for First Year group on average.

The results show that on average the First Year group used more verbal cognitive actions per minute for the non-architectural description. However, again, the differences are not statistically significant (Ttest p=0.30).

3.3.2.2.2 - Number of verbal cognitive actions per minute Diploma Year group

Table 5.31 presents the results for the number of verbal cognitive actions per minute for the Diploma Year group.

Table 5.31: Diploma Year group -Number of verbal cognitive actions per minute

	Non-Architectural Number of verbal actions per minute	Architectural Number of verbal actions per minute
Diploma Year 01	19.09	16.83
Diploma Year 02	17.56	21.57
Diploma Year 03	14.54	15.60
Diploma Year 04	20.71	14.76
Diploma Year 05	21.25	23.65
Diploma Year 06	27.96	26.00
Diploma Year 07	14.86	24.23
Diploma Year 08	17.50	16.25
Diploma Year 09	15.20	19.31
Diploma Year 10	17.14	20.95
Diploma Year 11	25.00	24.77
Diploma Year 12	20.40	17.35
Diploma Year 13	14.70	19.35
Diploma Year 14	15.29	17.55
Diploma Year 15	12.69	12.72
Average	**18.79**	**19.17**
Standard Deviation	**4.22**	**4.01**

Figure 5.60 shows the average of these results for the same subject group

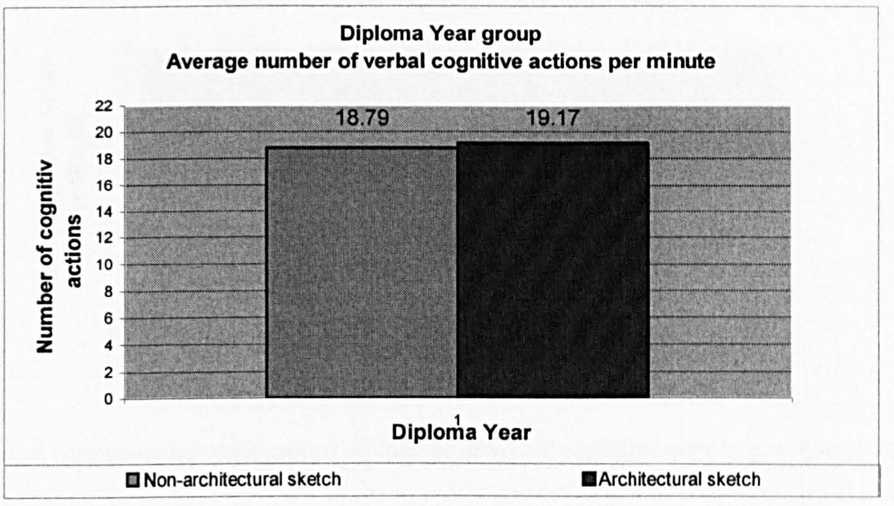


Figure 5.60: Number of verbal cognitive actions per minute for Diploma Year group on average.

The results show that on average the Diploma Year group used more verbal cognitive actions per minute for the architectural sketch. However, again, this difference is not statistically significant (Ttest p=0.45).

3.3.2.2.3 - Number of verbal cognitive actions per minute Comparison between groups and sketches

From the findings, it is possible to compare both groups. Table 5.32 shows the results for number of verbal cognitive actions per minute for both groups on average.

Table 5.32 – Number of verbal actions per minute on average: comparison between groups and sketches

	Non-architectural sketch Number of verbal cognitive actions per minute on average	Architectural sketch Number of verbal cognitive actions per minute on average
First Year group	16.22	15.20
Diploma Year group	18.79	19.17

Figure 5.61 shows the average of these results for both subject groups.

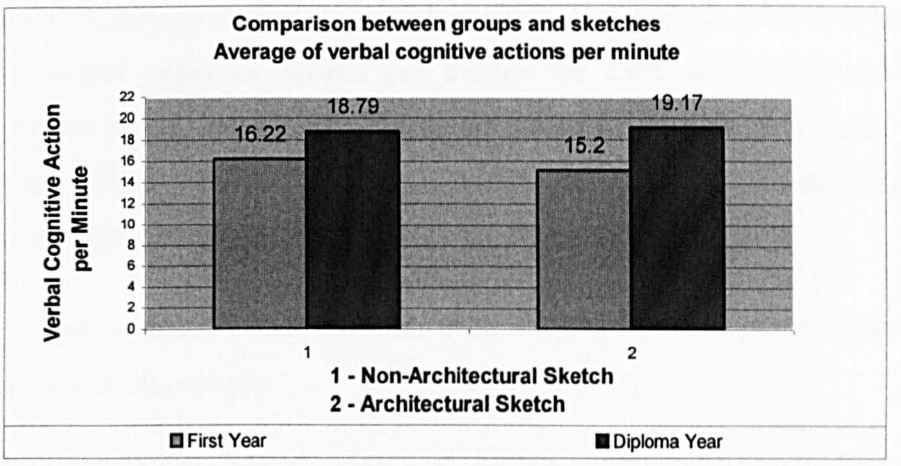


Figure 5.61: Comparison between groups – Number of verbal cognitive actions per minute on average

The results show that in both descriptions the Diploma Year students used more verbal cognitive actions per minute than the novices. The difference found for non-architectural sketch again is not statistically significant (Ttest non-architectural p=0.26) but the difference found for the architectural image is statistically significant (Ttest architectural p=0.006).

Therefore, these results seem to support early findings of this work. They suggest that expert architecture students used more segments per minute, more verbal cognitive actions per minute and complete the same tasks in a shorter time than novice students. The results find support in existing literature about novices and expert designers (Suwa 1997; Casakin 1999; Kokotovich 2000; Kavakli 2001; Kavakli 2002).

3.3.2.2.4 - Number of verbal cognitive actions per minute Individual subject

Similarly it was found that there was a great variation in number of verbal cognitive actions per minute of individual subject within both groups. It varies from a minimum of 6.95 cognitive actions per minute to a maximum of 25.00 cognitive actions per minute for the non-architectural sketch and from a minimum of 5.58 cognitive actions per minute to a maximum of 26.00 cognitive actions per minute for the architectural sketch.

Again, this suggests that the use of an alternative analysis with the comparative number of verbal cognitive actions per minute for each subject between the two sketches seems to be reasonable. The question that arises is how many students required more verbal cognitive actions per minute for the non-architectural image and how many for the architectural one.

In order to answer this question each subject was examined separately and Figure 5.62 shows the results.

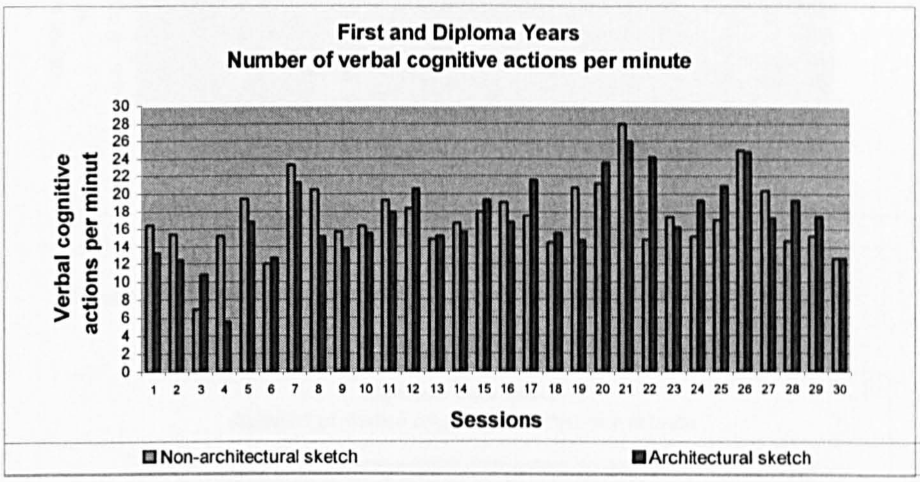


Figure 5.62: Number of verbal cognitive actions per minute for both subject groups

The results show that the majority of subjects in the whole group used more verbal cognitive actions per minute for the non-architectural sketch. Figure 5.63 shows that within the whole group of 30 students, 16 of them (53%) used more verbal cognitive actions per minute for the non-architectural image and 14 of them (47%) used more verbal cognitive actions per minute for the architectural.

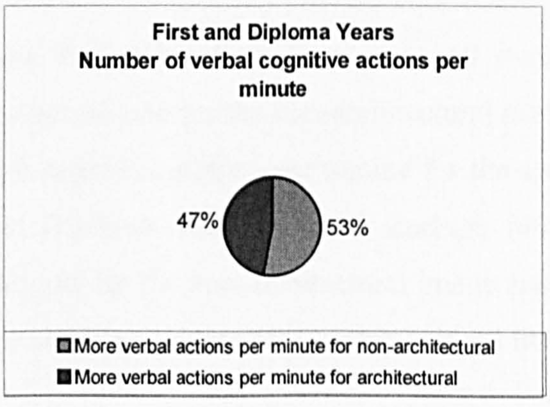


Figure 5.63: Number of verbal cognitive actions per minute for the whole group of subjects

These results are different for each of the subject groups separately. Figure 5.64 shows the number of verbal cognitive actions per minute for each subject for First Year group and Figure 5.65 show the results for the Diploma Year group.

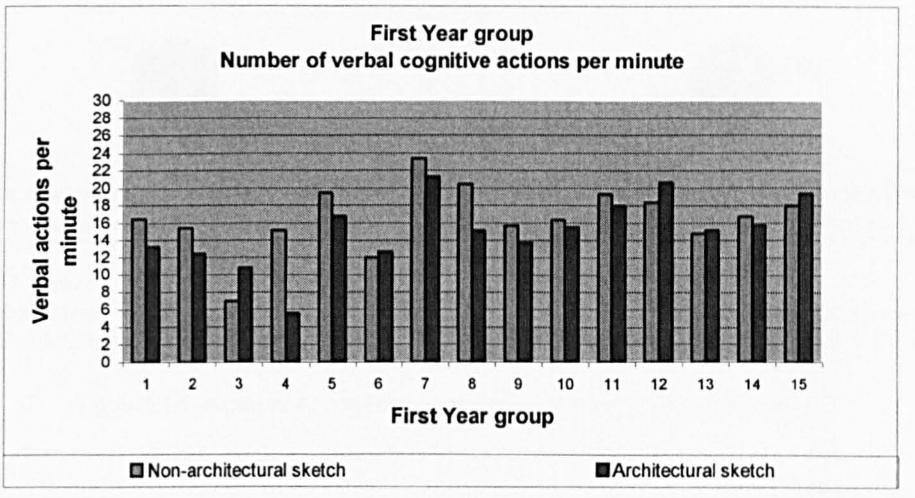


Figure 5.64: Number of verbal actions per minute for the First Year group

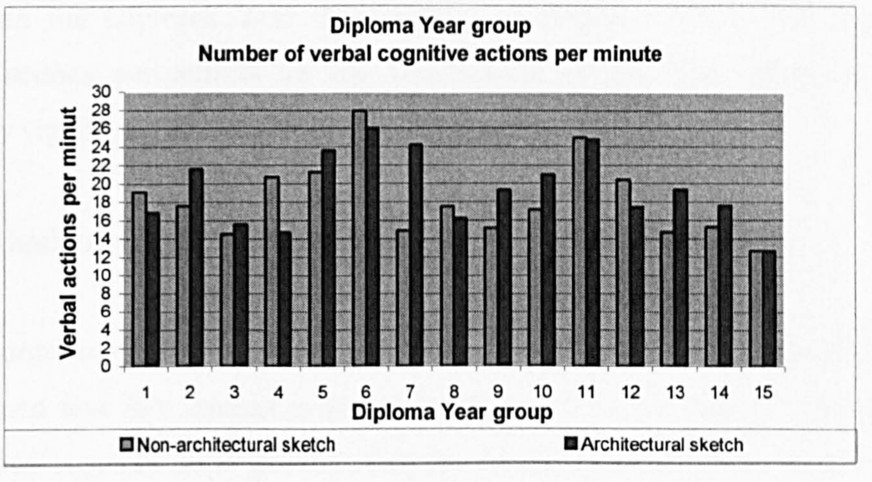
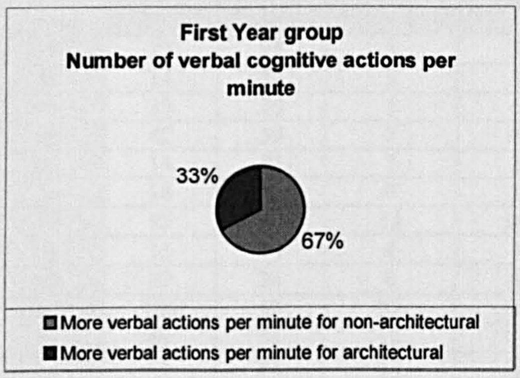
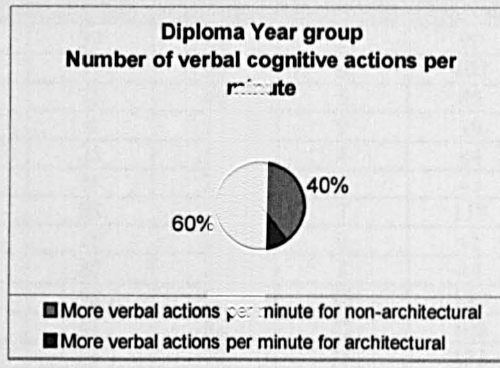


Figure 5.65: Number of verbal actions per minute for the Diploma Year group

The results show that within First Year group 10 students (67%) used more verbal cognitive actions per minute for the non-architectural sketch and only 5 students (33%) used more verbal cognitive actions per minute for the architectural one. On the other hand, within the Diploma Year group, 6 students (40%) used more verbal cognitive actions per minute for the non-architectural image and 9 of them (60%) used more verbal cognitive actions per minute for the architectural image.

Figure 5.66 presents the results for both groups of subjects





First Year: 15 students
10 more verbal actions per minute for non-archit (67%)
5 more verbal actions per minute for archit (33%)

Diploma Year : 15 students
6 more verbal actions per minute for non-archit (40%)
9 more verbal actions per minute for archit (60%)

Figure 5.66: Number of segments per minute for both groups of subjects

The results show that the majority of subjects of First Year group (67%) used more verbal cognitive actions per minute for the non-architectural sketch. On the other hand within the Diploma Year the majority of subjects (60%) used more verbal cognitive actions per minute for the architectural sketch. The difference found is statistically significant (Chi-Squared p=0.001).

3.3.2.3 - Number of general, feature and reflective references

In order to go further in this analysis the verbal cognitive actions per categories are examined and this section presents the results. The question of interest here is which sketch required more general, feature or reflective references to be described. The results are presented first per subject group on average and second per individual subject separately.

3.3.2.3.1 - Number of general, feature and reflective references
First Year group

Table 5.33 shows the results for number of verbal cognitive actions per categories for the First Year group.

Table 5.33: First Year group – Number of verbal cognitive actions per categories

First Year group	Non-Architectural sketch				Architectural sketch			
	General	Feature	Reflective	TOTAL	General	Feature	Reflective	TOTAL
01	23	25	3	51	39	49	2	90
02	14	20	3	37	39	56	12	107
03	33	30	1	64	35	40	5	80
04	42	59	7	108	6	13	0	19
05	14	21	2	37	25	55	4	84
06	18	12	0	30	16	26	1	43
07	95	60	13	168	58	52	7	117
08	13	24	4	41	16	25	0	41
09	39	24	6	69	20	21	3	44
10	106	50	27	183	78	86	16	180
11	69	58	12	139	41	52	15	108
12	65	48	12	125	51	70	15	136
13	48	43	7	98	56	55	6	117
14	63	46	8	117	72	66	16	154
15	43	27	4	74	25	36	3	64
Average	**45.66 (51%)**	**36.46 (41%)**	**7.26 (8%)**	**89.4 (100%)**	**38.46 (42%)**	**46.8 (51%)**	**7.0 (7%)**	**92.26 (100%)**

Figure 5.67 shows the average of these results for the same subject group.

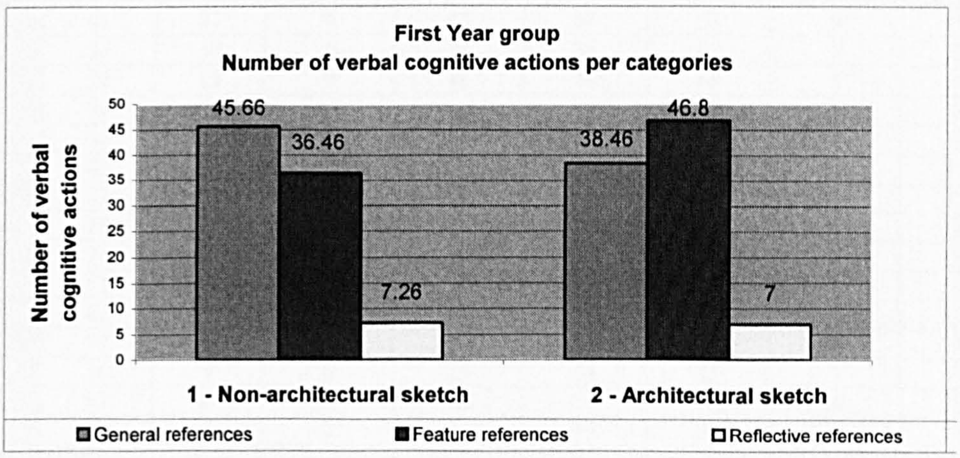


Figure 5.67: The average of verbal cognitive actions per categories for the First Year group.

The difference found between sketches is not statistically significant (Ttest p=0.95). Figure 5.68 presents the percentage of these results for the same subject group

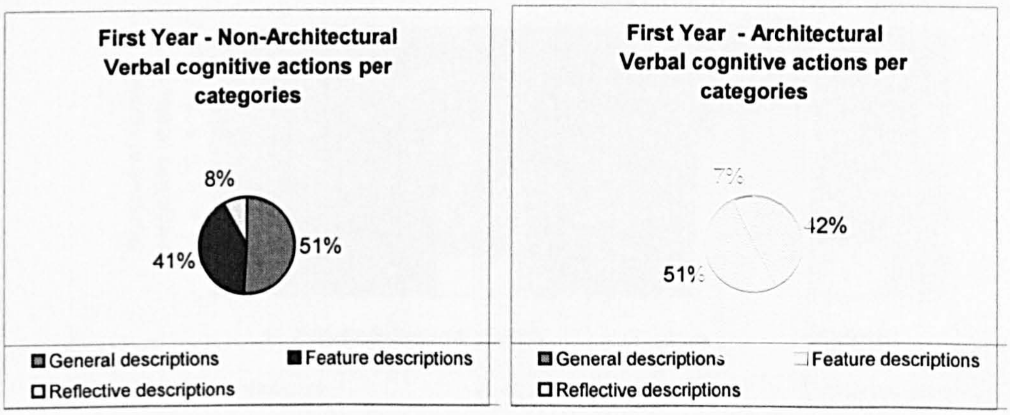


Figure 5.68: The percentage of number of verbal cognitive actions per categories for First Year group

These results show that First Year group used more general (51%) than feature (41%) or reflective references (8%) for the non-architectural image. On the other hand the same group used more feature (51%) than general (42%) or reflective references (7%) for the architectural image. This difference again is not statistically significant (Ttest p=1)

3.3.2.3.2 - Number of general, feature and reflective references Diploma Year group

Table 5.34 shows the results for number of verbal cognitive actions per categories for the Diploma Year group

Table 5.34: Diploma Year group - Number of verbal cognitive actions per categories

Diploma Year group	Non-Architectural sketch				Architectural sketch			
	General	Feature	Reflective	TOTAL	General	Feature	Reflective	TOTAL
01	41	37	6	84	38	54	9	101
02	36	30	6	72	35	40	7	82
03	30	18	0	48	47	48	8	103
04	74	58	13	145	33	27	2	62
05	30	14	7	51	47	41	9	97
06	82	58	11	151	42	57	18	117
07	32	19	4	55	48	60	18	126
08	16	18	1	35	8	17	1	26
09	24	14	0	38	27	29	0	56
10	11	20	5	36	15	28	1	44
11	62	56	12	130	73	80	13	166
12	77	57	19	153	36	42	14	92
13	16	9	0	25	34	25	1	60
14	93	61	28	182	130	117	55	302
15	22	9	2	33	19	36	1	56
Average	43.06 (52%)	31.86 (39%)	7.6 (9%)	82.53 (100%)	42.13 (42.5%)	46.73 (47%)	10.46 (10.5%)	99.33 (100%)

Figure 5.69 shows the average of these results for the same subject group.

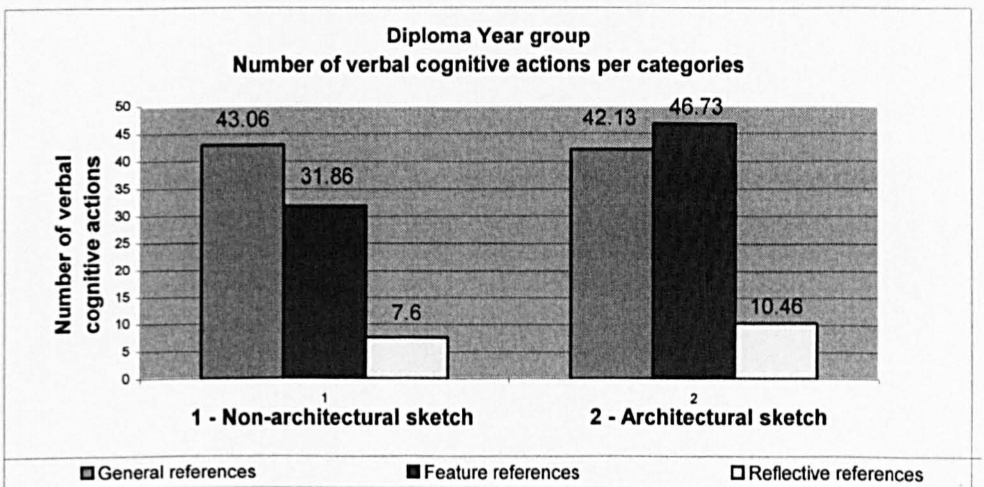
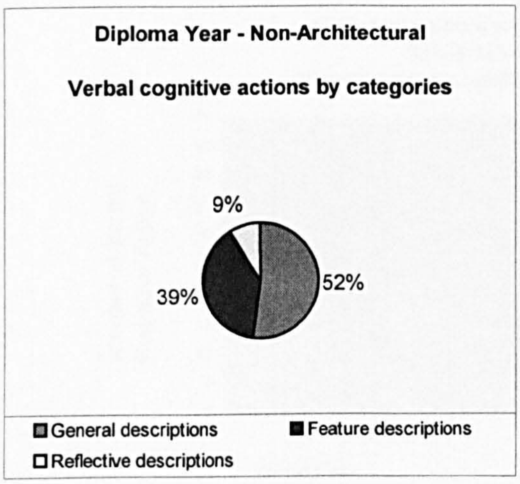


Figure 5.69: The average of verbal cognitive actions per categories for the Diploma Year group.

The difference found is not statistically significant (Ttest p=0.73). Figure 5.70 presents the percentage of these results for the same subject group



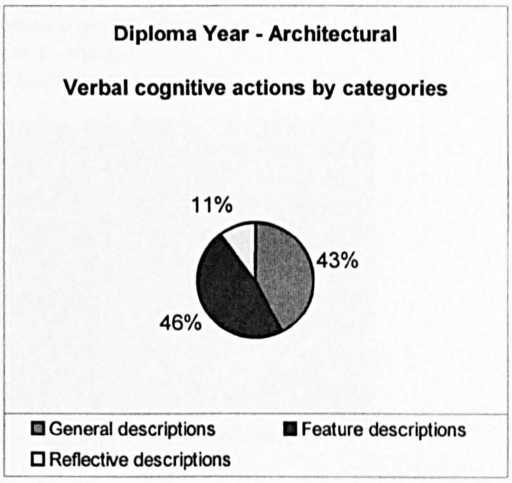


Figure 5.70: The percentage of number of verbal cognitive actions per categories for Diploma Year group

The results show that the Diploma Year group used more general (52%) than feature (39%) or reflective references (9%) for the non-architectural image. On the other hand, the same group used more feature (46%) than general (43%) or reflective references (11%) for the architectural image. The difference again is not statistically significant (Ttest p=1).

3.3.2.3.3 - Number of general, feature and reflective references Comparison between groups and sketches

From all these findings both groups can be compared. Table 5.35 shows the results for number of verbal cognitive actions per categories for both subject groups on average.

Table 5.35 – Number of verbal actions per categories: comparison between groups and sketches

	Non-architectural sketch Verbal cognitive actions per categories			Architectural sketch Verbal cognitive actions per categories		
	General	Feature	Reflective	General	Feature	Reflective
First Year group	45.66	36.46	7.26	38.46	46.8	7.0
Diploma Year group	43.06	31.86	7.6	42.13	46.73	10.46

Figure 5.71 shows the results for non-architectural sketch and Figure 5.72 shows the results for architectural sketch

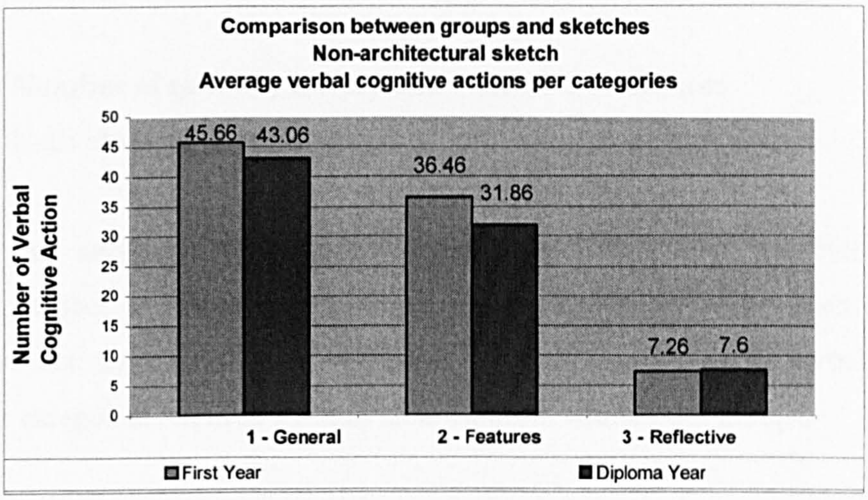


Figure 5.71: Non-Architectural sketch – verbal cognitive actions per categories

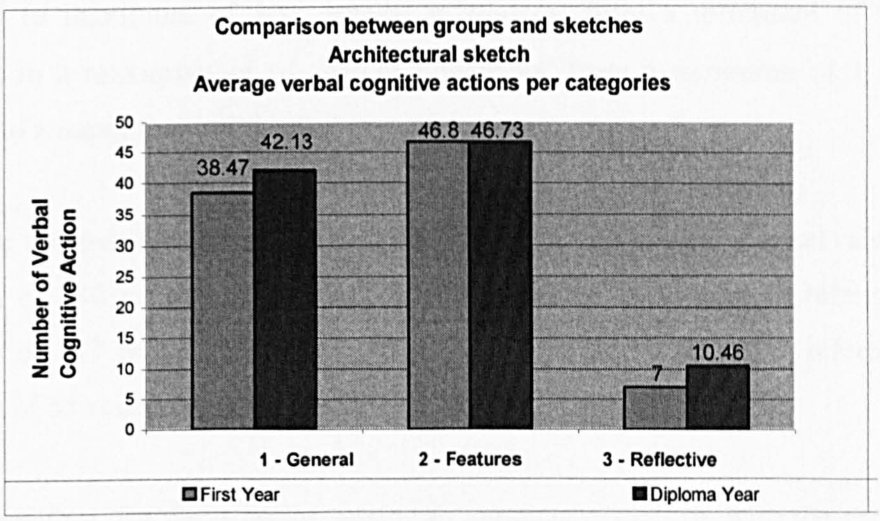


Figure 5.72: Architectural sketch – verbal cognitive actions per categories

The same results were found for both groups and sketches. For the non-architectural sketch both groups used more general references than feature and reflective references. On the other hand, for the architectural sketch they used more features references than general and reflective.

Some differences were also found, but not statistically significant. For the non-architectural sketch, the expert group used less general and feature references and the same number of reflective references than novices. However, these differences are not statistically significant (Ttest general references p=0.80; feature references p=0.49).

For the architectural image the expert group used the same number of symbolic references and more general and reflective references than novices. Again the differences found are not statistically significant (Ttest general references p=0.69; reflective references p=0.38).

3.3.2.3.4 - Number of general, feature and reflective references Individual subject

In this section the number of verbal cognitive actions per categories for individual subject is examined. Although again, the differences between groups on average are not significant, there is a great variation on number of verbal cognitive actions per categories required by individual subjects within both groups.

For the non-architectural sketch this varies from a minimum of 11 general references to maximum of 106 general references; from a minimum of 9 feature references to a maximum of 61 feature references; from a minimum of 1 reflective reference to a maximum of 28 reflective references.

For the architectural sketch it varies from a minimum of 6 general references to maximum of 130 general references; from a minimum of 13 feature references to a maximum of 117 feature references; from a minimum of 0 reflective references to a maximum of 55 reflective references.

Therefore, for these reason again, an alternative analysis with the comparative number of verbal cognitive references for each subject between the two sketches, are used. However, as significant difference for reflective references for both groups was not found, only general and feature references are going to be analysed. The question that arises is how many students required more general or more feature references and for describe which sketch.

Figure 5.73 presents the number of verbal cognitive actions per categories for the whole subject group for non-architectural sketch. Figure 5.74 shows the results for architectural sketch.

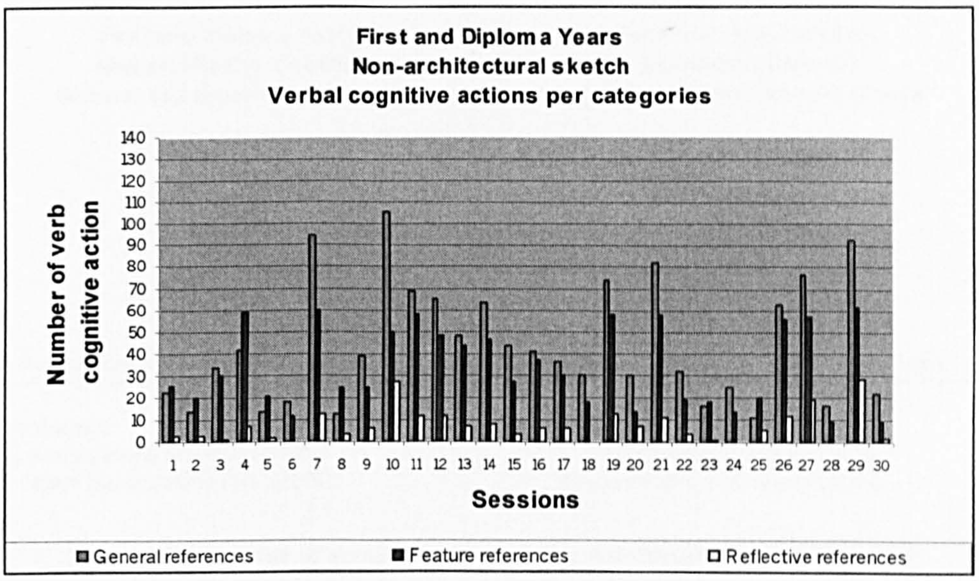


Figure 5.73: Verbal cognitive actions per categories for the whole group for non-architectural sketch.

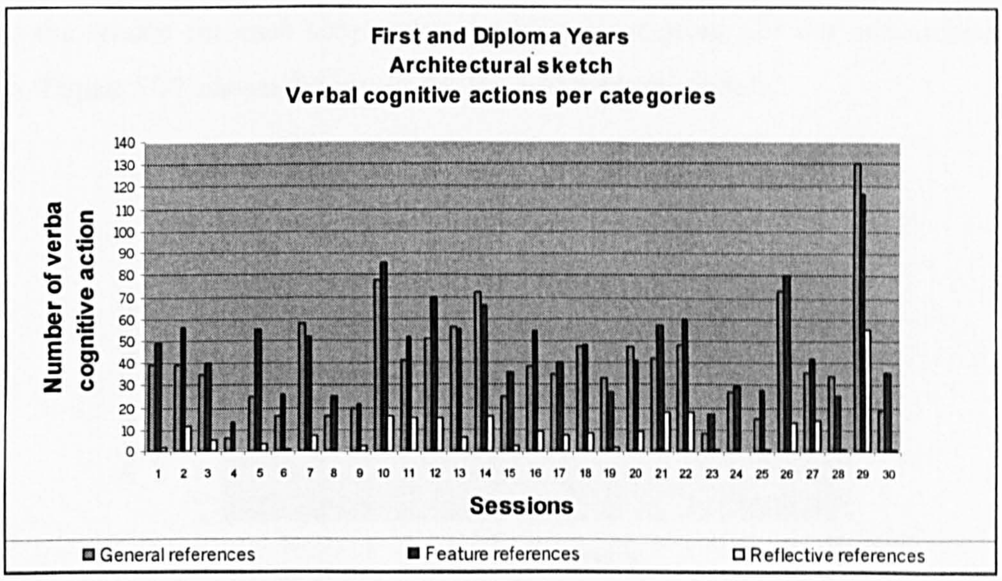
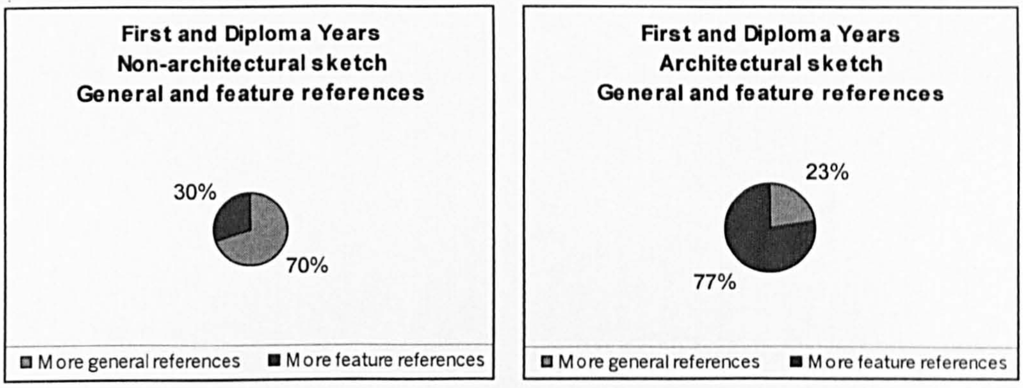


Figure 5.74: Verbal cognitive actions per categories for the whole group for architectural sketch.

According to the results for the non-architectural sketch, the majority of subjects in the whole group used more general than feature references. On the other hand, for the architectural image the majority of students used more feature than general references. Figure 5.75 shows that within the whole group of 30 students, for the non-architectural sketch 21 of them (70%) used more general references and 9 of them (30%) used more feature references. For the architectural sketch only 7 students (23%) used more general references and 23 students (77%) used more feature references. This difference between sketches is statistically significant (Chi-Squared $p=0.001$).



30 students
21 more general references (70%)
9 more feature references (30%)

30 students
7 more general references (40%)
23 more feature references (60%)

Figure 5.75: Number of verbal cognitive actions per categories for both groups.

These results are different for each of the subject groups separately. Figure 5.76 shows the results for each subject for the First Year group for the non-architectural sketch. Figure 5.77 shows the results for the architectural sketch.

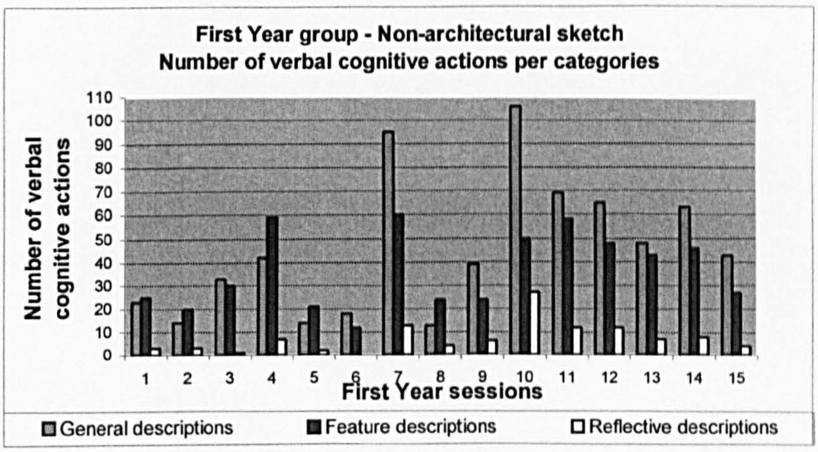


Figure 5.76: The results for First Year group – Non-Architectural sketch

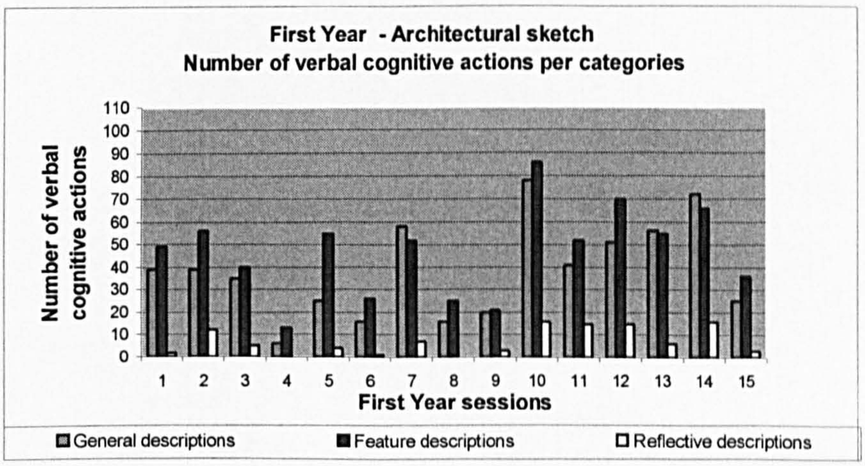


Figure 5.77: The results for First Year group –Architectural sketch

Figure 5.78 shows the results for the First Year group for the non-architectural sketch. Figure 5.79 shows the results for the architectural sketch.

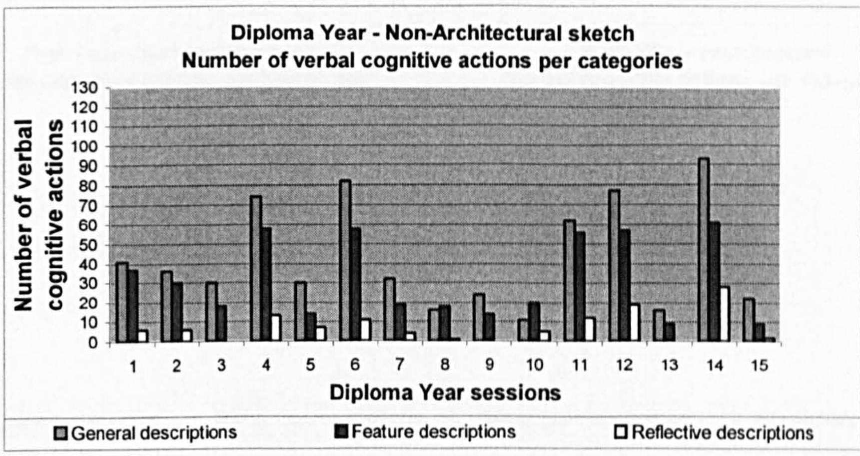


Figure 5.78: The results for Diploma Year group – Non-Architectural sketch

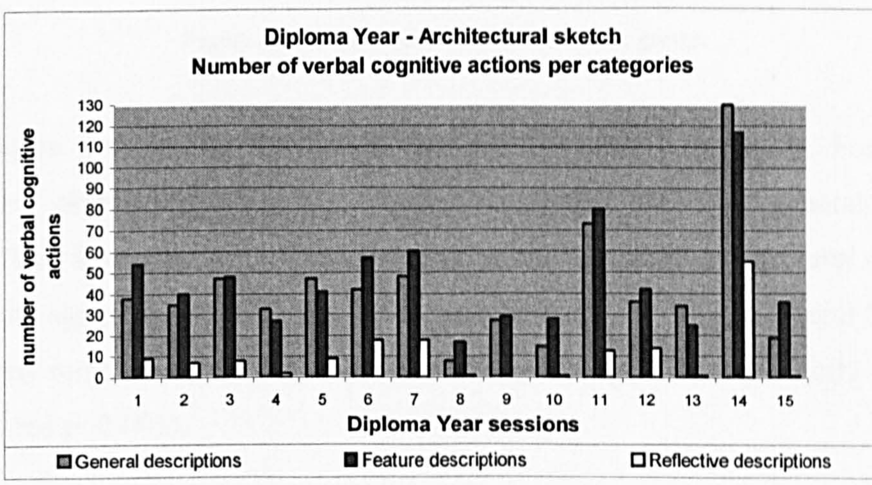
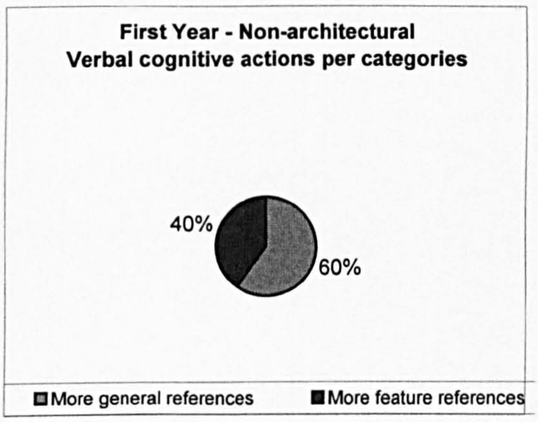


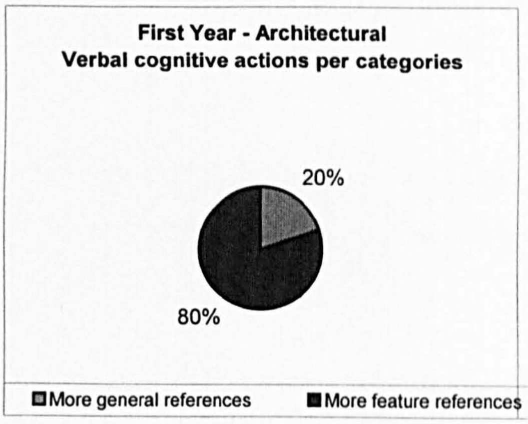
Figure 5.79: The results for the Diploma Year group - Architectural sketch

According to the results, 60% of subjects in the First Year group used more general than feature references for the non-architectural sketch. On the other hand, 80% of them used more feature than general references for the architectural image. The same results were found for the Diploma Year students. The majority of expert students (80%) used more general than feature references for the non-architectural sketch and 73% of them also used more feature than general references for the architectural image.

Figure 5.80 shows the results for the First Year group. For the non-architectural sketch, 9 students (60%) used more general references and 6 of them (40%) used more feature references. The architectural sketch was the opposite, only 3 students (20%) used more general references and 12 students (80%) used more feature references. The difference found is statistically significant (Chi-Squared p=0.001).



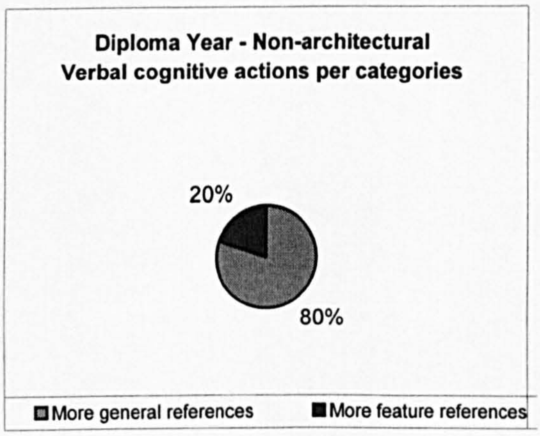
15 students
9 more general references (60%)
6 more feature references (40%)



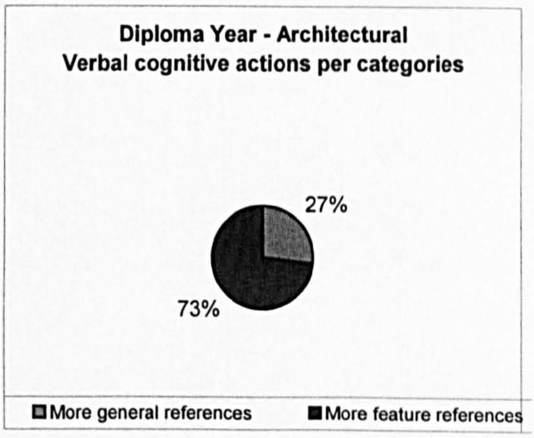
15 students
3 more general references (20%)
12 more feature references (80%)

Figure 5.80: The results for the First Year group.

Figure 5.81 shows the results for the Diploma Year group. For the non-architectural sketch they show that 12 students (80%) used more general references and only 3 of them (20%) used more feature references. The architectural sketch was the opposite again, only 4 students (27%) used more general references and 11 students (73%) used more feature references. The difference again is statistically significant (Chi-Squared p=0.001).



15 students
12 more general references (80%)
3 more feature references (20%)



15 students
4 more general references (27%)
11 more feature references (73%)

Figure 5.81: The results for the First Year group.

Together these findings seem to support the idea that the architectural sketch took longer to be described, required more segments per minute, more verbal cognitive actions per minute and also required more feature references, which involve the use of formal and symbolic descriptions.

3.3.2.4 - Number of formal and symbolic references

The objective of this section is to examine the two specific subcategories of verbal cognitive actions: formal and symbolic references. The question posed is which sketch required more formal or more symbolic references to be described.

The results are presented first by subject groups on average and then by individual subject.

3.3.2.4.1 - Number of formal and symbolic references
First Year group

Table 5.36 presents the results for the number of formal and symbolic references for the First Year group.

Table 5.36: First Year group – Number of formal and symbolic references

First Year group	Non-Architectural sketch		Architectural sketch	
	Formal	Symbolic	Formal	Symbolic
01	9	16	31	18
02	5	15	53	3
03	19	11	37	7
04	36	23	4	9
05	15	6	43	12
06	2	10	18	8
07	32	28	26	26
08	18	6	23	2
09	23	1	21	0
10	38	12	52	34
11	22	36	40	12
12	30	18	56	14
13	25	18	29	26
14	22	24	42	24
15	13	14	13	23
Average	**20.6**	**15.86**	**32.53**	**14.53**

Figure 5.82 shows the average of these results for the same subject group.

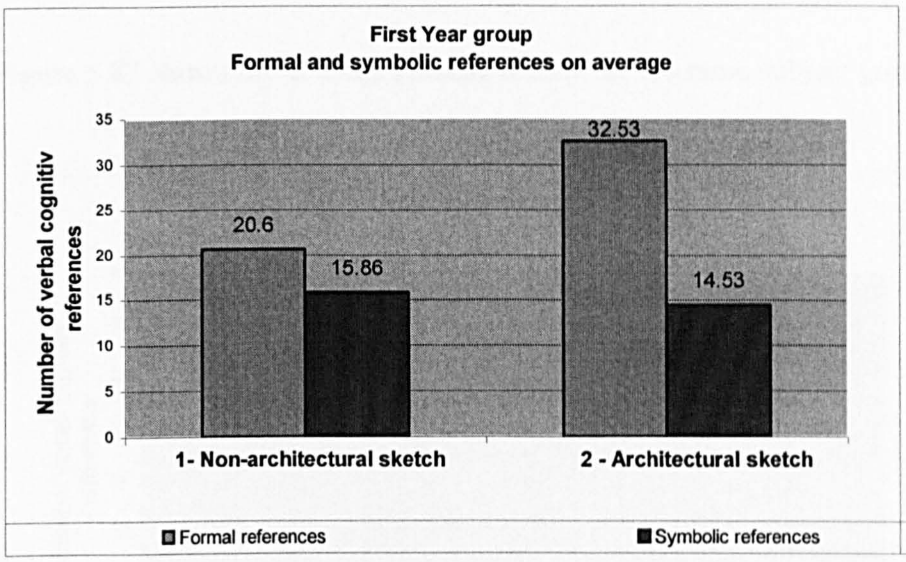


Figure 5.82: The average number of formal and symbolic references for First Year group.

The results show that First Year group used more formal than symbolic references for both types of sketch. For the non-architectural sketch the difference is not statistically significant (Ttest p= 0.20). However, for the architectural sketch the difference found is statistically significant (Ttest p= 0.0009).

3.3.2.4.2 - Number of formal and symbolic references Diploma Year group

Table 5.37 presents the results for the number of formal and symbolic references for the Diploma Year group.

Table 5.37: Diploma Year group – Number of formal and symbolic references

Diploma Year group	Non-Architectural sketch		Architectural sketch	
	Formal	Symbolic	Formal	Symbolic
01	18	19	37	17
02	13	17	33	7
03	12	6	35	13
04	35	23	14	13
05	10	4	30	11
06	33	25	43	14
07	13	6	55	5
08	7	11	10	7
09	11	3	28	1
10	7	13	4	24
11	10	46	58	22
12	32	25	27	15
13	7	2	18	7
14	28	33	41	76
15	6	3	21	15
Average	16.13	15.73	30.26	16.46

Figure 5.83 shows the average of these results for the same subject group.

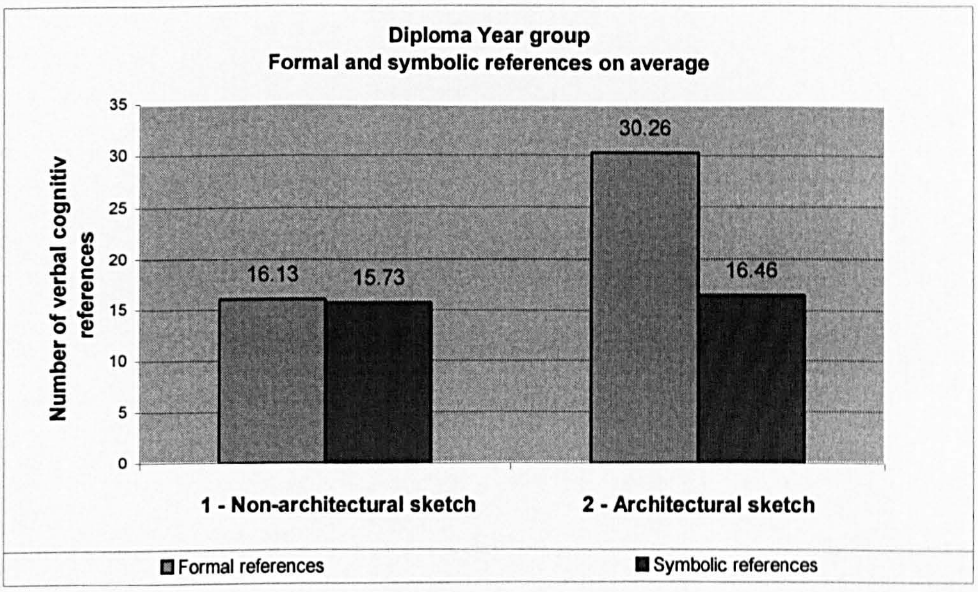


Figure 5.83: The average of formal and symbolic references for Diploma Year group.

The results show that Diploma Year group also used more formal than symbolic references for both types of sketch. For the non-architectural sketch, again the difference is not statistically significant (Ttest p= 0.92). However for architectural sketch the difference found is statistically significant (Ttest p= 0.03).

3.3.2.4.3 - Number of formal and symbolic references Comparison between groups and sketches

From these findings it is possible to compare both groups. Table 5.38 shows the results for number of formal and symbolic references for both groups on average.

Table 5.38 –Formal and symbolic references on average: comparison between groups and sketches

	Non-architectural sketch		Architectural sketch	
	Formal references	**Symbolic references**	**Formal references**	**Symbolic references**
First Year group	20.6	15.86	32.53	14.53
Diploma Year group	16.13	15.73	30.26	16.46

Figure 5.84 shows the results for the non-architectural sketch and Figure 5.85 shows the results for the architectural sketch

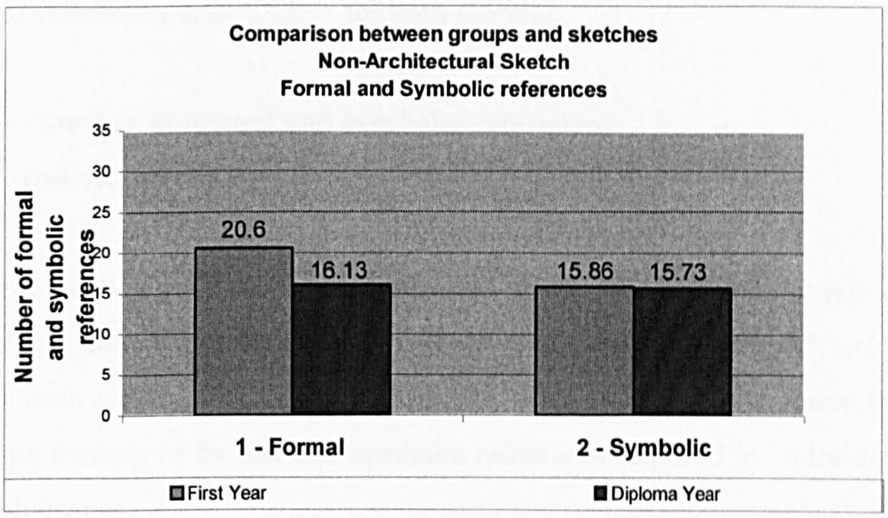


Figure 5.84: Comparison between groups: Non-Architectural sketch – Formal and symbolic references.

The results show that for the non-architectural sketch the expert group used less formal and less symbolic references than novices. However, these differences are not statistically significant (Ttest formal references p=0.25; symbolic references p=0.97).

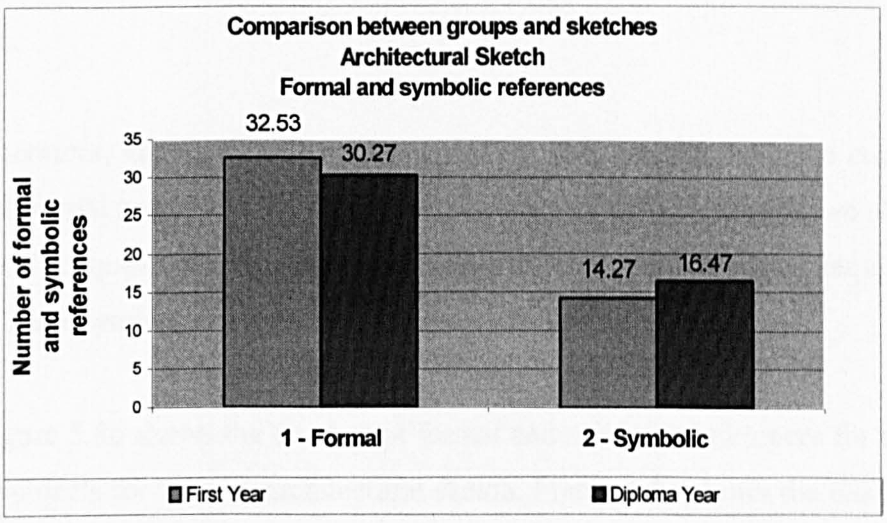


Figure 5.85: Comparison between groups: Architectural sketch - Formal and symbolic references.

The results show that for the architectural image, the expert group used less formal references and more symbolic references than novices. Again these differences found are not statistically significant (Ttest formal references p=0.69; symbolic references p=0.71).

The results also show similarities between groups and sketches. Both groups used more formal than symbolic references for both sketches. The expert group used less formal references than novices for both sketches.

3.3.2.4.4 - Number of formal and symbolic references Individual subject

This section analyses the number of formal and symbolic references for individual subject. The interest is to identify the number of formal and symbolic references each student used for each different image. Again, it was found that a huge variation on number of formal and symbolic references required by individual student within both groups.

For the non-architectural sketch this varies from a minimum of 2 formal references to maximum of 38 formal references and from a minimum of 1 symbolic reference to a maximum of 46 symbolic references. For the architectural sketch it varies from a minimum of 4 formal references to maximum of 58 formal references and from a minimum of 0 symbolic references to a maximum of 76 symbolic references.

Therefore, again, for this reason, an alternative analysis with the comparative number of formal and symbolic references for each subject between the two sketches is presented. The question necessary to be asked is how many students required more formal or more symbolic references and for which sketch.

Figure 5.86 shows the number of formal and symbolic references for the whole group of subjects for the non-architectural sketch. Figure 5.87 shows the results for the architectural sketch.

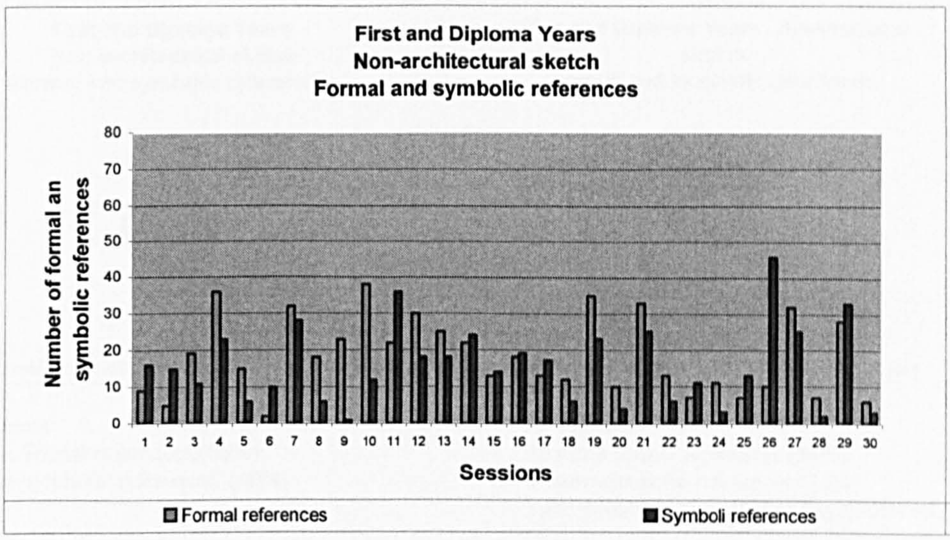


Figure 5.86: Formal and symbolic references for non-architectural sketch.

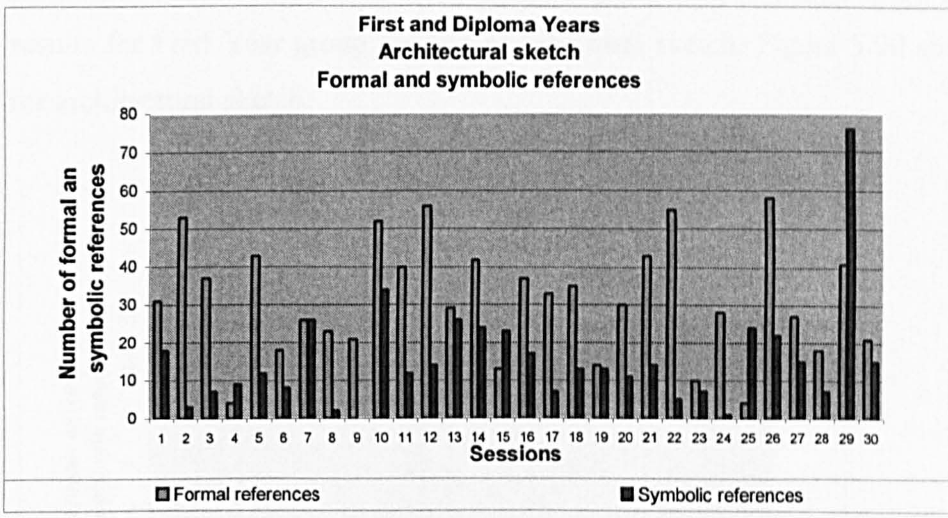
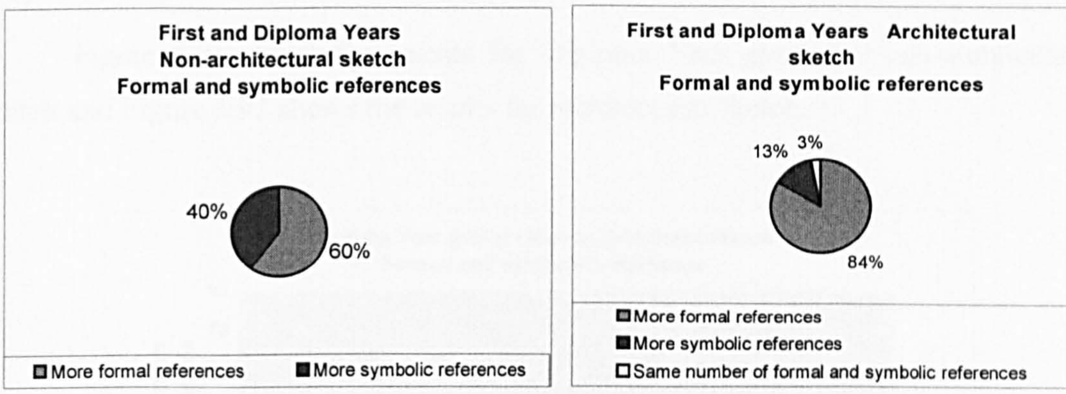


Figure 5.87: Formal and symbolic references for architectural sketch.

According to the results, a majority of 30 students used more formal than symbolic references for both sketches. For the non-architectural sketch, 18 of them (60%) used more formal references and 12 of them (40%) used more symbolic references. For the architectural sketch, 25 students (84%) used more formal references, only 4 students (13%) used more symbolic references and just 1 student (3%) used the same number of formal and symbolic references for both images. Figure 5.88 shows these results.



30 students
18 more formal references (60%)
12 more symbolic references (40%)

30 students
25 more formal references (84%)
4 more symbolic references (13%)
1 same number of formal and symbolic ref (3%)

Figure 5.88: Number of formal and symbolic references for both groups.

These results are true for each of the subject groups separately. Figure 5.89 shows the results for First Year group for non-architectural sketch. Figure 5.90 shows the results for architectural sketch.

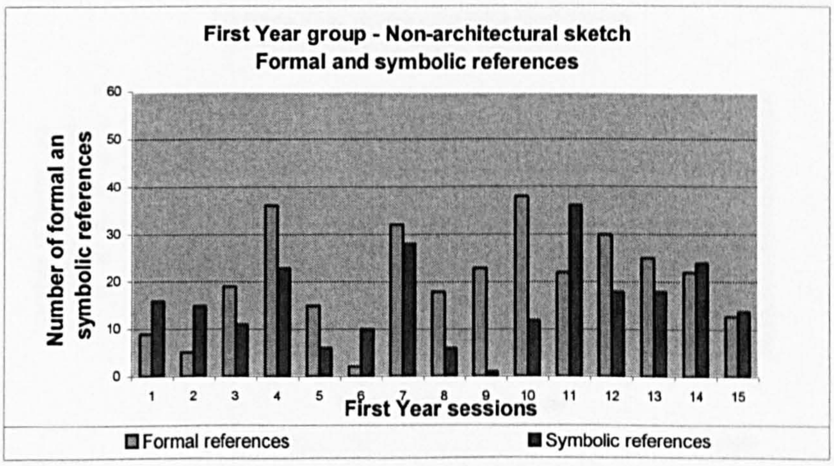


Figure 5.89: Formal and symbolic references for First Year group for non-architectural sketch.

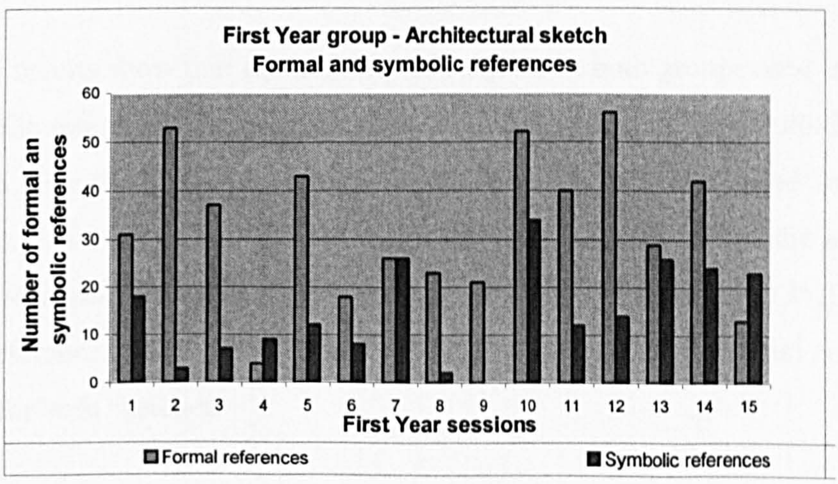


Figure 5.90: Formal and symbolic references for First Year group for architectural sketch.

Figure 5.91 shows the results for Diploma Year group for non-architectural sketch and Figure 5.92 shows the results for architectural sketch.

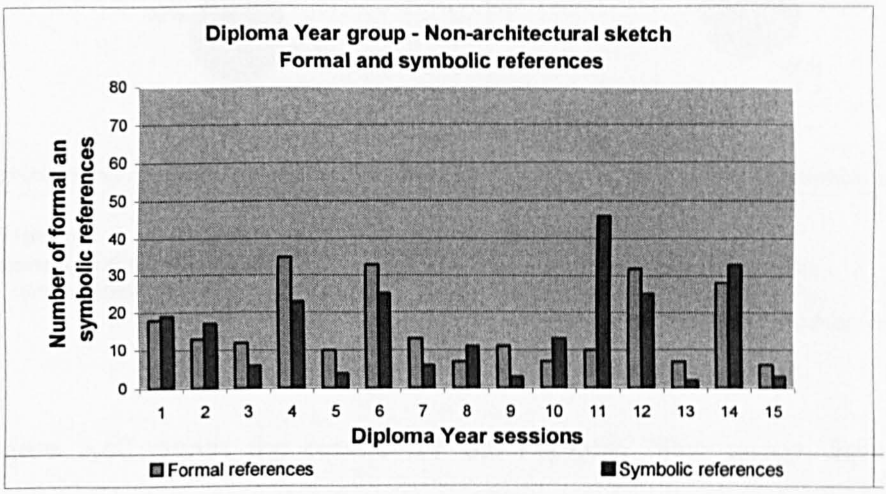


Figure 5.91: Formal and symbolic references for Diploma Year group for non-architectural sketch.

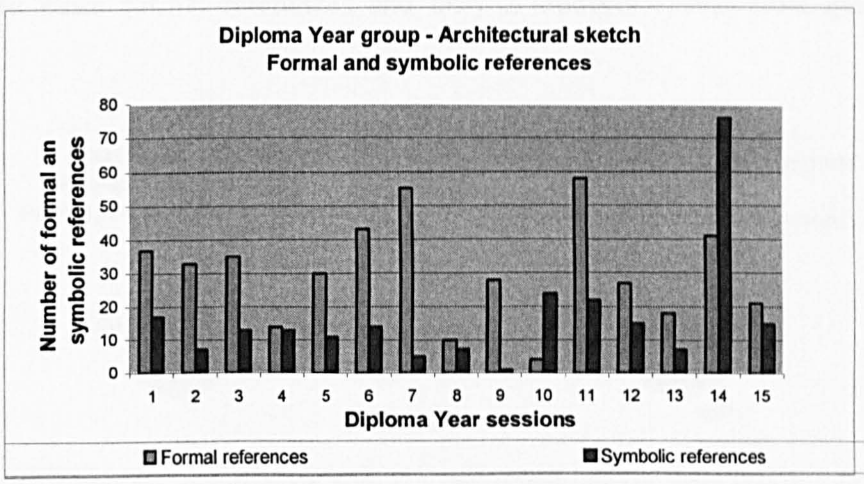
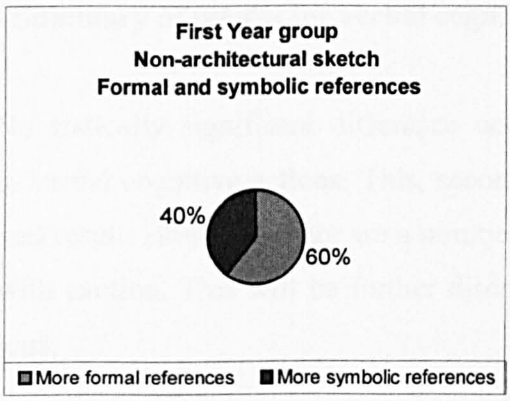
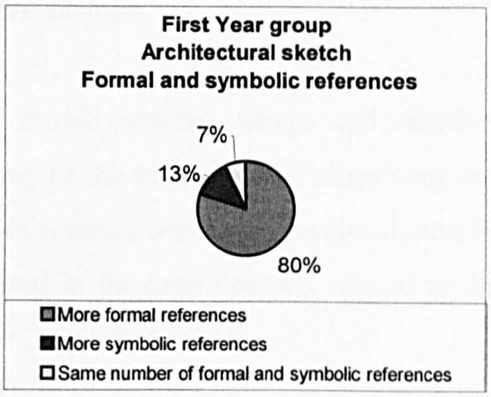


Figure 5.92: Formal and symbolic references for Diploma Year group for architectural sketch.

The results show that the majority of subjects in both groups used more formal than symbolic references for both sketches. Figure 5.93 shows the results for the First Year group. For the non-architectural sketch, 9 students (60%) used more formal references and 6 of them (40%) used more symbolic references. For the architectural sketch, 12 students (80%) used more formal references, 2 students (13%) used more symbolic references and 1 (7%) student used the same number of formal and symbolic references for both sketches.



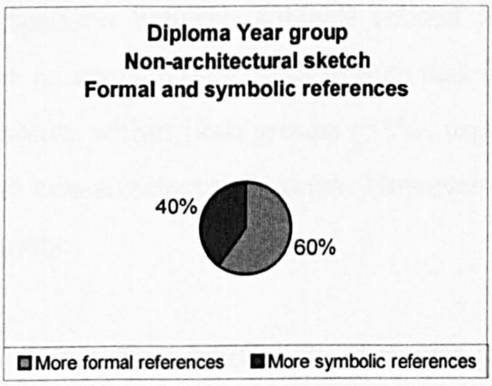


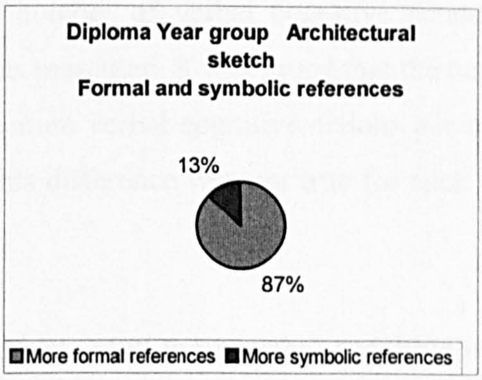
15 students
9 more formal references (60%)
6 more symbolic references (40%)

15 students
12 more formal references (80%)
2 more symbolic references (13%)
1 same number of formal and symbolic references

Figure 5.93 shows the results for First Year group.

Figure 5.60 shows the results for the Diploma Year group. For the non-architectural sketch they show that 9 students (60%) used more formal references and 6 of them (40%) used more feature references. For the architectural sketch, 13 students (87%) used more formal references and only 2 students (13%) used more feature references.





15 students
9 more formal references (60%)
6 more symbolic references (40%)

15 students
13 more formal references (87%)
2 more symbolic references (13%)

Figure 5.94 shows the results for Diploma Year group.

The results indicate that the majority of students within both groups used more formal references for both sketches. They used more formal references for the architectural image and more symbolic references for the non-architectural image.

This suggests that the architectural sketch appears to require more formal references to be described. On the other hand, the non-architectural sketch seems to allow more symbolic references.

3.3.2.5 - Summary of results for verbal cognitive actions

No statically significant difference was found between groups and sketches related to verbal cognitive actions. This, according to the author, was a surprising and unexpected result. However, there are a number of reasons why these results should be treated with caution. This will be further discussed in the next chapter, related to the conclusions.

Although not statistically significant difference when analysed separately, taken together, the results could suggest a general picture about groups and sketches. Both groups of students used more verbal cognitive actions on average for the architectural sketch than for the non-architectural one. The expert group used more verbal cognitive actions per minute on average for both sketches than the novice group. For the non-architectural sketch the difference found is not statistically significant but for the architectural one it is.

Again, a great variation between individual subjects was found. For this reason a comparison between subjects related to number of verbal cognitive actions per minute on average they taken in each task was presented. It was found that the majority of students within both groups (53%) used more verbal cognitive actions per minute for the non-architectural sketch. However this difference was not true for each group separately.

It was found that 67% of novice students used more verbal cognitive actions per minute for the non-architectural sketch and 60% of expert students used more verbal cognitive actions per minute for the architectural sketch.

A comparison between subjects related to formal and symbolic references was also presented. It was found that the majority of students within both groups used more formal than symbolic references for both sketches. This difference was also true for each group separately and greater for the architectural image.

Summarizing, the expert architecture students used on average more number of segments per minute and more number of verbal cognitive actions per minute than the novices for both sketches. These results seem to support previous studies about novices/expert designers (Goldschmidt 1994; Suwa 1997; Gero 1998; Suwa 1998; Kavakli 2002).

3.3.3 – Easy and hard to describe

During the review task in the end of each session, the subjects were asked to identify the easier and the harder sketch to describe and to justify their answer. Although the architectural sketch seemed to be denser to description and requested more time, more segments and more verbal cognition actions, some subjects pointed it as the easier one.

Table 5.39 shows the results for the First Year group for the easier/harder sketch to describe and the reasons. Table 5.40 shows the results for the Diploma Year group.

Table 5.39: First Year group – Easier and harder sketch to describe

	Non-Architectural	Architectural	Reasons
First Year 01	Hard	Easy	Looks like a room, easy to describe
First Year 02	Easy	Hard	Easy to associate with pictures, ponds
First Year 03	x	x	-
First Year 04	Easy	Hard	Much more difficult, more confusing
First Year 05	x	x	-
First Year 06	Easy	Hard	Can relate to something. Like a picture, sun, ponds
First Year 07	Easy	Hard	Hard to describe but easy to remember
First Year 08	x	x	-
First Year 09	Easy	Hard	Both quite hard but non-architectural easier to describe
First Year 10	Hard	Easy	Easy to work with proportions
First Year 11	Hard	Easy	Easy more geometric things
First Year 12	x	x	-
First Year 13	x	X	-
First Year 14	x	x	-
First Year 15	Easy	Hard	Easy to say where the things are

Table 5.40: First Year group – Easier and harder sketch to describe

	Non-Architectural	Architectural	Reasons
Diploma Year 01	Hard	Easy	Easier to describe the floor plan than the abstract image
Diploma Year 02	Easy	Hard	More simple. The objects look like objects. Turd shape
Diploma Year 03	Easy	Hard	Representing things as golf flags, sun.
Diploma Year 04	Hard	Easy	Easy look like corridor, plan.
Diploma Year 05	Easy	Hard	Very simple picture
Diploma Year 06	Easy	Hard	I know what a sausage looks like
Diploma Year 07	Easy	Hard	Much easier. Simple.
Diploma Year 08	Hard	Easy	Make sense to me and I can remember what I said
Diploma Year 09	Hard	Easy	Much easier to describe
Diploma Year 10	Easy	Hard	Simple, easier to describe
Diploma Year 11	x	x	-
Diploma Year 12	Hard	Easy	Easy to relate with lift, stair.
Diploma Year 13	Easy	Hard	Less confusing
Diploma Year 14	x	x	-
Diploma Year 15	Hard	Easy	Look like a plan. Easy to relate with each other

The results show that for the First Year group, 6 students (40%) pointed the non-architectural sketch as the easier, 3 students (20%) pointed the architectural one as the easier and 6 students (40%) did not answer the question. On the other hand, for the Diploma Year group, 7 students (47%) pointed the non-architectural sketch as the easier, 6 students (40%) pointed the architectural one as the easier and only 2 students (13%) did not answer the question.

Figure 5.95 shows the results for both year groups.

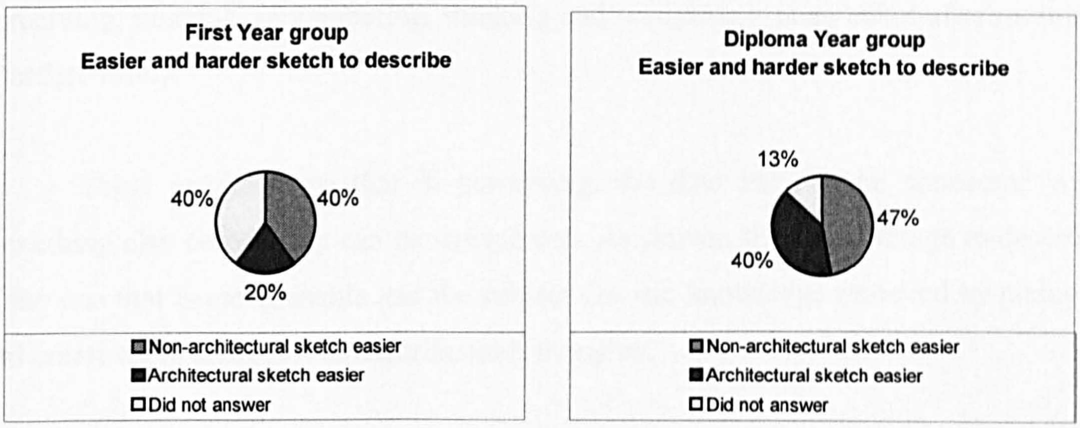


Figure 5.95: Easier/ harder sketch to describe for both groups.

The results show that both subject groups found the non-architectural sketch easier to describe. The results also show that the experts' option for the architectural sketch as the easiest one was two times larger than the novice's option.

According to these results, the easier sketch to describe is always the one that has meaning and subjects can create analogies to describe the thoughts. It appears to be confirmed by some answers given to explain the options: 'easier to associate with pictures, pound, tick, sun'; 'hard, no reference to me, no sense'; 'easy to related to some thing'; 'hard, more abstract'; 'easier, geometric things'.

3.4 – Conclusions related to verbal data

The most immediately feature of these results is the enormous variety in responses and it was expected in this type of experiment. This work supports Bartlett and suggests that uniformity and simplicity of stimuli are no guarantee of uniformity and simplicity in response, particularly at the human level (Bartlett 1950). There is no doubt that the same stimuli are different for each subject, and obviously the records made in recall are different also.

Sometimes, in this experiment, a sketch was presented and the subject reports much more than was there. It seems that subject fills the gaps of his/her perception by the aid of what he/she has experienced before. It appears to be supported by Bartlett when suggesting that a great amount of what goes under the name of perception is, in fact, recall (Bartlett 1950). According to Bartlett, every human cognitive reaction – perceiving, imaging, remembering, thinking and reasoning – is an effort after meaning (Bartlett 1950).

These results show that in perceiving, the data have to be connected with something else before they can be assimilated. As shown, the easier image to describe is the one that is recognisable and the subject can use knowledge retrieved by memory and create more analogies to describe their thoughts.

The experiment shows that the common method of a subject is to respond to whatever is presented as unitary. Names were commonly used with very simple images and occupied a position of greater importance during the descriptions. The names, in many cases, determined what was perceived. This again seems to be supported by Bartlett (Bartlett 1950; Bartlett 1958).

The results show that, to complete the same tasks, expert architecture students used more segments per minute, more verbal cognitive actions per minute and also requiring less time than novice architecture students. These findings appear to be in agreement with others researches (Goldschmidt 1994; Suwa 1997; Gero 1998; Suwa 1998; Kavakli 2002) and suggest the mental imagery condition, not the drawing condition, as the greater benefit to designers related to the non-designers.

4 – THE ANALYSIS OF THE DRAWINGS

This fourth part of the chapter is dedicated to the analysis of the drawings produced during the experiment. There are two types of drawings: Drawings made during the description tasks (Annex VI) and drawings made during the remembering task (Annex VII). Because of the focus of the research only those drawings made during the description tasks are analysed.

There are sixty drawings, where thirty are related to the non-architectural sketch and thirty to the architectural one. Initially, 7 referees were asked to rank these drawings. All referees are architects and staff from the School of Architecture at The University of Sheffield.

Firstly, the referees were asked to compare the drawings with the two original sketches and separate them into four groups: A, B, C and D with approximately the same number of drawings in each one. Group A contains the most accurate drawings and group D contains those less accurate. By accurate drawings this research means those drawings that better reproduced the original one.

Secondly, the referees were asked to organize the drawings inside each group from the best (A1, B1, C1 and D1) to the worst (A8, B7, C7, D8). The referees did not have a time limit to complete the tasks and they were free to modify their ideas until they were sure about them.

A statistically high level of concordance between referees was found (Kendall Coefficient of Concordance for non-architectural sketch $w=0.80$ and architectural sketch $w=0.74$). Therefore, all the analysis is based on the results of the average referees ranking.

The first section presents the ranks from the referees. The second section presents the average of these ranks for each sketch. The third section presents the standard deviation of these ranks for each sketch. The fourth section compares the ranks for the first and second descriptions for each subject within both groups. The fifth section only examines the descriptions better ranked and the sixth and last section presents the summary of the results.

4.1 –Rank per type of sketch

Table 5.41hows the final ranks per type of sketch.

Table 5.41Rank for both sketches

F=First Year; D=Diploma Year. The numbers represents the sessions.

Non-architectural sketch								
Referees		1	2	3	4	5	6	7
Group A	01	D6	D12	D6	D6	D6	D6	D6
	02	D7	F11	F2	D14	D14	D7	F11
	03	D11	D6	F7	D4	D11	D12	D4
	04	F11	D7	F11	D7	F9	D14	F9
	05	D12	F10	D12	F10	F7	D4	D15
	06	F10	F7	D11	D2	D12	F10	D11
	07	F7	F9	D14	D12	F11	D11	F2
Group B	08	D4	D14	D7	F14	D2	F7	D13
	09	F9	D15	F9	F11	D15	F14	D10
	10	F5	F2	D13	D11	D13	D2	D12
	11	D14	D2	D15	F2	D4	F9	D1
	12	D2	F8	F10	F7	F2	F11	D7
	13	D1	F5	D2	F3	D7	F2	F10
Group C	14	D13	D10	D4	D13	F10	D15	F7
	15	D15	F3	F14	F9	F14	F8	D2
	16	D10	D11	D8	D15	D1	D1	D8
	17	F6	D1	D9	F5	F3	D10	D14
	18	F8	D4	F13	F15	F8	D8	F3
	19	F2	F6	D10	D1	D9	D13	F4
	20	F14	D9	F3	F8	D8	F5	F12
Group D	21	F1	D13	F6	D10	D10	F6	F14
	22	D9	F14	F5	F6	F4	D5	F5
	23	D8	F4	D1	D8	F5	F15	D5
	24	F13	D5	F8	F4	F15	F4	D3
	25	F4	D8	F4	D5	F6	F3	F13
	26	D5	F13	D5	F12	F13	D3	F15
	27	F15	D3	F12	F13	D5	F12	F8
	28	D3	F15	D3	D3	F12	D9	F6
	29	F12	F12	F15	D9	D3	F13	D9
	30	F3	F1	F1	F1	F1	F1	F1

Architectural sketch								
Referees		1	2	3	4	5	6	7
	01	F10	F1	D14	D14	D13	F10	F15
	02	F15	F10	F11	F9	F10	D2	F1
	03	F11	D14	D11	F11	F15	F1	D6
	04	F9	D2	F14	F1	D14	F11	D14
	05	F1	D3	D2	F10	F1	F9	F9
	06	D14	F15	F15	F15	D2	F15	F7
	07	D2	D13	F10	D2	F9	D7	F10
	08	D13	F11	D12	D12	F11	D13	D15
	09	D10	D6	F1	D13	D3	D6	D13
	10	D3	D7	F7	D11	D7	D11	D2
	11	D15	F9	D5	D6	D6	D14	D7
	12	F14	D15	F9	D7	F14	D3	D10
	13	F7	F12	D3	F7	D11	D15	D4
	14	F6	D5	D13	D5	D15	D1	F11
	15	F2	D8	D6	F14	F12	D4	D12
	16	D12	D1	D15	D3	F6	D9	D11
	17	D7	D10	D7	F13	D12	F4	D3
	18	D1	D12	F5	D9	D4	F2	F2
	19	D6	F14	D9	D10	D10	D12	D1
	20	D4	F5	D1	D15	D8	F6	F14
	21	F8	F7	F12	D1	F5	F14	F12
	22	F13	F2	D10	F2	F7	F3	D5
	23	F4	D11	D8	D4	D1	F8	F5
	24	D8	F8	F6	F5	D5	F12	D8
	25	F3	F6	F8	F8	D9	F7	F13
	26	F5	F3	F3	F12	F8	F5	D9
	27	D5	F13	F2	F6	F3	D8	F4
	28	D9	D9	D4	D8	F2	D5	F8
	29	F12	F4	F4	F3	F4	D10	F6
	30	D11	D4	F13	F4	F13	F13	F3

Before this study goes further in this analysis, it seems to be useful verify the level of agreement between referees. The Kendall Coefficient of Concordance test can be used for this purpose. A summary of the test is presented.

X= sum of square of differences,
Y= N x (N^2-1) / 12 where N is the number of drawings
Kendall's coefficient of concordance W = X/Y

1 - Non-Architectural Sketch
X = 1808.26
Y = 30 x (900-1) / 12
Y = 2247.5
Kendall's coefficient
W = X/Y
W = 1808.26 / 2247.5
W = 0.80

2 - Architectural Sketch
X = 1661.08
Y = 30 x (900-1) / 12
Y = 2247.5
Kendall's coefficient
W = X/Y
W = 1661.08 / 2247.5
W = 0.74

The results show that the referees present a high level of concordance for both sketches. The results also show that referees have a slightly higher level of concordance for the non-architectural sketch than for the architectural one.

4.2 – Average of ranks per type of sketch

Based on the results from the referees, each drawing has 7 different ranks. In this section the average of these ranks will be examine. The question posed is which sketch got a better rank on average.

4.2.1 - Average of ranks per type of sketch

First Year group

Table 5.42 shows the average for the non-architectural sketch and Table 5.43 shows the results for the architectural sketch.

Table 5.42: FIRST YEAR group - Average of ranks - Non-architectural sketch

	1	2	3	4	5	6	7	Average	AVERAGE
F1	21	30	30	30	30	30	30	28.71	17.61
F2	19	10	02	11	12	13	07	10.57	
F3	30	15	20	13	17	25	18	19.71	
F4	25	23	25	24	22	24	19	23.14	
F5	10	13	22	17	23	20	22	18.14	
F6	17	19	21	22	25	21	28	21.85	
F7	07	06	03	12	05	08	14	7.85	
F8	18	12	24	20	18	15	27	19.14	
F9	09	07	09	15	04	11	04	8.42	
F10	06	05	12	05	14	06	13	8.71	
F11	04	02	04	09	07	12	02	5.71	
F12	29	29	27	26	28	27	20	26.57	
F13	24	26	18	27	26	29	25	25	
F14	20	22	15	08	15	09	21	15.71	
F15	27	28	29	18	24	23	26	25	

Table 5.43: FIRST YEAR - Average of ranks - Architectural sketch

	1	2	3	4	5	6	7	Average	AVERAGE
F1	05	01	09	04	05	03	02	4.14	16.37
F2	15	22	27	22	28	18	18	21.42	
F3	25	26	26	29	27	22	30	26.42	
F4	23	29	29	30	29	17	27	26.28	
F5	26	20	18	24	21	26	23	22.57	
F6	14	25	24	27	16	20	29	22.14	
F7	13	21	10	13	22	25	06	15.71	
F8	21	24	25	25	26	23	28	24.57	
F9	04	11	12	02	07	05	05	6.57	
F10	01	02	07	05	02	01	07	3.571	
F11	03	08	02	03	08	04	14	6	
F12	29	13	21	26	15	24	21	21.28	
F13	22	27	30	17	30	30	25	25.85	
F14	12	19	04	15	12	21	20	14.71	
F15	02	06	06	06	03	06	01	4.28	

Figure 5.96 shows the results for the First Year group.

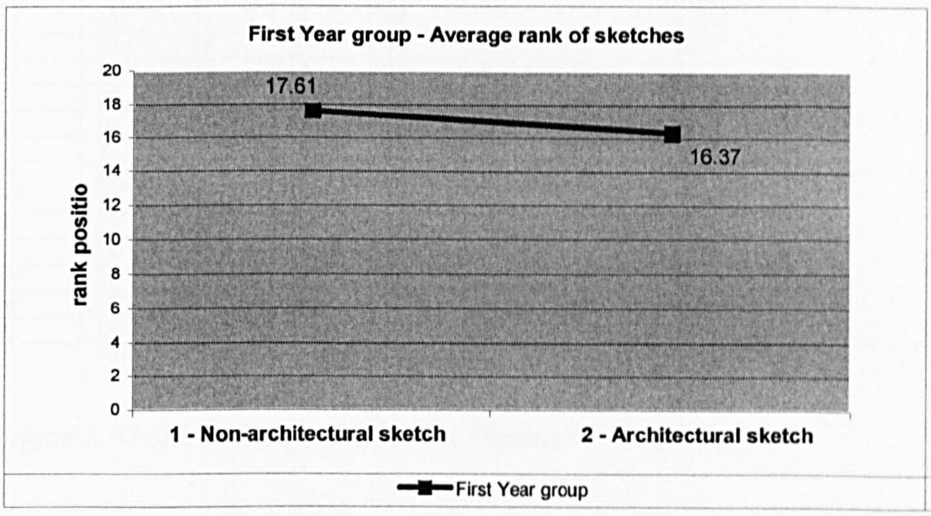


Figure 5.96: The results for average of ranks for the first Year group.

The results show that the First Year group got a better rank on average for the architectural sketch than for the non-architectural one. However this difference found is not statistically significant (Ttest p=0.68).

4.2.2 - Average of ranks per type of sketch

Diploma Year group

Table 5.44 shows the average for the non-architectural sketch and Table 5.45 shows the results for the architectural sketch.

Table 5.44: DILOMA YEAR group - Average of ranks - Non-Architectural sketches

	1	2	3	4	5	6	7	Average	AVERAGE
D1	13	17	23	19	16	16	11	**16.42**	**13.38**
D2	12	11	13	06	08	10	15	**10.71**	
D3	28	27	28	28	29	26	24	**27.14**	
D4	08	18	14	03	11	05	03	**8.85**	
D5	26	24	26	25	27	22	23	**24.71**	
D6	01	03	01	01	01	01	01	**1.28**	
D7	02	04	08	04	13	02	12	**6.42**	
D8	23	25	16	23	20	18	16	**20.14**	
D9	22	20	17	29	19	28	29	**23.42**	
D10	16	14	19	21	21	17	09	**16.71**	
D11	03	16	06	10	03	07	06	**7.28**	
D12	05	01	05	07	06	03	10	**5.28**	
D13	14	21	10	14	10	19	08	**13.71**	
D14	11	08	07	02	02	04	17	**7.28**	
D15	15	09	11	16	09	14	05	**11.28**	

Table 5.45: DIPLOMA YEAR group - Average of ranks - Architectural sketch

	1	2	3	4	5	6	7	Means	MEAN
D 1	18	16	20	21	23	14	19	18.71	14.62
D 2	07	04	05	07	06	02	10	5.85	
D 3	10	05	13	16	09	12	17	11.71	
D 4	20	30	28	23	18	15	13	21	
D 5	27	14	11	14	24	28	22	20	
D 6	19	09	15	11	11	09	03	11	
D 7	17	10	17	12	10	07	11	12	
D 8	24	15	23	28	20	27	24	23	
D 9	28	28	19	18	25	16	26	22.85	
D10	09	17	22	19	19	29	12	18.14	
D11	30	23	03	10	13	10	16	15	
D12	16	18	08	08	17	19	15	14.42	
D13	08	07	14	09	01	08	09	8	
D14	06	03	01	01	04	11	04	4.28	
D15	11	12	16	20	14	13	08	13.42	

Figure 5.97 shows the results for the Diploma Year group.

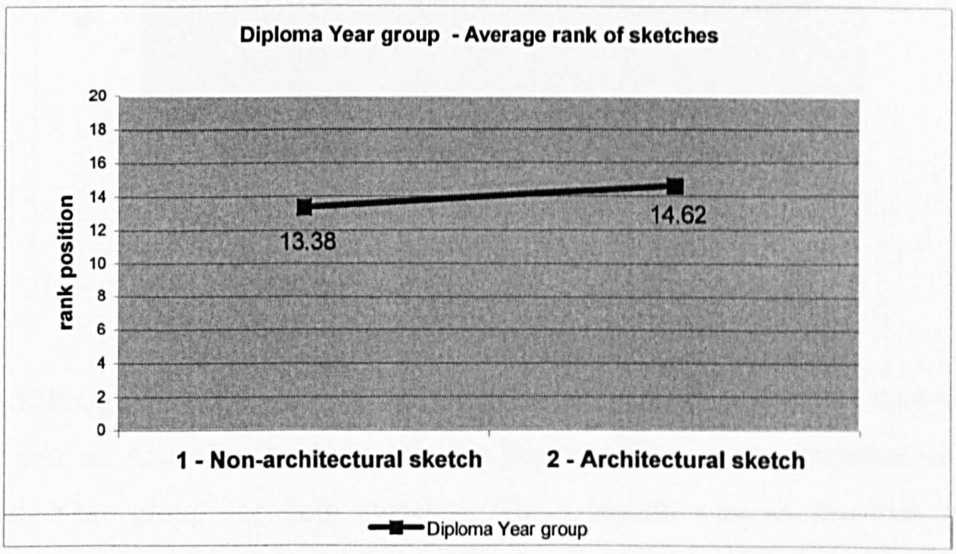


Figure 5.97: The results for average of ranks for the first Year group.

The results show that the Diploma Year group got a better rank for the non-architectural sketch than for the architectural one. However, again, this difference found is not statistically significant (Ttest p=0.62).

4.2.3 - Average of ranks per type of sketch

Comparison between groups and sketches

These results allowed a comparison between groups and sketches. Table 5.46 shows the average of the ranks for both groups.

Table 5.46: Summary of results – Average of ranks per sketch

	Non-architectural sketch Average of ranks	Architectural sketch Average of ranks
First Year group	17.61	16.37
Diploma Year group	13.38	14.62

Figure 5.98 shows the results for both groups.

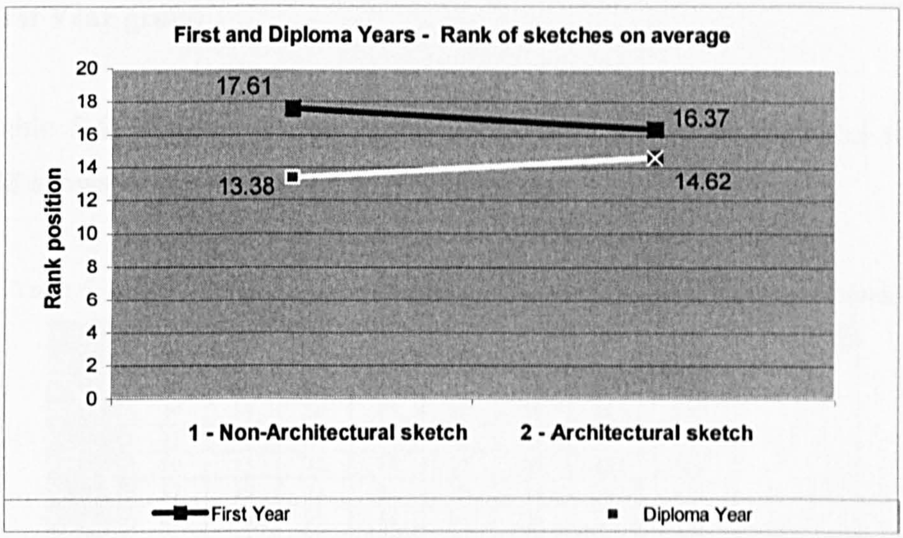


Figure 5.98: Rank of sketches on average for both groups

Although the results are not statistically significant, taken together they present a general pattern. According to the results, the Diploma Year group got better ranks than the First Year group for both sketches. These results support previous research comparing expert and novice designers (Suwa and Twersky 1997; Suwa, Purcell and Gero 1998; Gero and McNeill 1998; Goldschmidt, G. 1994).

These better ranks for Diploma Year students could be associated with the early findings of this work, where these students used more segments per minute and more verbal cognitive actions per minute than novice students to describe the same images.

However, the results also present an unexpected finding. They show that Diploma Year students got a slightly better rank for the non-architectural sketch and First Year students got a slightly better rank for the architectural one. It was considered unexpected as the opposite was expected. This will be further commented in the next chapter, related to the conclusions.

4.3 - Standard deviation of ranks per type of sketch

In this section the standard deviation of ranks are examined. The question here is which sketch presents a larger deviation.

4.3.1 - Standard deviation of ranks per type of sketch
First Year group

Table 5.47 shows the standard deviation for the non-architectural sketch and Table 5.48 shows the results for the architectural sketch.

Table 5.47: FIRST YEAR group – Standard deviation of ranks - Non-architectural sketch

	1	2	3	4	5	6	7	SD	SD
F 1	21	30	30	30	30	30	30	3.40	1.04
F 2	19	10	02	11	12	13	07	5.25	
F 3	30	15	20	13	17	25	18	5.93	
F 4	25	23	25	24	22	24	19	2.11	
F 5	10	13	22	17	23	20	22	5.01	
F 6	17	19	21	22	25	21	28	3.67	
F 7	07	06	03	12	05	08	14	3.89	
F 8	18	12	24	20	18	15	27	5.11	
F 9	09	07	09	15	04	11	04	3.90	
F10	06	05	12	05	14	06	13	4.07	
F11	04	02	04	09	07	12	02	3.77	
F12	29	29	27	26	28	27	20	3.10	
F13	24	26	18	27	26	29	25	3.46	
F14	20	22	15	08	15	09	21	5.64	
F15	27	28	29	18	24	23	26	3.74	

Table 5.48: FIRST YEAR group – Standard deviation of ranks - Architectural sketch

	1	2	3	4	5	6	7	SD	SD
F 1	5	1	9	4	05	03	02	2.60	1.54
F 2	15	22	27	22	28	18	18	4.82	
F 3	25	26	26	29	27	22	30	2.63	
F 4	23	29	29	30	29	17	27	4.71	
F 5	26	20	18	24	21	26	23	3.04	
F 6	14	25	24	27	16	20	29	5.63	
F 7	13	21	10	13	22	25	06	7.01	
F 8	21	24	25	25	26	23	28	2.22	
F 9	4	11	12	2	07	05	05	3.69	
F10	1	2	7	5	02	01	07	2.69	
F11	3	8	2	3	08	04	14	4.28	
F12	29	13	21	26	15	24	21	5.73	
F13	22	27	30	17	30	30	25	4.94	
F14	12	19	4	15	12	21	20	5.99	
F15	2	6	6	6	03	06	01	2.21	

Figure 5.99 shows the results for the First Year group.

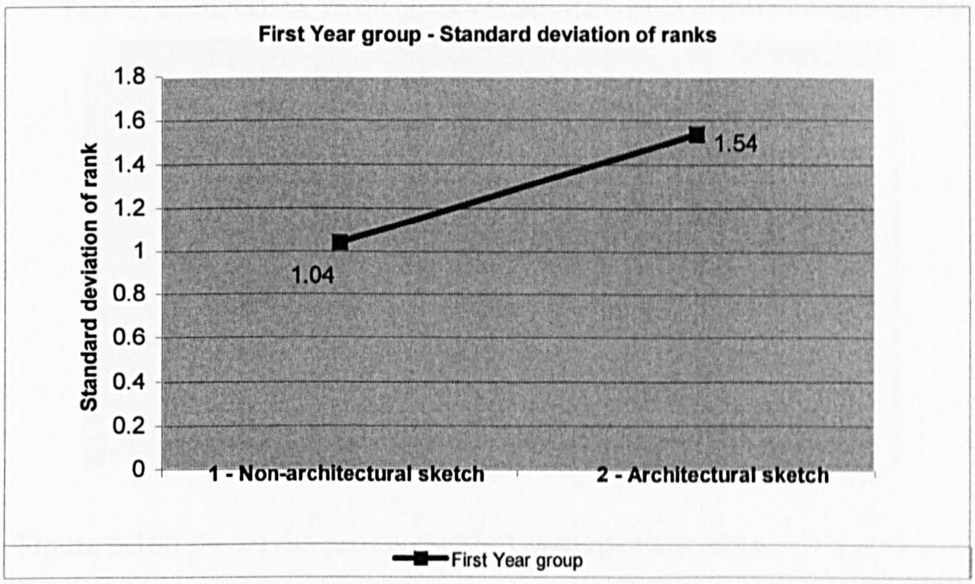


Figure 5.99: The results for standard deviation of ranks for the First Year group.

The results show that the First Year group got a larger deviation for the architectural sketch than for the non-architectural one. However, this difference found is not statistically significant (Ttest p=0.98).

4.3.2 - Standard deviation of ranks per type of sketch

Diploma Year group

Table 5.49 shows the standard deviation for the non-architectural sketch and Table 5.50 shows the results for the architectural sketch.

Table 5.49: DIPLOMA YEAR group– Standard deviation of ranks - Non-architectural sketch

	1	2	3	4	5	6	7	SD	SD
D 1	13	17	23	19	16	16	11	3.90	1.46
D 2	12	11	13	06	08	10	15	3.03	
D 3	28	27	28	28	29	26	24	1.67	
D 4	08	18	14	03	11	05	03	5.75	
D 5	26	24	26	25	27	22	23	1.79	
D 6	01	03	01	01	01	01	01	0.75	
D 7	02	04	08	04	13	02	12	4.61	
D 8	23	25	16	23	20	18	16	3.62	
D 9	22	20	17	29	19	28	29	5.12	
D10	16	14	19	21	21	17	09	4.27	
D11	03	16	06	10	03	07	06	4.53	
D12	05	01	05	07	06	03	10	2.87	
D13	14	21	10	14	10	19	08	4.85	
D14	11	08	07	02	02	04	17	5.40	
D15	15	09	11	16	09	14	05	3.94	

Table 5.50: DIPLOMA YEAR group – Standard deviation of ranks - Architectural sketch

	1	2	3	4	5	6	7	SD	SD
D 1	18	16	20	21	23	14	19	3.03	1.72
D 2	7	4	5	7	06	02	10	2.54	
D 3	10	5	13	16	09	12	17	4.15	
D 4	20	30	28	23	18	15	13	6.37	
D 5	27	14	11	14	24	28	22	6.90	
D 6	19	9	15	11	11	09	03	5.03	
D 7	17	10	17	12	10	07	11	3.74	
D 8	24	15	23	28	20	27	24	4.39	
D 9	28	28	19	18	25	16	26	5.04	
D10	9	17	22	19	19	29	12	6.54	
D11	30	23	3	10	13	10	16	9.01	
D12	16	18	8	8	17	19	15	4.57	
D13	8	7	14	9	01	08	09	3.82	
D14	6	3	1	1	04	11	04	3.45	
D15	11	12	16	20	14	13	08	3.82	

Figure 5.100 shows the results for the Diploma Year group.

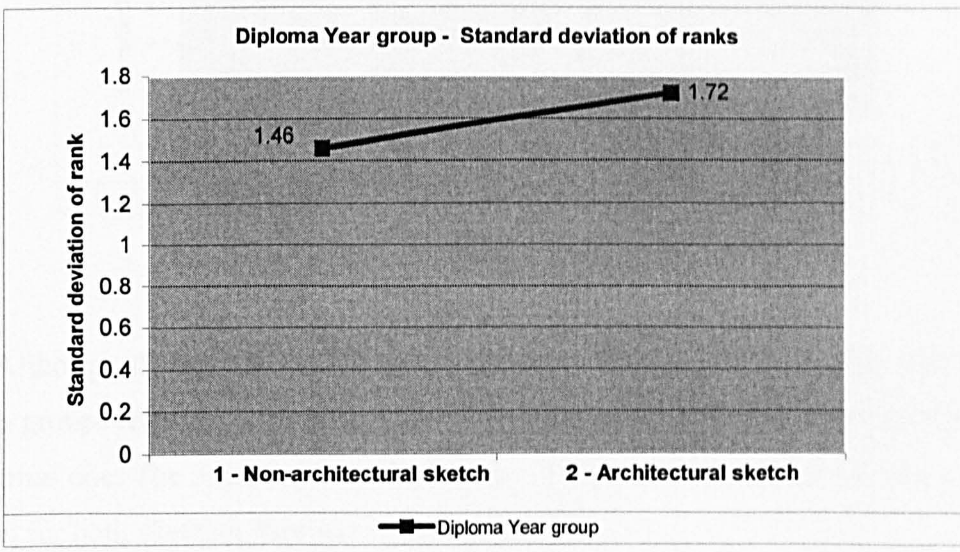


Figure 5.100: The standard deviation of ranks for the Diploma Year group.

The results show that the Diploma Year group received a larger deviation for the architectural sketch than for the non-architectural one. However, this difference found is not statistically significant (Ttest p=0.07).

4.3.3 - Standard deviation of ranks per type of sketch
Comparison between groups and sketches

These results allowed a comparison between groups and sketches. Table 5.51 shows the standard deviation of ranks for both groups.

Table 5.51: Summary of results – Standard deviation of ranks

	Non-architectural sketch Standard deviation of ranks	Architectural sketch Standard deviation of ranks
First Year group	1.04	1.54
Diploma Year group	1.46	1.72

Figure 5.101 shows the results for standard deviation for both groups.

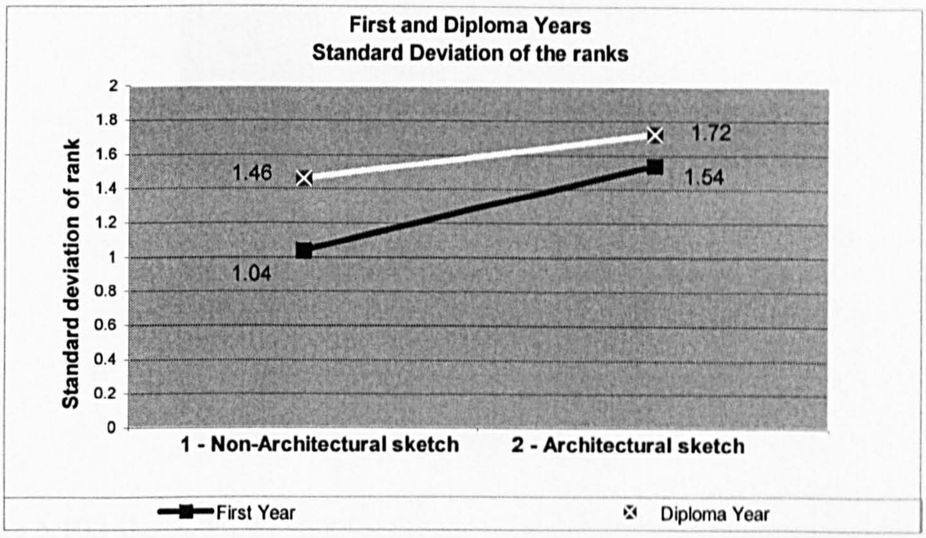


Figure 5.101: The standard deviation of the ranks.

Although the results are not statistically significant, taken together they show that both groups received a larger deviation for the architectural sketch than for the non-architectural one. The results also show that the Diploma Year group presented a larger deviation for both sketches than the novice group.

4.4 – Rank for first and second descriptions

In this section the rank of the first and second descriptions are examined. The question posed is which description got a better rank on average. Was it the second because it took longer than the first one? If yes, what the subjects did to get a better rank should be examined.

In order to answer this question, the rank of each description was taken separately. The results are presented per subject group and compared.

4.4.1 - Rank for first and second descriptions

First Year group

Table 5.52 shows the results for ranks of first and second descriptions.

Table 5.52: Ranks for first and second description for the First Year group

First Year group		
Sessions	**Rank first description**	**Rank second descriptions**
1	30	20
2	22	11
3	20	30
4	29	23
5	18	24
6	22	23
7	16	7
8	19	27
9	7	8
10	9	1
11	6	3
12	28	21
13	28	26
14	15	14
15	4	27
Average	**18.2**	**17.66**

Figure 5.102 shows the average of these results for the same subject group.

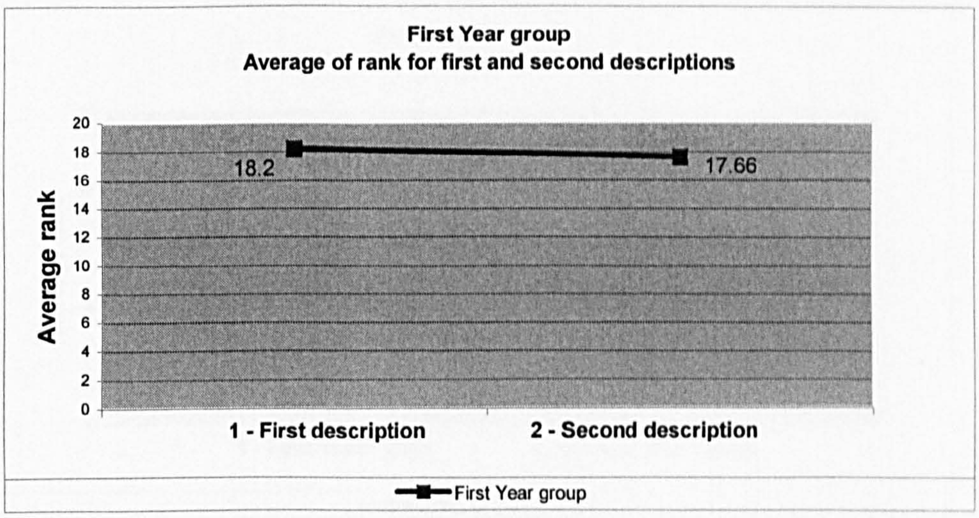


Figure 5.102: Average of ranks for first and second description for the First Year group

The results show that the First Year group got a better rank for the second description on average. However, the difference is not statistically significant (Ttest p=0.87)

4.4.2 - Rank of first and second descriptions

Diploma Year group

Table 5.53 shows the results for ranks of first and second description.

Table 5.53: The results related to ranks for first and second description for the Diploma Year group

Diploma Year group		
Sessions	Rank first description	Rank second descriptions
1	16	18
2	5	12
3	29	10
4	20	10
5	25	19
6	9	1
7	4	11
8	26	21
9	25	24
10	17	17
11	5	15
12	13	2
13	14	8
14	3	6
15	13	12
Average	14.93	12.4

Figure 5.103 shows the average of these results for the same subject group.

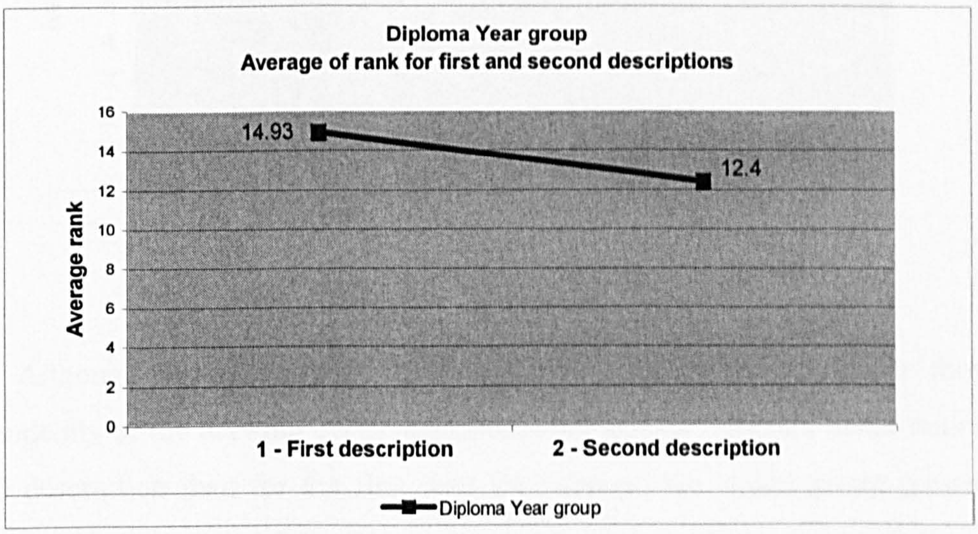


Figure 5.103: Average of ranks for first and second description for the Diploma Year group

The results show that the Diploma Year group also got a better rank for the second description on average. However, the difference found is not statistically significant (Ttest p=0.37)

4.4.3 - Rank of first and second descriptions

Comparison between groups and sketches

From all these findings it is possible to compare the groups and sketches. Table 5.54 shows the results.

Table 5.54: Average for rank for firs and second description per group

	Average rank first description	Average rank second description
First Year group	18.2	17.66
Diploma Year group	14.93	12.4

Figure 5.104 shows the average of ranks for first and second descriptions for both groups.

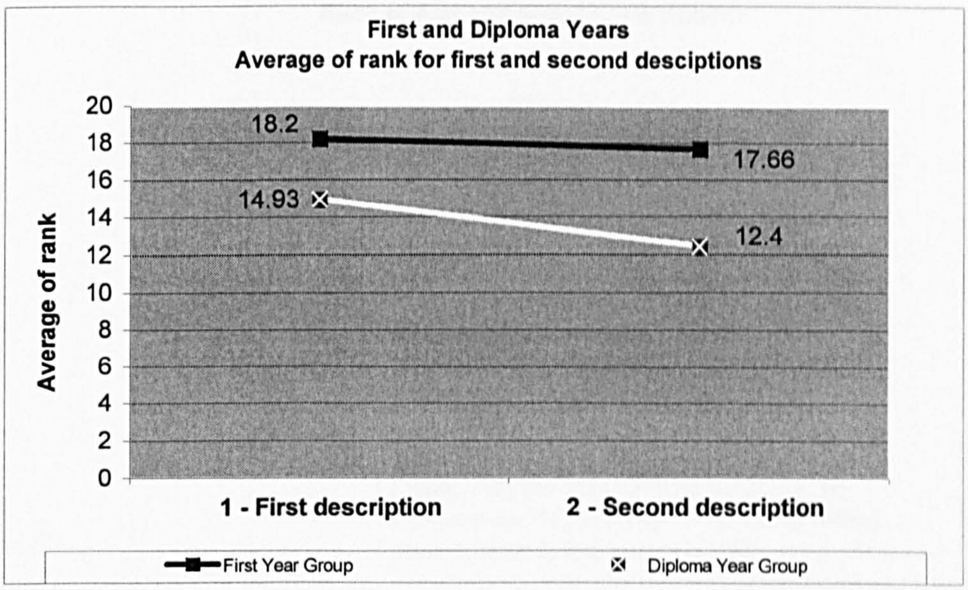


Figure 5.104: Firs and second description ranks on average

Although not statistically significant, these results taken together show that independently of the drawing being described, both groups present a better rank for the second description than for the first one. On average, the expert group present both descriptions better ranked than the novice group. This seems to suggest that probably there is learning taking place during the experiment.

4.4.4 - Rank of first and second descriptions

Individual subject

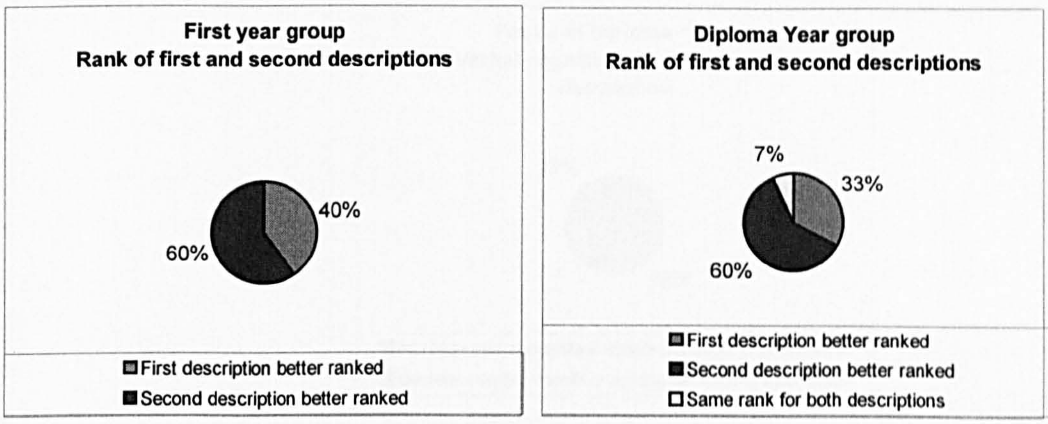
In this section it will be asked how many students got a better rank for the second description. The whole group of students and each group are examined separately.

For the whole group of 30 students it was found that 11 students (37%) got a better rank for the first description and 18 of them (60%) got a better rank for the second description. Only 1 student (3%) got the same rank for both descriptions. Figure 5.105 shows the results.

30 students
11 better rank for the first description (37%)
18 better rank for the second description (60%)
1 same rank both descriptions (3%)

Figure 5.105: Rank for first and second descriptions for the whole subject group

This result was also true for each group separately. Figure 5.106 shows the results for both subject groups. For the First Year group, it was found that 40% of students got a better rank for the first description and 60% of them got a better rank for the second one. For the Diploma Year group, 33% of students got a better rank for the first description, 60% of them got a better rank for the second description and only 7% of them got the same ranking for both descriptions.



First Year: 15 students
6 better rank for first description (40%)
9 better rank for second description (60%)

Diploma Year: 15 students
5 better rank for first description (33%)
9 better rank for second description (60%)
1 same rank both descriptions (7%)

Figure 5.106: The results for ranks for first and second description for both groups

These results show that, independently of the drawing being described, 60% of each group got a better rank for the second description.

4.5 - Description better ranked

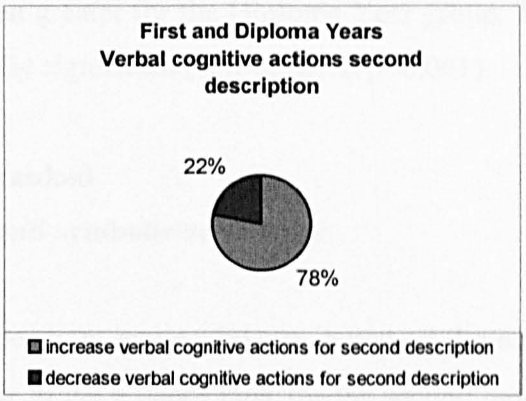
In this section only those subjects who got a better rank for the second description are going to be examined. This represents 60% of each group. The question of interest here is what the subjects did to get a better rank in the second description. The number of verbal cognitive actions and the number of formal and symbolic references for each description are compared.

4.5.1 - Description better ranked

Number of verbal cognitive actions

Of those who got a better rank for their second description it can be looked to see whatever this relates to the number of verbal cognitive actions they employed.

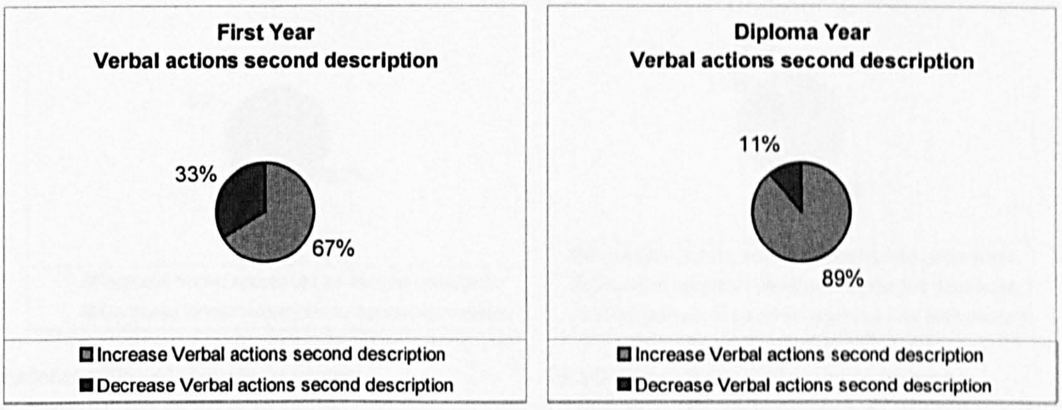
Figure 5.107 shows the results for the whole group of 18 students. It was found that 14 students (78%) increased the number of verbal cognitive actions and only 4 students (22%) decreased the number of cognitive actions.



18 students (60% of the whole group)
14 increase verbal cognitive actions
4 decrease verbal cognitive actions

Figure 5.107: Number of verbal cognitive actions for both groups of students

This result was also true for each group separately. Figure 5.108 shows the results for each group. For the First Year group, it was found that within 9 students, 6 of them (67%) increased the number of verbal cognitive actions for the second description and only 3 of them (33%) decreased. For the Diploma Year group, within 9 students 8 of them (89%) increased the number of verbal cognitive actions for the second description and only 1 student (11%) decreased.



First Year: 9 students (60% of the whole group)
6 increase verbal cognitive actions (67%)
3 decrease verbal cognitive actions (33%)

Diploma Year: 9 students (60% of the whole group)
8 increase verbal cognitive actions (89%)
1 decrease verbal cognitive actions (11%)

Figure 5.108: Students that got a better ranking in the second description.

The results show that in order to get a better rank for the second description the majority of students within each group increased the number of verbal cognitive actions.

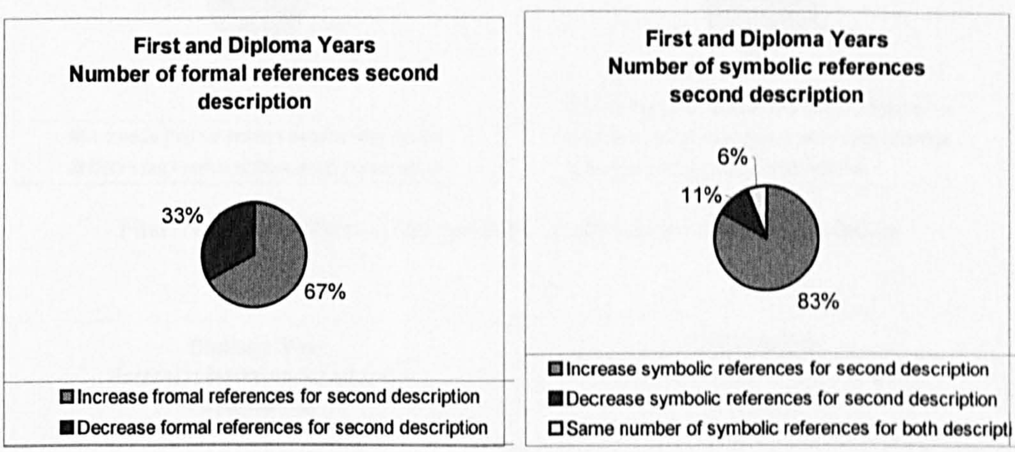
This difference again is even greater for the Diploma Year group. The difference found between groups is statistically significant (Chi-Squared p=0.001).

4.5.2 - Description better ranked

Number of formal and symbolic references

This section examines how many students increased the number of formal and symbolic references in order to get a better rank for the second description. The results are presented first for the whole group of students and then per each group separately.

Figure 5.109 shows the results for the whole group of 18 students. For formal references, it was found that 12 students (67%) increased the number of formal references and 6 students (33%) decreased the number of these references. For symbolic references, it was found that 15 students (83%) increased the number of symbolic references, 2 students (11%) decreased the number of these references and only 1 student presented the same number of symbolic references for both descriptions.



18 students (60% of the whole group)
12 increase formal references (67%)
6 decrease formal references (33%)

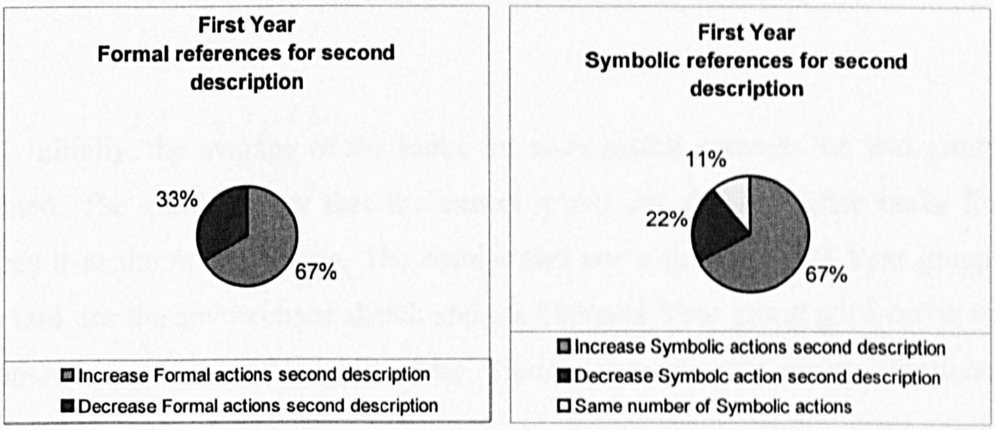
18 students (60% of the whole group)
15 increase symbolic references (83%)
2 decrease symbolic references (11%)
1 decrease symbolic references (6%)

Figure 5.109: The number of formal and symbolic references for both groups of students

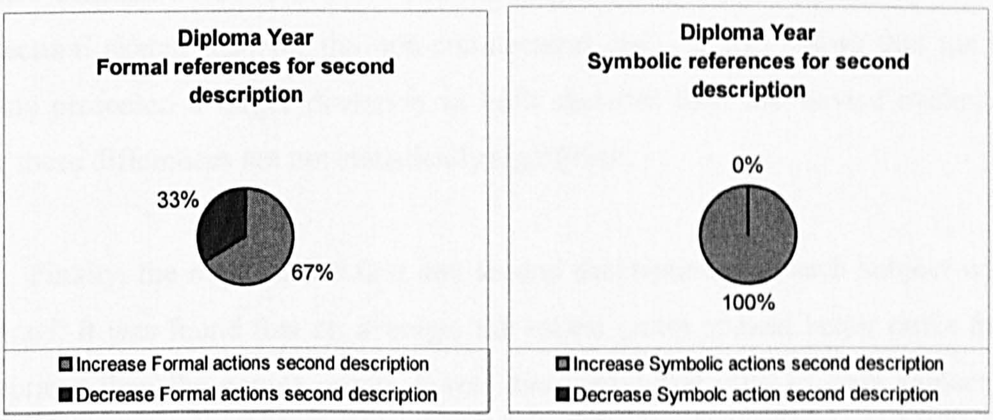
This result again was also true for each group separately. Figure 5.110 shows the results for each group.

For the First Year group, for formal references it was found that within 9 students, 6 of them (67%) increased the number of formal references and only 3 of them (33%) decreased these references. For symbolic references it was found that within 9 novice students, 6 of them (67%) increased the number of symbolic references for the second description, 2 students (22%) decreased these references and just 1 student (11%) presented the same number of symbolic references for both descriptions.

For the Diploma Year group, for formal references it was found that within 9 students 6 of them (67%) increased the number of formal references for the second description and only 3 of them (33%) decreased these references. For symbolic references it was found that within 9 expert students, all of them (100%) increased the number of symbolic references for the second description.



First Year group: Formal and symbolic references for second description



Diploma Year group: Formal and symbolic references for second description

Figure 5.110: Formal and symbolic references for both groups for the second description.

According to the results, both groups increased formal and symbolic references in order to get a better rank for the second description. It was found no difference between both groups for the number of formal references and a statistically significant difference for number of symbolic references (Chi-Squared p=0.001). The results show that all expert students increased the symbolic references but this did not happen with novices.

4.6 – Summary of results related to drawings

Because of the research's focal interest, only those drawings made during the description tasks were analysed. Firstly they were ranked by seven different referees all architects and staff at School of architecture at The University of Sheffield. A high level of agreement between referees was found. Therefore, all the analysis was based on these results.

Initially, the average of the ranks for each sketch between the two groups, are examined. The results show that the expert group got slightly better ranks for both sketches than the novice group. The results also show that the First Year group got a better rank for the architectural sketch and the Diploma Year group got a better rank for the non-architectural one. However, these differences are not statistically significant.

The standard deviation of these ranks for each sketch between the two groups was also examined. The results show that both groups present a larger deviation for the architectural sketch than for the non-architectural one. It also shows that the expert students presented a larger deviation in both sketches than the novice students. But again, these differences are not statistically significant.

Finally, the rank for the first and second descriptions for each subject was also examined. It was found that on average, the expert group present better ranks for both descriptions than the novice group. It was discovered that 60% of each subject group got a better rank for the second description than for the first one.

For these reason, it was analysed what these students (60% of each group) did to get a better rank for the second description. Subsequent analysis found that 78% of them increase the number of verbal cognitive actions for the second description, 67% of them increase the formal references and 83% of students increase the symbolic references. In each case these differences were even greater for the Diploma Year students.

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Chapter 6

Conclusion

CHAPTER 6 – CONCLUSION

1 – INTRODUCTION

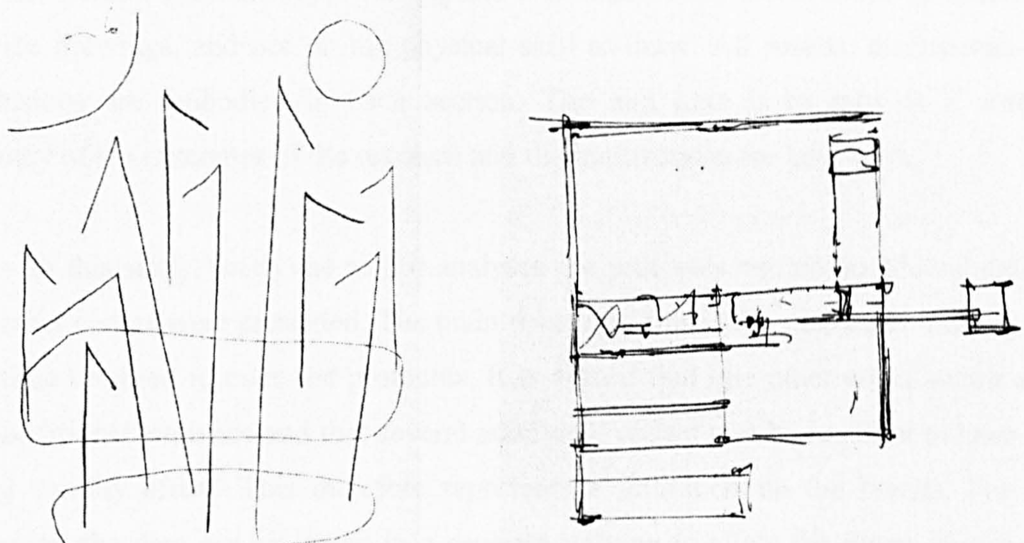
This chapter is concerned with the final conclusions of this research and their implications for future work. It is divided into four sections. This first section provides a short introduction to the chapter. The second section presents some results and limitations of the analysis method. The third section presents final considerations and future implications for later research. The fourth and last section of this chapter contains the bibliographic references.

This research examined the interaction between conceptual sketches, visual perception and verbal description. The focus was on the mental process involved in the interpretation and description of sketches. The question investigated was how novice and expert architecture students use knowledge and memory to describe the information they perceive from conceptual sketches and any differences between the groups. It is argued that this may help to inform us about the way they might think while sketching in the early design process.

In order to examine this interaction between designers and sketches, the research conducted an experiment on visual perception and verbal description with novice and expert architecture students. Chapter 4 presented the methodology employed in this experiment and identified some limitations.The experiment requires architecture students to describe two images to another student who cannot see the images, but must reproduce them from the verbal description.

One image is a non-architectural sketch (Paul Klee/1939) and the other is an architectural sketch (Mies van der Rohe/1935). Figure 6.01 shows the two sketches used during the experiment. Basically, the architectural sketch belongs to the design context, that is, to the process of searching new thoughts for a design solution. The non-architectural sketch belongs to an art context and does not relate to design.

The reason for using these images was to investigate how they might give rise to both formal (geometric and physical features) and symbolic (analogies to something else) references in the descriptions, and why. Ideally we would like to use a large number of images, but the evidence from the two pilot studies (Chapter 4) strongly suggested this was unpractical within sensible lengths of experimental sessions.



Non-Architectural sketch
Paul Klee - Double Island 1939

Architectural sketch
Mies van der Rohe –Floor plan 1935

Figure 6.01: Images selected for the experiment

The experiment investigated differences in the way novice and expert architecture students interact and describe conceptual sketches. In particular, how they use formal and symbolic verbal references to describe conceptual sketches, and to what extent this helps to understand how they might think while sketching. The use of formal and symbolic verbal references during the description process might reflect the way they think and the way new thoughts emerge.

If this proved to be right, the expert students' descriptions would be higher in quality and richer in formal and symbolic references than the novices' descriptions, because of their training in recognizing features in visual displays, and their ability to use prior knowledge and memory more effectively to create analogies while describing what they are seeing. Expert students should also be able to use more formal and symbolic verbal references to describe geometric and physical composition of drawings, as well as use precedents and analogies referring to ideas external to the drawings.

2 – RESULTS AND DISCUSSIONS

In order to analyse the protocols, this research developed a unique approach. The analysis method used retrospective reports and focused on the abilities to think and describe drawings, and not on the physical skill to draw. All results, discussions and conclusions are embodied in each section. The aim here is to provide a concise summary of the outcomes of the research and the implications for later work.

In this study, solely the author analysed the protocols and no double validations with other coders were presented. The main reason for this is the extensible training and then time required to code the protocols. It is argued that one other coder worth adds little additional evidence and that several additional coders will be required to have any strong validity effect. This therefore represents a limitation on the results. For this reason, all the data are presented in a separate volume to allow for future approaches and other findings that could be contrasted with this research.

Two general patterns emerged from the results. First, few statistically significant differences between groups and sketches were found when compared on average. Second, large variations between individual subjects were found related to many of the issues. For these reasons, both an analysis per group on average and an alternative analysis using a comparison between individual subjects were presented. All the results taken together present an overview regarding the groups and sketches.

This lack of significant differences was surprising and both unexpected and interesting result, as it is reasonable to expect differences between the two groups. However, some reasons as to why these results should be treated with caution will be presented comprehensively later in this chapter.

There are however some important statistically significant differences between the groups related to the number of segments per minute, the number of verbal cognitive actions per minute and the use of formal and symbolic references while describing the same images.

The statistically significant differences found enabled further analysis on the interaction of description, the image described and the drawing produced between the two subject groups.

2.1 – The interaction of the description and the image described

This section examines the interaction of the description and the image described. The results show that the expert group used more segments per minute and more verbal cognitive actions per minute on average for both descriptions than the novices. Where their expertise was greater, that is, with the architectural sketch, this effect was significantly more pronounced. The difference found for the architectural sketch was statistically significant and for the non-architectural sketch it was not significant. This seems to support the results of previous studies of what novice and expert designers perceive in design sketches (Suwa 1997; Gero 1998; Suwa 1998).

A great variation between individual subjects related to the number of segments per minute and number of verbal cognitive actions per minute for each type of sketch was found. The majority of all subjects (64%) used more segments per minute for the non-architectural sketch and 53% of all of them also used more verbal cognitive actions per minute for the non-architectural sketch. However this difference was not true for each group separately.

For the novice group, it was found that the majority of students used more segments per minute (87%) and more verbal cognitive actions per minute (67%) for the non-architectural sketch. On the other hand, the majority of expert students used more segments per minute (53%) and more verbal cognitive actions per minute (60%) for the architectural sketch.

It was found that 54% of all subjects took longer to describe the architectural image and 67% of them took longer to remember the same sketch. These differences were true for each group separately, and even greater for the expert students. The results show that 53% of novice students and 60% of expert students took longer to describe the architectural sketch, and that 60% of novice students and 73% of expert students took longer to remember the architectural sketch.

It was also discovered that the majority of all students used more segments and more verbal cognitive action for the architectural sketch (67% used more segments and 64% used more verbal cognitive actions). These differences were true for each group separately, and even greater for the expert group than for the novice group. It was found that 60% of novices and 73 % of experts required more segments for the architectural image and 53% of the novice group and 73% of the expert group required more verbal cognitive actions for the architectural sketch.

It was also found that both groups of students used more formal than symbolic references for both sketches. For both subject groups the difference found for the architectural sketch was statistically significant and for non-architectural one it was not significant. For the non-architectural sketch it was 60% of them and for the architectural one it was 84% of them. This difference was true for each group separately and again even greater for the expert students.

The architectural sketch gave rise to more formal references than the non-architectural one. It was apparent that 80% of novices and 87% of experts used more formal references for the architectural image. The results show that the non-architectural sketch allowed the use of more symbolic references than the architectural one.

Next, the subjects were required to identify the easier and harder image to describe and justify their answer. Both groups chose the non-architectural sketch as the easier to describe. This suggests that the easier image to describe is the one that presents a greater potential for connection with something else by analogy, allowing the use of more symbolic references.

The harder image to describe, the architectural one, required more formal verbal references from both groups. This seems to suggest that facility to associate conceptual sketches with something else, by analogy, might support the designer's interaction with them.

2.2 – The interaction of the description and the drawing produced

This section discusses the interaction of the description and the drawing produced. The question asked was which sketch generated from the description got a better rank on average and why. In order to answer this question, the ranks of the drawings produced from the descriptions were compared. It was found that the expert group presented slightly better ranks for both drawings. This seems to suggest that the better rank could be associated with the number of verbal cognitive actions per minute used for the description.

2.2.1 – First versus second descriptions

In each session each subject described both the architectural and the non-architectural sketch but in a randomly order. It was found that 60% of each subject group got a better rank for the second than the first description no matter what order the sketches were presented. It seems therefore worth analysis the differences between the first and second description for these 60% of students whose performance appears to improve in the second description. The question asked was what they did to get a better rank. To answer this question, first, the number of verbal cognitive actions was compared and, second, the number of formal and symbolic references used in each description was also a significant consideration.

It was found that 78% of all students that got a better rank for the second description increased the number of verbal cognitive actions. This difference was even greater for the expert students (89% of them increased the number of verbal cognitive actions) than for novice students (67% of them increased the number of verbal cognitive actions). This could be related to the learning process taking place during the experiment and also could suggest that the better rank could be associated with the number of verbal cognitive actions subjects used per minute.

Next, the use of formal and symbolic references during the descriptions was contrasted. All students that got a better rank for the second description in turn also increased the number of formal and symbolic references. It was found that 67% of all students increased the number formal references and 83% of them increased the number of symbolic references.

In each case these differences were greater for the Diploma Year students. The results show that all expert students (100%) that got a better rank for the second description increased the number of symbolic references, but this did not happen with the novices.

2.3 – Why were there fewer significant difference between subject groups?

No statistically significant difference was found related to description times, number of segments, number of verbal cognitive actions, and final ranking of sketches. These might be seem to be surprising and interesting results that appear to bring some views expressed in the design literature with respect to differences between novice and expert designers into question.

There are at least two ways in which to interpret these findings. First, this suggests that perhaps there is no significant difference between the two groups related to these issues. The experiment was designed to examine different thoughts involved in the process of description of conceptual sketches, and not in the actual process of sketching and designing. It appears that the most significant differences between these two groups – novices and experts – could be the thoughts involved in the process of sketching while looking for a specific design solution, and not describing a sketch within a non-design context.

The second way to approach these findings could be ask to relevant questions related to the methodology and procedures adopted in this research.

The first question could be related to the experiment itself. The experiment focused exclusively on the mental process involved in the interpretation and verbal description of conceptual sketches, and not on the actual sketching activity neither on the design process itself. However, the tasks clearly involved mental synthesis, as participants were asked to analyse the images and describe their thoughts. Mental synthesis is considered to be fundamental for any design activity.

If mental synthesis is one of the core aspects of design process, then expert design students should be better at both analysis and description of conceptual sketches than novices. Was this research wrong in assuming that novices would do these tasks differently to experts?

Another possible explanation could be related to the subject groups. Only architecture students formed the groups, and even first year students might be seen to belong to the same culture. This probably represents a limitation for the findings. It seems reasonable to suggest that a major difference could be obtained between very expert architects with at least 20 years of professional practice and novices from a population of first year law students with little sketching experience.

According to previous cognitive literature, individual or common interests could also affect performance during the description tasks (Bartlett 1950). At the time of the experiment, First Year students were much easier to invite to participate than Diploma Year students. Expert students were heavily involved with other work and preoccupied in the studio.

Another explanation could be related to the standard of students, which was not matched between groups. It is possible for example, that the first year students were the top students of the group and the diploma students were not. However, as it was difficult to find a clearly relevant way to identify the better students, they were randomly invited. There are also some extreme outlying sessions within both groups that deserve to be revisited. They seem to represent some misunderstanding regarding the tasks and can potentially confuse the results (e.g. session 29).

3 – FUTURE RESEARCH AND IMPLICATIONS

Evidence from both cognitive psychology and design literature supports the idea that architects, especially in the conceptual stages of the design process, have a strong interaction with their own sketches. This interaction with drawings seems to be more relevant to designers than the physical skill to draw.

There are some studies that already indicate what role sketching may play in design (Goldschmidt 1991; Lawson 1994; Goel 1995; Lawson 1997; Kokotovich 2000; Rodgers 2000; Tovey 2003). However, there have been a small number of empirical studies that have focused on the role of these representations in the early design process and, despite their importance sketches seem to have a perceived low status.

This research revealed that expert architecture students used more verbal cognitive actions per minute than novices while describing the same images. This suggests that the way they describe and the way they use formal and symbolic verbal references might reflect the way they think and the way new thoughts might emerge during the interaction with sketches.

If this is right, this could support future research to approach the designer's reasoning process in a more rational and critical way. The results appear to suggest that the designer's interaction with sketches may be, in part, tied to the facility to associate them with something else using analogy. However, there is no evidence yet if this is also true in a design context and this is clearly indicative of the next step to examine.

3.1 – Future work

This section is concerned with future work that can be addressed and articulated within the sample and the data provided. New approaches and different analysis of the descriptions and drawings are possible, and surely this can support further research on the designer's interaction with conceptual sketches.

Because of the objective of this research, it concentrates only on the analysis of verbal cognitive actions used by the participants while describing the images. However, in the videotapes it is possible to see a strong link between verbal and physical cognitive actions, which suggests a very interesting field for new research. The question that might be asked is if there are connections between the participants' mental activity and their body language while analysing and describing conceptual sketches. If yes, what might this suggest about mental synthesis, body language and sketching activity during the design process? Are there differences between the two groups and the two images?

This research focused on the participants as a group and did not deeply analyse just one subject separately. Based on the results, it seems to be possible to investigate the interaction of the best drawing produced, that is, the one that got a better rank from the referees, and the description that it was originated from. Is the better rank related to the length of the description or to the number of verbal cognitive actions used by the subject? Is it related to the number of formal and symbolic references used during the description?

The longest and the shortest descriptions and their influence in the drawings produced could also be examined. The descriptions that used more and less number of verbal cognitive actions, more and less formal/symbolic references and their impact on the drawings produced could be compared.

During the experiment the participants were required to remember and to draw by memory what they described. However, no analysis was conducted to investigate the relationship between remembered information and its previous description. Did the subjects remember the images in the same sequence as they described them? Is there any connection between the way we describe things and the way we remember them? If yes, how can this help to understand how designers' might remember relevant information while searching for a design solution? What are the differences between novice and expert designers related to this?

All these considerations suggest interesting fields for new research.

3.2 – Future implications

This research suggested that identifying some verbal cognitive actions during the process of interaction and description of conceptual sketches could support future research into the designer's reasoning process while sketching, and might inform as to how they approach design. This could also help to study how designers interact with conceptual sketches and how they might use drawings to allow new and unexpected thoughts to emerge. Therefore, the preceding discussions seem to have inevitable implications for design education and practice, implications that are essential for researchers to address and articulate.

This research intended to contribute to the investigation of how and when to teach drawings skills to designer students, and especially, how to use conceptual sketches to allow unexpected ideas to surface while sketching and examining them. The results of this study suggest that the facility to associate the sketches with something else seems to promote the interaction with them. These appear to be fundamental issues for teaching drawings skills on schools of architecture. However, there are some questions that seem to remain unanswered. What are the implications of this on CAD? Can computers also support this early design activity?

The general agreement between researchers seems to suggest none really intend to completely replace freehand sketching at the conceptual stage (Tovey 1989; Goldschmidt 1994; Goel 1995; Gross 1996; Lawson 1997a; Suwa 1997; Tovey 1997). There is no reason to assume that, if emergence and imagery can be amplified using sketches, they also can be further amplified using a computer. However, little has been published on sketch recognition and diagram interpretation and little research on CAD has been conducted on requirements for computer-supported sketching.

This thesis agrees with Cross and it is also suggested that if the purpose is to develop interactive systems that support design, it is necessary and important to start with knowledge of the human designer's cognitive behaviour (Cross 1999). The author also believes that if research intends to emulate human cognitive activities, it should address the question: 'what are we learning from this research about how people think?' and as Cross suggested, maybe people can learn something about the nature of human design cognitive through looking from the computational perspective (Cross 1999).

This research intended to contribute to the better understanding of how designers think, perceive and describe sketches, and then, motivate new research for computational tools that possess the functionality of enriching perception. The suggestion was that such computer tools should be intuitive and their use should not require specialized knowledge to facilitate emergence and reinterpretation.

It can be assumed that free hand sketching is still prevalent in the conceptual phase of design, and computers can support freehand sketch activity, but more work and more research is needed. Inevitably the new generation of computers should hold enough knowledge to be able to interpret conceptual sketches and to approach design problems.

However, it seems to be necessary that these computer tools allow designers to communicate with them in a much more natural form of language and they should be able to infer meaning and intention and then, they could indeed be a useful partner in the design studio. Until that time, this study is in agreement with Lawson and concludes that computers can assist with various jobs for people in design, but whether this can really be called computer-aided-design remains questionable (Lawson 1997b).

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