SIMILARITIES AND DIFFERENCES IN COMPUTER USER'S MENTAL MODELS OF COMPUTER DYNAMICS

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ABSTRACT

This dissertation explores the mental models applied when computers are used by tertiary sector 'clerical' employees from different backgrounds and with different levels of experience with, and knowledge of, computers.

The study was conducted in three stages. In STAGE 1, interviews were conducted to categorise the level of knowledge and experience of the users, and to establish their socio-cultural backgrounds. STAGE 2 established their 'mental models' of the inside of a computer by means of sketches. STAGE 3 assessed sketches of subjects' mental models of the dynamic operations of the computer saving a file. Cluster analysis was conducted to establish groupings of subjects with similar usership background, and sketches. Further analysis was conducted on the resulting cluster solutions.

It was found that user knowledge and experience with computers was predominantly impacted on by exposure to computers, received during employment in an organisation, and by race group.

Similarities and differences in metaphors were identified. In STAGE 2, which considers 'what a computer is', cluster members used human; abstract technical; detailed techno-mechanical; light-based and alphabet-based metaphors. In STAGE 3, which necessitated a 'what a computer does' perspective, mental models were expressed in terms of record-player/filing cabinet; save key-based; techno-mechanical and menu-based metaphors. As speculated by Denham (1993), subjects generally found their abstract views of what a computer 'is', to be inadequate when describing what it 'does', and changed their models substancially from those used in STAGE 2 to those adopted in STAGE 3.

In both stages, subjects who made use of few (usually one) application systems used explicit, detailed metaphors in their models. In contrast, those using several systems adopted broad, non-explicit models combining features derived from the various application and operating systems. The impact of the adopted systems on mental models was further demonstrated in STAGE 3, where subjects sketched what they encountered in their interaction with the computer. In accordance with past research, it was shown that as expertise increased, the accuracy and applicability of models increased.

Company training was found to impact significantly on complex tasks, and is thus pertinent for error reduction. Fortunately, socio-cultural background, which cannot be manipulated, only impacts on simpler, less critical tasks which need not be changed.

Cluster themes and similarities and differences in their members' mental models were easily identifiable. This demonstrates the usefulness of annotated sketches, with an accompanying descriptive paragraph, as an investigative tool in research on mental models.

DECLARATION

I declare that this dissertation is my own, unaided work. It is being submitted for the degree of Master of Arts in the University of the Witwatersrand, Johannesburg. It has not previously been submitted for any degree or examination in any other University, nor has it been prepared under the aegis or with the assistance of any other body or organization or person outside of the University of the Witwatersrand, Johannesburg.

L. E. Koping.

31st day of January, 1995.

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"Our chief want in life, " said Emerson, "is someone who will make us do what we can." (in James, 1965, p174).

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LIST OF ABBREVIATIONS

APPLIC : The number of application systems which the subjects has ever used.

BRAIN : This included labelling of any components of the sketch as brain or heart, or mentioning a brain or heart in the descriptive paragraph. It implied the use of a human analogy.

CABINET : Any sketches which included several compartments in the form of a filing cabinet or a concertina file, with each compartment alphabetised was identified as a cabinet.

COL : This included labelling of any wires/mechanisms in the sketch as having colours, or mentioning coloured wires or mechanisms in the descriptive paragraph.

COMMUNIC : Any form of communication between the components of the computer. Words which were used in this category included 'communicating', 'sending', feeding information' and 'telling'.

CONFID : The level or confidence about using any computers. The ratings were chosen according to a scale of 1 to 10, in which 1 implied the highest level of confidence, and 10, the lowest.

CPU : central processing unit.

CPUSEP : Any acknowledgement (in the annotation of the sketch or in the descriptive paragraph) of a processing unit (generally labelled the CPU) as a separate unit, and not referred to as the brain or memory.

DISKS : This included labelling of any components of the sketch as discs, or mentioning a floppy disc in the descriptive paragraph.

DISKSAVE : Any mention of the information being saved to a disc.

DRW1CLUS : Name of Cluster Solution containing Clusters according to the sketches of the inside of an inactive computer.

EDUC : Current Education Level of the subject (eg. STD. 8, matric, matric and degree).

EXTERNAL : External features of a computer, such as the screen, keyboard and cords which connect the computer to a plug. EXTERNAL thus included labelling or drawing of any of these components in the sketch, or mentioning any of them in the descriptive paragraph.

FAMNUM : Number of people living in the same house / flat / apartment / cottage as the subject.

FILECLUS : Name of Cluster Solution containing Clusters according to the sketches of the inside of a computer which is saving a file.

FILECOP : FILECOP refers to implications in the sketches of the computer making a copy of the file before, or when saving it.

FILESEC : This refers to the belief that there is a separate section in which the file is stored.

FNAL/FNCTNAL : The sketches were rated as functional if they included any explanation of how the components interact, the functions of various components, or step by step descriptions of what happens inside the computer. Functionality (FNAL and FNCTNAL) thus implies a perspective shown in the sketches, based on what the computer 'does', rather than merely what it 'is'.

FREQUSE : The frequency with which the person used the computer in the time period mentioned in YEARSEXP, expressed in terms of days per week.

GENDER : The gender of the subject (Female or Male).

HCI : Human-computer interaction.

LANG : Home Language of the subject (English, Afrikaans, Portuguese, Zulu, Sotho etc.)

LETTER : The existence of LETTERS in the mental models was defined as the inclusion of letters anywhere in the sketch or descriptive paragraph, other than on the keyboard's keys. More specifically, it generally referred to the use of letters, mechanisms labelled as letters, or reference to the alphabet, existing either behind the screen, or in the box.

LIGHTS : Drawings of bulbs and labels or descriptions of lights in the annotation or descriptive paragraph were included here.

LOCKIN : Reference to an analogy that the file / information is 'locked in' to the computer.

MAGNET : Any reference to a magnetic force which moves (generally pulling) the information within the computer.

MARITAL : Marital Status (Married, Single, Divorced, Widowed, Separated).

MEMORY : This included labelling of any components of the sketch as memory, or mentioning memory in the descriptive paragraph.

MENU : This included any reference to, labelling of or illustration of a menu, or options on the screen, from which to choose.

NATION : Subject's Nationality.

ORG : The organisation in which the subject was employed when the study was conducted.

OS : The number of operating systems which the subject has used.

PGM : Whether the subject has ever written any programmes on the computer, for example, programming in BASIC.

RACE : Race Group of Subject (White, Black, Indian, Coloured).

RECPLAY	:	RECPLAY refers to the use of a record player analogy. These subjects generally used the term 'information reader' or 'needle' that 'reads' information off the 'disc' or 'record'. The records are generally depicted as having separate sections on which the file information is encoded.
SAVEKEY	:	SAVEKEY refers to mental models in which it is stated that a single save key must be pressed to save the file. This key is thus 'preprogrammed' to save the file.
SECTION	:	Any sketch which indicated that the computer had separate sections, each having a different purpose was included into this category.
SIMILAR	:	The sketch in the third stage was considered SIMILAR to that of the same subject in the second stage if the features included in the sketch, annotation and discussion were similar. For example, sketches were not similar if that of the second stage included a memory, a CPU and wires while that of the third depicted a filing cabinet.
STORCOM	:	This included labelling of any 'storage components' of the computer within the sketch, or mentioning such components in the descriptive paragraph.
TECHNIC	:	Bentley (1981) notes that a new language has developed alongside the advent and growth of computers. Acronyms and computer-jargon often dazzles novice users, for example 'byte' and 'CPU'. Knowledge of these words implies familiarity with literature dealing with computers, or people who have technical knowledge of computers. Technical words which were included here were 'ROM', 'RAM', 'bytes', 'directory', 'path' and 'gates'. If two or more of these words were used, the sketch was classified as TECHNIC.
TIMESPAN	:	The approximate amount of time (in hours) that the subject spends in each session on the computer.
TRAIN	:	The amount of training (formal or informal) received in Computer Science - including training regarding working on an application or operating system.
USERCLUS	:	Name of Cluster Solution which includes the Clusters based on the Usership Data - regarding knowledge and Experience of Users.
WIRES	:	This included labelling of any components of the sketch as wires or cables, or mentioning wires or cables in the descriptive paragraph.
WIREFEED	:	Any references to the wire 'feeding' the information through, or moving it around.
YEARSEXP	:	The time period, stated in years, over which the subject has used computers.

LIST OF TABLES

Table | Page

1. Stability of Individual Differences which Effect Human-User Interactions, Listed from the Most to the Least Stable....2

2. Distribution, within the Organisations, of Subjects of Different Nationalities....38

3. Frequencies of Subjects in each Race Group in the Three Organisations....39

4. Number of Females and Males in the Sample from Each Organisation....41

5. Education Levels of Subjects from the Various Language Groups....44

6. Pseudo F and Pseudo t**2 Values for Clusters Solutions with 6, 7 AND 8 Clusters, Derived by the Cluster Analysis Procedure Implemented on the Usership Data....68

7. The Means and Standard Deviations of Several of the Variables Used to Assess the Positions of the Clusters on the Two-Dimensional Conceptual Space....70

8. Tabulation of the Number of Operating and Application Systems used within Various Clusters....75

LIST OF TABLES (cont.)

Table Page

9. Confidence Levels Reported by the Subjects in the Various Usership Clusters....................76

10. Frequencies of Years Experience with Computers for Members of Clusters A to G....................77

11. Frequencies of Programme Writing Skills in Cluster A to G....................78

12. Tabulation of Frequencies with which Cluster Members Score in Terms of Frequency of Use of a Computer....................79

13. Tabulation of Frequencies with which Cluster members Used the Computer Daily, in terms of Hours....................79

14. Fisher's Exact probabilities for Associations Between USERCLUS Clusters and Various Socio-Cultural Background Variables....................82

15. Frequencies of Subject Membership in Each Race Group in the Three Organisations....................83

16. Pseudo F and Pseudo t**2 Values for Clusters Solutions with 4, 5 AND 6 Clusters, Derived by the Cluster Analysis Procedure Implemented on the Data from the First Sketches....................86

17. Number of Occurrences of Human Analogies and External Features of a Computer in Sketches of Subjects in Clusters H to L....................88

LIST OF TABLES (cont.)

Table Page

18. Number of Occurrences of technical Terminology and Functional Perspectives in Clusters H to L.......89

19. Frequencies of Occurrences of Wire, Section and Communication References by Cluster H Members.......89

20. Frequency of Occurrence of Coloured Wires and Technical Terms in Clusters H to L.......91

21. Frequencies of Communication Illustration and/or Recognition in the Sketches in the DRW1CLUS Solution.......93

22. Table Portraying that the Only Subjects who Included Lights, Operated through Wires, in their Mental Models were the Four Members of Cluster K.......94

23. Table Portraying that the Only Subjects who Included Letters in their Mental Models were the Five Members of Cluster L.......95

24. Fisher's Exact probabilities for Associations Between DRW1CLUS Clusters and Various Socio-Cultural Background Variables.......96

25. Tabular Summary of the Frequencies with which Subjects in Each Cluster in the DRW1CLUS Solution Referred to the Dominant Themes Identified in the Sketches.......98

26. Pseudo F and Pseudo t**2 Values for Clusters Solutions with 3, 4 AND 5 Clusters, Derived by the Cluster Analysis Procedure Implemented on the Data from the Second Sketches.......102

27. Tabulation of Use of Cabinet and Record Player Analogies in Mental Models of Subjects from Clusters M, N, O AND P.......104

Table Page

28. Tabulation of Number of References to Wires and External Features of the Computer in Sketches of Subjects from Clusters M, N, O and P....105

29. Table Showing the Only References to Magnetic Forces Falling into Cluster M....106

30. Representation of Sketches within the Clusters which Resembled Previous Sketches of the Same Subjects....107

31. None of the Subjects Omitted Wires or [illegible]ms in Their Sketches in Cluster P....108

32. Fisher's Exact probabilities for Associations Between FILECLUS Clusters and Various Socio-Cultural Background Variables....109

33. Tabular Summary of the Frequencies with which Subjects in Each Cluster in the FILECLUS Solution Referred to the Dominant Themes Identified in the Sketches....112

34. The Frequencies with which Subjects in this Study Fell into Each Dual-Membership Category in the USERCLUS and DRW1CLUS Cluster Solutions....117

35. The Frequencies with which Subjects in this Study Fell into Each Dual-Membership Category in the USERCLUS and FILECLUS ClusterSolutions....120

36. The Frequencies with which Subjects in this Study Fell into Each Dual-Membership Category in the DRW1CLUS and FILECLUS Cluster Solutions....123

LIST OF FIGURES

Figure Page

1. Two-Dimensional Conceptual Space Diagrammatically Representing the Possible Relationships between the Naive-Expert and Novice-Experienced User Categories....4

2. Fischer's (1991, p7) Model Illustrating User Interaction with the Computer......10

3. Examples of Directional Signs Bearing Irrelevant Directional Information.......13

4. Two Metaphors of a Wordprocessing System....16

5. Composition of Language Groups within each Race Group....40

6. Graphic Presentation of the Education levels Achieved within the Different Race Groups....43

7. Tree Diagram of the Clusters (A to G) in the USERCLUS Solution which Resulted from Cluster Analysis....69

8. Diagrammatical Representation of the Means and Standard Deviations of Several of the Variables used to Assess Positions of Clusters on the Two-Dimensional Conceptual Space....71

9. Approximate Positions of the Clusters on the Two-Dimensional Conceptual Space....85

10. Tree Diagram of the Clusters (H to L) in the DRW1CLUS Solution which Resulted from Cluster Analysis....87

11. Overview of Distinguishing Cluster Characteristics Recapitulated by a Representative Sample of Sketches from Each Cluster within the DRW1CLUS Solution....99

LIST OF FIGURES (cont.)

Figure **Page**

12. Tree Diagram of the Clusters (M to P) in the FILECLUS Solution which Resulted from Cluster Analysis....103

13. Overview of Distinguishing Cluster Characteristics Recapitulated by a Representative Sample of Sketches from Each Cluster within the FILECLUS Solution....113

14. Diagrammatical Presentation of the Frequencies with which Subjects in this study fell into Each Dual-Membership Category in the USERCLUS and DRW1CLUS Solutions....117

15. Diagrammatical Presentation of the Frequencies with which Subjects in this study fell into Each Dual-Membership Category in the USERCLUS and FILECLUS Solutions....120

16. Diagrammatical Presentation of the Frequencies with which Subjects in this study fell into Each Dual-Membership Category in the DRW1CLUS and FILECLUS Solutions....123

LIST OF SKETCHES

Sketch		Page
1.	Sketch by Subject 39 who Illustrated an Abstract Mental Model, which Emphasised the existence of Coloured Wires	90
2.	Abstract Sketch by Subject 17 Acknowledging Functional Features, but Giving no Indication of How they Operate	91
3.	Functional Perspective Showing Stages through which Information Passes	92
4.	Mental Model Based on Letters which are Manipulated by Wires	95
5.	Sketch Showing Mechanical/Electronic Features of a Computer	107
6 and 7.	Drawings from Cluster H, Showing Mental Models Based a Human Analogy	99
8, 9 and 10.	Abstract Mechanically Based Illustrations of the Inside of the Computer, with No Functional Implications	99
11 and 12.	Mental Models with Emphasis on Communication and Functionality in the most 'Technically Advanced Sketches' of Cluster J	100
13.	View of a Computer as a Screen with a Light behind it, which 'Lights Up' Relevant Information	101

LIST OF SKETCHES (cont.)

Sketch		Page
14 and 15.	Characteristic View of a Computer as a Screen with Letters behind it, which are 'Manipulated' by Wires	101
16.	Sketch from Cluster M, Showing the Use of a Filing Cabinet Analogy	113
17.	Sketch from Cluster M, Showing the Use of a Record-Player Analogy	113
18.	Illustration from Cluster N of a Magnetic Force which 'Moves' Information	113
19.	Sketch from Cluster N, Including Annotations Regarding a File 'Locking Away' Metaphor	113
20.	Mechanically Oriented Mental Model Including External Features	114
21.	Mechanical View of the Computer, with Reference to a Functional Save Key with Communication Implied in Terms of Connections	114
22.	Mental Model Including a Menu. It Shows the Impact of Exposure to a Particular Application System in the Conceptualisation of the Functioning of a Computer	115

CONTENTS

Page

Abstract....ii
Declaration....iv
Acknowledgements....v
List of Abbreviations....vi
List of Tables....ix
List of Figures....xiii
List of Sketches....xiv

PART I : PAST RESEARCH

Chapter Page

1. INTRODUCTION....1

2. KNOWLEDGE AND EXPERIENCE....3

3. MENTAL MODELS....6

Problems with Compatibility Between the User's, the Designer's and the System's Models....18
The Impact of Socio-Cultural Background on Mental Models....20
Investigating Computer User's Mental Models....28

4. SUMMARY OF PART I....30

CONTENTS (cont.)

Page

PART II : THE PRESENT RESEARCH

5. AIMS AND RESEARCH QUESTIONS.....31

6. METHODOLOGY AND MEASURING INSTRUMENTS.....33

Research Design.....33
Subjects.....36
Procedure and Measuring Instruments Used.....44
STAGE 1 : Interviews.....45
STAGES 2 and 3 : Sketches.....47
Validity and Reliability.....49

7. DATA ANALYSIS.....50

Content Analysis.....50
Statistical Analysis Techniques.....54
Cluster Analysis.....54
Ward's Cluster Analysis.....57
Frequency Distributions.....61
Fisher's Exact Test.....63
Graphs of Frequency Distributions.....64
Measures of Central Tendency.....65
Measures of Variability.....66

CONTENTS (cont.)

Page

8. RESULTS AND DISCUSSION....67

Results of Cluster Analysis....67
Clustering of Usership Data....67
Clustering based on STAGE 2 Sketches....86
Clustering based on STAGE 3 Sketches....102
Relationship between the three Cluster Solutions....116
USERCLUS * DRW1CLUS....118
USERCLUS * FILECLUS....119
DRW1CLUS * FILECLUS....122

9. CONCLUSIONS, LIMITATIONS AND IMPLICATIONS OF THE PRESENT RESEARCH....126

APPENDICES....131

LIST OF REFERENCES....143

PART 1. PAST RESEARCH

CHAPTER 1 : INTRODUCTION

McCormick and Sanders (1982) purport that systematic patterns of design arose in the past century. Grandjean (1982) explains that these patterns emphasise the man and machine forming two separate parts of a system, and having a reciprocal relationship. The resulting system, which marries the operator and the device is commonly referred to as the 'Man Machine System' (MMS). The MMS is defined as "An operating combination of one or more persons with one or more equipment components; they interact to bring about some desired output from given inputs." (Huchingson, 1982, p17). Yates (1989) stresses that in the rapidly developing technological age this perspective is the key to success in meeting increasingly complex needs that are arising. At a time when the world's information base doubles every three years, the use of computers is increasing rapidly in all spheres of life. As such, the importance of designing the human-computer interface to optimally accomodate both the user and the accomplishment of the task is essential. Individual factors which distinguish one user from another have practical implications for the human-computer interaction (HCI) and thus for the interface design. Some of these factors are expanded on in TABLE 1 and APPENDIX 1. This study will consider personal knowledge as the primary determinant of the HCI, while considering the impact of socio-cultural background factors on 'knowledge'.

TABLE 1.
STABILITY OF INDIVIDUAL DIFFERENCES WHICH EFFECT HUMAN-USER INTERACTIONS, LISTED FROM THE MOST TO THE LEAST STABLE.

PERSONALITY FACTORS	Intelligence, Extroversion/Introversion
COGNITIVE STYLES	Field (In)dependence, Impulsive/Reflective.
LEARNING STYLES	Heuristic/Systematic.
PERSONAL KNOWLEDGE	KNOWLEDGE and EXPERIENCE,

(Adaptation of table from Waern, 1989, p113).

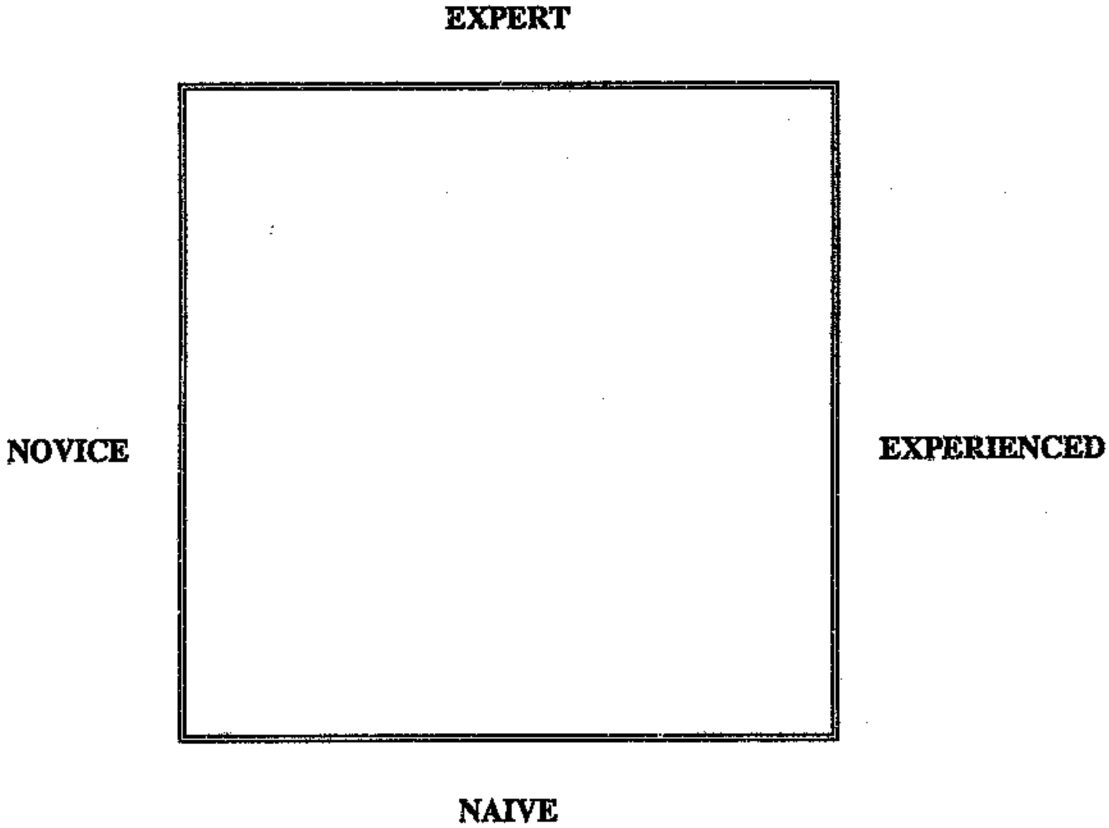
Personal knowledge, experience and 'mental models' of the dynamic operations of the computer are responsible for differences in individual performance. For many adults, the use of prior knowledge is an intentional strategy. Prior knowledge may also be used unintentionally. In any particular situation only a selected part of all prior knowledge will be evoked, and will influence behaviour (Waern, 1989). Knowledge and experience are thus the most useful factors for making recommendations about the design of the computer and training systems so as to optimise the ease of use of computers. Literature covered in this section will explain the method of, and need for the categorisation of users according to knowledge and experience. It will also clarify what is meant by the term 'mental model'; distinguish between three such models; and explain how and why background variables (such as age, organisational membership, gender, nationality, home language and education level) could impact on these models.

CHAPTER 2 : KNOWLEDGE AND EXPERIENCE

When referring to HCI, the term 'user' is generally understood as a person who uses the computer. This label can be divided into several categories. In this dissertation, the division will be based on the four categories which are suggested by Fisher (1991) as they refer to prior experience and knowledge regarding the task and the system. These categories are 'novice', 'naive', 'experienced' and 'expert'. They can be represented in a two-dimensional conceptual space (FIGURE 1).

A distinction must be made between the 'novice' and 'naive' user. " A novice in the broadest sense denotes a person who is new or inexperienced in a certain task or situation...with continued exposure to the task, and tools, the novice gains experience" (Fisher, 1991, p438). A naive user, however, "may be regarded as lacking developed powers of analysis, reasoning or critical capability in a particular situation...someone who needs to use computers in a meaningful way for particular tasks, but who does not need (or want) to develop knowledge of the operating system or application being used." (Ibid., p439). [An operating system is the system which schedules programmes for execution, controls the use of input and output devices and provides utility functions for all of the programmes run on the computer (eg. DOS). The application system is the 'package' which is used (eg. Wordperfect)].

A second distinction which is necessary to make is between the terms 'experienced' and 'expert'. According to Fisher (1991, p439) an experienced user, in contrast to a novice user, "has developed skills or knowledge from extensive exposure to participation...says nothing about the quality of experience." The expert, in contrast to the naive user, "gains and intentionally uses skills and knowledge about the dynamic substrates of the operating system." (ibid., p439).



(Fisher, 1991, p440).

FIGURE 1.
TWO-DIMENSIONAL CONCEPTUAL SPACE DIAGRAMMATICALLY REPRESENTING THE POSSIBLE RELATIONSHIPS BETWEEN THE NAIVE-EXPERT AND NOVICE-EXPERIENCED USER CATEGORIES.

Yates (1989) explains that an individual can be experienced in some ways and novice in others but as the population of users expands, the majority are likely to be naive and novice. The computer has thus had to become more efficient, easy to use, consistent, logical and natural (Moran, 1981). Barnard et al. (1981) advocate that for a computer to be truly 'usable' it must be *compatible* with the characteristics of human perception and action as well as with their cognitive communication skills, understanding, memory and problem solving. Pertaining to compatibility, Nickerson (1986) emphasises that the information in man and machine is organised very differently, and effective interaction requires that information flows both from the person to the computer and vice versa. The challenge lies in finding more effective ways of organising and presenting information for human comprehension, assimilation and retention since after-all, the human-computer-interface is the major determinant of information exchange, and thus, of the success or failure of computer systems (Nickerson, 1986). Sime and Coombs (1983) pose the question "Why can't computers be more like me?". Young (1981) maintains that computers *can* be more compatible with the users, and he suggests that for an interface device to be satisfactory its intended users should be able to formulate a 'mental model' of the devices which could guide their actions and help them to interpret its behaviours.

CHAPTER 3 : MENTAL MODELS

Modelling mental functioning relies on cognitive systems which often defy the 'guidelines' for human-computer interface design. Accordingly, researchers in the field of cognitive systems have placed an increasing emphasis on cognitive mapping processes to determine users' mental models, metaphors and images of key system dynamics and components (Fisher & Newcombe, 1990; Woods & Hollnagel, 1987). Downs and Stea (1973) define cognitive mapping as a process composed of a series of psychological transformations by which an individual acquires, codes, stores, and decodes information about the relative locations and attributes of phenomena in his or her everyday environment. Human behaviour is dependent on cognitive maps or mental models. Such a map is not necessarily a 'map' in the true sense of the word as it does not necessarily display the physical properties of such a pictorial graphic model. Instead, a cognitive map tends to be complex, abstract and selective while comprising generalised representations of the real world (Downs and Stea, 1973). Rutherford and Wilson (1991) note that the term 'mental model' has different connotations. Despite the lack of explicit definitions of mental models in the literature, researchers seem to accept and understand the concept intuitively (Hanisch et al., 1991).

Chapanis (1961) describes mental models as "analogies ... representations, or likenesses, of certain aspects or complex events, structures or systems, made by using symbols or objects that in some way resemble the thing being modelled." (cited in Waern, 1989, p96). Waern (1989) justifies the importance of mental models by stating that without representation, all we would be able to do is to act. We could never plan, decide, predict, or use prior knowledge. As such, particular model requirements are necessary, and the form of the model is important. Three types of models which Fischer (1991) and Johnson (1992) discuss are the:

(a) User's model (models the users have of the system and the tasks).

(b) Designer's model of the user (the models that designers have of users, tasks, and technologies relevant to the design of a system).

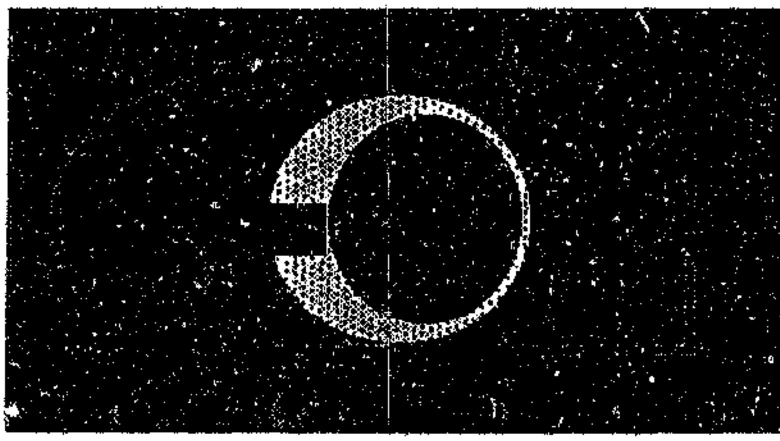
(c) System's model of the user. (The model the system has of the users and the tasks)

The term **'Users' models of systems'** has been referred to by many researchers (for example Ziegler and ...inger, 1991; Craik, 1943; Wickens, 1992; Johnson, 1992; Fischer, 1991; Finan, 1962; Johnsson-Laird, 1980; Brown & Booth, 1989; Rutherford & Wilson, 1991; Hanisch et al., 1991; Collicott, 1986; and Finlayson et al., 1989) when discussing the user's conception of the system, which is often referred to as their 'image' or 'cognitive representations' of a system (Hanisch et al., 1991). These researchers explain models as being based on experience, self-exploration, training, manuals, observation and accidental encounters, and therefore as differing from one individual to another. Piaget et al. (1960) explain that all our comings and goings provide, through time, the mental frame of reference for the many images (cognitive maps) formed of objects and situations. Finlayson et al. (1989) add that we develop generalised concepts for categories of events and objects so that new experiences can be readily placed into a meaningful frame of reference. Based on these frames of reference, the physical plan ... can construct the necessary features and their relationships in a meaningful way. Craik (1943) affirms that mental models simplify reality by omitting irrelevant details, chunking concepts and procedures and reducing the working memory load.

Moran (1981) depicts the 'user's model' as an integral part of the user interface. They "allow the user ... to bring experience and expectations from the real world to bear when attempting to perform a task involving the computer." (Blumenthal, 1990, p659). Fischer (1991, p3) adds that since "reality is not user-friendly ... Models play a crucial role ... and help to increase ... comprehensibility." Young (1981) explains that an appropriate model can be helpful, even necessary, for effectively dealing with system intricacies - an inadequate model can represent both misconception and error (cited in Fisher & Newcombe, 1990). Thus system features should be integrated in users cognitive representations (Hanisch et al., 1991; Johnson-Laird, 1980; Ziegler & Bullinger, 1991). Van Laethem (1990) supports this view and adds that novices perform better, with lesser errors in these cases, compared to when they learn with manuals. Accordingly, Fisher and Kaplan (1990) suggest that the command language also be matched to the conceptual model of the user.

Norman (1983) distinguishes between a mental model and a conceptual model in order to explain the disparities between user representation and system properties. He describes a mental model as the unobservable set of representations in the users mind. A conceptual model, however, is an observable manifestation of system components offered to the user by the designer as an explanation of the system - sometimes deliberately as a basis for the user to develop relevant mental models. When this conceptual model is not provided, a user will still build a mental model, however, it will probably be based on a combination of clues and interpretations during the HCI. This often results in idiosyncratic and incorrect mental models (Fisher & Newcombe, 1990). Fisher (1991, p7) proposed a model (FIGURE 2) which is pertinent to the understanding of user interaction with the computer, as it incorporates many of the above mentioned concepts, including mental and conceptual models, while comparing them to the actual system.

Waern (1989) purports that a computer system's reality can differ between people because of the way a computer is actually used. She distinguishes between 'outer tasks' (for example wordprocessing) which do not touch on the system itself, and 'inner tasks' which are concerned with handling the actual computer system. Waern (1989) notes that to a user who is engaged in an outer task, the computer reality is contained in the concepts and procedure used to perform the particular task. Thus, a user of a wordprocessing system will essentially be concerned with the reality of concepts such as words, paragraphs and pages, and the corresponding activities such as typing, inserting and deleting. As such, these users hardly distinguish between the 'system' and the 'task'. In accordance with this view, Norman (1983, p185) states "you use computers when you use many modern automobiles, microwave ovens ... and calculators. You don't notice the computer because you think of yourself as doing the task, not as using the computer." He adds that in the same sense, you do not go to the kitchen to use an electric motor; you go to use the blender. The motor is part of the task, although the blender is essentially a pure motor and the specialized attachments which it drives. Waern (1989) maintains that the difference between the system and the task is more likely to be acknowledged by a computer programmer who is more familiar with the operating system(s), and can choose which reality to present to the user. The essence of this argument is that the way in which one interacts with the computer will determine the mental model which is formulated. The reverse relationship also impacts on the users performance - the mental model which is formed impacts on the way in which the computer is used.



D1 : The subset of concepts that users know and use without any problems.

D2 : The subset of concepts that users use only occasionally.

D3 : The User's Model of the system.

D4 : The actual system.

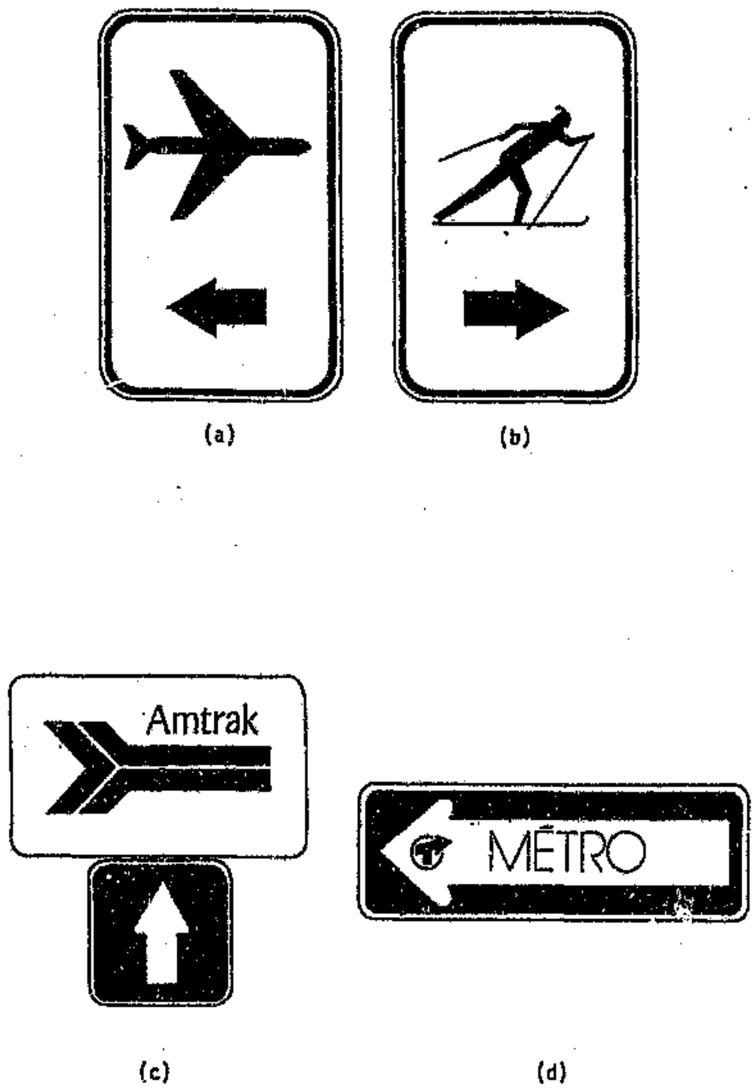
FIGURE 2.
FISCHER'S (1991, p7) MODEL ILLUSTRATING USER INTERACTION WITH THE COMPUTER.

Barber (1988) believes that 'mental models' are based on EXPECTATIONS of the action-effect relationship. It relates to the schema-based approach of program understanding, which assumes that the activation of knowledge structures (schema) stored in memory create expectations about information in the program. Waern (1989) stipulates that the nature of the linkage between the device and the outcomes need not be understood, but expectations are still formulated. For example, drivers may have a clear understanding of the consequence of turning a steering wheel of a car, without having or needing any information regarding how this is physically achieved. These expectations can succeed, or fail. If something occurs, for which the user has no expectations, or even contradicting expectations, the user is likely to experience conflict between the model (s)he employs to understand the system and the system's output. This results in people reassessing and improving their model to account for the factor(s) - thus the difference between novice and experienced users (Detienne, 1991). Barber (1988) exemplifies such 'model adaptation' by stating that when steering a boat with a tiller, difficulties may arise because the tiller has to be held in the opposite direction to that in which the boat is to travel. He adds that it usually does not take long for the beginner to correct the inappropriate tendency (based on the inappropriate mental model) to turn the tiller the wrong way. However, he warns that use of the incorrect model is prone to return when the person is in a panic situation.

Waern (1989) believes that two essential factors to include in the definition of a user's model are the idea that a model represents reality and is symbolic, and that the model has a structure similar to that of reality. They can even be partly false and still be useful. Fischer (1991) explains that it is not always a correct model which is desirable, but rather one which is understood by everyone, and which supports rather than paralyses action. Hanisch et al. (1991) refer to this concept as the 'validity' of mental models, and emphasise the correspondence between a mental model and the system's output. Similarly, both Barber (1988) and Sime (1981) emphasise that compatibility of the design with mental models of the user population is essential. The displays, actions and outcomes must be matched as closely as possible to the users' models since people find it easier to follow logical rules if the relevant material is meaningful in content. Examples (FIGURE 3) were offered by Whitaker and Sommer (1986) of signs bearing directional information which could disrupt people's responses to the stimuli (in Barber, 1988, p94).

The importance of stereotypes is illuminated in FIGURE 3's examples. Stereotypes come about because of 'reinforcement' - the pattern of rewards and punishment associated with a particular action shapes ones expectations and thus mental models. It has been suggested by some theorists that tasks with a sufficiently high degree of stimulus-response compatibility demand so few central-processing resources and monitoring during execution that they may be considered 'automatic' (Barber, 1988).

Craik (1943) purports that a model is also a means of communicating ideas about the reality to others. Definitions, concepts and rules used in the models must be formalised to ensure standardised understanding. Computers need formalisation to a greater extent than people do. This poses problems to the 'naive' person since they are not accustomed to the formalisation. Metaphors are widely implicated as part of an individual process of goal directed, learner-initiated learning, particularly where learning occurs in complex domains of high abstraction. This is typical when building models or learning computer dynamics (Carroll & Thomas, 1982; Brown & Booth, 1989; Wickens, 1992). It is thus often suggested that a computer should be introduced to novice users by drawing an analogy between the computer and a situation which is familiar to the user (Fisher & Kaplan, 1990). In accordance with the perception of 'expectation-based' mental models, Hanisch et al. (1991) show in their research of novice and expert users of a phone system that novice users had a deficient mental model of the system. They recommend the use of experts' models in designing training courses to aid novices in acquiring an accurate presentation of the system. Brown and Booth (1989) state that it is commonly accepted that we learn by building on existing knowledge, and thus we can use metaphors as the basis on which to build. If the metaphor is limited, so will be the development of the user's model. As Carey notes "if you change a person's representation of the task, you change the way the person does the task." (in Mendes, 1984, p39).



(a) airport – conflicting; (b) skier – concordant; (c) Amtrak – orthogonal; (d) Metro – conflicting. (From Whitaker and Sommer 1986)

(Barber, 1988, p94).

FIGURE 3.
EXAMPLES OF DIRECTIONAL SIGNS BEARING IRRELEVANT DIRECTIONAL INFORMATION.

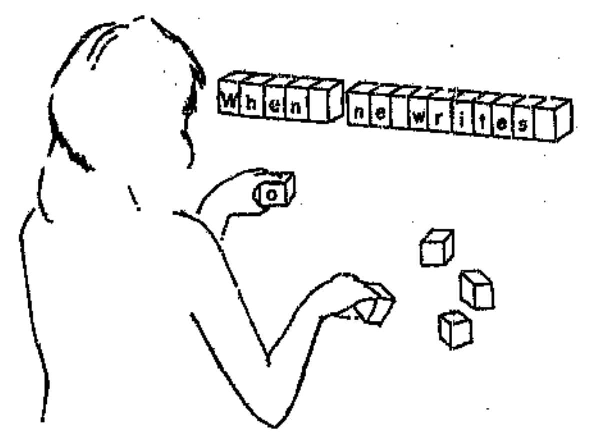
Waern (1989) and Halasz & Moran (1983) agree that it is often necessary to combine several models to explain the computer to the novice user as users seldom have a model of the system as a whole. Each user selects his own part of the task in the system reality for modelling, and at each level of abstraction, there must be a mental model representation (Rutherford & Wilson, 1991). Halasz and Moran (1982), however, suggest that while an analogy is where a whole unknown system is thought to behave at some level of abstraction in the same way as a known system, a metaphor only refers to part of an unknown system. Based on this view, they argue that an analogy can result in a limited view of the system - and thus faulty incomplete reasoning. The novice may not know which aspects of the models are applicable to other situations, and which are not. It is preferable to use metaphors. An example offered by Waern (1989) is that a filing cabinet analogy may be used for files in a computer, whereas a guard analogy would be used to explain the use of a password. When learning, prior knowledge which resembles the situation is evoked and "transferred" to facilitate learning, providing the actions to be performed and the goal resemble those of the prior situation. It delays learning when goals and conditions are similar, but the required actions are different.

Since transfer of knowledge from past experience to the task at hand depends on similarities between the present and the past situations, we should consider how similarities can be specified. Similarity is a subjective term, and subjects can differ greatly in their perception of similarities between computerized and non-computerized tasks. Waern (1989) describes a study by Waern and Raebenius (1985) which aimed to discover which metaphor was the more useful for learning a wordprocessing system - a typewriter metaphor, or a building block metaphor. She exemplifies the typewriter analogy with the statement (p104) "A word-processing system is like a typewriter. You can type a text by tapping the keys. If you want to correct something, you can delete and type over at a single stroke." (FIGURE 4(a)). To elucidate the building block metaphor, she offers the following statement (p105) : "You can insert new text by putting in new blocks with new letters, and you can delete text by taking blocks away. Changing letters is equivalent to exchanging one block for another." (FIGURE

4(b)). Two groups of subjects were each presented with one of these metaphors and with different tasks (keyboard use and spacial rearrangement tasks). She advocates that this research showed that when teaching a wordprocessor, a typewriter analogy is useful for learning some (keyboard use), and building blocks for other (spacial rearrangement) functions. The results showed no difference in performance times between the groups, however, it did impact on the manual reading times. The typewriter metaphor resulted in shorter manual reading times for tasks requiring text changes with no particular spacial components. The post-experimental comments of the subjects indicated that some of the subjects began to form models of their own in which the proposed metaphor was supplemented with further low-level details. Some months later, several subjects reported using the building blocks metaphor when they began to write their own reports. This shows that the metaphor must be both valid and perceived by the user as being appropriate to the task at hand. An important finding in this research was that, especially for 'naive' users, a model may be consciously explicit in its functional dimension without being consciously explicit regarding processes or structures.

According to Schmalhofer and Kuhn (1991), in previous research (Norman, 1983), it has been argued that the user's mental model (how-it-works knowledge) is very important for understanding their interactions with a system. Various experimental studies have shown that these how-it-works instructions can be more effective than how-to-do-it instructions (Schmalhofer, 1987; Kieras and Bovair, 1984), which may be explained by the fact that the former are more general (in Schmalhofer and Kuhn 1991).

(4a) A Typewriter Metaphor of a Wordprocessing System.



(4b) A Building-Block Metaphor of a Wordprocessing System.

(Waern, 1989, pp104-5)

FIGURE 4.
TWO METAPHORS OF A WORDPROCESSING SYSTEM.

Besides designing a system which is compatible with the user's mental model, several other factors must also be considered for 'good design'. These include attractiveness, visibility, constraints, functionality, affordances, natural mappings, feedback and durability. Problems occur when designers make one dominate the others. Norman (1988) purports that designers go astray for three reasons. Firstly, the reward structure of the design community puts aesthetics first. Secondly, designers must please their clients who are seldom typical users. Thirdly, designers are also not typical users.

The first two reasons offered by Norman (1988) are related in that the emphasis is moved from functionality to 'sellability'. The third reason is perhaps the most important with regard to computer design - "designers ... often forget that what matters most is the efficiency and performance of the total man-computer system, of which their computer is only a part." (Shackel, 1981, p14). Norman (1988) explains that problems arise due to 'naive psychology'. Naive psychology refers to the fact that people project their own thoughts and beliefs into the actions and beliefs they perceive other people to have. In their work, designers often become 'expert' with the device, and design in accordance with their mental models, which become far more complex than that of the user. This is because the designer is constantly developing his/her model, which reflects the reality of the computer system closely. In other words, "users of different levels of involvement and experience tend to represent dynamic computer processes at different levels of metaphor." (Fisher & Kaplan, 1990, p387). Designers become so proficient with the product that they can no longer predict the areas that will cause difficulties. If the designer cannot anticipate errors, the design cannot minimize their occurrence or their consequences (Norman, 1988). The second type of model (the user's being the first) which impacts on the usability of the system is thus the **'designer's model of the system'**. As early as 1962 Gagne (p37) had realized that "The best system development is that which includes consideration of system operation." To which Shackel adds "Unless these human factors problems are foreseen in the design stage then a sub-optimum system is the inevitable result." (1981, p15).

Hollnagel and Woods (1983) hypothesise that designers build into their systems a model, either implicitly or explicitly stated, of the user's characteristics. This 'system's image of the user' is called the **'system's model'**. It must (1) possess an image of both the physical characteristics and cognitive processes of the user; (2) assume an image of how the 'cognitive systems' of the machine and the user interact; (3) be dynamic, since both the users and their task may change over time (Fisher and Newcombe, 1990); (4) customize explanations so they cover exactly what the users need to know; (5) provide differential descriptions of new concepts in relation to known concepts of the user's model; and (6) present information through user specific filters, focusing on the parts which seem most relevant to the user, and keeping active systems quiet most of the time (Fischer, 1991).

3.1. Problems with Compatibility Between the User's, the Designer's and the System's Models

Marguiles (1981, p256) responds to Karl Marx's words "Even facilitating work becomes a means of torment since the machine does not liberate the worker from his task but rather strips work of its content" by stating "our goal...must not be to liberate man from work, but to liberate man from inhuman [cruel, merciless] working conditions." To achieve this, it is essential in designing the system to obtain a compatibility between both the designer's model and the user's model, and between the system's model and the user's model. The emphasis is thus on the ***user's model*** which "could be used to design interfaces suited to particular individuals...by giving clearer insight into the mental structures and functions underlying human error." (Grant, 1990, p1017).

Users should not have to adapt their models to an inconvenient interface; instead, the interface should be tailored to suit the user's mental model (Mendes, 1984).

Damodoran (1981) states that the minimal user support required to sustain HCI ensures i) users meet the system input requirements and ii) system output is received and understood in the way intended. Human-computer interface design compatibility generally involves a matching of the input and output modality (Barber, 1988).

Computers are often seen as infallible and, as Norman (1988) notes, users often resort to self-blame if they err, rather than attributing blame to the designer who should have minimised possibility of such errors occurring. Regarding the design problems in HCI, he opines that the computer designers give little or no feedback regarding what operations are expected. People are often faced with a blank screen and arbitrary, if any, instructions are given to direct them. He adds that regarding user errors, computers offer no clear explanation as to where or what the problem is, or what can be done to remedy it. Palme (1981) exemplifies this by stating that if the user enters "45" as a name, the computer should reply "I do not understand numerical names" rather than "Illegal memory reference" or "array bounds error". Also, many operations are 'dangerous' as they do not ensure that work cannot be deleted by pressing the incorrect button or forgetting to save. Warnings regarding such events are often referred to in a manual which is looked at once and then stored for safe keeping (Norman, 1988). Palme (1981) adds that such messages, as well as the HELP facility should be based on a program that has been tested on many people, and the questions asked by these people have been collected and processed.

Fisher and Newcombe (1990) warn that what cannot be assumed is that for any user group there will be a shared set of mental models, no matter what extent of uniformity of training and other factors may be evident. Other background factors may impact on mental models. These factors thus deserve further attention.

3.2. The Impact of Socio-Cultural Background on Mental Models

Prior to discussing value laden terms such as culture, the term **'socio-cultural'** as used in this research needs clarification. Brown (1972) notes that the terms culture and society are often used interchangeably although they differ. While a society is a permanent, relatively large and stable group of people who live and work together - their culture is the way they behave. White (1972) illustrates some of the views of culture as 'intangible' (Linton, 1945); 'character traits' (Boas, 1938) and 'routine' (in Brown, 1972). Thornton (1988, p22) and White (1972) quote Edward Tylor's definition of culture, which is still regarded as a definitive definition of the concept :"Culture or civilization is that complex whole which includes knowledge, belief, art, morals, law, custom, and any other capabilities and habits acquired by man as a member of society." From this definition it can be deduced that culture is not inherent, but is something one gains through normal social interaction and experiences (Machet, 1989). Culture is an adaptive mechanism - a body of ready made solutions to the problems encountered by the group. It is thus dynamic (Brown, 1972).

Because people intertwine brain and body, it is difficult to categorise cultural activities separately from other human activities. Goodnow (1969) states that studies must identify the skills common to people from many backgrounds, the skills that differentiate them; the features of milieu that may account for these similarities and differences; and whether the same answer means the same thing in different cultures (Pick, 1980). Starr and Wilson (1980) and Burger (1973) support Rohner's (1975) view that universalistic research must be comparative in nature. Dorgan (1991) cautions that emphasising the differences between cultures increases differentiation between groups, and creates antagonism and stereotypes. Accordingly, Starr and Wilson add that the similarities between the cultures must be emphasised and used to generate theories, computer programmes, training and teaching techniques of greatest possible generality. Similarly, Frijda and Jahoda (1969) opine that the ultimate goal is the elaboration of general behaviour laws. "A cultural mosaic consists both of discrete elements and the lines which form their boundaries and join them together." (Brembeck and Hill, 1973, p21). One must encourage the cultural essence of each group to flourish, while simultaneously providing the cement which holds the total mosaic together (Brembeck and Hill, 1973).

Hudson (1969) notes that pictorial material and teaching methods may be relevant to one cultural group, but not to another. This is important to note for education, marketing and safety (in warning signs). Berry (1986) emphasises the need to 'pitch' the material in the appropriate way for people from different socio-cultural groups. Similarly, Duke (1990) and Ramirez III (1988) argue that programmes that are not based on the unique learning styles of the people are unfair as they reject their cultural background, and create conflicts by forcing them to question the values and learning experiences which they have acquired at home. The results of this practice are reflected in school drop-out rates and in the low level of educational attainment of members of minority groups. It is the teaching, rather than the learning style that prevents the child from learning (Hilliard III, 1992). Shinn (1972) adds that what is of concern in teaching is not the particular set of values to which one adheres, but rather the ability to relate to all students irrespective of their culture or background.

Socio-cultural variables are difficult to study as they are not easily controllable, and they are often value laden. These variables include race, home language and education. Dorgan (1991) questions whether the use of race as a determinant of culture is logically and morally feasible. Some argue that race stands apart from culture in that it is innate and physical, not learned after birth (Brown, 1972). In contrast, researchers such as Bullivant (1986) and Brembeck and Hill (1973) include race and ethnic origins as cultural characteristics. For example, Machet (1989) notes that in South Africa, the Afrikaaners, English speaking Whites, and Blacks form different ethnic groups, each of which has their own culture. This is indicated by the fact that members of each group generally choose to attend different churches and schools - two of the main institutions for imparting values to children in the socialization process.

Kaplan (1988) demonstrates that culture impacts on our point of reference in terms of language used. He notes that in Western cultures, one might say 'I see him' showing that we interpret actions as brought on by our own will. The Eskimos in Greenland, however, state 'he appears to me' as they perceive events as happening to them. Thus, any attempt to eliminate our human perspective from our picture of the world would lead to absurdity. Markers of essays written in foreign languages have received criticisms such as 'lacks organisation'. Kaplan (1988) attributes this to the student's use of a rhetoric that violates the reader's expectations.

Stueber (1973) stated that education is generally defined within a single cultural context. It has, for example, been defined as a function of a particular society at a particular time, rooted in some actual culture and expressing the philosophy and recognised needs of that culture. According to Neff (1973), education and culture are inseparable as culture entails learned modes of behaviour that are socially transmitted from one generation to another and from society to society. These processes that are learned in turn owe their continued exi e to culture.

The relation between the above mentioned variables is continually demonstrated in the literature and the definitions of the variables. For example, Machet's (1989) definition of ethnicity embodies concepts such as a **common culture and language**; an awareness of group solidarity and a common historical background; a common race-semantic norm image; and a group identity and feeling of a common destiny by all group members. Due to the difficulty in clarifying the distinction between these concepts, for the purpose of this dissertation, the term 'socio-cultural background' will encompass ethnic, educational and language differences as the aspects are difficult to separate.

The past literature has generally adopted an approach which imposes cultural groupings as independent variables, assuming that one aspect - culture, education or intelligence, for example - impacts on behaviour in a certain way, disregarding their interaction. Further, the extent of acculturation is often not considered as a variable.

Berry (1986) explains that acculturation occurs when people migrate, and 'westernization' influences behaviour of individuals. Burger (1973) identifies three goal systems of cultural assimilation : (1) Anglo conformity - the complete renunciation of one's ancestral culture for the values of the Anglo-Saxon core group; (2) melting pot - combination of the cultures to form a new culture; and (3) cultural pluralism - various cultures co-existing. Dorgan (1991) sees South Africa as having a 'melting pot' society. For example, it is not unusual to see a White teenager wearing traditional Bantu beads. In contrast, Burger (1973) purports that cultural separatism is intensifying rather than diminishing. The question is thus raised whether different techniques must be implemented for developing training and computer systems for people from different cultures. Various arguments for and against this suggestion exist, possibly due to inconsistency in methodology and operational definitions of culture. In order to overcome such limitations, the present research argues for an exploratory study which makes no presuppositions regarding which variables will, or will not, influence mental models of subjects. More specifically, several 'background variables' which relate to one another (such as education, home language and ethnic group) should all be considered, and only included as independent variables if their impact on the subjects' mental models is clearly identifiable.

"Our culture ... exercises a profound influence over us. It organises the way we learn to see the world ... we see how important our culture is in providing us with explanations of the world we live in, and how it directs our attitudes and feelings as well as our ideas. Of course, we all add a unique element to that understanding; but we are still very much at the mercy of what our culture *teaches* us about life." (Bantock, 1968, pp2-3). "Different cultures appear to cultivate different abilities, interests, and perceptions." (Du Preez, 1986, p83). We cannot assume that people of different cultures attach the same meanings to visual symbols or ability to transform visual imagery (Du Preez, 1986). Shinn (1972) states that one's social background is influential in the way one perceives the social universe.

Deregowski (1984) maintains that human perceptual mechanisms are essentially the same throughout the species. Cultural influences shape the mechanisms by accentuating certain characteristics so that different perceptual skills result. During this shaping, features which are encouraged in one culture may be thwarted in another. Culture, like a gardener training a tree, trains the mechanism to suit its own purpose. As the shape of the tree reflects the actions of the gardener, so the perceptions of an individual reflect his cultural experience, yet the tree remains a tree (Deregowski, 1984). Machet (1989) adds that culture determines the stimuli that a person perceives and the way that they are interpreted and understood. More specifically, one selects stimuli which are meaningful in terms of one's culture and omits those that are confusing or strange.

Goodnow (1969) found that culture had a greater impact on performance than did intelligence or education level. Hudson (1969) adds that informal instruction in the home and habitual exposure to pictures played a much larger role in influencing perceptions than did formal education. Ramirez III (1988) discusses Lesser's finding that members of different ethnic groups display different patterns of intellectual ability, each group performing better in some areas than in others. The studies show intellectual ability as a manifestation of culturally unique learning styles, as each culture emphasises the importance of achievement in certain areas. Similarly, Cole and Bruner (1974) state that intellectual equality exists between all people according to the 'doctrine of psychic unity', and that experience (which includes background) impacts on the performance of individuals. What is perceived depends on the observer's frame of reference which is in turn determined by one's cultural socialization.

Piotrowski (1935) concludes that vision in true perspective is not a natural phenomenon, but depends largely on education, environment, maturity, intelligence, the nature of the task and 'conscious attitude' (in Deregowski, 1980). It has been argued that European cultures 'cause' their members to excel on visual cues, while traditional African cultures foster excellence on auditory and kinaesthetic cues (Lonner and Triandis, 1980). Du Preez (1986) discusses literature which shows that Western children are better able to express abstract concepts than traditional children. While illiterate Blacks and both Black and White workers with primary school education perceived pictures they were shown, two-dimensionally, White school children became increasingly three dimensional in their perception of the pictures as their level of education increased. Black samples of high educational level did not show a corresponding increase in 3-D perception. Du Preez (1986) adds that many replications of this study's findings (eg. Mundy-Castle, 1966) exist. In accordance with this, in South Africa many Blacks have difficulty in perceiving and interpreting a 3-D picture that involves depth perception because their culture has not taught them how to 'read' this type of picture. In another study, hunting peoples possessed good visual discrimination and spacial skill. These skills diminished as hunting skills diminished. Also, the relationships between ecological and psychological variables appeared to covary systematically. These studies support the 'carpentered world' hypothesis which states that the human visual system is usually *functional* across species, but specific conditions affect how the visual system is utilized within different ecologies (Lonner & Triandis, 1980).

Much of the past research has focused on personality and culture. It has only been more recently that interest has shifted to the relationship between culture and cognitive style (Frijda and Jahoda, 1969). Pick (1980) notes that most of the research in this area considers perception and how people's knowledge of objects and concepts is organised. One's mental model is based on perception, which may be influenced by socio-cultural background, however, the research dealing with perception generally refers to perception of 'concrete objects which the subject can see', rather than perception of abstract concepts in the subject's mind. Thus, as seen above, in past research, the researcher has generally presented the subjects with a 'concrete', specific illustration, and established how they perceive the picture. More pertinent to the present study is the ability to materialise a perception - the complement of the former. More specifically, to produce drawings based on perceptions of an abstract concept.

Goodnow (1969) stresses the importance of tapping the 'images in the head' or mental models of subjects in order to determine the differences between the images of different cultures and their performance. Barber (1988) mentions the culturally determined differences in stereotypes. In traffic lights in Western cultures, red is used to warn of danger, and to tell the driver to stop, while green implies one can move past the light. He adds that if one wants to switch on a room light, one does not have to think twice about whether to push the switch up, or down. Ones expectations are so strong and are shared by so many people from ones national community that it can be described as a 'population stereotype', yet the population stereotypes differ according to the population. If one is from the United States, one will expect the movement to be 'up' for on, yet it will be 'down' for on if one is British. He emphasises that the existence of such opposite conventions show us that there is nothing 'natural' about this particular stereotype. Smith (1981) showed that 'norms' which strongly contradict 'natural' tendencies may prevent stereotype formation. In a paper-an-pencil test, he found that the two most common designs for a cooker-hob control arrangement in the US (the left pair of controls operate two front burners) were not among the four most popular patterns chosen by the US subjects. (in Barber, 1988).

"Performance is strongly affected by cultural factors." (Du Preez, 1986, p80) and "Overwhelming data also exist to show that cultural groups vary with respect to behavioural style." (Hilliard III, 1992, p371). One of the sharpest differences among cultural groups may lie in tasks where the child has to carry out some spacial shuffling or transforming in his head (using mental models), without the benefit of actually physically moving the material around. Past actions may serve as an 'action model' or a reference point on which to base future perceptions of relationships. Thus, Du Preez (1986) argues that in order to move from a physical to a mental shuffling, we may need to practice with actually moving the objects. He adds that cultures differ in the practice they provide in mental as against physical shuffling. For example, there is a great difference between the middle class British children who play with toys ('shapies' and jigsaw puzzles) and the child who has no toys. Familiarity with the material seemed to be a significant factor in the abstraction. Mental shuffling of images may be necessary to adapt mental models images as tasks change, or as one thinks a problem through sequentially. The impact of culture here is thus important.

Many tasks used to assess people's spacial skills require them to build a model, copy a form, or make some kind of a production (Deregowski, 1980). In sum, different cultural groups use different, complex spacial reference systems. Hudson (1969) found that Blacks used a 'twisted perspective' in which a combination of profile and frontal view was used in drawings. For example, although an antelope was drawn in profile, two ears and four legs were clearly visible. Motor cars drawn in side view showed two headlights and the front grill. While the unacculturated Black man draws what he knows, to identify an object, the White man draws what he sees. Further, the unacculturated Black sample represented objects without any consideration of size. In Western pictures, size indicates distance. Pick (1980) states that when judgements are required about features of real objects, uneducated adults who are familiar with the objects are at least as accurate and sometimes more accurate than are those who had formal education. When the judgement required is artificial, educated people are more accurate.

Familiarity with the relevant objects and with the type of task to be performed, and formal education are associated with apparent cultural differences in how people represent and classify objects. For example, Lloyd (1971) found that Nigerian children from 'elite homes' in which mothers were educated and the children attended schools, and from 'traditional homes' in which mothers were uneducated and most children were not in school - the children from 'elite homes' outperformed those from 'traditional homes' (Pick, 1980). When people know something about the objects they are doing something with, and when formal education is equivalent, cultural differences in how people represent objects are minimal or absent (Pick, 1980).

Research dealing with socio-cultural factors has thus generally identified marked differences between the performance of people from different backgrounds. This research has, however, imposed cultural groupings as independent variables, rather than being exploratory in nature. When considering socio-cultural impact on the perception and modelling of the components of a computer in terms of mental models, the possibility cannot be excluded that a techno-culture has developed, merging their similarities and differences. The literature intimates that this theory has not been investigated as yet.

3.3. Investigating Computer Users' Mental Models

Extensive research, using a wide range of research techniques, deals with computer users' mental models. It revolves around imaginative assumptions about the HCI, and explores the rational explanations of manifest operations. The relevant literature consists of an accumulation of different ways of embroidering the problem. Both support for and criticisms of previous research methods used in this area exist.

Visser and Morais (1991) focused on knowledge used by programmers whom they interviewed. The interviews used open ended questions concerning the main aspects of the user's activities. By means of content analysis, they found that different types of knowledge have different mental representations. In defence of their use of interviews, they state that interviews may not give precise data, but are useful to collect general information about user mental models, and to identify objects to be developed by other methods that will be used. Similarly, van der Veer (1985) used qualitative descriptions by users of an accounting system to establish their mental models. They were asked to describe the system to some other people. Models were generally described according to one of three levels - task level (in terms of the task performed), syntax level (according to the commands) and interaction level (according to the input made and feedbacks obtained from the system) (in Waern, 1989).

Denham (1993) also considered mental models, however, she used drawings by subjects as a method of data collection in order to determine the components, conduits and causal effects of the mental models of computer dynamics used by children aged nine to fourteen. Her motivation to use drawings as opposed to the more popular verbal descriptions stemmed from the fact that subjects often discuss the study, and this could bias the findings as diffusion threatens internal validity of research. Denham (1993) also justifies this technique by stating that it reduces the intimidation associated with face-to-face questioning and it overcomes the fear of saying something silly, or being unable to express what one means. Further, in protocols, she contends, a great deal of prompting is necessary to find out exactly what the subject means as 'hidden processes' remain untackled. People interpret rather than know, what happens inside the computer, and the interview does not allow the promotion of thinking through a non-linear problem.

A possible threat to the generalisability of Denham's (1993) findings beyond the United Kingdom (UK), where the research was conducted, is apparent in the emphasis in various sketches on trains and railway lines, which are vastly used in the UK but not in South Africa. Also, unlike in South Africa, computers are dominant in the UK education system, and the UK is more technologically advanced. It could thus be hypothesised that people from the UK have a more sophisticated level of knowledge of the 'components of a computer' than those of South Africa.

Other researchers who utilised sketches in their research were Finlayson et al. (1989). They found drawings to have considerable promise as an investigative and communicative tool in their research which considered mental models that children have of their houses. Finlayson et al. (1980) noted a high degree of accuracy regarding detail, despite a lack of drawing skill. They found no significant difference in the way that children from different ethnic groups drew their houses. Deregowski (1980) advocates that drawings depict a subjects' internal representation of an object, and little cross-cultural variation is likely to be found on tasks involving abstraction of essential features of simple three dimensional stimuli.

CHAPTER 4 : SUMMARY OF PART I

The importance of correct human-computer interface design to optimise usability of computer environments is lucid from the vast amount of research which has previously been conducted in this area. The views expressed thus far are consistent since they share a common theoretical basis. While several references have been made to individual differences such as personality and cognitive and learning styles, the one issue which dominates HCI research is that of knowledge. Although different terms have been used by different researchers, knowledge is invariably discussed in terms of mental models, and the two dimensional conceptual space (novice-experienced and naive-expert). Compatible arrangements of displays, controls and feedback relative to mental models are essential. They are what people *expect*. The compatible arrangement will generally produce the best performance in terms of speed, accuracy and qualitative aspects. Compatibility can be considered in terms of information-processing ideas - as a matter of the recoding operations intervening between registration of the stimulus and the production of the appropriate response. It follows that population stereotypes are those which necessitate the least amount of recoding, and what people are reflecting in their choice of a preferred response is one requiring the least recoding effort (Barber, 1988).

Researchers have generally assumed that the mental models that have been established reflect those of the entire population, and ignore that socio-cultural background may impact on the mental models and population stereotypes of people from different backgrounds - thus making the external validity of their research questionable. Subsequently, knowledge and the closely related socio-cultural background, were chosen as the independent variables in the present research, to establish the extent to which mental models of computer dynamics are impacted on by these factors, and whether universal similarities and/or differences in these mental models can be identified to form the basis for human-computer interface design, and training in computers. The methodology of the present study draws on the above mentioned research.

PART 2: THE PRESENT RESEARCH (METHODOLOGY, ANALYSIS, RESULTS AND DISCUSSION)

CHAPTER 5 : AIMS AND RESEARCH QUESTIONS

The term 'mental models' refers to the subjective cognitive conceptions or 'images in the head' of dynamic operations of 'systems', formed by experience, self-exploration, training and observation (Fischer, 1991; Rutherford & Wilson, 1991). Much of the past research on human-computer interfaces was based on the investigation of mental models, regarding specific computer dynamics and operations, from specific samples of computer users. Generalisability of the mental models found in such studies is usually ignored, yet these models are the basis of the recommendations offered.

Past HCI research has often acknowledged the importance of considering similarities and differences in mental models of computer users with different levels of expertise and experience. They have, however, failed to establish the extent to which socio-cultural background variables are associated with them. These variables include organisational membership, age, nationality, race, home language, gender, marital status and education. The present research aims to achieve both of these objectives.

Previous research generally assumed that one aspect - education or intelligence, for example - impacts on behaviour in a certain way. It disregards the interaction of these factors, and the impact of acculturation on 'socio-cultural background characteristics' of subjects. This study does not impose cultural groupings as independent variables, as was generally done before. Instead, this is an exploratory study which makes no pre-suppositions regarding which variables will, or will not, influence mental models of subjects. The variables which have been listed in the previous paragraph as 'user socio-cultural background' are considered in terms of their relevance to groupings of subjects which are imposed by CLUSTER ANALYSIS. They are only discussed in the results section if their impact on the subjects' mental models are clearly identifiable.

Mental models are often subjected to different task constraints in different studies. To assess the generalisability of findings in this regard, this research also aims to establish the extent to which task constraints (for example, is the computer active, or inactive. If it is active - what operation is it performing) influence mental model application and modification.

As such, in this 'qualitative' study, the research question is : 'Are there distinguishable differences between the mental models of tertiary sector computer users from different backgrounds?'. This incorporates three questions. Firstly, ' To what extent do these users rely on different metaphors and analogies to explain un-encountered computational dynamics?'. Secondly, 'What is the association between user background and observable differences and similarities in their mental models?'. Thirdly, 'To what extent does the type of operation (inactive vs. active) used in the research, impact on the metaphors adopted by subjects?'.

The use of sketches as opposed to interviews in order to obtain information regarding mental models is a relatively new concept which warrants further attention. Thus a further exploratory feature of this research is to establish the feasibility of using sketches as a measuring instrument in research on mental models, using adults as subjects.

CHAPTER 6 : M HODOLOGY AND MEASURING INSTRUMENTS

6.1. Research Design

This research design is an EX POST FACTO, FIELD RESEARCH CASE STUDY which uses WITHIN SUBJECTS and 'IMPOSED' BETWEEN SUBJECTS comparisons.

Christensen (1988) explains that in an ex post facto study, the groups differ according to variables (in this dissertation -knowledge, experience and background) and their behaviour is recorded to determine if they respond differently in a common situation (expression of the mental models). Inability to control the group of subjects or the variable(s) of interest are also typical in ex post facto studies (Christensen, 1988). In this dissertation, there was no control over the group from whom subjects were selected, as the subjects were already employed in the positions in the participating companies. There was also no control over the variables of interest, since the effects had taken place in the past (past knowledge and experience), hence the name 'ex post facto' which means 'after the fact' (Mason and Bramble, 1978). This design is generally used in non-experimental research such as field research (Kerlinger, 1986).

Kerlinger (1986) states that "any scientific studies ... that are non-experimental, and that are done in life situations like ... institutions ... are considered field studies." (1986, p372). Katz divides field studies into exploratory and hypothesis testing studies. This research was exploratory which "seeks what is", rather than predicting relations to be found (cited in Kerlinger, 1986). Christensen (1988) adds that a field study is a method of descriptive research. The investigator actively interacts with the subjects in the collection of data, unlike in a naturalistic study. Limitations of this method are those associated with all non-experimental research - decreased generalisation of findings to the broader population, and possibility of extraneous effects which cannot be controlled. Despite this, it is useful since it allows the investigator to research problems that could not otherwise be studied (Mason and Bramble, 1978).

The data was collected from three companies, and as such, this is a case study. Christensen (1988), Mason and Bramble (1978) and Kazdin (1980) describe a case study as giving an in depth description based on observation of the case under investigation. The experiences are described in great detail so that the description captures as much of the unique characteristics of the situation as possible (Kazdin, 1980). Yin (1981) adds that a case study is useful for exploratory research in which one seeks to explain the behaviour of individuals. Since case studies are conducted in the absence of experimental control, it is difficult to interpret many of the observed behaviours. The purpose of a descriptive case study is thus to call attention to the existence of various behaviours on which experimental research can later be conducted (Kazdin, 1980).

A case study tends to magnify details about behaviour - especially when conducted as a case report - which may otherwise be lost (Kazdin, 1980). A case report may include several cases that are used as the basis for drawing conclusions about behaviour. Although each case is studied individually, the information is aggregated so as to reveal relationships that extend beyond more than one individual. The traditional case study can be criticised because of the ambiguous information it provides, since the information can be interpreted in so many ways. The advantage of a case report is that observations based on several individuals rule out the possibility of idiosyncratic findings characteristic of one person. A group of subjects can be treated as a single unit rather than as several individual cases (Kazdin, 1980). This approach has been adopted for the present research.

In this repeated measures, within-subject design, the same subjects were repeatedly assessed after participating in all experimental treatment conditions. The effects of an independent variable are reflected by differences observed within subjects (Keppel et al., 1992). "Considerations pertaining to the variables that are to be studied may dictate whether a within-subject design is likely to be appropriate." (Kazdin, 1980, p167). In this study, this design has the practical advantages of needing a small group of subjects, and being cost effective. Also, since subjects are perfectly matched, the design is very sensitive (Kazdin, 1980). As there is no treatment being administered, no control group is necessary. The within-subject design was therefore appropriate (Kerlinger, 1986) in this study.

Cluster analysis results in imposed groupings of subjects. Once the most favourable cluster solutions are chosen, comparisons can be made between the resulting imposed groups. As such, this research used a between-subjects design to consider the relationship between imposed groups resulting from cluster analysis, in the form of a contrasted groups design. Here assignment of subjects to groups is predetermined (by Cluster Analysis in this case), and one compares the existing groups to each other (Gottsdanker, 1978; Bless and Achola, 1988).

The independent variables were 'knowledge' and 'experience' with respect to the use of computers; and 'socio-cultural background' (age, organisational membership, gender, nationality, home language, education and so on). Although these variables cannot be manipulated, they may account for most of the differences in mental models of computer dynamics. Extraneous variables were controlled for to an extent by random selection.

6.2. Subjects

"No matter how brilliant the technical concept and execution of a system, it is doomed to failure if the users for whom it is intended will not use it. Thus the needs and abilities of the user must be understood, and must be allowed to influence the design, however much this may compromise an elegant technical solution or incur short-term financial penalties." (Yates, 1989, p246). The critical concern when selecting the sample is that the information obtained from the sample can be extrapolated to the entire user population (McCormick and Sanders, 1982). Crellin (1990) emphasises Norman's (1988, p155) view that "There is no substitute for the interaction with and study of actual users."

Eighty subjects (Approximately 80% of original sample of convenience) were randomly selected from the volunteers in two manufacturing companies (32 and 37 subjects in each company) and a broadcasting company (10 subjects). This was achieved by placing pieces of paper - each containing the name of a volunteer - in a hat, and randomly selecting them. These volunteers were tertiary sector 'clerical' employees who use computers as an integral part of their daily work, and who all perform similar operations (such as data capturing) on the computer. All subjects were assured of anonymity, and it was explained to each subject that there could be no personal gain or penalisation for participation, or lack thereof, in the study. Further, subjects were informed that they could withdraw at any stage of the research, as participation was voluntary.

In order to describe the sample in terms of socio-cultural background, Frequency Procedures (discussed in CHAPTER 7) were implemented on the data obtained from the first section of the interviews discussed below. Use of frequency contingency tables (combinations of categories of variables) enables the reader to examine the interrelations between the sections, and compare them to one another, qualitatively (APPENDIX 2). The total number of subjects in each level of the factors which are considered are listed in SYNOPSIS 1.

SYNOPSIS 1

Total number of subjects in the sample, in each level of the factors which were included in the exploration of socio-economic background variables on mental models.

ORGANISATION

ORG I	=	38
ORG II	=	32
ORG III	=	10

MARITAL STATUS

MARRIED	=	42
SINGLE	=	26
DIVORCED	=	7
WIDOW	=	3
SEPARATED	=	2

GENDER

FEMALE	=	71
MALE	=	9

FAMNUM

1	=	7
2	=	17
3	=	14
4	=	25
5	=	8
6	=	6
7	=	2
11	=	1

NATIONALITY

SOUTH AFRICAN	=	71
BRITISH	=	3
PORTUGUESE	=	2
SWAZI	=	2
ITALIAN	=	2

EDUCATION

STD 8	=	14
STD 9	=	17
MATRIC	=	33
STD 8+DIPLOMA	=	6
MATRIC+DIPLOMA	=	9
MATRIC+DEGREE	=	11

RACE

WHITE	=	52
BLACK	=	22
INDIAN	=	5
COLOURED	=	1

LANGUAGE

ENGLISH	=	28
AFRIKAANS	=	26
BILINGUAL (E/A)	=	1
ZULU	=	6
SOTHO	=	6
BILINGUAL (E/P)	=	3
TSWANA	=	6
XHOSA	=	1
VENDA	=	1
PEDI	=	1
SWAZI	=	1

It is generally accepted that nationality, race and language groups are all closely related to each other, and to culture. In this sample, seventy one of the subjects were South African. The other nine were British, Portuguese, Swazi and Italian. Members of the different nationality groups were found in all three organisations (TABLE 2).

TABLE 2.
DISTRIBUTION, WITHIN THE ORGANISATIONS, OF SUBJECTS OF DIFFERENT NATIONALITIES.

NATIONALITY	ORG I	ORG II	ORG III
South African	32	31	8
British	2	0	1
Portuguese	2	0	0
Swazi	2	0	0
Italian	0	1	1

Of the fifty-two White subjects, forty-two were South African, three were British, two, Portuguese, and two, Italian. The twenty-two Black subjects comprised twenty South African and two Swazi subjects. All of the Black subjects in this sample were employed in Organisations I (77% of the Black members of the sample) and II. The White members of the sample were distributed through the three companies, with nineteen, twenty-six and seven subjects in Organisations I, II and III, respectively. All three organisations had either one or two Indian subjects, and the only Coloured person in the sample was employed in Organisation III (TABLE 3). While the South African subjects were aged 19 to 58 years old (23 of these subjects were under 26 years old), the ages of the foreigners ranged from 27 to 56 years.

TABLE 3.
FREQUENCIES OF SUBJECTS IN EACH RACE GROUP IN THE THREE ORGANISATIONS.

	ORG I	ORG II	ORG III
WHITE	19	26	7
BLACK	17	5	0
INDIAN	2	1	2
COLOURED	0	0	1

Within each race group, there may be a further cultural distinction based on language group. Dorgan (1991) maintains that in South Africa, language groups are increasingly difficult to identify. As the society is evolving, it is generating shared systems of meanings that transcend the strict classification of language-groups. This is evident in this sample, as two categories (English-Afrikaans (E/A) and English-Portuguese (E/P) speaking) were necessary for subjects who regarded themselves as bilingual. A complicating factor in this categorisation is that while two subjects have equal ability in two languages, one may consider himself as bilingual, and the other may not.

The English and Afrikaans speaking subjects were approximately equally represented in the sample, with twenty-eight and twenty-six subjects, respectively. Six subjects fell into each Zulu, Sotho and Tswana speaking group. One subject fell into each of the other language groups (FIGURE 5). The largest group (fourteen subjects) in Organisation I spoke English. In contrast, most (twenty-one) of Organisation II's members spoke Afrikaans. In Organisation III, nine of the ten subjects were English speaking.

Kaplan (1988) explains that language impacts on our point of reference. For example, essays written in foreign languages have received criticisms such as 'the material is all there, but it seems out of focus' as the author's and the reader's points of reference differ. The previous (section 3.2) example of different points of reference between Western cultures who say 'I see him', showing that we interpret actions as brought on by our own will, and Eskimos who state 'he appears to me', as they perceive events as happening to them, exemplifies this point. As such, it is conceivable that a relationship may exist between home language and mental model formation.

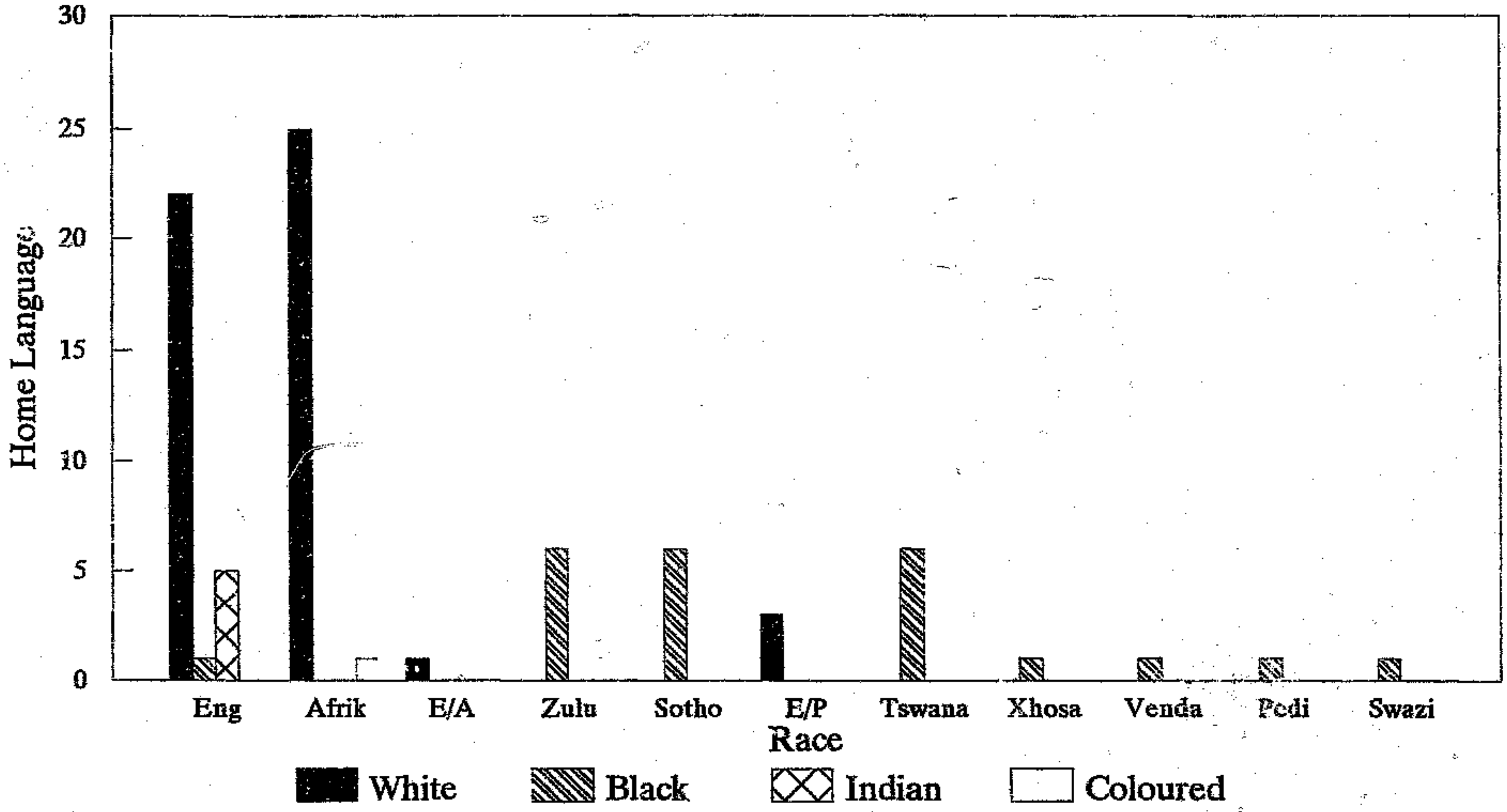


FIGURE 5.
COMPOSITION OF LANGUAGE GROUPS WITHIN EACH RACE GROUP.

TABLE 4.
NUMBER OF FEMALES AND MALES IN THE SAMPLE FROM EACH ORGANISATION.

	ORG I	ORG II	ORG III
FEMALE	34	27	9
MALE	3	5	1

As seen in TABLE 4, the proportions of males to females were roughly equal in organisations I and II. Of the seventy-one female subjects, sixty-two were South African. All nine male subjects were also South African. Forty-nine of the female subjects were White, eighteen were Black, three, Indian, and one, Coloured. The male subject group comprised of three White, four Black and two Indian subjects. Except for two male subjects who were 43 and 52 years old, the males were all between 21 and 33 years of age.

During the Apartheid era in South Africa, closely related to race and language, were imposed socio-economic classes. Schlemmer (1973) explains that race has, to an extent, determined socio-economic class in that Black people, because they are Black, have been pushed into low-status positions. The apartheid system entrenched existing social class boundaries between the different race groups (Davies, 1986). Some of the consequences were reflected in the sample. For example, Blacks generally believe that they should have several children who can look after them in their old age as they had no insurance policies or saving schemes. Possibly due to such cultural differences, in this sample, the largest households of 7 (two subjects) and 11 (one subject) people all fell into the Black group who were employed in Organisation I. In contrast, forty-eight of the White subjects had between 2 and 4 people living in their homes. Despite these extremes, most of the subjects (fifty six) in the three companies had 2 to 4 people living in their homes. As with this socio-economic variable, the other variables which tap social class differences indicated that the tertiary sector clerical level workers generally came from similar socio-economic backgrounds, with slight variations (APPENDIX 3).

Sewell and Martin (1976) assert that an individual's position in the social structure often determines educational and economic opportunities which impact on occupational choice. Howell and Frese (1979) contend that differences in career aspirations are more closely connected with socio-economic status than with race. Kohn (1970) found that members of different social classes have different experiences and develop different occupational aspirations. Working class families tended to entrench in their children values of conformity to external authority. These values impact on the individual's vocational choice. Thus, members from lower socio-economic classes tend to enter occupations requiring conformity (Kohn, 1970) such as tertiary sector clerical level jobs. It is therefore not surprising that in this sample, the socio-economic class of the subjects did not differ significantly between the subjects. The levels of the socio-economic variables were generally broadly distributed within a range of values applicable to a working-class (as opposed to middle or upper-class) sample.

The education levels and home languages were widely distributed through the sample's age groups. Thirty-three subjects had obtained a matric level education. Twenty-eight of these were South Africans. All three British subjects fell into this education level. Nine subjects had matric and a diploma, and eleven had matric and a degree. The education levels (Std 8, Std 9, matric; Std 8 and diploma; matric and diploma and matric and degree) of the subjects was widely distributed among the White and Black subjects. In the White group of subjects, twenty had matric. There were between four and eight subjects in each of the other education levels. Similarly, in the Black group, the majority (nine) of the subjects had a matric level of education. Six Black subjects had achieved the highest level of education in the sample, namely matric and a degree. Four of the Indian subjects had a matric level education, and the fifth Indian had standard 8 and a diploma. The Coloured subject had a standard 8 education (FIGURE 6).

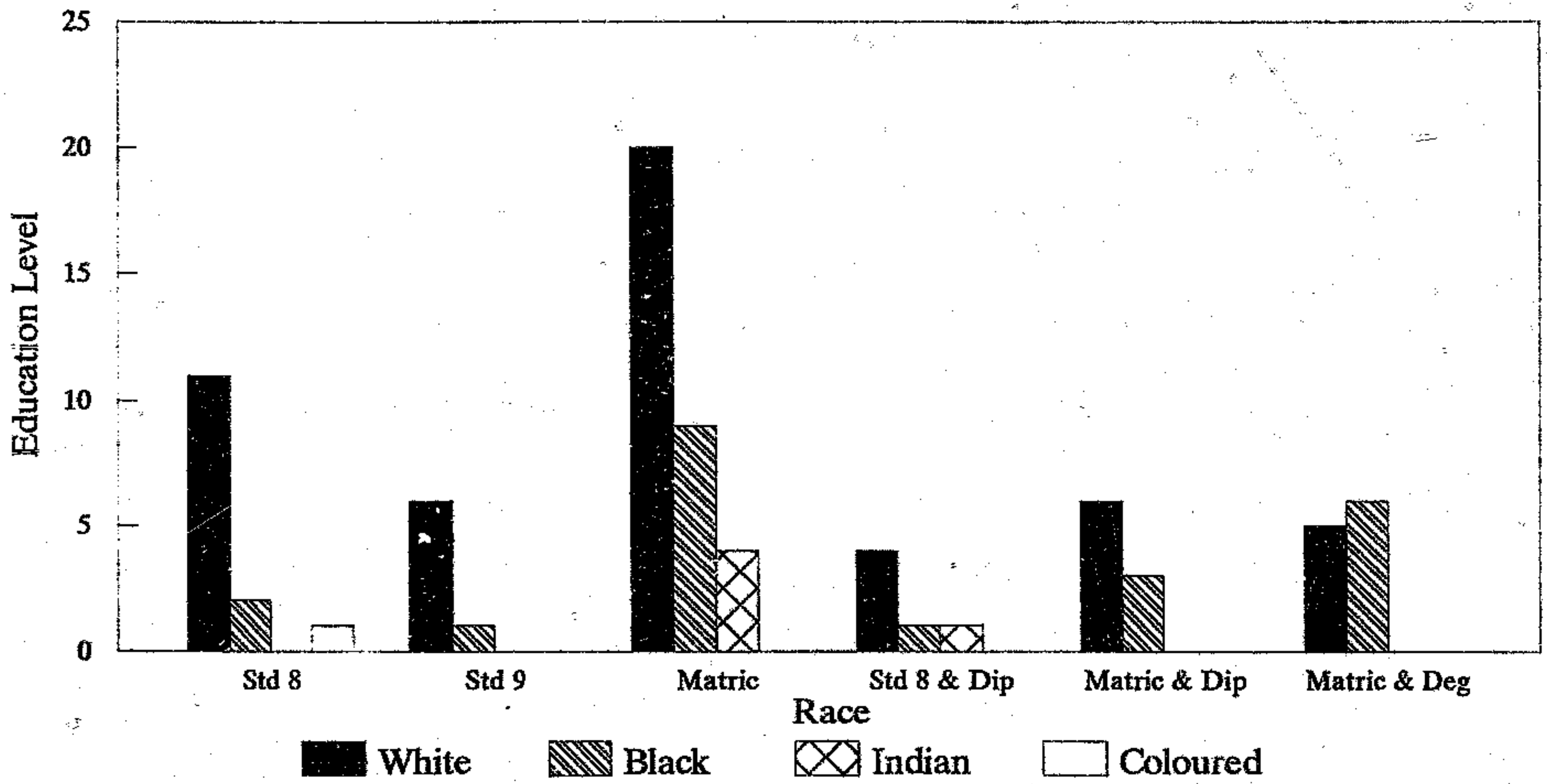


FIGURE 6.
GRAPHIC PRESENTATION OF THE EDUCATION LEVELS ACHIEVED WITHIN THE DIFFERENT RACE GROUPS.

A more detailed analysis of the distribution of subjects within these race groups according to language is obtainable from TABLE 5.

TABLE 5.
EDUCATION LEVELS OF SUBJECTS FROM THE VARIOUS LANGUAGE GROUPS.

	STD 8	STD 9	MATRIC	STD 8 + DIPLOMA	MATRIC + DIPLOMA	MATRIC + DEGREE
ENGLISH	3	3	13	2	[illegible]	3
AFRIKAANS	6	4	10	2	2	2
BILINGUAL (E/A)	1	0	0	0	0	0
ZULU	0	0	4	0	2	0
SOTHO	0	0	3	1	1	1
BILINGUAL (E/P)	2	0	1	0	0	0
TSWANA	1	0	1	0	0	3
XHOSA	0	0	0	1	0	0
VENDA	0	0	0	0	0	1
PEDI	0	0	0	0	0	1
SWAZI	1	0	0	0	0	0

Exploratory research was conducted on this sample in order to ascertain whether these background variables influenced the development of mental models.

6.3. Procedure and Measuring Instruments Used

The study was conducted in three sequential stages, namely an interview and two sessions in which subjects were asked to sketch their perceptions of computer dynamics. Measurement was obtained at different times, depending on departmental availability.

6.3.a. STAGE 1 : Interviews

Interviews were conducted in order to obtain 'Usership data' to categorise the subjects according to their level of knowledge and experience, and their socio-cultural backgrounds. According to Bless and Achola (1988), this method is useful in exploratory research and case studies, as it enables the interviewer to intervene. Each subject was interviewed individually, following a briefing.

The first section of the interview (APPENDIX 4) was based on a questionnaire which obtained the personal details of the individuals. Its questions refer to gender; age; organisational membership; nationality; home language; education; marital status and living conditions (number of people staying together) to establish the socio-cultural backgrounds of subjects. As was shown in CHAPTER 3, many authors (including Machel, 1989; Kaplan, 1988; Neff, 1973), demonstrate that these variables are all closely related. Changes in one of these variables often implies changes in others. For example, in South Africa, due to the past Apartheid system, Black South Africans generally have lower levels of education, and more people living together in one residence, than do White South Africans. Thus, nationality, home language and race are closely related both to each other, and to education. Organisational membership was included in these variables to assess whether organisational influence (in terms of choice of application systems and training methods), as compared to socio-cultural factors, impacts on mental model formation.

The second section of these interviews (APPENDIX 4) covered 'Usership data' which establish levels of experience and knowledge which the user has. Questions in this section were based on the criteria in Fisher's (1991) list:

- * Duration of use (Overall time using similar tools - expressed in YEARS).
- * Frequency of use in a specified time period.(eg. DAILY)
- * Time per session (in HOURS).
- * Breadth of experience (determined by number and type of application system and operating system used).
- * Relative training in computer science.

Confidence with computers was also assessed. Subjects were asked to rate their confidence level on a ten point rating scale, where 1 = complete confidence and 10 = no confidence.

The type of interview used here was a scheduled, structured interview which is based on an established questionnaire (Bless and Achola, 1988). The questions were factual, rather than abstract, which made them easy to answer as the subjects knew the answers, and were familiar with the possible response categories. There were no value laden questions such as 'how "happy" are you?' (Bailey, 1987). Advantages of this type of interview are that the competence and influence of the interviewer are not very important as the answers to the questions are generally straight forward, but if necessary, the interviewee and interviewer can clarify aspects of the questions and responses. Also, interviews can be administered to respondents who cannot read or write and the interviewer can ensure that the respondent has not omitted difficult questions. Their disadvantages include cost in time and money, and that the presence of an interviewer may be perceived as threatening anonymity of respondents (Bless and Achola 1988; Bailey, 1987). The advantages of close-ended questions in which the respondent can only choose from the categories provided by the researcher are that 1) data is standardised thus making coding both easy and objective; 2) they are not very time consuming and seldom engender a high refusal rate; and 3) they generally do not result in worthless and irrelevant information. Despite these advantages, disadvantages to such questions exist in that 1) they cannot be used when possible answer categories are not known; 2) they do not allow the respondent to answer in as much detail as s/he wants, and to clarify responses; and 3) they do not allow opportunity for creativity and self-expression (Bailey, 1987).

This data was combined and used for the categorisation of the users into the two dimensional conceptual space (novice-experienced and expert-naive). Cluster analysis (discussed in CHAPTER 7) was then performed on the 'usership data'.

6.3.b. STAGES 2 and 3 : Sketches

According to Bailey (1987), the advantages of using sketches, which in themselves are a form of open ended questions, are that (1) they can be used when possible answer categories are not known; (2) they allow the respondent to answer in as much detail as s/he wants, and to clarify responses; and (3) they allow opportunity for creativity and self-expression. Despite these advantages, disadvantages of this method exist in that 1) data is not standardised thus making coding both difficult and subjective; 2) they are very time consuming and often engender a higher refusal rate; and 3) they may result in worthless and irrelevant information.

Denham (1993) tapped mental models through sketches in order to determine the components, conduits and causal effects of the mental models used by children aged nine to fourteen. Her motivation to use drawings as opposed to the more popular verbal descriptions stemmed from the fact that subjects often discuss and spread information, and this could bias the findings as diffusion threatens internal validity of research. Denham (1993) also justifies this technique by stating that it reduces the intimidation associated with face-to-face questioning and it overcomes the fear of saying something silly, or being unable to express what one means. Further, in protocols, she contends, a great deal of prompting is necessary to find out exactly what the subject means as 'hidden processes' remain untackled. People interpret, rather than know, what happens inside the computer, and the interview does not allow the promotion of thinking through a non-linear problem.

Other researchers who used sketches in their research were Finlayson et al. (1989). They found drawings to have considerable promise as an investigative and communicative tool in their research which considered mental models that children have of their houses. They found no significant difference in the way that children from different ethnic groups drew their houses. The methodology of the present study drew on the above research.

STAGE 2

This stage aimed to obtain qualitative data in the form of annotated sketches of the *'inside of a computer'* (Finlayson et al., 1989) (APPENDIX 5). Sketches were analyzed to determine the users' mental models. In accordance with Denham's (1993) study, in each company, all subjects were simultaneously asked to sketch what they believe 'exists under the lid' of the computer - so as to prevent diffusion. Also, it was stressed that there is no 'right' or 'wrong' answer. A model must, according to Waern (1989), explain three factors to the person. These are (1) 'what' is performed - the computer functions, for which only the output of the computer is modelled. (2) 'how' it is performed - the processes by which the functions are performed, and (3) 'why' it is performed, which concerns the implementation of the system. The model has to mirror reality to serve this purpose. In accordance with research by Denham (1993), it was expected that the sketches would be based on two perspectives, namely what the computer 'is' and what it 'does'. The sketches were thus used to elicit the respondent's unique views of the computer's "dynamic processes".

STAGE 3

Following research by Denham (1993), STAGE 3 extended on the second stage in that subjects were asked to recall their earlier work, and sketch the 'inside of a computer' which is *performing a simple operation*, annotating their drawings where possible (APPENDIX 6). The operation that was chosen according to the job descriptions and tasks performed at work by the subjects was **'saving a file'**. The objective was to assess whether mental models are modified when they are subjected to task constraints. This is in accordance with Halasz & Moran's (1983) recognition that users seldom have a model of the system as a whole. Each user selects his/her own part of the task in the system reality for modelling, and at each level of abstraction, there is a mental model representation. Whether the subject used the perspective of what a computer 'is' or of what it 'does' in the previous stage was predicted to impact on the extent to which the models change in this stage. Waern (1989, p99) notes that it is "possible that people who can represent the structure of reality in a model, are nevertheless unaware of the consequences in terms of processes and functions."

In STAGE 2 and STAGE 3, besides having to annotate the sketches, subjects were also asked to give a paragraph explaining what they sketched so as to minimize incorrect subjective interpretation of the sketches by the raters. The researcher's role was to prompt the respondents whenever their answers were vague or ambiguous. These stages each lasted approximately 15 minutes.

6.4. Validity and Reliability

All measures of validity are concerned with the extent to which different variables actually measure what was intended (Sanders and Mccormick, 1987). Face validity refers to the extent to which a measure *looks* as though it measures what it intended to measure. It can play an important role in influencing the motivation of the subjects participating in the research (Sanders and Mccormick, 1987). Construct validity refers to the extent to which the measure is *actually* tapping the underlying construct of interest (Sanders and Mccormick, 1987). Reliability refers to the consistency of the measures over time, or across the sample. Technically, it is the extent to which the measuring instrument is free from error (Sanders and Mccormick, 1987). Reliability and face and construct validity of the interview questions are clear, since the questions were based on theory. For example, the first interviews were based on criteria in Fisher's (1991) list noted above (p45) - used for placing individuals within the two-dimensional conceptual space. Stages two and three are closely modelled on Denham's (1993) work. The reliability and validity of the sketches as measuring instruments used to investigate mental models, were considered in this study as one of its exploratory features.

On completion of the three stages of data collection in each organisation, data analysis was used to assess similarities and differences between subjects' mental models, and to identify any associations between these characteristics and subject background variables.

CHAPTER 7 : DATA ANALYSIS

Qualitative data gathered through observation are almost always categorical, and thus discrete. All qualitative measurement is nominal. Nominal measurement is essentially a classification system which uses exhaustive, mutually exclusive categories. Quantitative data can be either continuous or discrete (Bailey, 1987). The present research used both qualitative (for example, the theme categories on which the underpinned mental model sketches) and quantitative (for example age and years of experience with computers) data. The data obtained using the above mentioned measuring instruments, were categorised according to frequency of occurrence of themes by means of content analysis performed on the sketches and descriptive paragraphs. Cluster analysis was then performed on the two sets of data in order to obtain cluster solutions for each stage. The statistical analysis which was performed on the resulting cluster solutions and background data included frequency tables, means and standard deviations.

7.1. Content Analysis

According to Berelson (1952, p18), content analysis is "a research technique for the objective, systematic, and quantitative description of the manifest content of communication." (in Holsti, 1969). It is a research methodology which utilizes a set of procedures to make valid inferences from text. Despite the diversity of definitions of content analysis, a broad agreement exists on the requirements of objectivity (each step of the process must be carried out according to rules); systematicness (in- or exclusion of variables is decided according to rules); and generality (findings must have theoretical generalizability) (Holsti, 1969).

Compared with other data generating and analysing techniques, content analysis has several advantages according to Weber (1985). Those relevant to this research are :

1) Content analytic procedures operate directly on text or transcripts of human communication which is a central aspect of social interaction.
2) The procedures combine what are thought to be antithecal modes of analysis (qualitative and quantitative operations).
3) Compared with techniques such as interviews, content analysis yields unobtrusive measures in which the communication is not influenced, thus decreasing subject reactivity.

A central idea in content analysis is that many words of text or other form of communication - sketched features in this research - are classified into much fewer categories. Units of sketches classified into the same categories are presumed to have similar meanings. Weber (1985) lists the following several basic steps which are included in content analysis, whether conducted by human or machine. Content Analysis entails defining the universe of variables that are to be observed, considering the units of analysis by observing and measuring variables and then quantifying and tabulating the data by either placing people into categories, or forming categories according to people (Kerlinger, 1986). The following steps are thus implemented:

<u>Step 1</u> : Define the recording units. There are six common options - word, word sense, sentence, theme, paragraph and whole text. This research has used the 'theme' as the unit of analysis for the usership and performance data. It considers (1) the perceiver, (2) the perceived or agent of action, (3) the action and (4) the target of action.

<u>Step 2</u> : Define the categories. This includes decisions regarding whether the categories must be mutually exclusive and the breadth of the categories.

<u>Step 3</u> : Test coding on sample 'text'.

<u>Step 4</u> : Assess accuracy and reliability.

<u>Step 5</u> : Revise coding rules if necessary, and return to step 3 until reliability and validity are achieved.

<u>Step 6</u> : Code the 'text'.

<u>Step 7</u> : Assess reliability and validity.

There is no simple 'right way' to do content analysis. Each investigator must judge which methods are best for the particular research. The classification system must be both reliable and valid. Problems with reliability and validity usually grow out of the ambiguity of word meanings in the text, and of category definitions or other coding rules (Weber, 1985).

Reliability

Three types of reliability are pertinent to content analysis :
'stability' (the extent to which results of content analysis are stable over time) ; 'reproducibility' (inter-rater reliability referring to the extent to which content analysis by different raters produces the same results) and 'accuracy' (how well the text classification corresponds to the norm). Krippendorff (1980) purports that researchers often fail to assess the reliability of their coding (in Weber, 1985). In this study, the three raters agreed on the interpretations of ten randomly selected sketches, and then rated ten other sketches. Their interpretations coincided to a vast extent, resulting in an inter-rater reliability of 0.74. It was found that the raters all identified the same themes, and any differences in judgement tended to be of omission, rather than of disagreement. "And art itself may be defined as a single-minded attempt to render the highest kind of injustice to the visible world..." (Conrad in , Deregowski, 1984) yet if one considers how one can recognise a picture of an elephant, whether in the form of an accurate photograph or a cartoon character, it is clear that symbolic elements enable one to view an artists intention - the pictures have certain 'typical orientations' (Deregowski, 1980). Dorgan (1991) adds that a continued adherence at a very deep psychological level to the relations of meaning exists.

In past research, the researcher has generally presented the subjects with a 'concrete', specific illustration, and established how they perceive the picture. The impact of culture on perception, as researched in these studies, is important in the present research only in so far as the raters' culture may influence their perception of the themes depicted in the sketches. This was overcome by using raters from different backgrounds to establish mutually acceptable definitions of thematic categories.

Validity

Content analysis must have internal and external validity. Further, construct (convergent and divergent validity), face and semantic validity are all necessary (Weber, 1985).

One major difficulty with content analysis is that there is too much information in texts and their detail precludes analysis without some form of data reduction. By utilising too specific a definition of variables, although high reliability will be achieved, part of the essential core of the variables may be missed (Weber, 1985). This is referred to by Kerlinger (1986, p490) as "the molar-molecular problem." The molar approach takes large behavioural wholes as units of observation. The molecular approach, by contrast, takes segments of behaviour as units of analysis. The former relies on subjective inferences to a much greater degree than the latter. In the social sciences, especially with content analysis, it is impossible to make flat generalisations without inferences. The level of inference necessary is important, and a medium degree should be aimed at. Too specific categories may be rigid and inflexible, thus making analysis difficult, and sometimes even trivial (Kerlinger, 1986).

Due to this subjectivity, experimenter expectancies can be seen as a threat to internal validity. This refers to the influence of the experimenter's expectations regarding the outcome of the research. It results in bias of interpretations, and the use of facial and verbal cues during the investigation. The use of a descriptive paragraph, coupled with the sketches, aimed to decrease the threat of incorrect subjective interpretation of the sketches. Experimenter attributes may also influence subjects by influencing subject reactivity. Demand characteristics, Hawthorn effect, 'good subject effect' and response sets may all influence findings, and they should be kept in mind when doing content analysis (Christensen, 1988).

7.2. Statistical Analysis Techniques

There are many statistical tests that can be used to analyze the data obtained from research. Elementary statistical procedures which are often applied in data analysis, and have been used in the present research are:

* **Cluster Analysis**, which separates data into constituent groups.
* **Measures of central tendency** - eg. mean, mode.
* **Dispersion** of scores - eg. variance, range.
* **Frequencies of scores.**
* Various tests which consider whether the findings are **statistically significant**, in other words, whether the results could have occurred by chance.

Analysis of the data was conducted both qualitatively and quantitatively. Qualitative analysis included content analysis of the data, identification of common themes emerging from the cluster solutions and considering the dispersion of the scores. Quantitative analysis improves accuracy of the analysis. The Fisher's exact test was therefore conducted on the background variables, where possible.

7.2.a. Cluster Analysis

Cluster analysis is the generic term for a wide variety of techniques which separate data into constituent groups (Everitt, 1974). These techniques empirically form classes, types, groups, categories, or clusters of highly similar entities by creating a classification scheme for unclassified data (Aldenderfer & Blashfield, 1984). More specifically, cluster analysis is a "multivariate statistical procedure that starts with a data set containing information about a sample of entities and attempts to reorganise these into relatively homogenous groups." (Aldenderfer & Blashfield, 1984, p7). The groups are not defined a priori, but are formed as suggested by the data, such that objects in a given cluster tend to be similar to each other in some senses, and objects in different clusters tend to be dissimilar (SAS Institute, 1990).

Types of clusters listed in the SAS Institute (1990) include :

(1) **Disjoint clusters.** Placing each entity into mutually exclusive categories.

(2) **Hierarchical clusters.** The only kind of overlap allowed between clusters is when one cluster is contained within another cluster.

(3) **Overlapping clusters** where clusters are not mutually exclusive, and

(4) **Fuzzy clusters** defined by probability of each member in a cluster.

Hierarchical techniques are either agglomerative or divisive. In the agglomerate techniques, each observation begins in a cluster by itself. The two closest clusters are merged to form a new cluster that replaces the two old clusters. This merging is repeated until only one cluster is left. The various clustering methods differ in how the distance between the two clusters is computed. Divisive techniques operate in the opposite direction (Lorr, 1983). Hierarchical clustering is practical for small sample sizes and data sets (SAS Institute, 1990) such as those in this dissertation.

Tree diagrams are often closely associated with hierarchical clustering techniques. The tree procedure draws dendograms (also called phenograms) using the output from the hierarchical clustering procedure (SAS Institute, 1990). Trees are two dimensional diagrams illustrating the fusions or divisions which have been made at each successive stage (Everitt, 1980). Agglomerate trees thus form from the branches to the root, and divisive, from the root to the branches. Agglomerate methods are the most popular of the clustering techniques (Lorr, 1983), and were used in this dissertation.

Aldenderfer and Blashfield (1984) summarise the principle applications of cluster analysis as being for:- the development of typologies or classifications; investigating conceptual schemes for grouping entities; hypothesis generation through data exploration; and hypothesis testing. The former accounts for the most frequent use of this method. In the context of the present research, cluster analysis was used to reduce the data by summarising the information available on the relationship between entities, to explore the data, and ascertain whether the predictions made regarding the groups of subjects were realized. As such, cluster analysis was considered to be an appropriate statistical technique. Despite the apparent justification for the use of cluster analysis, several limitations of this method must be noted.

1) Applying different clustering techniques to the same data set can yield different results since the techniques have been developed across different disciplines. Hence, an inappropriate technique will yield inappropriate clustering (Aldenderfer & Blashfield, 1984).

2) Although the strategy of cluster analysis is cluster seeking, its operation is structure-imposing since "clustering methods are used to discover structure in data that is not readily apparent by visual inspection or by appeal to other authority." (Aldenderfer & Blashfield, 1984, p116). In this way, clustering differs from other discriminant analysis procedures which seek to assign objects to already existing groups.

   It is thus important to know which of the groups that have emerged are real, natural and meaningful, and which have merely been imposed on the data by the clustering method. The majority of clustering methods begin by calculating distances (similarities) between entities. The methods of determining similarity between entities is complex.

3) No universal agreement exists on what constitutes a cluster because there is no single definition that is sufficient - thus generalisations about cluster analysis are vague (Everitt, 1980).

7.2.a.i. WARD'S Cluster Analysis

Ward's method is designed to optimise the minimum variance within clusters (Ward, 1963). This objective function is more commonly known as the within-group sum of squares or the error sum of squares (ESS).

$$ESS = \Sigma X_i^2 - 1/n(\Sigma X_i^2). \text{ (Everitt, 1980)}$$

In Ward's minimum variance method, the distance between two clusters is the ANOVA sum of squares between the two clusters added up over all the variables. At each generation, the within cluster sum of squares is minimised over all subdivisions obtainable by merging the two clusters from the previous generation (SAS Institute, 1990).

In the first step of the clustering process, each entity is its own mutually exclusive cluster and the error sum of squares is zero. The method functions by those 'clusters' that result in the minimum increase in the ESS (Aldenderfer & Blashfield, 1984). Each cluster previously formed is treated as one unit. When the complete hierarchical solution has been obtained, the ESS value can be compared to determine the relative homogeneity of the groups formed. At each step of the analysis, union of every possible pair of clusters is considered and the two clusters whose fusion results in the minimum increase in the ESS are combined (Everitt, 1980). A sharp increase in the ESS indicates that much of the accuracy has been lost by reducing the number of groups (Lorr, 1983).

Ward's method joins clusters to maximise the likelihood at each level of the hierarchy under the following three assumptions :

1] multivariate normal mixtures.

2] equal spherical covariance matrices.

3] equal sampling probabilities.

However, Ward's method tends to join clusters with a small number of observations and is strongly biased towards producing clusters with approximately equal numbers of observations (SAS Institute, 1990). Also, the clusters found can be ordered in terms of their overall elevation (Aldenderfer & Blashfield, 1984). Another problem with Ward's Cluster Analysis is that once assigned to a group, the subdivisions are fixed permanently, and cannot be changed if a preferable subdivision combination is found (Lorr, 1983).

Despite these problems, many simulation studies comparing various cluster analysis methods have found the two methods with the best overall performance to be average linkage and Ward's methods. However, the results of such studies are often inconsistent and often confusing (SAS Institute, 1990). Inevitably, any cluster analysis requires computational resources (Lorr, 1983). For the present research, the SAS statistical package (SAS Institute, 199...) was chosen, and Ward's cluster procedure was chosen from the eleven available clustering procedures.

This procedure prints a history of the clustering process, and provides statistics useful for estimating the number of clusters in the population from which the data was sampled (SAS Institute, 1990). All of the clustering methods are based on the agglomerative hierarchical procedure. In Ward's method, the distance is computed according to the formula :

$$D_{kl} = B_{kl} = \|\bar{X}_k - \bar{X}_l\|^2 / (1/N_k + 1/N_l).$$

f $d(x,y) = \|X-Y\|^2 /2$, then the combinatorial formula is:

$$D_{jm} = ((N_j+N_k)D_{jk} + (N_j+N_l)D_{jl} - N_jD_{kl}) / (N_j+N_m).$$

The choice of Ward's method for this research is justified by its optimisation of minimum variance within clusters and a small data set was used and clusters with equal numbers were not required, thus undue bias was eliminated. The data was standardised to a mean = 0, and a standard deviation = 1 since the different variables had different units and scale sizes which may have distorted the findings and made data incomparable.

Once cluster analysis was performed, analysis of the number of clusters yielded in the data set was further aided by the nested tree structure of a dendogram from which one can establish where to "cut" the tree so that the optimal number of groups is found (Aldenderfer & Blashfield, 1984). This fundamental step is amongst the two as yet unsolved problems of cluster analysis (Everitt, 1979). Firstly, the lack of an appropriate null hypothesis (When do no clusters exist?), and secondly, the complex nature of multivariate sampling distributions of unknown structure (Aldenderfer & Blashfield, 1984).

In response to these two constraints, social scientists have used two basic approaches to determine the number of clusters available in the data set. These are heuristic procedures and formal tests. Since few formal tests have been well understood or widely accepted, the former are the most commonly used (Aldenderfer & Blashfield, 1984). One heuristic procedure is to graph the number of clusters suggested by the dendogram against the fusion or amalgamation coefficient (Numerical value at which the cases merge to form clusters shown along the y-axis of the dendogram). Where the graph begins to 'flatten', it can be assumed that new information is depicted by the following mergers of clusters (Aldenderfer & Blashfield, 1984).

Another procedure is to examine the values of the fusion coefficients to discover a significant 'jump' in their values. A 'jump' implies that two relatively dissimilar values have merged, and that the number of clusters prior to the merger is the most probable solution (Aldenderfer & Blashfield, 1984). A problem is that many small jumps in the coefficient can make identifying the 'correct' jump difficult. There are no satisfactory methods for determining the number of clusters (Everitt, 1979).

Milligan and Cooper (1985) and Cooper and Milligan (1984) compared thirty methods for estimating the number of population clusters using four hierarchical clustering methods. Two criteria which performed best in these studies were the Pseudo F statistic and the Pseudo t^2 statistic (In SAS Institute, 1990). The Pseudo F statistic developed by Calinski and Harabasz (1974) is also referred to as $J_e(2)/J_e(1)$ by Duda and Hart (1973). It can be transformed into the Pseudo t^2 statistic. It is advised that one looks for consensus amongst these two statistics, that is, local peaks of the Pseudo F statistic combined with a small value of the Pseudo t^2 statistic, and a larger Pseudo t^2 for the next cluster fusion. These criteria are only appropriate for compact or slightly elongated clusters that are roughly multivariate or normal (SAS Institute, 1990).

According to the SAS Institute : Statistics Manual (1985), the Pseudo F statistic for a given level is

$$\text{Pseudo F} = ((T-P_G)/(G-1)) \;/\; (P_G/(n-G))$$

and the Pseudo t^2 statistic for joining C_K and C_L is

$$\text{Pseudo } t^2 = B_{KL} \;/\; ((W_K+W_L)/(N_K+N_L-2)).$$

It must be noted that although the Pseudo F and t^2 statistics may be useful indicators of the most suitable cluster solution, they are not distributed as F and t^2 random variables. If data is independently, randomly sampled from a multivariate normal distribution with a scalar covariance matrix, and if the clustering method allocated observations randomly to clusters (which no clustering method does), then the Pseudo F would be distributed as an F random variable with v and $v(N_K+N_L-2)$ degrees of freedom (SAS Institute, 1985). The Pseudo t^2 statistic differs from the Hotelling's T^2 in that the latter uses a general symmetric covariance matrix instead of a scalar covariance matrix (SAS Institute, 1985).

7.2.b. Frequency Distributions

"Distributions have probably been too little used in the behavioral sciences and education ... Some research problems ... can be better solved using distribution analysis." (Kerlinger, 1986, p131). Spiegel (1972) justifies the importance of frequency tables. He states that when summarising large masses of raw data, it is often useful to distribute the data into classes or categories and to determine the number of individuals who belong to each class. This number is referred to as the class frequency. A tabular arrangement of data by categories/classes together with the corresponding class frequencies is termed a *frequency distribution/frequency table*. Thus, as McCall (1990, p28) explains, "A frequency distribution indicates the number of cases observed at each score value or within each interval of score values in a group of scores". Frequency tables show the distribution of variables. For example, if variable A has 6 possible values, a frequency table for A shows how many observations in the data set have the first value of A, the second value of A, and so on (SAS Institute, 1990).

Data which is summarised in a frequency table is often referred to as grouped data. An important advantage of this technique (which occurs at the expense of loss of much of the original detail of the data) is the clear 'overall picture' which is obtained, and in vital relationships, thereby made evident (Spiegel, 1972). Options which can be included in frequency tables are frequencies, cumulative frequencies, percentages of the total frequencies, and cumulative percentages for each cell or level of the variable (SAS Institute, 1990).

Frequency tables can be implemented on data to produce one-way to n-way frequency and crosstabulation tables (SAS Institute, 1985). Frequency tables serve two purposes. Firstly, it is a descriptive procedure in the sense that it produces frequency counts and cross-tabulation tables which enable one to describe ones data in a concise, clear way based on qualitative analysis. For example, they can be used to see if data is distributed in a normal form. Secondly, they can be used as a statistical procedure from which one can establish relationships among variables (SAS Institute, 1990; Kerlinger, 1986). Various tests of measures of association draw on frequency tables. In choosing measures of association, one must consider the study design, the measurement scales of the variables (nominal, ordinal, ratio or interval), the type of association that each measure is designed to detect and any assumptions required for valid interpretation of a measure. The tests must thus be appropriate for the data set. One such technique is the Pearson Chi-Square. It is appropriate for all kinds of variables and can detect any kind of association (SAS Institute, 1990). It is "a statistic based on categorical data in which the observed frequencies with which different classes of responses occur are compared with expected frequencies derived from theoretical or empirical considerations." (Keppel et al., 1992, p598). McCall (1990) explains that the Pearson Chi-Square Test is used when one wants to compare them in terms of the similarity with which those observations are distributed among several discrete and mutually exclusive categories. The statistical question which can be answered with chi-square is whether the groups differ in the relative distribution of observations among the different categories. The null hypothesis is thus : In the population, the two groups do not differ in their relative frequency distribution of people among the categories (McCall, 1990). Chi-square is a measure of the discrepancy which exists between observed and expected frequencies of observations (Spiegel, 1972). This is a non-parametric technique which considers nominal data which is distribution free (McCall, 1990).

According to McCall (1990), the assumptions of the Chi-Square test are :

(1) the samples are ***independent*** of each other.This implies that unrelated and different sets of subjects have been selected.

(2) The subjects within each group must be ***randomly*** and ***independently*** sampled.

(3) Each observation must qualify for ***one and only one*** category in the classification schemes.

(4) The ***sample size must be relatively large.***

The probabilities (p values) yielded by the Chi-Square are approximations/estimates yielded by the distribution. They are not exact possibilities. A limitation of the Chi square is that the distribution of differences between the expected and the observed values only approximates the chi-square distribution if the cell frequencies (expected values) are large enough (having values of at least 5). If the values are less than 5, one cannot assume the distribution to be chi-square, and using the chi-square as an assessment technique may result in spurious findings (Bailey, 1987).

In such cases, the probability that the relationship is statistically significant can be computed exactly using the Fisher's exact test which also draws on frequency tables (Bailey, 1987).

7.2.b.i. Fisher's Exact Test

The Fisher's exact test yields the probability of observing a table that gives at least as much evidence of association as the one actually observed, given that the null hypothesis is true (SAS Institute, 1990). It assumes that the row and column margins are fixed. Despite the weaknesses of this method which include the laboriousness of the computations, this is the only method to use when many cell frequencies are less than 5 (Bailey, 1987; SAS Institute, 1990). The hypergeometric probability (p) of every possible table is computed. The p-value is defined as

$$\mathrm{PROB} = \sum_{A}^{p}$$

For a two-tailed test, A is the set of tables in which p is less than or equal to the probability of the observed table (SAS Institute, 1990).

Fisher's exact test was performed on the data due to the frequent occurrence of small cell sizes. The computational algorithm that was used was the network algorithm given by Mehta and Patel (1983). Although this algorithm is faster than previous algorithms by orders of magnitude, it has the disadvantage of computational time which may be prohibitive, depending on the table and sample sizes (SAS Institute, 1990). More specifically, this test is generally not practical, in terms of CPU time and memory that is necessary, when

$$\frac{n}{(r-1)(c-1)} > 5$$

where n is the sample size of the table and r and c are the number of rows and columns, respectively. This practicality increases as the sample size, per degree of freedom, decreases towards zero (SAS Institute, 1990).

7.2.b.ii. Graphs of Frequency Distributions

Various graphs can be used to describe a frequency distribution. One such graph is the frequency histogram. This is a set of rectangles plotted in terms of two axes (Spiegel, 1972). The horizontal axis (called the abscissa) indicates the midpoints of the intervals, or the category. The vertical dimension (ordinate) corresponds to the frequency with which scores are found in the categories on the abscissa (McCall, 1990). Another graph is the frequency polygon which is a line graph of class frequency plotted against class mark/score. It can be obtained by connecting mid-points of the tops of rectangles in the frequency histograms (Spiegel, 1972).

Frequencies differ in four important ways, namely with respect to (1) central tendency, (2) variability, (3) skewness, and (4) kurtosis (McCall, 1990). "The central tendency of a distribution is a point on the scale corresponding to a typical, central, representative score. ... Variability is the extent to which scores in a distribution deviate from their central tendency. ... Skewness refers to an asymmetrical distribution in which the scores are bunched on one side of the central tendency and trail out on the other. ... The **kurtosis** of a distribution is the 'curvedness', or 'peakedness' of the graph." (McCall, 1990, pp42 - 45). "There is little doubt that measures of central tendency and variability are the most important tools of behavioural data analysis." (Kerlinger, 1986, p133).

7.2.c. Measures of central tendency

Sets of measures are too complex to understand readily. They are 'represented' by measures of central tendency (Kerlinger, 1986). Measures of central tendency are the easiest and most direct descriptive statistical procedures (SAS Institute, 1985).The three main measures of central tendency - the mean, mode and median - are epitomes of the sets of measures from which they are calculated (Kerlinger, 1986). The most common measure of central tendency of a group of scores is the **arithmetic mean**, or average. The term "mean" used here, refers to the sample mean. It is "a value which is typical or representative of a set of data." (Spiegel, 1972, p45). The mean is symbolized by $\bar{X}$ (read X bar), and is computed by adding all of the scores, and dividing the sum by the number of scores in the distribution (McCall, 1990). Means cannot be calculated for nominal data, but can be calculated for all numerical data (SAS Institute, 1985).

Two properties of the mean have been outlined by McCall (1990) and Spiegel (1972). The first is that the algebraic sum of the deviations about the mean is zero. In other words, if one subtracts the mean from each score in the distribution, the sum of the differences is zero. The second is that the sum of squared deviations about their mean is less than the sum of the squared deviations of the same score about any other value.

The **median** is the point which divides the distribution into two parts, such that equal numbers of scores fall above and below that point. The **mode** is the most frequently occurring score (McCall, 1990). Spiegel (1972) maintains that one must consider the intended purpose of the measure of central tendency, the type of data and their advantages and disadvantages when choosing which one to use. For example, extreme scores may distort the mean, but the mode may be more useful for a realistic description of the data set. In a data set of scores of 1, 44, 44, 44, 1118, the mode (44) is a more realistic representation than the mean (250.2). The mean, mode and median will all be the same score if the data is normally distributed.

7.2.d. Measures of Variability

Variability is defined by McCall (1990, p60) as "the extent to which the scores in a distribution differ from their central tendency." The **range**, **variance** and **standard deviation** are all measures of variability. The range may be determined by subtracting the largest score in the distribution from the smallest score. It is not sensitive to the variability of *all* scores, only to the differences between the two most extreme scores. Two numerical indices which overcome this limitation are the variance and its square root - the standard deviation. In calculating the variance, one calculates the value of each score, minus the mean and squares this value. This is done for each score and the sum of the values is then divided by the number of scores in the distribution, to give the variance. To obtain the standard deviation, the variance is square rooted. This is generally done to obtain a measure of variability in the original units of measurement, rather than squared units which are obtained in variance calculations (McCall, 1990).

CHAPTER 8 : RESULTS AND DISCUSSION

The results of the data analysis were considered both in terms of similarities and differences between the mental models of cluster members, and of the association between the background variables and these clusters. A summary of the distribution of the background variables for the members of the clusters is presented in APPENDIX F. For each cluster solution, the characteristics of the clusters which were qualitatively identified are reported, followed by the quantitative outcomes of Fisher's exact tests which substantiate the former.

8.1. Results of CLUSTER ANALYSIS

8.1.a. Clustering of Usership Data

Cluster analysis performed on the usership data regarding computer-related knowledge and experience, obtained from the eighty subjects, was analyzed in order to identify the most comprehensive cluster solution. With its 'peak' in the Pseudo F, accompanied by the 'trough' in the Pseudo t^2, and the discernability of distinguishing characteristics of the clusters in the tree diagram (FIGURE 7), the seven cluster solution (referred to as USERCLUS) was identified as the most favourable solution. As shown in TABLE 6, this solution's Pseudo F increased from 23.7 to 24.3, and then remained reasonably stable. The Pseudo t^2 dropped substancially from 13.2 to 5.9, and then increased to 9.8.

TABLE 6.
PSEUDO F AND PSEUDO t^2 VALUES FOR CLUSTER SOLUTIONS WITH 6, 7 AND 8 CLUSTERS, DERIVED BY THE CLUSTER ANALYSIS PROCEDURE IMPLEMENTED ON THE USERSHIP DATA.

NUMBER OF CLUSTERS	PSEUDO F	PSEUDO t^2
8	23.7	13.2
7	24.3	5.9
6	24.5	9.8

These seven clusters accounted for almost 97% of the variance. For the purpose of this study, to facilitate discussion, the members of this cluster solution (USERCLUS) were referred to as Cluster A, Cluster B ... Cluster G. Analysis of this cluster solution was based on a combination of PROC MEANS and PROC FREQ procedures chosen from the SAS statistical package (SAS Institute, 1990). These give means and frequency tables as their outputs. The two procedures have been used in combination as although the means are necessary to obtain an overall view, extreme values (maximum and minimum values) may distort the means and mask the true characteristics of the cluster. The frequency tables overcome this problem by providing a framework which facilitates direct comparisons between the frequencies of theme occurrences within each cluster. APPENDIX E, TABLE 7 and FIGURE 8 offer a broad overview of the main distinguishing features of this cluster solution. They are discussed in more detail below.

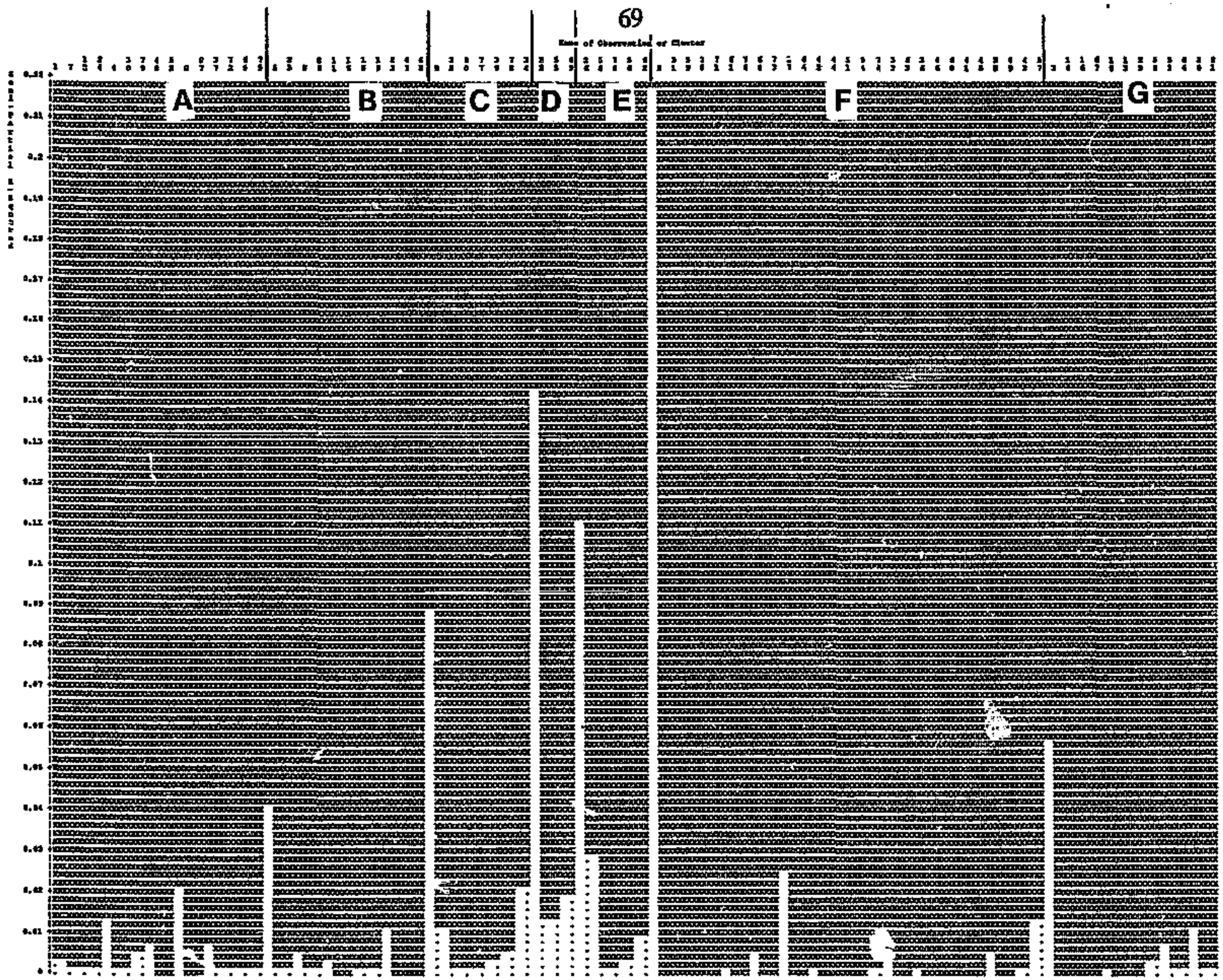


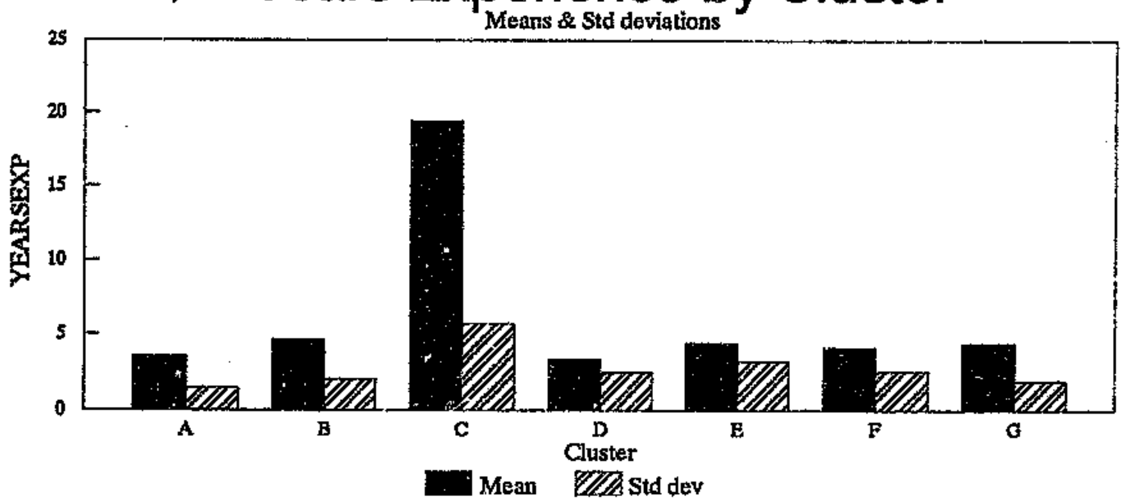
FIGURE 7.

TREE DIAGRAM OF SUBJECTS BELONGING TO THE CLUSTERS (A TO G) IN THE USERCLUS SOLUTION WHICH RESULTED FROM CLUSTER ANALYSIS.

TABLE 7.
THE MEANS AND STANDARD DEVIATIONS OF SEVERAL OF THE VARIABLES USED TO ASSESS POSITIONS OF CLUSTERS ON THE TWO-DIMENSIONAL CONCEPTUAL SPACE.

CLUSTER	A	B	C	D	E	F	G
YEARSEXP							
N	15	11	7	3	5	27	12
Mean	3.533	4.636	19.428	3.333	4.400	4.111	4.416
Std Dev	1.457	2.013	5.711	2.516	3.209	2.531	1.928
Minimum	1	2	13	1	2	1	1
Maximum	6	9	29	6	10	12	8
TIMESPAN							
N	15	11	7	3	5	27	12
Mean	5	5.909	6.571	3	3.200	4.259	6.333
Std Dev	1.732	1.578	1.511	3.464	2.049	1.852	1.497
Minimum	2	3	4	1	1	1	2
Maximum	7	7	8	7	5	7	7
CONFID							
N	15	11	7	3	5	27	12
Mean	2.266	5.545	2.428	3.666	3.600	2.851	6.083
Std Dev	0.961	1.128	0.975	1.527	1.673	0.718	1.083
Minimum	1	4	1	2	1	1	5
Maximum	4	8	4	5	5	4	8
OS							
N	15	11	7	3	5	27	12
Mean	1.933	2	2	1.666	1.800	1	1
Std Dev	0.258	0	0.577	0.577	0.447	0	0
Minimum	1	2	1	1	1	1	1
Maximum	2	2	3	2	2	1	1
APPLIC							
N	15	11	7	3	5	27	12
Mean	3.800	3.272	3.142	2.333	3.200	1.222	1.116
Std Dev	1.567	1.190	1.167	1.527	2.774	0.506	0.389
Minimum	2	2	2	1	1	1	1
Maximum	6	5	6	4	8	3	2
TRAIN							
(level)	15	11	7	3	5	27	12
N	2.800	2.181	2.142	4	2	1.333	1.333
Mean	1.082	0.404	0.690	0	1.224	0.679	0.778
Std Dev	1	2	1	4	1	1	1
Minimum	4	3	3	4	4	4	3
Maximum							

8.1) Years Experience by Cluster



8.2) Time Span by Cluster

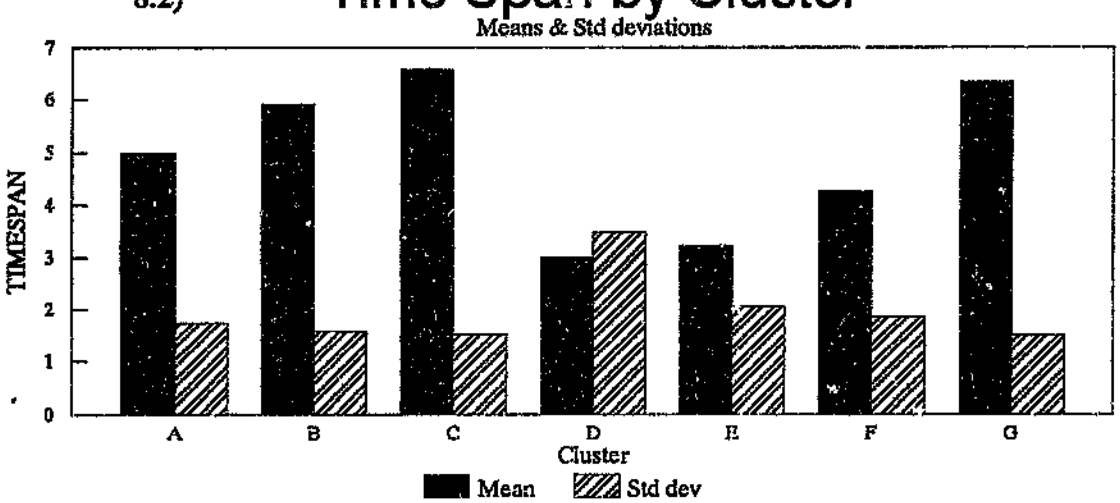
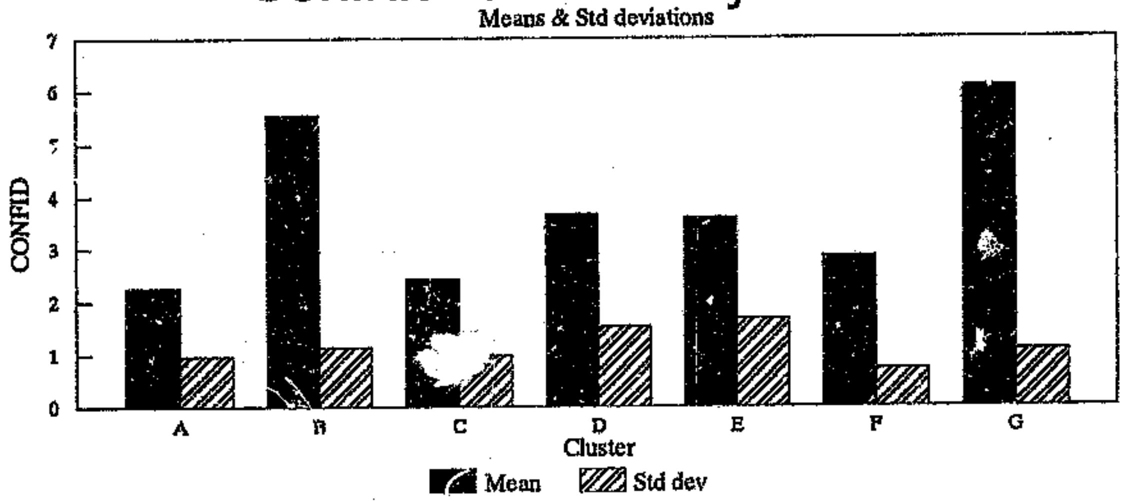


FIGURE 8.

DIAGRAMMATICAL REPRESENTATION OF THE MEANS AND STANDARD DEVIATIONS OF SEVERAL OF THE VARIABLES USED TO ASSESS POSITIONS OF CLUSTERS ON THE TWO-DIMENSIONAL CONCEPTUAL SPACE.

8.3) Confidence Level by Cluster



8.4) Number of Operating Systems by Cluster

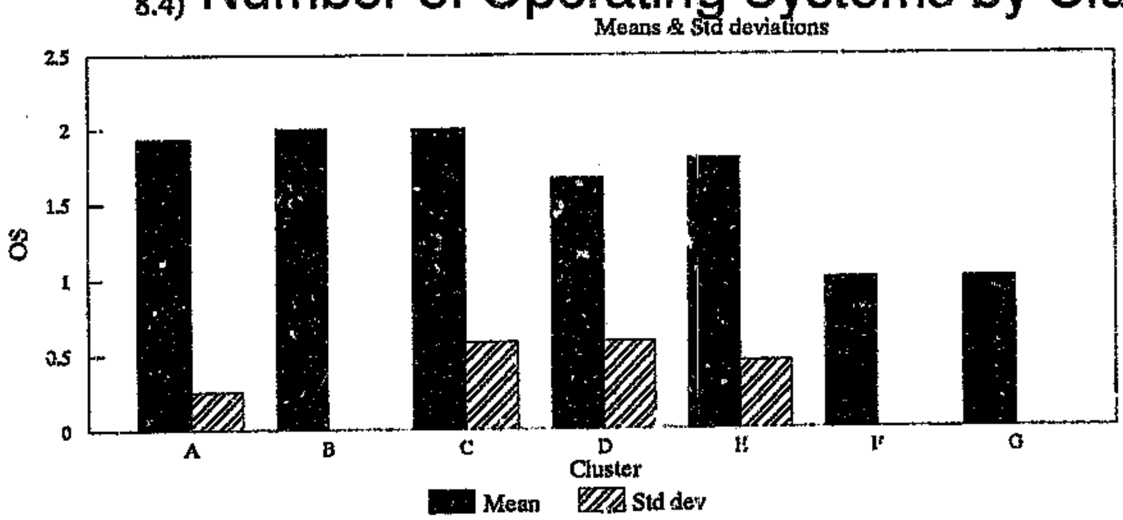
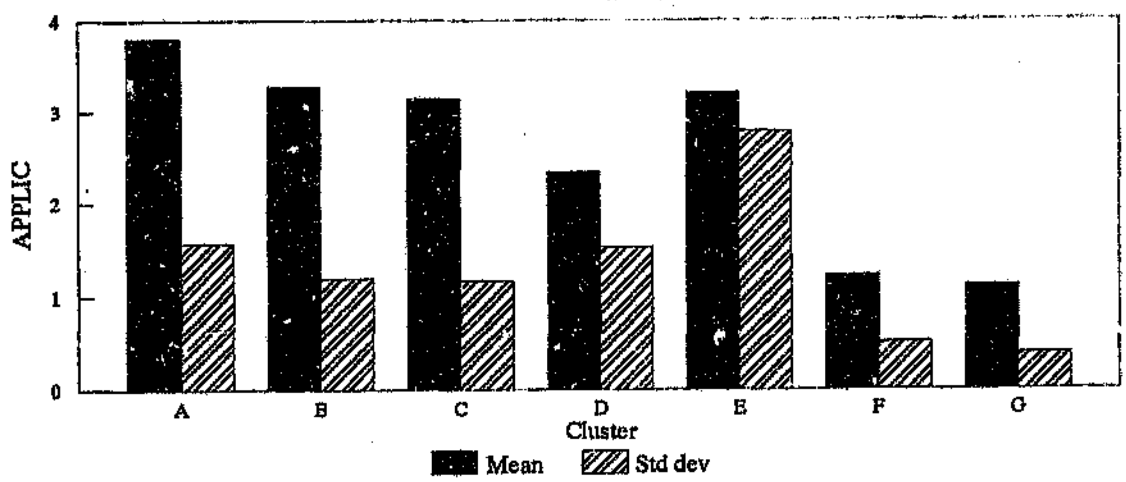


FIGURE 8 (cont.).
DIAGRAMMATICAL REPRESENTATION OF THE MEANS AND STANDARD DEVIATIONS OF SEVERAL OF THE VARIABLES USED TO ASSESS POSITIONS OF CLUSTERS ON THE TWO-DIMENSIONAL CONCEPTUAL SPACE.

8.5) Number of Application Systems by Cluster

Means & Std deviations



8.6) Level of Training by Cluster

Means & Std deviations

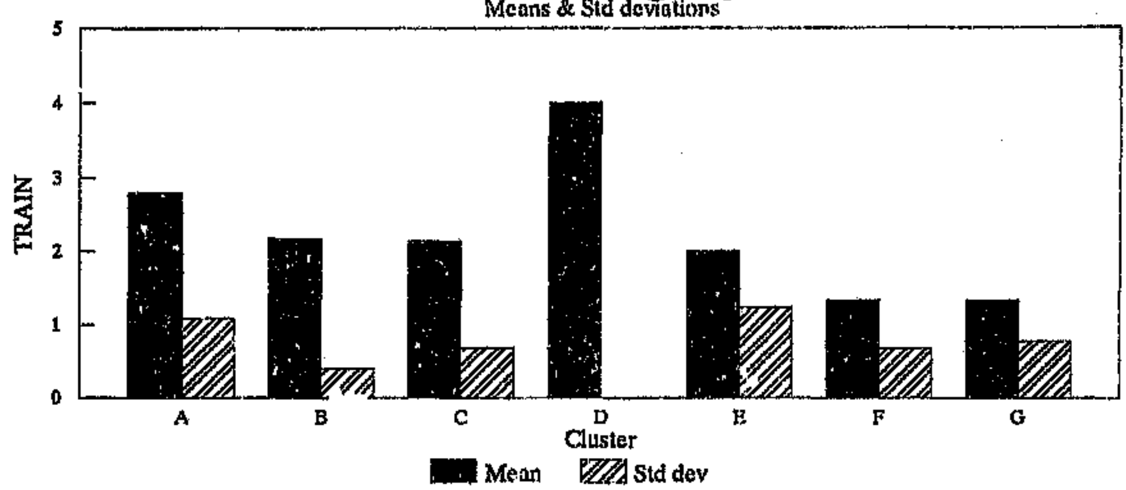


FIGURE 8 (cont.).

DIAGRAMMATICAL REPRESENTATION OF THE MEANS AND STANDARD DEVIATIONS OF SEVERAL OF THE VARIABLES USED TO ASSESS POSITIONS OF CLUSTERS ON THE TWO-DIMENSIONAL CONCEPTUAL SPACE.

CLUSTER A

Cluster A comprised of fifteen subjects. This category was characterised by high confidence levels, with a mean of 2.266 - the lowest mean confidence score in this cluster solution, implying that this was the most confident group of subjects (the confidence rating scale used was a 10 point scale with '1 = complete confidence', and '10 = no confidence'). More specifically, confidence ratings in this cluster ranged from levels 1 to 4, with two thirds of the members selecting ratings of 1 or 2 from the ten point scale. This confidence may be partly attributed to the relatively high level of training received by subjects in this cluster - six subjects had completed a college level computer course. All members of this cluster had between 1 and 6 years of experience with computers (mean = 5 years), during which they had each used 2 to 6 application systems, with a mean of 3.8 - the highest of the application system means in the USERCLUS group. Also, except for one subject, they had all used 2 operating systems (TABLE 8). The members of this cluster therefore demonstrate a relatively high level of experience in comparison to the other clusters' members.

It must be noted that based on interviews, it was established that clerical level workers only use a limited variety of simpler operations available in the application system(s), and that their level of experience within each application system increases rapidly until reaching a low ceiling level due to the limited job requirements. As such, to consider levels of experience, in this sample, below the limited ceiling level within one application system would be arbitrary. For the purpose of this study, the meaning of the term 'experience' has been extended to include the experience with *computers* (number of application systems in which low levels of experience are obtained) rather than within each application system. This extension seems more feasible in distinguishing between the experience of the subjects.

TABLE 8.
TABULATION OF THE NUMBER OF OPERATING SYSTEMS AND APPLICATION SYSTEMS USED WITHIN VARIOUS CLUSTERS.

CLUSTERS	A	B	C	F	G
OS					
1	1	0	1	27	12
2	14	11	5	0	0
3	0	0	1	0	0
APPLIC					
1	0	0	0	22	10
2	4	4	4	4	2
3	4	2	1	1	0
4	1	3	0	0	0
5	3	2	1	0	0
6	3	0	1	0	0
8	0	0	0	0	0

Thirteen of these subjects were South African, one was Italian, and one was Swazi. Twelve were White, and the remaining three were Black. Two males were included in this cluster. There were five English, seven Afrikaans, one Zulu, one Sotho and one Tswana speaking subject, with a wide range of educational levels. These subjects came from all three organisations. The ages of the members of this cluster were widely distributed across the age range of the sample (19 - 58 years). In keeping with the sample's demographic characteristics, none of these subjects had more than five people living in their homes. From these frequencies, it is clear that no one background variable can be isolated as impacting directly on determining who would be classified as members of Cluster A.

CLUSTER B

Eleven subjects fell into this cluster. In contrast to Cluster A, the confidence ratings ranged from 4 to 8, with the highest mean confidence rating (5.545) in the USERCLUS clusters (mode = 5), implying the lowest mean level of confidence within this cluster solution (TABLE 9).

TABLE 9.
CONFIDENCE LEVELS REPORTED BY THE SUBJECTS IN VARIOUS USERSHIP CLUSTERS.

CLUSTERS	A	B	C	F	G
CONFID					
1	3	0	1	1	0
2	7	0	3	6	0
3	3	0	2	16	0
4	2	1	1	4	0
5	0	6	0	0	4
6	0	2	0	0	5
7	0	1	0	0	1
8	0	1	0	0	2

The members of Cluster B had used computers for between 2 and 9 years. Seven of the subjects used the computer for approximately 7 hours per day, and four used it for 3 to 5 hour sessions. All of the subjects were only shown how to operate the application packages in the work environment. Two subjects had completed an additional one week computer course. The subjects had used 2 to 5 application systems on 2 operating systems (TABLE 8). Although their experience mirrors that of Cluster A, their expertise seems slightly lower.

All of the members of Cluster B were South African. Six were married, and five, single. Nine of these subjects were White (three English speaking and six Afrikaans), and the remaining two subjects were Black (Sotho and Tswana speaking). These subjects all came from Organisations I (two subjects) and II (nine subjects). The subjects in this group were generally younger than those in other groups (between 20 and 28 years old and two subjects were 36 years old). Again the members of this cluster did not come from homogenous backgrounds, and no distinguishing background variables could be identified for this cluster, except that they were all South African, and none were employed in organisation III. This may be coincidental as the entire sample is predominantly South African, and employed in organisations I and II.

CLUSTER C

Cluster C consisted of seven subjects who all had over 13 years of experience (TABLE 10) with computers in which they worked for 4 to 8 hours a day.

TABLE 10.
FREQUENCIES OF YEARS EXPERIENCE WITH COMPUTERS FOR MEMBERS OF CLUSTERS A TO G.

CLUSTERS	A	B	C	D	E	F	G
YEARSEXP							
1	2	0	0	1	0	2	1
2	1	1	0	0	1	7	1
3	4	3	0	1	2	4	2
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
13	0	0	1	0	0	0	0
15	0	0	1	0	0	0	0
17	0	0	2	0	0	0	0
20	0	0	1	0	0	0	0
25	0	0	1	0	0	0	0
29	0	0	1	0	0	0	0

They had generally only been shown how to use the relevant applications in the company setting. Each subject had used 2 to 6 application systems (See TABLE 8). Due to the length of time and number of application systems in this cluster, the members of this cluster were probably the most experienced in the sample. They had the highest mean scores for YEARSEXP (19.428 years) and TIMESPAN (6.571 hours). As could be expected, these subjects fell towards the upper extreme of the age range in the sample - generally being between 31 and 58 years of age, and their confidence ratings ranged from 2 to 4 (TABLE 9), showing a high confidence level.

Five of the subjects in this cluster were South African, the other two were British and Italian. There were six White and one Indian female subjects in this group. Their home languages, education levels and organisational membership varied across the levels within each category. The only distinguishing feature here was the lack of Black members in this cluster.

CLUSTER D

Only three subjects (22; 55 and 69) were grouped into this cluster. Their confidence levels were 4, 2 and 5, respectively. Their experience ranged from 1 to 6 years (mean = 3.33 years). This cluster contained the subjects who worked the fewest hours per day, as indicated by the lowest mean score of 3 hours for this variable. The features which distinguished these subjects from the others were their ability to write simple computer programmes (TABLE 11), and their completion of college level computer courses. As such, Cluster D appears to hold the most expert subjects in the sample.

TABLE 11.
FREQUENCIES OF PROGRAMME WRITING SKILLS IN CLUSTER A TO G.

CLUSTERS	A	B	C	D	E	F	G
PGM							
no	15	11	7	0	5	27	12
yes	0	0	0	3	0	0	0

Although distinguishing features such as the subjects' completion of degrees or diplomas after school can be identified for this cluster, because it is small, extrapolation from this data is questionable.

CLUSTER E

Five subjects belonged to Cluster E (subjects 26; 50; 56; 62 and 70). This category was discernable from the other clusters in that its members did not work with computers daily (TABLE 12). In contrast to Cluster C, they had only used computers for between 1 to 5 hours per day (mean = 3.200 hours) (TABLE 13). Further, subject 56 had 10 years experience, while the others had 2 to 4 years experience with computers. Surprisingly, most of this cluster's members used 2 or more application systems (mean = 3.200) within the comparatively short time period.

TABLE 12.
TABULATION OF FREQUENCIES WITH WHICH CLUSTER MEMBERS 'SCORED' FOR THE VARIABLE FREQUENCY OF USE OF A COMPUTER.

CLUSTERS	A	B	C	D	E	F	G
FREQUSE							
Daily	15	11	7	2	0	27	12
Other	0	0	0	1	5	0	0

TABLE 13.
TABULATION OF FREQUENCIES WITH WHICH CLUSTER C AND E MEMBERS USED THE COMPUTER DAILY.

CLUSTERS	C	E
TIMESPAN (hrs)		
1	0	2
2	0	0
3	0	0
4	1	1
5	1	2
6	0	0
7	3	0
8	2	0

The distribution of socio-cultural variables in this group mirrored that of Cluster B's members. They differed in that their education level attained was slightly higher than that of Cluster B's members. As was noted in Cluster B, the members of this cluster did not come from homogenous backgrounds, and no distinguishing background variables could be identified, except that they were all South African, but this may be coincidental as the entire sample was predominantly South African. It appears that background did not impact on usership level to a great degree as, if this were the case, the members of Clusters B and E could be expected to have been grouped together. Instead, two clusters have fallen between them, implying a large distance, and therefore a marked distinction, between Clusters B and E.

CLUSTER F

Twenty-seven subjects were clustered together in Cluster F. All of these subjects had used only 1 operating system, and twenty-two, had used only 1 application system. Four subjects had used 2 application systems (TABLE 8). Further, twenty-six of these subjects had only been shown how to use the application(s) at work. Most of the members of this cluster had 2 to 6 years of experience (mean = 4.111 years). Surprisingly, despite this lack of experience, the confidence levels in this group were high - they ranged from level 1 to 4. Six of the subjects had rated confidence at level 2, and sixteen at level 3 (the mode).

Two of the British subjects were members of this category, as were twenty-three South African, one Portuguese and one Swazi subject. The marital status, gender, home language and ages of these subjects were widely distributed. Most (59%) of the Black subjects in the sample belonged to this cluster. More specifically, there were ten White, thirteen Black, three Indian and one Coloured subject in this cluster. Over half (sixteen subjects) of the members of this cluster had a matric level education. Five subjects had studied post-school courses, and six had achieved levels of education below matric. Ten of the subjects (over one third of this clusters members) lived with three other people. Twenty of the subjects were employed at Organisation I, three at Organisation II, and four at Organisation III. Again, no single background variable could be identified as pertinent to this cluster except for its large group of Black subjects.

CLUSTER G

The twelve remaining subjects who comprised Cluster G, were distinguishable from Cluster F by their low confidence ratings which ranged from level 5 to level 8, with a rating mean of 6.083 (TABLE 9). All of these subjects had used 1 operating system, and ten had used only 1 application system. Two had used 2 application systems. They had all used computers daily for between 1 and 8 years (mean = 4.416 years).

While subjects 20 and 21 had attended a one week training course in one application, the other ten subjects had only been shown once how to use the application(s) in the company settings.

All of these subjects were female, eleven of whom were White. Nine of the twelve subjects were Afrikaans speaking. The remaining three spoke English, Zulu and Sotho at home. Another distinct feature of this cluster is that none of these subjects continued their education after leaving school. The members of this cluster were all employed in Organisations I (four subjects) and II (eight subjects). This appears to be the most demarcated cluster in the USERCLUS solution in terms of background attributes. This grouping can thus be identified as a sub-culture in the sample.

As the overall significance of background variables in influencing USERCLUS cluster membership could not easily be recognised from the crude qualitative analysis conducted thus far, Fisher's exact test was necessary to establish a more refined assessment of the impact of socio-cultural background on USERCLUS groupings.

FISHER'S EXACT RESULTS.

Owing to the size of this cluster solution, the Fisher's exact test could not be implemented on several of the variables (eg. LANGUAGE and FAMNUM) as this test is impractical in terms of CPU time and memory that is necessary, when

$$\frac{n}{(r-1)(c-1)} > 5$$

Thus when n=80 (sample) and c=7 (clusters/columns), and r=rows being the number of rows taken by the levels of the other variable, the formula becomes

$$\frac{80}{(r-1)(6)} > 5.$$

With these limitations in mind, Fisher's exact test was performed only where possible, to yield the results displayed in TABLE 14. As an alpha of 5% was chosen, these figures indicate that the only socio-cultural background variables which impacted significantly on subjects' experience and knowledge with computers were race and organisational membership. As such, there was a significant relationship between ones cluster membership in the USERCLUS solution, and ones race group and organisational membership. In accordance with Kohn's (1970) finding that members of different social classes have different experiences and develop different occupational aspirations, it is not surprising that socio-economic variables have not been associated with different clusters, as they are generally uniform throughout the sample.

TABLE 14.
FISHER'S EXACT PROBABILITIES FOR ASSOCIATIONS BETWEEN USERCLUS CLUSTERS AND VARIOUS SOCIO-CULTURAL BACKGROUND VARIABLES.

VARIABLES	PROBABILITY	SIGNIFICANCE
USERCLUS * RACE	**0.02**	**SIGNIFICANT**
USERCLUS * MARITAL	0.96	Not Significant
USERCLUS * NATION	0.80	Not Significant
USERCLUS * GENDER	0.06	Not Significant
USERCLUS * ORG	**0.00023**	**SIGNIFICANT**

As was discussed in the qualitative assessment of the data, Cluster F's members were predominantly Black. Thirteen out of the twenty-two Black subjects in the sample belonged to this cluster which consisted of subjects who generally had a lower experience level as they had generally used only 1 application and 1 operating system. The majority (twenty) of Organisation I's thirty-eight employees belonged to Cluster F. In contrast, Cluster C did not have any Black members. Clusters A, B and G had predominantly White members employed in Organisation II. An index which is closely related to race group is language. If the USERCLUS * LANGUAGE and USERCLUS * EDUC relationships were also significant, it would support the argument that South Africa's past Apartheid era impacted on opportunities in terms of knowledge and experience with computers. Unfortunately, the Fisher's exact test does not have the ability to cope with tables of these sizes, and these relationships could not be quantitatively established.

The finding that both organisation and race were significantly distinguishable between the clusters may be attributable to the race group memberships within each organisation. More specifically, approximately 70% of the Black subjects in this sample belonged to Organisation I, and 50% of the White sample came from Organisation II and Organisation III had no Black subjects (TABLE , - it is thus not surprising that a significant difference between organisations would have a corresponding significant difference in race group. The probability that one is not rejecting a true null hypothesis incorrectly is much greater for the significant difference between organisation and cluster membership than for race group and cluster membership. It can therefore be speculated that membership in an organisation, which is influenced by the application and operating systems which are used, is the feature which impacts on usership, and that membership in the race groups is a coincidental byproduct of the organisation's respective selection criteria. Alternatively, the differences could be attributed to the past Apartheid era which may have limited opportunities for training and experience with computers for different race groups. For example, most of the Black subjects were members of Cluster F, who had used only one application system, and had little experience with computers. It cannot, however, be ignored that there were also many White subjects who belonged to the less experienced clusters (Clusters F and G).

TABLE 15.
FREQUENCIES OF SUBJECT MEMBERSHIP IN EACH RACE GROUP IN THE THREE ORGANISATIONS.

	ORG I	ORG II	ORG III
WHITE	19	26	7
BLACK	17	5	0
INDIAN	2	1	2
COLOURED	0	0	1

The distinct features associated with each cluster in the USERCLUS solution can be summarised as follows. *Cluster A* members had high confidence levels possibly attributable to their high (for the sample) level of training and their experience in at least two application systems. *Cluster B* members had low confidence levels although they had used two or more operating and application systems for approximately the same time period as Cluster A. This is possibly because nine of the subjects had only been shown how to use the application system(s) in the company setting. *Cluster C* members had the most experience with computers (over 13 years, working 5 to 8 hours a day on 2 to 5 application systems) and were very confident although they had not received any college level training relating to computers. In contrast, members of *Cluster D* had the highest level of expertise as they could write programmes, and all had received a college level training in computers. *Cluster E* members had a broad range of experience in different occupational settings but its members did not work daily on the computer. The primary feature which distinguished *Clusters F* and *G* was the confidence levels, being high in the former, and low in the latter. Although Cluster A and B seem to mirror Clusters F and G respectively, Cluster A and B members were experienced in more applications than those of Clusters F and G who used very few (usually one) application systems, and had very little, if any, training. The only background variable which could be identified as being significantly associated with the clustering were organisational and race group memberships.

Roughly speaking, the following diagram (FIGURE 9) summarises the positions of the USERCLUS clusters on Fisher's (1991, p440) two-dimensional conceptual space so that comparisons can be more clearly contemplated. This is merely a diagrammatic representation - not based on any statistical calculations. The clusters reveal that the subjects all fell into a segment in which novice and naive characteristics are predominant.

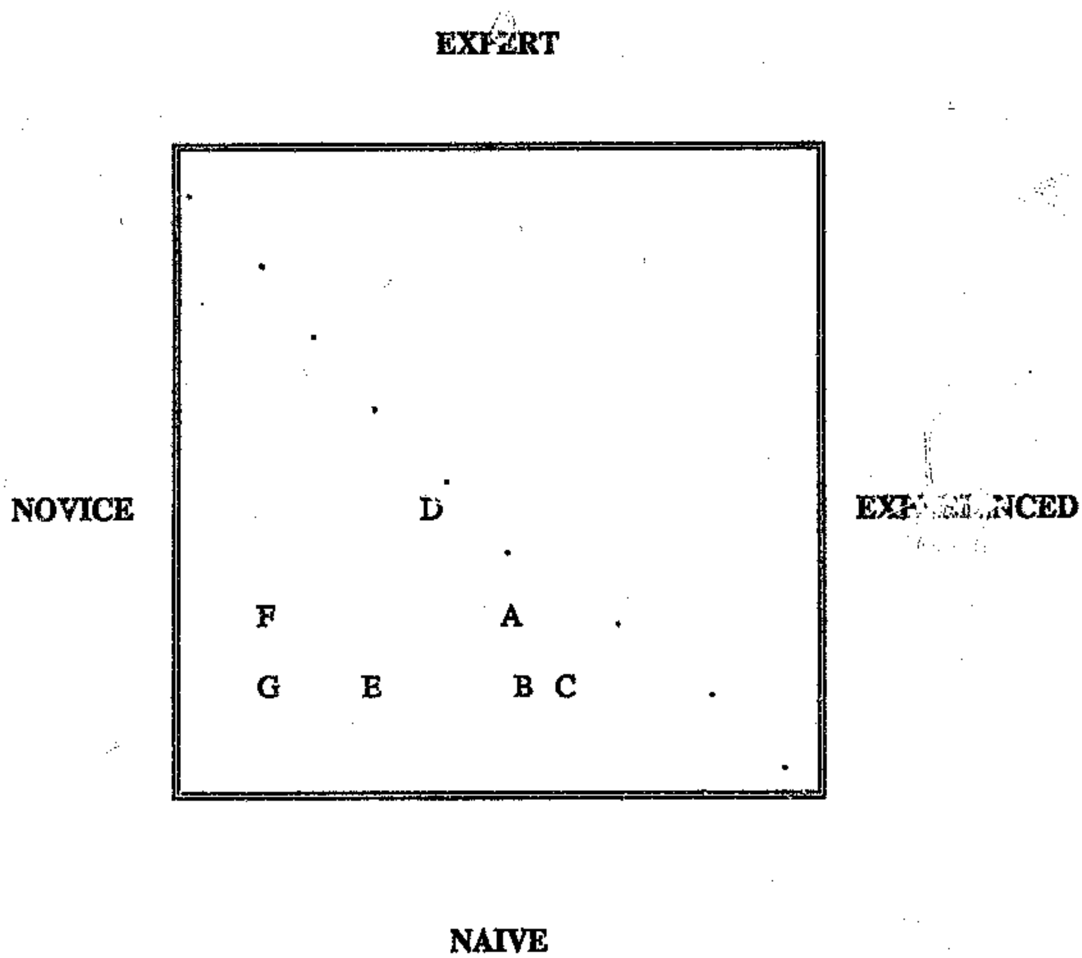


FIGURE 9.
APPROXIMATE POSITIONS OF THE CLUSTERS ON THE TWO-DIMENSIONAL CONCEPTUAL SPACE.

8.1.b. Clustering based on STAGE 2 Sketches of 'WHAT IS INSIDE THE COMPUTER?'

Reporting of results from the analysis of the data from STAGE 2 (sketch of 'what is inside the computer - under the lid') will follow the same format as that of the previous stage. Qualitatively identified distinguishing characteristics of each cluster are reported, followed by quantitative outcomes of Fisher's exact test of association between the clusters and the background variables.

Based on analysis of the tree diagram (FIGURE 10) and Pseudo F and t^2 values, a five cluster solution (referred to as DRW1CLUS) was identified as having clearly delineating attributes for its cluster groupings. There was a dramatic drop and then rise in the Pseudo t^2 from 25.6 down to 7.2, and then up to 11.8 (TABLE 16). Although the Pseudo F did not peak at this cluster solution, it did not fluctuate greatly. The combination of the Pseudo F and t^2 values were the most favourable of the possible solutions. This cluster solution explained 68% of the variance. The groups in the DRW1CLUS cluster solution have been named Cluster H, Cluster I ... Cluster L in order to facilitate discussion of the results.

TABLE 16.
PSEUDO F AND PSEUDO t^2 VALUES FOR CLUSTER SOLUTIONS WITH 4, 5 AND 6 CLUSTERS, DERIVED BY THE CLUSTER ANALYSIS PROCEDURE, IMPLEMENTED ON THE DATA OBTAINED FROM THE FIRST SKETCHES.

NUMBER OF CLUSTERS	PSEUDO F	PSEUDO t^2
6	12.9	25.6
5	12.8	7.2
4	12.0	11.8

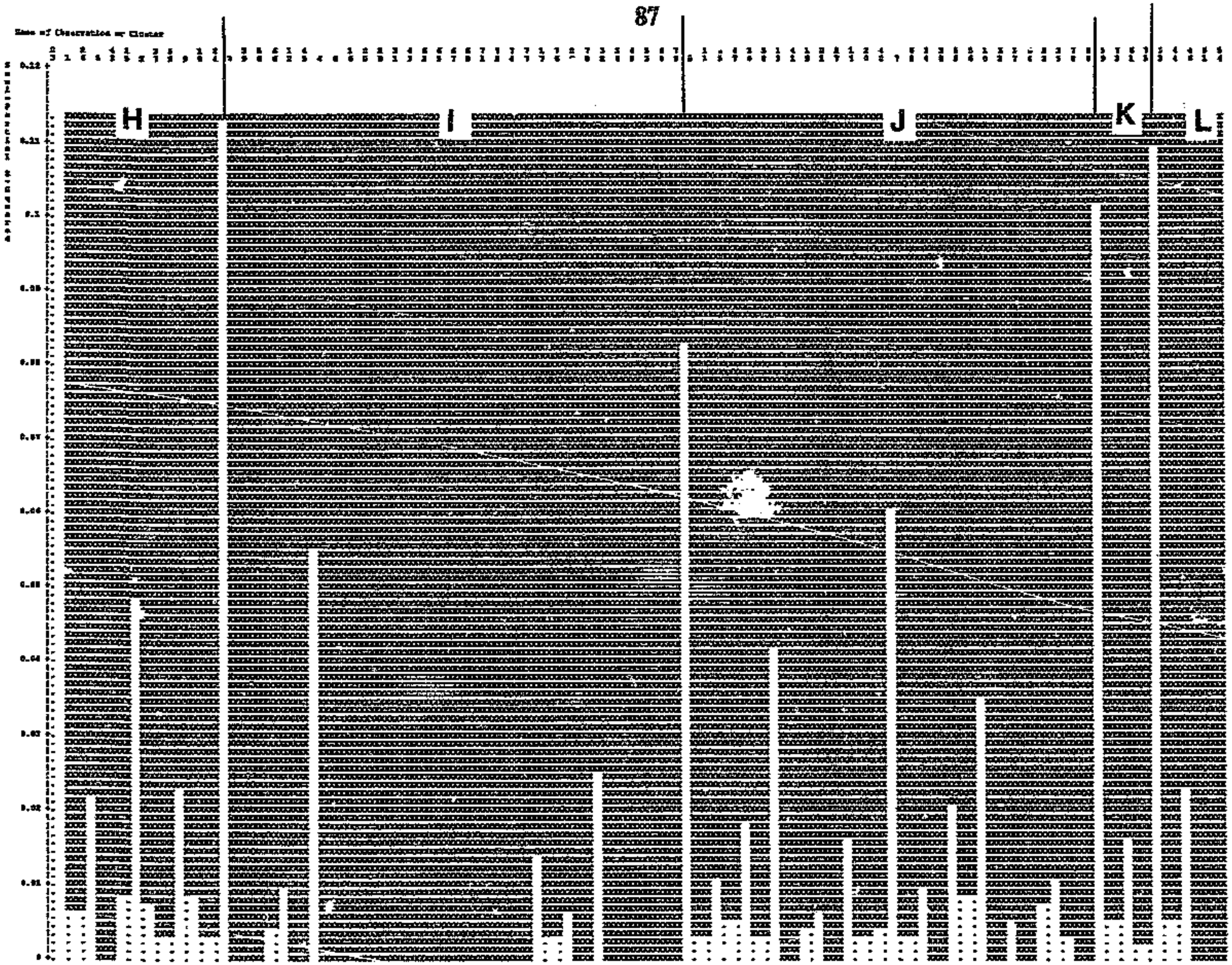


FIGURE 10.

TREE DIAGRAM SHOWING MEMBERS IN THE CLUSTERS (H TO L) OF THE DRW1CLUS SOLUTION WHICH RESULTED FROM CLUSTER ANALYSIS.

CLUSTER H

Cluster H consisted of eleven subjects (1; 2; 8; 9; 15; 18; 24; 26; 37; 48 and 52). Nine of these subjects used a ***human analogy*** in their mental models. Closely related to perceiving the computer as having human qualities, rather than as an electronic device, was another discerning attribute in this cluster - only subject number 1 sketched the external features of a computer (TABLE 17). The term 'external features' included illustration of, or reference to, features such as the screen, keyboard and cords which connect the computer to a plug.

TABLE 17.
NUMBER OF OCCURRENCES OF HUMAN ANALOGIES AND EXTERNAL FEATURES OF A COMPUTER IN SKETCHES OF SUBJECTS IN CLUSTERS H TO L.

CLUSTERS	H		I		J		K		L	
	n.	yes	no	yes	no	yes	no	yes	no	yes
BRAIN	2	9	31	0	27	1	4	0	5	0
EXTERNAL	10	1	25	6	15	13	2	2	1	4

Surprisingly, two subjects in Cluster H showed a knowledge of technical terminology (Acronyms and 'Computer jargon' which includes words such as 'ROM', 'RAM', 'bytes', 'directory', 'path' and 'gates'. If two or more of these words were used, the sketch was classified as having technical terminology), and most cluster members demonstrated a functional view of the computer which was seldom apparent in sketches of members of other clusters, as is demonstrated in TABLE 18. The sketches were classified as functional if they included any explanation of how the computer components interact, the functions of various components, or step by step descriptions of what happens inside the computer. As such, consideration of what the computer 'does', rather than merely what it 'is', was evident in this group.

TABLE 18.
NUMBER OF OCCURRENCES OF TECHNICAL TERMINOLOGY AND FUNCTIONAL PERSPECTIVES IN CLUSTERS H TO L.

CLUSTERS	H		I		J		K		L	
	no	yes	no	yes	no	yes	no	yes	no	yes
TECHNIC	9	2	31	0	17	11	4	0	5	0
FNCTNAL	2	9	29	2	15	13	2	2	4	1

A subgroup within this cluster which differed from the other subjects, consisted of subjects 2, 9, 18, 24, 37 and 52. In contrast to the other members of Cluster H, the members of this subgroup all referred to wires, and did not imply any form of communication (except for subject 37 in terms of the computer 'speaking') or the existence of separate sections (TABLE 19). When subjects did imply sections, they were not in 'computer' section terms, but rather in terms of a human analogy, for example, 'brain', 'heart' and so on.

TABLE 19.
FREQUENCIES OF WIRE, SECTION AND COMMUNICATION REFERENCES BY CLUSTER H MEMBERS.

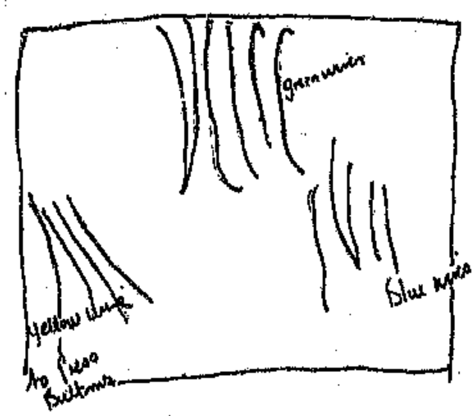
CLUSTER	H	
	no	yes
WIRES	5	6
SECTION	6	5
COMMUNIC	4	7

All of the subjects in this cluster were South African. Ten were White (five of whom were English, and 5 Afrikaans speaking), and two, Black (both Tswana speaking). Two of the cluster members were male. Cluster H's subjects all came from Organisations I and II, and had up to four people living with them. The education levels and ages in this cluster varied widely. Sketches thus did not appear to differ significantly because of background factors in this cluster, except that subjects were predominantly White employees, none of whom were employed in organisation III.

CLUSTER I

The thirty-one subjects in Cluster I all used wires in their sketches. This included labelling of any components of the sketch as wires or cables, or mentioning wires or cables in the descriptive paragraph. Although the sketches were more mechanically oriented than those of the previous cluster and there was no reference to a human analogy, they were ***very abstract***. Only four of the subjects recognised the existence of separate sections within the computer.

Six subjects labelled the wires as having different colours, implying a knowledge of what the inside of technical appliances look like. Despite this, the lack of knowledge beyond past observations was apparent from the omission of technical terms in the sketches (TABLE 20). The illustrations could have depicted the inside of any technical device - implying that the subjects had seen the 'electrical board' inside an electronic device, but were not well informed as to the details of how it functions, or the positioning and connections which were used. This cluster's members did not depict any functional features, except for subjects 17 and 76 who mentioned that functions do exist, but gave no indication of how they operate, or what the functions are.

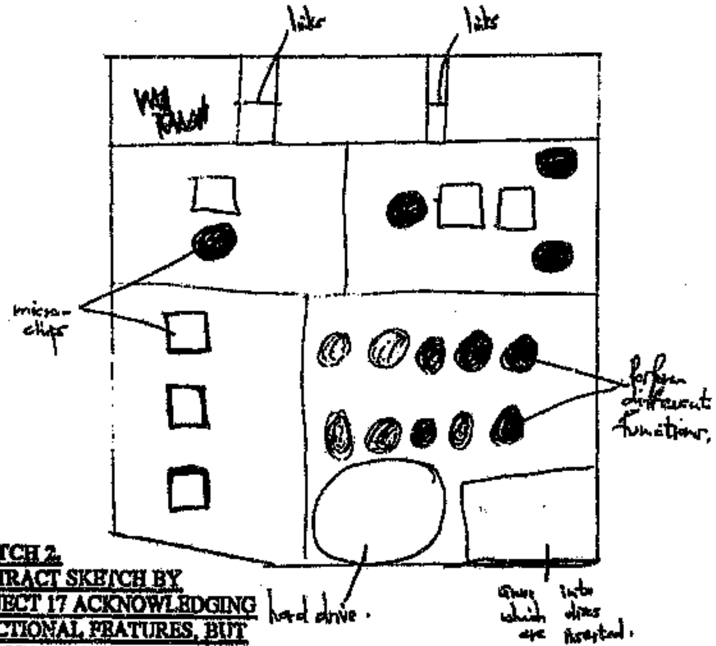


SKETCH 1.
SKETCH BY SUBJECT NUMBER 39 WHO ILLUSTRATED AN ABSTRACT MENTAL MODEL, WHICH EMPHASISED THE EXISTENCE OF COLOURED WIRES.

TABLE 20.
FREQUENCY OF OCCURRENCE OF COLOURED WIRES AND TECHNICAL TERMS IN CLUSTERS H TO L.

CLUSTERS	H		I		J		K		L	
	no	yes	no	yes	no	yes	no	yes	no	yes
COL	9	2	25	6	28	0	2	2	5	0
TECHNIC	9	2	31	0	17	11	4	0	5	0

Only two subjects mentioned memory at all and no subjects alluded to any form of communication. However, five subjects sketched discs, and a hard drive was included by four subjects.



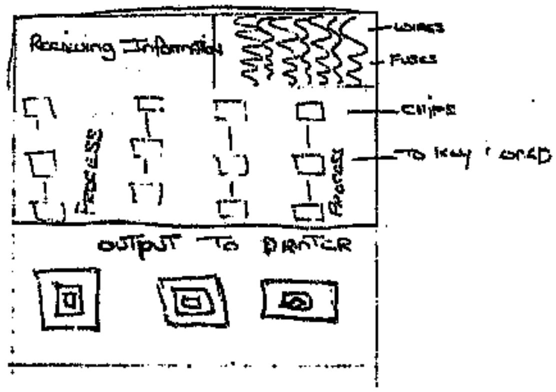
SKETCH 2.
ABSTRACT SKETCH BY SUBJECT 17 ACKNOWLEDGING FUNCTIONAL FEATURES, BUT GIVING NO INDICATION OF HOW THEY OPERATE.

Nine subjects drew external features of the computer. These subjects appear to have viewed the computer from an external orientation, with wires which exist behind the screen, communicating almost instantaneously with the keyboard. For example, in the sketches of subjects 36, 40, 53, 60 and 79, computing was depicted as occurring behind the screen. As in the previous cluster, this cluster's members' views seemed simplistic, based on 'drawing what one sees'- what the computer 'is'.

All of the non-South African subjects (except for the British group), belonged to Cluster I. This cluster cannot, however, be seen as representing non-South Africans as twenty-five of the thirty-one subjects in this cluster were South African. Twenty-three of these subjects were White, four were Black, three, Indian, and one, Coloured. All but one were female. There were ten English, fourteen Afrikaans, one Zulu, two Sotho, three bilingual (E/P) and one Swazi speaking subjects in this cluster. Although the majority of these subjects (sixteen) had a matric level education, the education levels of the other members of this cluster were evenly distributed along the scale on either side of this level. The number of people living in their homes and marital status of the subjects also varied across the group. Fourteen, eleven and six subjects in this cluster were employed in organisations I, II and III, respectively. The ages of Cluster I's members ranged widely from 19 to 58 years. From this dispersion of scores, it can be seen that this is a large cluster with no distinct background variables.

CLUSTER J

Twenty-eight subjects constituted Cluster J. In this cluster, the move from an abstract to a more detailed technological metaphor is clear. All of the members of this cluster (except for subject 33) sketched wires and electronic components and some mechanical words such as 'mother board' were apparent. Eleven subjects used technical terminology in the annotation of their sketches. Five of the subjects drew discs and three labelled an area the CPU. Twelve of the subjects included a storage/memory function in their sketches. Although the computer was still generally viewed in terms of external features by fourteen subjects, with subjects 78 and 80 insinuating computing occurring behind the screen. Fourteen subjects made no reference to external features. Thirteen subjects predominantly viewed the computer from a functional perspective - considering what the computer 'does', rather than solely what it 'is'.



SKETCH 3.
FUNCTIONAL PERSPECTIVE SHOWING STAGE THROUGH WHICH INFORMATION PASSES ACCORDING TO THE MENTAL MODEL OF SUBJECT 38.

Ten subjects noted different sections in a computer, and communication between these sections was acknowledged by fourteen subjects (TABLE 21). With its members' recognition of factors such as memory, wires, sections, communication and functional aspects, this cluster presented the most 'technically' advanced mental models of the five cluster solution.

TABLE 21.
FREQUENCIES OF COMMUNICATION ILLUSTRATION AND/OR RECOGNITION IN THE SKETCHES IN THE DRW1CLUS SOLUTION.

CLUSTERS	H		I		J		K		L	
	no	yes	no	yes	no	yes	no	yes	no	yes
COMMUNIC	4	7	31	0	14	14	3	1	5	0

All three British subjects were members of Cluster J. The UK emphasises computers in the education system to a greater degree than South Africa does, and this could be offered as an explanation for this grouping. It can be argued that there were also twenty-five South Africans in this cluster. Eighteen, nine and one of the cluster members were White, Black and Indian, respectively. Four of these subjects were male. The home languages in this cluster varied, with subjects being categorised into almost all of the language groups, and the ages of these subjects spanned the range of ages in the sample. As in the previous cluster, most of these subjects (mode = 11) had achieved a matric level education, but the remaining subjects were evenly distributed on either side of this level. Ten of these subjects had three people living with them, while the other subjects had up to five people living with them. Again, subjects came from all three companies. As was seen above, no one pertinent feature could be identified here.

CLUSTER K

Subjects 59; 61; 73 and 75 formed Cluster K. The discriminating feature of sketches in this cluster was the reference to ***lights/bulbs inside the computer*** which were illustrated, described or labelled in the sketches. Further, all of these subjects explained that wires are necessary for the lights to function. They depicted a ***'holistic view'*** of a screen with a light behind it which functioned to 'light up' the relevant information by means of wires (TABLE 22). None mentioned memory or different sections in the computer.

TABLE 22.
TABLE PORTRAYING THAT THE ONLY SUBJECTS WHO INCLUDED LIGHTS, OPERATED THROUGH WIRES, IN THEIR MENTAL MODELS WERE THE FOUR MEMBERS OF CLUSTER K.

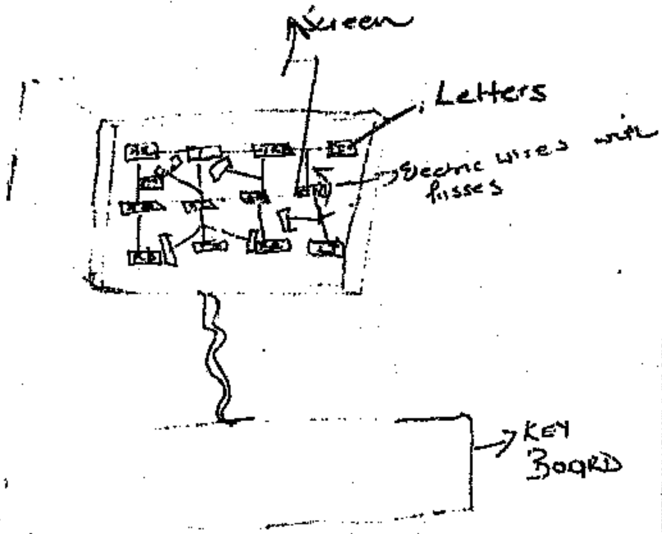
CLUSTERS	H		I		J		K		L	
	no	yes	no	yes	no	yes	no	yes	no	yes
WIRES	5	6	0	31	2	26	0	4	2	3
LIGHTS	11	0	31	0	28	0	0	4	5	0

The members of this cluster were all South African and were all married. Their ages ranged from 30 to 44 years old. The distribution of the categorisation of these subjects on the other variables varied considerably, and no other distinguishing attributes could be identified.

CLUSTER L

The five subjects (33; 44; 46; 51 and 54) in Cluster L made no reference to a memory/brain or communication of any sort (TABLE 21). Only one subject identified functional features. All except subject 33, saw the computing as occurring behind the screen, included external features in the sketch, and referred to wires of some sort.

Further, unlike any of the subjects in other clusters, all of these subjects delineated the use of ***letters inside the computer.*** In a similar conception as that of members of the previous cluster, these subjects generally saw wires as determining what happened with the letters (TABLE 23). Again, as before, no explanation was given regarding 'how' the functioning of the computer occurs.



SKETCH 4.
MENTAL MODEL BASED ON LETTERS WHICH ARE 'MANIPULATED' BY WIRES.

TABLE 23.
TABLE PORTRAYING THAT THE ONLY SUBJECTS WHO INCLUDED LETTERS IN THEIR MENTAL MODELS WERE THE 5 MEMBERS OF CLUSTER L.

CLUSTERS	H		I		J		K		L	
	no	yes	no	yes	no	yes	no	yes	no	yes
LETTERS	11	0	31	0	2[illegible]	0	4	0	0	5

A feature distinct to this cluster was that all subjects were Black, female South Africans. Two spoke Zulu, one Sotho, one Tswana and one Venda. These subjects were relatively young (25 to 36 years old). All except for one had a matric level education and three people living with them. Also, these subjects were all from company I. As such, the members of this cluster have several characteristics which were lucid, and it can be classified as a distinct sub-culture. There are two primary factors which may account for this distinction - both are related to personnel functions. Firstly, selection procedures in Organisation I may be oriented towards selecting Black, relatively young women. Secondly, the training used in this organisation may encourage the development of a particular type of mental model. However, although most of the Black members of the sample (77%) came from this organisation, this organisation's participants were predominantly White (nineteen subjects) (TABLE 15), and as such, the selection procedures and training alone do not fully explain the disparity between this group and the other DRW1CLUS clusters. Race was thus probably a cultural variable which does impact on mental model formation. Fisher's exact test was used to establish quantitatively whether a significant association existed between the clusters and any of the background variables.

FISHER'S EXACT RESULTS.

Fisher's exact tests were conducted, where the CPU time and memory permitted, to establish whether a significant relationship existed between the DRW1CLUS clusters and the background variables. The results appear in TABLE 24.

TABLE 24.
FISHER'S EXACT PROBABILITIES FOR ASSOCIATIONS BETWEEN DRW1CLUS CLUSTERS AND VARIOUS SOCIO-CULTURAL BACKGROUND VARIABLES.

VARIABLES	PROBABILITY	SIGNIFICANCE
DRW1CLUS * EDUC	0.490	Not Significant
DRW1CLUS * RACE	**2.29E-03**	**SIGNIFICANT**
DRW1CLUS * MARITAL	0.320	Not Significant
DRW1CLUS * NATION	0.579	Not Significant
DRW1CLUS * GENDER	0.063	Not Significant
DRW1CLUS * ORG	**0.024**	**SIGNIFICANT**

From TABLE 24, it can be seen that again, as in the cluster solution for USERCLUS, those of DRW1CLUS had distinct racial groups dominating the various clusters. For example, Cluster L's members were all Black, while the membership of Clusters H, I and J was predominantly White. Most of the Indian subjects were categorised into Cluster I. In contrast to the previous stage, in the analysis of the DRW1CLUS data, the probability of the null hypothesis for DRW1CLUS * RACE being rejected incorrectly is much lower than for the null hypothesis of DRW1CLUS * ORG.

It appears from these statistics that when considering what the inactive computer looks like, subjects use two sources from which they develop mental models - their background (race) and the organisation. More specifically, most people are aware of the existence of computers before they actually interact with them in any way. At this stage, the mental models which are formed would probably have their foundations in what people have been told, attitudes to computerisation, and so on, which are encountered during the socialization process. When they actually interact with the computer, they would probably build on the 'environmentally (race) based' conceptualisation of what a computer is, and expand it to include what they have been 'taught' in the organisational context.

In summation, *Cluster H* members used a functional view of a computer which communicates, based on a human analogy. *Cluster I* members submitted abstract sketches. Most of these subjects did not refer to memory, communication or functional features, but instead abstractly depicted the 'electronic board' found inside most electronic devices, while showing no knowledge regarding the details of its make up or its functions. *Cluster J* was characterised by the most realistic and functional mental models which included features such as discs, CPU, memory and communication means. Eleven subjects in this category included technical terms. Only Clusters H and J members in DRW1CLUS adopted a functional mental model of what a computer 'does'. Thus less than half of the sample assumed this perspective, revealing that the general perspective which is adopted for an inactive computer is based on what it 'is', rather than what it 'does'. In *Cluster K*, subjects generally used an holistic view of a screen with a light behind it which 'lights up' the relevant information by means of wires. No sections, memory or technical terms appeared in this cluster. Similarly, in *Cluster L*, the subjects generally saw wires as determining what happens with letters which were depicted as existing behind the screen. These distinguishing features can be identified in TABLE 25. Race and organisational membership again differed significantly between the clusters. Diagrammatically, the distinguishing features of these clusters were summarised in FIGURE 11 by a representative sketch from each cluster. It must, however, be noted that these sketches are shown without the descriptive paragraphs which accompanied them. As such, the most explicit sketches were selected to indicate the pertinent features of the cluster members' mental models.

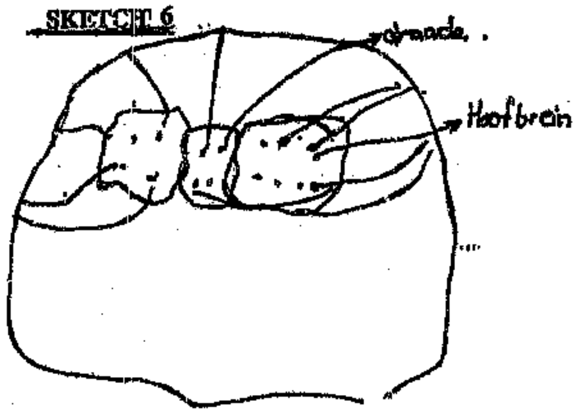
TABLE 25.

TABULAR SUMMARY OF THE FREQUENCIES WITH WHICH SUBJECTS IN EACH CLUSTER IN THE DRWICL[illegible] SOLUTION REFERRED TO THE DOMIN[illegible] THEMES IDENTIFIED IN THE SKETCHES.

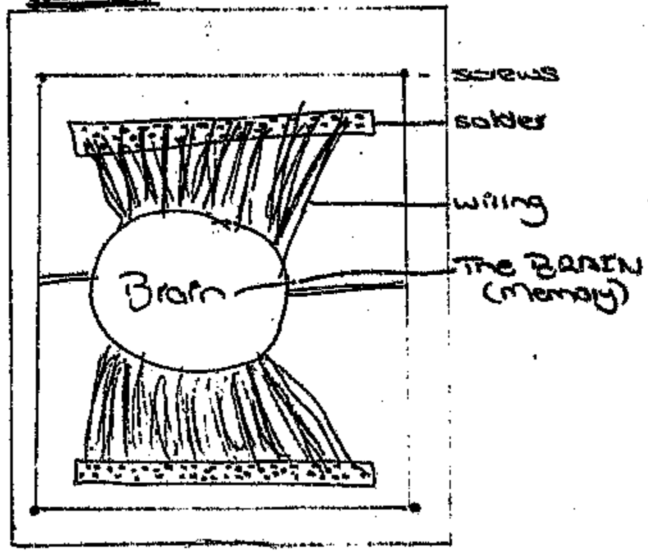
CLUSTER	H		I		J		K		L	
	no	yes	no	yes	no	yes	no	yes	no	yes
LETTER	11	0	31	0	28	0	4	0	0	5
WIRES	5	6	0	31	2	26	0	4	2	3
COL	9	2	25	6	28	0	2	2	5	0
BRAIN	2	9	31	0	27	1	4	0	5	0
TECHNIC	9	2	31	0	17	11	4	0	5	0
SECTION	6	5	27	4	18	10	4	0	3	2
COMMUNIC	4	7	31	0	14	14	3	1	5	0
EXTERNAL	10	1	25	6	15	13	2	2	1	4
MEMORY	9	2	29	2	15	13	4	0	5	0
FNCTNAL	2	9	29	2	15	13	2	2	4	1
LIGHTS	11	0	31	0	28	0	0	4	5	0

CLUSTER H

SKETCH 6



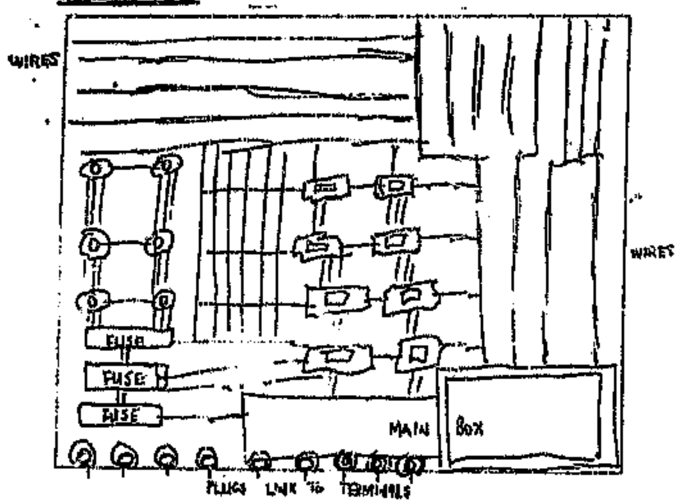
SKETCH 7



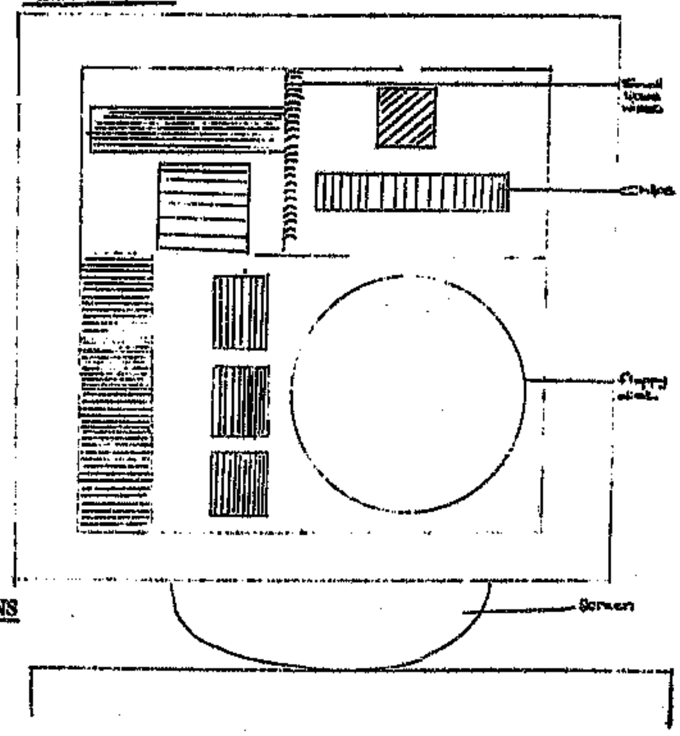
SKETCHES 6 AND 7.
DRAWINGS, FROM CLUSTER H, SHOWING MENTAL MODELS BASED ON A HUMAN ANALOGY, BOTH ACCOMPANIED BY AN EXPLANATION A THE DESCRIPTIVE PARAGRAPH OF 'HOW' THE COMPUTER FUNCTIONS.

CLUSTER I

SKETCH 8.



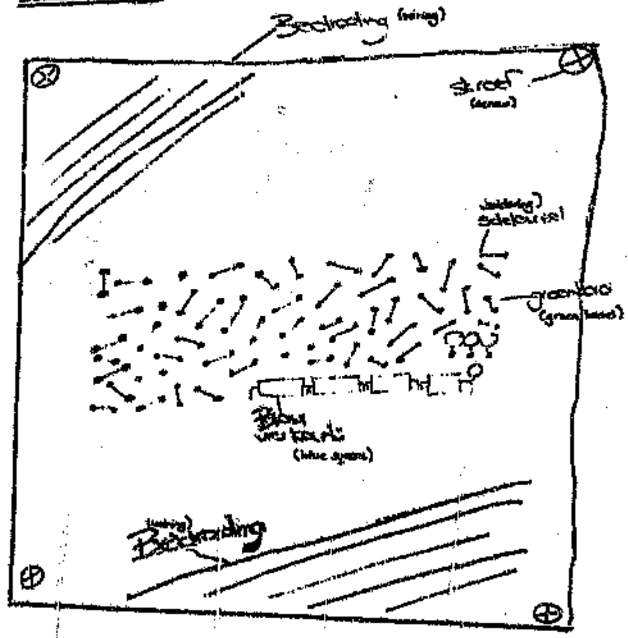
SKETCH 9.



SKETCHES 8, 9 AND 10.
ABSTRACT, MECHANICALLY BASED ILLUSTRATIONS OF THE INSIDE OF A COMPUTER, WITH NO FUNCTIONAL IMPLICATIONS, CHARACTERISTIC OF CLUSTER I.

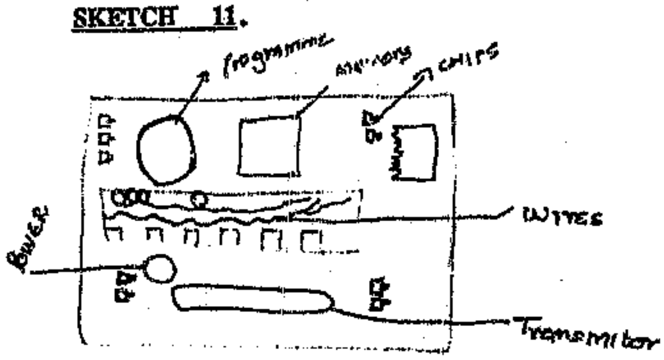
FIGURE 11.
OVERVIEW OF DISTINGUISHING CLUSTER CHARACTERISTICS RECAPITULATED BY A REPRESENTATIVE SAMPLE OF SKETCHES FROM EACH CLUSTER WITHIN THE DRWICLUS SOLUTION.

SKETCH 10.

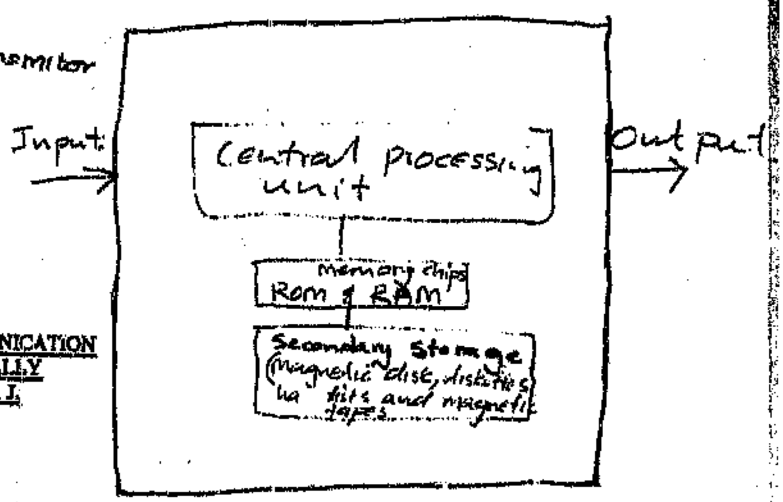


CLUSTER J

SKETCH 11.



SKETCH 12.

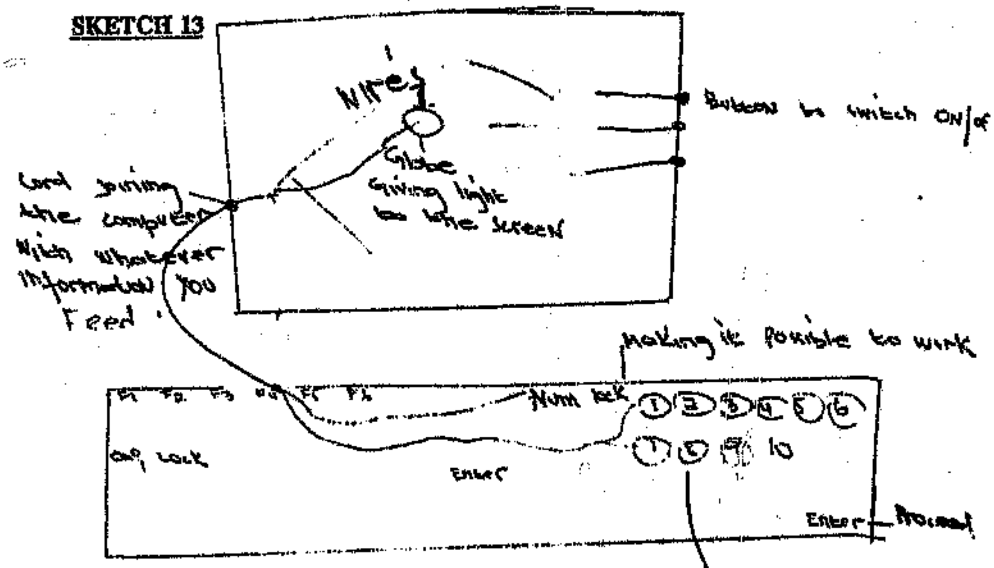


SKETCHES 11 AND 12.
MENTAL MODELS WITH EMPHASIS ON COMMUNICATION AND FUNCTIONALITY IN THE MCST 'TECHNICALLY ADVANCED' SKETCHES APPARENT IN CLUSTER J.

FIGURE 11 (cont.).
OVERVIEW OF DISTINGUISHING CLUSTER CHARACTERISTICS RECAPITULATED BY A REPRESENTATIVE SAMPLE OF SKETCHES FROM EACH CLUSTER WITHIN THE DFWICLUS SOLUTION.

CLUSTER K

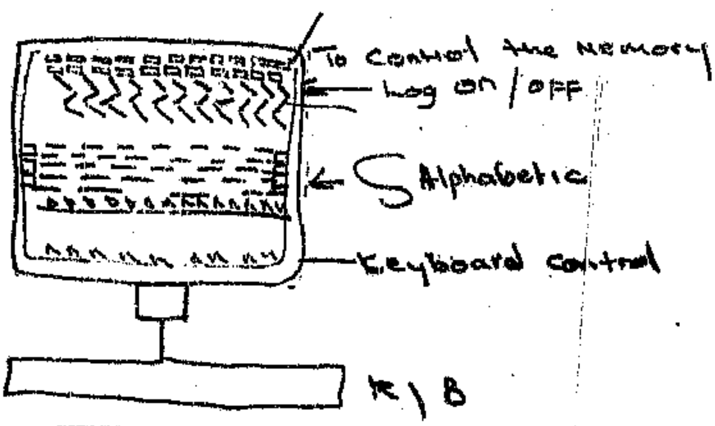
SKETCH 13



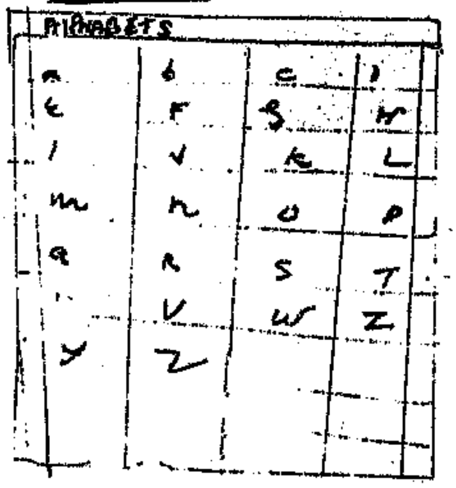
SKETCH 13.
VIEW OF A COMPUTER AS A SCREEN WITH A LIGHT BEHIND IT WHICH 'LIGHTS UP' RELEVANT INFORMATION BY MEANS OF WIRES. TYPICAL OF CLUSTER K.

CLUSTER L

SKETCH 14



SKETCH 15.



SKETCHES 14 AND 15.
CHARACTERISTIC VIEW OF A COMPUTER AS A SCREEN WITH LETTERS BEHIND IT, WHICH ARE 'MANIPULATED' BY WIRES, FROM CLUSTER L.

FIGURE 11 (cont.).
OVERVIEW OF DISTINGUISHING CLUSTER CHARACTERISTICS RECAPITULATED BY A REPRESENTATIVE SAMPLE OF SKETCHES FROM EACH CLUSTER WITHIN THE DRW1CLUS SOLUTION.

8.1.c. Clustering based on STAGE 3 Sketches of 'MOVING A FILE'

The sketches from STAGE 3, which considered mental models used when saving a file on a computer, were also qualitatively and quantitatively analyzed to establish whether similarities and/or differences existed between the mental models of subjects, and if so, whether they were associated with any background variables.

The Pseudo F which remained stable for a four cluster solution with a fluctuation of only 0.1 and t^2 value which dipped to 2.8 from 4.7, and then rose to 4.0 indicated the existence of four primary clusters (TABLE 26). Further, when considered in terms of the cluster tree (FIGURE 12), this solution (termed FILECLUS) produced the most conceptually distinct clusters.

TABLE 26.
PSEUDO F AND PSEUDO t^2 VALUES FOR CLUSTER SOLUTIONS WITH 3, 4 AND 5 CLUSTERS, DERIVED BY THE CLUSTER ANALYSIS PROCEDURE IMPLEMENTED ON THE DATA OBTAINED FROM THE SECOND SKETCHES.

NUMBER OF CLUSTERS	PSEUDO F	PSEUDO t^2
5	4.8	4.7
4	4.8	2.8
3	4.9	4.0

This cluster solution has been chosen although it only accounts for 41% of the variance as, although the ten and seven cluster solutions were also distinct and valid, use of these solutions would have resulted in only one or two members in up to six clusters. Using such small groups could threaten the internal and external validity of the study. The four clusters are referred to as Clusters M, N, O and P.

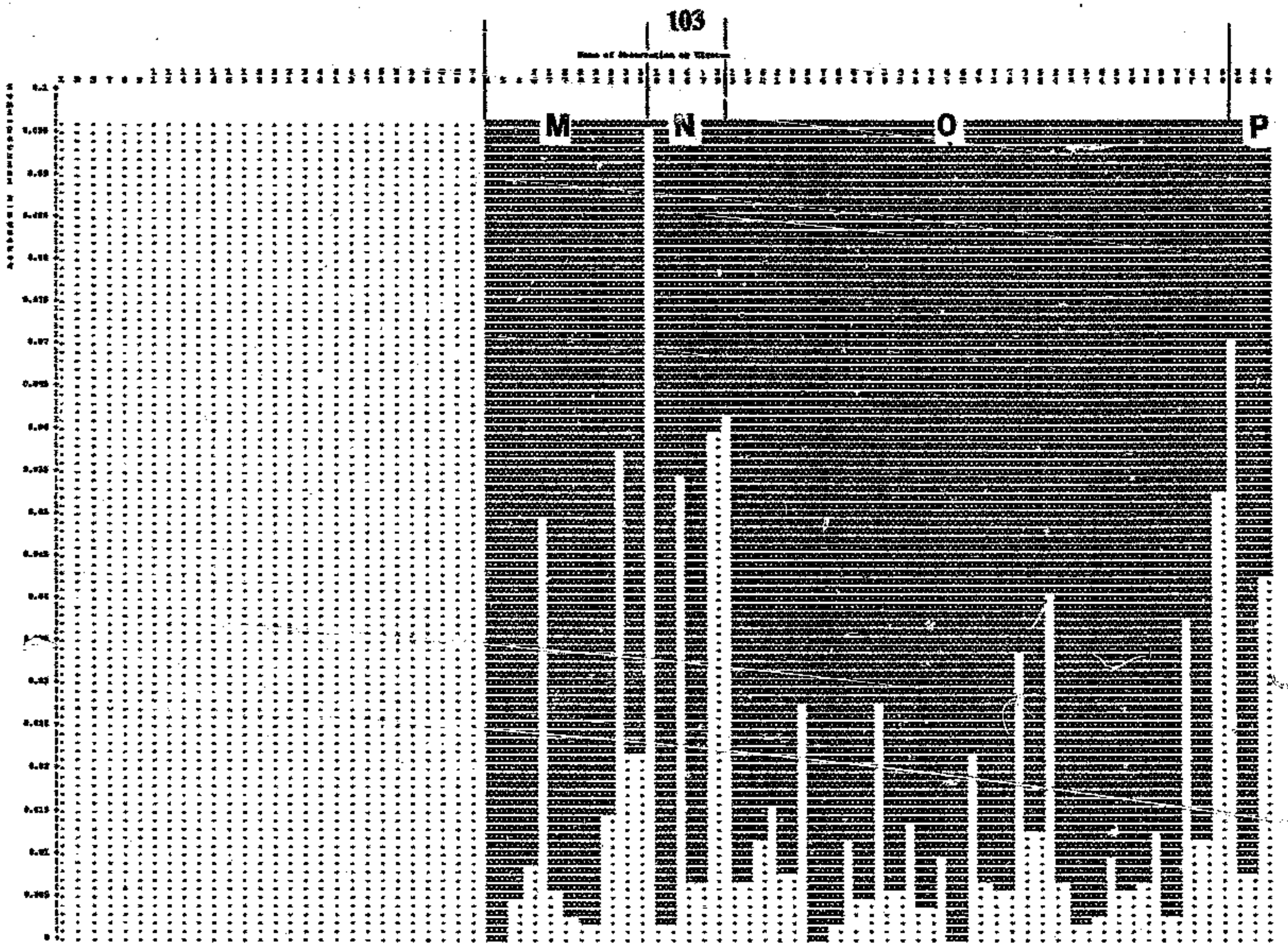


FIGURE 12.
TREE DIAGRAM OF THE SUBJECTS CATEGORISED INTO CLUSTERS (M TO P) IN THE FILECLUS SOLUTION WHICH RESULTED FROM CLUSTER ANALYSIS.

CLUSTER M

Eleven subjects were clustered together in Cluster M. The common feature in the mental models of subjects 4, 5, 6 and 26 was the use of a ***record player metaphor***. Subjects 17; 25; 27; 29; 30 and 32 all used a ***filing cabinet metaphor*** depicting separate storing compartments. They included several compartments in the form of a filing cabinet or a concertina file, with each compartment alphabetised. TABLE 27 illustrates that this cluster included all subjects who used these two metaphors.

TABLE 27.
TABULATION OF USE OF CABINET AND RECORD PLAYER ANALOGIES IN MENTAL MODELS OF SUBJECTS FROM CLUSTERS M, N, O AND P.

CLUSTER	M		N		O		P	
	no	yes	no	yes	no	yes	no	yes
CABINET	5	6	5	0	33	0	3	0
RECPLAY	7	4	5		33	0	3	0

Further, only two of this cluster's subjects' sketches resembled their sketches from the previous stage possibly because their previous metaphors were not substantial enough to cope with the images necessary for depicting the saving of a file. Few, if any, of these members referred to wires, memory or external features. The relationship between Cluster M and the other clusters is depicted regarding reference to wires and external features in TABLE 28.

TABLE 28.

TABULATION OF NUMBER OF REFERENCES TO WIRES AND EXTERNAL FEATURES OF THE COMPUTER IN SKETCHES OF SUBJECTS FROM CLUSTERS M, N, O AND P.

CLUSTER	M		N		O		P	
	no	yes	no	yes	no	yes	no	yes
WIRES	11	0	3	2	11	22	0	3
EXTERNAL	10	1	0	5	18	15	3	0

Only two subjects referred to different sections within the computer and used technical words. It is surprising that the only use of technical words fell into this category which used the most removed metaphors from a computer analogy. The other features of the sketches, however, imply that although they are aware of the terms, they are not familiar with the context in which they would be used. No communication was noted. Thus, the subjects in this cluster related to the computer in terms of everyday, 'non-technical' objects. The analogies used revealed that there was not a high level of awareness of technical aspects as their mental models were simplistic, and based on 'non-computerised' analogies.

Except for one subject who was Italian, all of the other members of this cluster were South African. Three were married, and eight, divorced. The subjects in this cluster were aged 19 to 38 years old. These subjects were White (six), Black (four) and Indian (one). Both males and females were included in this grouping. The White subjects were predominantly English speaking. The education level and number of people living together for each subject varied across the sample. Most (ten) of these subjects belonged to Organisation II.

CLUSTER N

Five subjects (numbers 10; 20; 39; 46 and 77) constituted the members of Cluster N.

Two of this cluster's subjects (10 and 20) were the only subjects in the sample who discussed a ***magnetic force*** which 'moves' the information (TABLE 29).

TABLE 29.
TABLE SHOWING THE ONLY REFERENCES TO MAGNETIC FORCES FALLING INTO CLUSTER M.

CLUSTER	M		N		O		P	
	no	yes	no	yes	no	yes	no	yes
MAGNET	11	0	3	2	33	0	3	0

Three subjects emphasised external features and wires, while these subjects, together with two others, included discs in their sketches. It is thus clear that this cluster's members were moving toward a more mechanical/technical view of the computer in terms of what the computer does, and 'how' it achieves this, rather than merely what it 'is'. Another feature which differentiates this cluster from the others is the analogy of a ***'save key'*** which, when pressed, 'locks' the file inside the computer. Subject 46 called this the CAPS lock key.

All members of Cluster N were South African females. Four were White (three English speaking, one Afrikaans speaking), and one, Black (Sotho speaking). These subjects were between 24 and 45 years of age. Four of the subjects lived with three other people. The other subject lived with 5 people. There was no education level or organisation membership which could be identified as representative of this group of subjects.

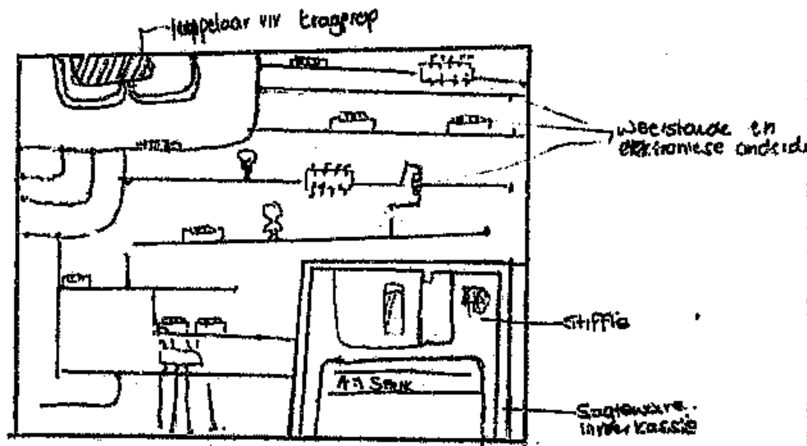
CLUSTER O

Cluster O comprised of thirty-three subjects. Four members of Cluster O depicted the computer in a functional manner. Twenty-two subjects included wires in their sketches. Eight subjects drew discs. A communication means was included by sixteen subjects in their sketches. Reference was made to memory by eleven subjects. None of the members of this cluster used technical words, nor did they use non-technical objects as metaphors. Most of their sketches resembled their previous sketches (TABLE 30).

TABLE 30.
REPRESENTATION OF SKETCHES WITHIN THE CLUSTERS WHICH RESEMBLED PREVIOUS SKETCHES FROM THE SAME SUBJECTS.

CLUSTER	M		N		O		P	
	no	yes	no	yes	no	yes	no	yes
SIMILAR	9	2	3	2	10	23	1	2

Twelve subjects compartmentalised the computer and explained that the information travels through the wires. Three subjects viewed the computer as saving the file to a disc. Four subjects gave no information regarding how the computer saved the file they merely drew the external components of the computer. Nine other subjects also included the external features in their sketches. The degree of detail given in the sketches varied, but in all of the sketches in this cluster, the emphasis was on ***mechanical/electronic features of a computer.***



SKETCH 5.
SKETCH SHOWING MECHANICAL/ELECTRONIC FEATURES OF A COMPUTER.

Of the thirty-three subjects in Cluster O, there were twenty-eight South Africans, three British subjects, one Portuguese and one Italian subject. Of these, twenty-one were White, eight Black, three Indian and one Coloured. Although most (eighteen) had achieved a matric level education, this cluster's distribution on education, number of people living together and organisational membership was widespread. Eighteen of these subjects spoke English at home, six Afrikaans, two fell into each category of Zulu, Sotho and Tswana speaking people, and one was identified in each of the Xhosa, Venda and English and Portuguese (bilingual) categories. The ages of these subjects ranged from 20 to 58 years of age. As shown here, no distinguishing background variables were identified as commanding this cluster.

CLUSTER P

Cluster P consisted of three subjects (36; 42 and 49). All of these subjects included wires in their sketches. The distinguishing feature in this group was their reference to ***menus*** (any reference to, labelling of, or illustration of a menu, or options on the screen, from which to choose) which have a ***'save key'*** option (TABLE 31).

TABLE 31.
SUBJECTS INCLUDED WIRES AND MENUS IN THEIR SKETCHES IN CLUSTER P.

CLUSTER	M		N		O		P	
	no	yes	no	yes	no	yes	no	yes
WIRES	11	0	3	2	11	22	0	3
MENU	11	0	5	0	33	0	0	3

The subjects in this cluster were all South African, English speaking females who had a matric level education, and came from Organisation I. Again, these subjects may be emerging as a cluster due to a distinct training style adopted in this organisation. They range from 24 to 29 years of age. Two of these women were White, and one was Indian. Two of these subjects lived with one other person, and the third subject lived with two people.

FISHER'S EXACT RESULTS.

As before, due to limitations of CPU time and memory, only selected Fisher's exact tests (results shown in TABLE 32) could be implemented to establish the significance of associations between the FILECLUS clusters and background variables.

TABLE 32.
FISHER'S EXACT PROBABILITIES FOR ASSOCIATIONS BETWEEN FILECLUS CLUSTERS AND VARIOUS SOCIO-CULTURAL BACKGROUND VARIABLES.

VARIABLES	PROBABILITY	SIGNIFICANCE
FILECLUS * FAMNUM	0.25	Not Significant
FILECLUS * EDUC	0.70	Not Significant
FILECLUS * LANG	0.17	Not Significant
FILECLUS * RACE	0.85	Not Significant
FILECLUS * MARITAL	0.38	Not Significant
FILECLUS * NATION	0.83	Not Significant
FILECLUS * ORG	**0.000037**	**SIGNIFICANT**

Of these, the only relationship which was significant was that of the FILECLUS * ORGANISATION (TABLE 32). This means that there was a significant difference between the sketches produced by the employees in the three different companies. For example, as was noted in the qualitative analysis discussed above, most (ten of eleven) of the members of Cluster M were employed in Organisation II and all of the members of Cluster P were employed in Organisation I.

The most feasible explanation for this significant difference in sketches between organisations can be found in the literature which states that models are strongly impacted on by training (in this case differing for different organisations), observation and accidental encounters (also differing due to slight differences in some of the tasks performed and the application packages used), and therefore differ according to exposure (Ziegler and Bullinger, 1991).

People in different cultures have been found to classify objects in different ways ie. according to different attributes. Familiarity with the relevant objects is also related to how people from different cultures classify things. When people are familiar with the objects they are asked to manipulate, they have knowledge about many features of those objects, and this knowledge may expedite classifying the objects in varied and complicated ways (Pick, 1980).

These findings also enable one to answer the question which was raised in the literature (CHAPTER 3) of whether different techniques must be implemented for developing training and computer systems for people from different cultures. The same techniques appear to impact similarly on people, irrespective of their background, as subjects from different backgrounds were similarly influenced by the company training.

It also supports Carroll & Thomas's (1982) explanation that when building mental models, metaphors are widely implicated as part of an individual process of goal directed, learner-initiated learning, particularly where learning occurs in complex domains of high abstraction. Similarly, it shows, as Waern (1989) noted, that a computer system's reality can differ between people because of the way a computer is actually used and taught. This finding accentuates the need to establish optimal metaphors for teaching purposes in companies as noted by several authors (eg. Fisher & Kaplan, 1990; Hanisch et al., 1991).

The lack of significant differences between race groups in FILECLUS, after the highly significant differences in DRW1CLUS, at first appears difficult to explain. It must be noted that the sample has changed slightly due to the attrition of the sample who participated in the final stage of the research. Despite this, nine of the twenty-two Black subjects, and nineteen of the fifty-one White subjects did not participate in the second stage, thus the proportions of subjects in each race category resembled that of the previous stage, making the sample equally representative of the race groups. As such, a more feasible explanation for race not impacting significantly on the mental models of subjects, while organisational membership is significant, lies in the nature of the task. The level of sophistication of ones mental model increases when one considers 'how' a computer performs a function. Saving a file is an operation which one has to be taught to implement. As such, when thinking about the operation, one will generally draw on what one has been taught in the organisation.

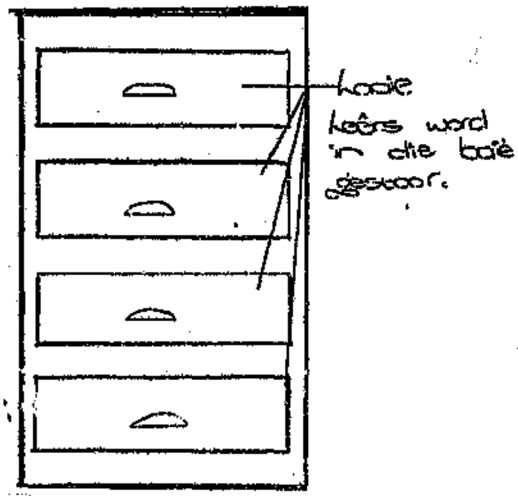
In summary, *Cluster M* subjects made use of record player and filing cabinet analogies, and their sketches bore no resemblance to their previous sketches. Members of *Cluster N* emphasised the save key locking the information into the computer, and the external features of the computer, thus combining computer- and non-computer-based metaphors in their models. *Cluster O* members adopted a more mechanical view of the computer. Technical/mechanical analogies to the inside of a machine were used, and the sketches generally resembled those of the previous stage. In *Cluster P*, wires, internal features of the computer and menus were emphasised. Thus a progression from external, non-technical to internal, technical metaphors could be seen in these four clusters. TABLE 33 provides a global view of the themes which emerged in these sketches, and their frequencies. Denham's (1993) assertion that people adapt their mental models according to the operation which is being considered is clearly indicated in the sketches from this stage. While only twenty-nine of the subjects used similar metaphors in this stage to the metaphors which they used in stage 2, twenty-three of the subjects had to use unrelated metaphors, as their original metaphors could not be extended to explain the filing operation. This finding has implications for researchers of mental models, as the models must be researched in the context of the task being considered, and findings cannot be generalised across tasks. The organisation to which the subjects belonged impacted on this cluster solution, showing that different metaphors are developed because of different organisation's choices in application packages and training that is used. Diagrammatically, the distinguishing features of these clusters were summarised in FIGURE 13 by a representative sketch from each cluster.

TABLE 33.

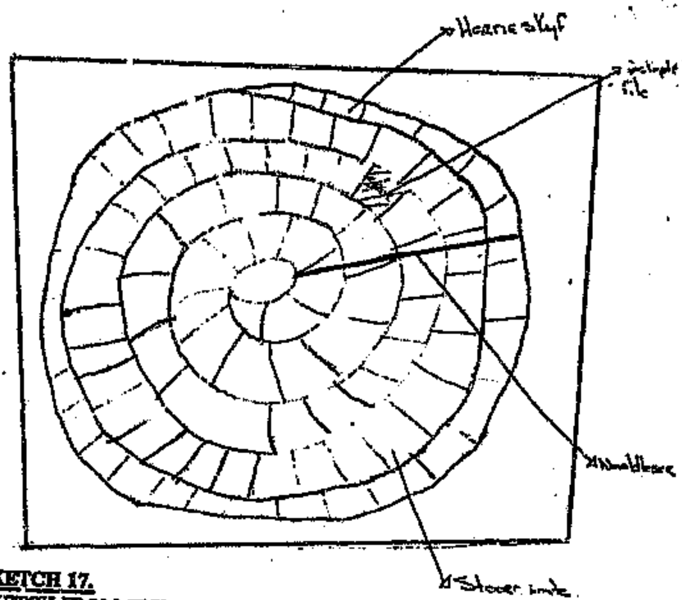
TABULAR SUMMARY OF THE FREQUENCIES WITH WHICH SUBJECTS IN EACH FILECLUS CLUSTER SOLUTION REFERRED TO THE DOMINANT THEMES IDENTIFIED IN THE SKETCHES.

CLUSTER	M		N		O		P	
	no	yes	no	yes	no	yes	no	yes
SIMILAR	9	2	3	2	10	23	1	2
MAGNET	11	0	3	2	33	0	3	0
CABINET	5	6	5	0	33	0	3	0
STORCOM	2	9	5	0	24	9	2	1
WIRES	11	0	3	2	11	22	0	3
MEMORY	10	1	4	1	19	14	2	1
BRAIN	10	1	5	0	31	2	3	0
RECPLAY	7	4	5	0	33	0	3	0
TECHNIC	9	2	5	0	33	0	3	0
SECTION	6	5	5	0	20	13	2	1
COMMUNIC	10	1	4	1	17	16	3	0
EXTERNAL	10	1	0	5	18	15	3	0
FNAL	11	0	4	1	25	8	3	0
DISCS	7	4	1	4	20	13	2	1
WIREFEED	10	1	5	0	20	13	2	1
DISKSAVE	11	0	4	1	33	0	3	0
FILECOP	11	0	5	0	32	1	3	0
FILESEC	11	0	5	0	33	0	2	1
CPUSEP	10	1	5	0	31	2	3	0
LOCKIN	11	0	3	2	33	0	3	0
SAVEKEY	11	0	3	2	28	5	1	2
MENU	11	0	5	0	33	0	0	3

CLUSTER M

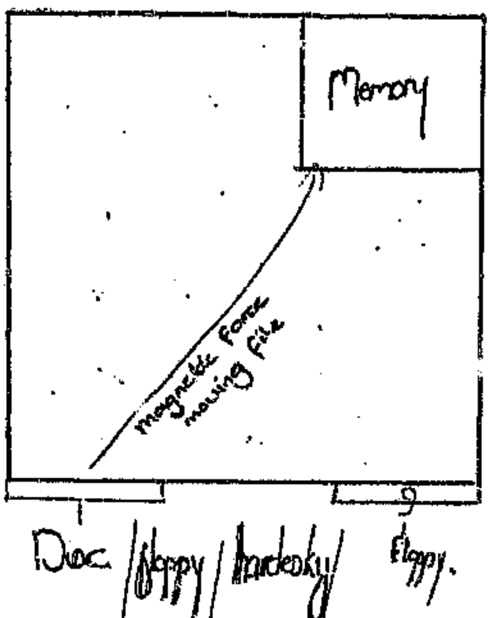


SKETCH 16.
SKETCH FROM CLUSTER M SHOWING THE USE OF A FILING CABINET ANALOGY.

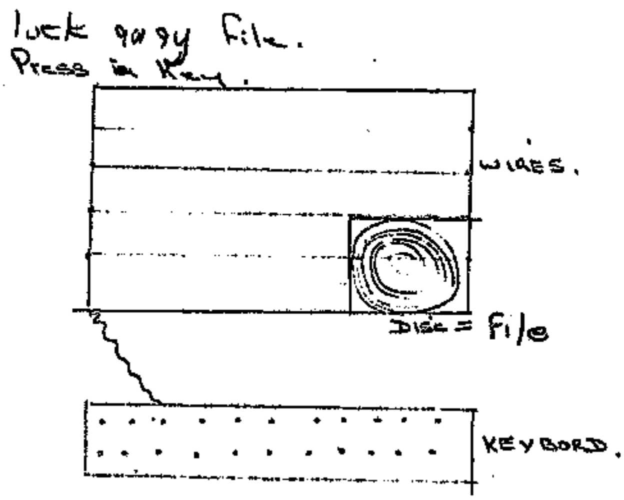


SKETCH 17.
SKETCH FROM CLUSTER M SHOWING THE USE OF A RECORD-PLAYER ANALOGY.

CLUSTER N



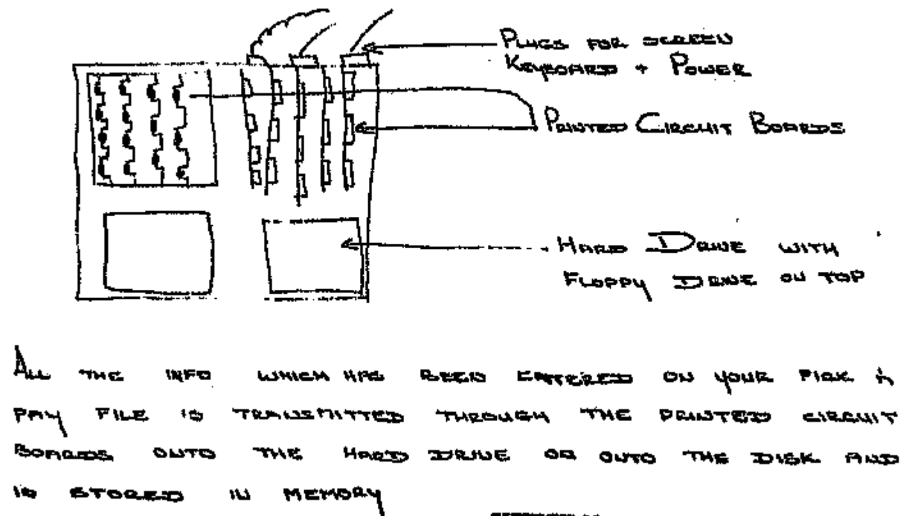
SKETCH 18.
ILLUSTRATION FROM CLUSTER N OF OF A MAGNETIC FORCE WHICH 'MOVES' INFORMATION.



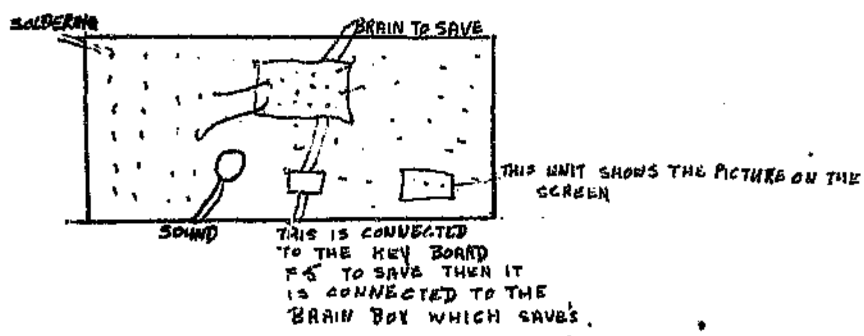
SKETCH 19.
SKETCH FROM CLUSTER N INCLUDING ANNOTATIONS REGARDING A FILE 'LOCKING AWAY' KEY METAPHOR.

FIGURE 13.
VERVIEW OF DISTINGUISHING CLUSTER CHARACTERISTICS RECAPITULATED BY A REPRESENTATIVE SAMPLE OF SKETCHES FROM EACH CLUSTER WITHIN THE FILECLUS SOLUTION.

CLUSTER O



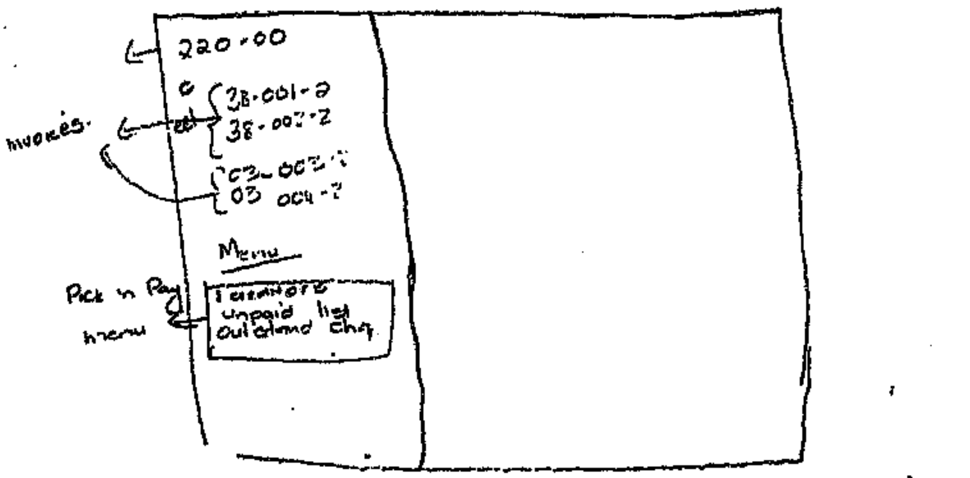
SKETCH 20.
MECHANICALLY ORIENTED MENTAL MODEL, INCLUDING EXTERNAL FEATURES.



SKETCH 21.
MECHANICAL VIEW OF THE COMPUTER, WITH REFERENCE TO A FUNCTIONAL SAVE KEY (F5), WITH COMMUNICATION IMPLIED IN TERMS OF CONNECTIONS.

FIGURE 13 (CONT.).
OVERVIEW OF DISTINGUISHING CLUSTER CHARACTERISTICS RECAPITULATED BY A REPRESENTATIVE SAMPLE OF SKETCHES FROM EACH CLUSTER WITHIN THE FILECLUS SOLUTION.

CLUSTER P



The file would be held in a special Section saved for PnP When it has to be used it will be reflected on the screen.

SKETCH 22.
MENTAL MODEL INCLUDING A MENU, SHOWING THE IMPACT OF EXPOSURE TO A PARTICULAR APPLICATION SYSTEM IN CONCEPTUALISATION OF A WHAT A COMPUTER LOOKS LIKE INSIDE, WHEN FILING A DOCUMENT.

FIGURE 13 (CONT.).
OVERVIEW OF DISTINGUISHING CLUSTER CHARACTERISTICS RECAPITULATED BY A REPRESENTATIVE SAMPLE OF SKETCHES FROM EACH CLUSTER WITHIN THE FILECLUS SOLUTION.

8.2. Relationship Between the Three Cluster Solutions

The simultaneous membership of subjects in three cluster solutions (USERCLUS for usership data; DRW1CLUS for the first sketches; and FILECLUS for the second sketches) have been qualitatively and quantitatively analyzed to determine whether any particular experience or knowledge influence mental models in a distinctive manner. For ease of discussion, subject membership in the three dual cluster solution categories, USERCLUS * DRW1CLUS (FIGURE 14); USERCLUS * FILECLUS (FIGURE 15); and DRW1CLUS * FILECLUS (FIGURE 16), were considered.

As no significant differences were apparent for the majority of the socio-cultural background variables (except for race and organisational membership) between the clusters within each cluster solution, consideration of these variables in dual membership categories of USERCLUS * DRW1CLUS and USERCLUS * FILECLUS would be superfluous. Further, because of the heterogeneity of the sample, the combination of characteristics makes direct comparisons between the subjects intricate and complicated. Also, although the Black subjects were generally found in the less experienced clusters, there were also many Whites in these clusters, and race could not be parallelled with levels of experience or expertise. For example, the two least experienced clusters were Clusters F and G, where Cluster F had 59% of the Black subjects in the sample, and Cluster G had only one Black subject, and eleven White subjects. The discussion of results regarding dual membership in the clusters did thus not deal with background variables. Instead, the relationship between cluster's usership positions on the two-dimensional conceptual space and the sketched mental models associated with these positions, were considered.

TABLE 34.
THE FREQUENCIES WITH WHICH SUBJECTS IN THIS STUDY FELL INTO EACH DUAL MEMBERSHIP CATEGORY IN THE USERCLUS AND DRW1CLUS CLUSTER SOLUTIONS.

	A	B	C	D	E	F	G
H	4	4	1		1	1	
I	7	2	3	1	2	9	7
J	3	4	3	2	2	9	5
K	1					3	
L						5	

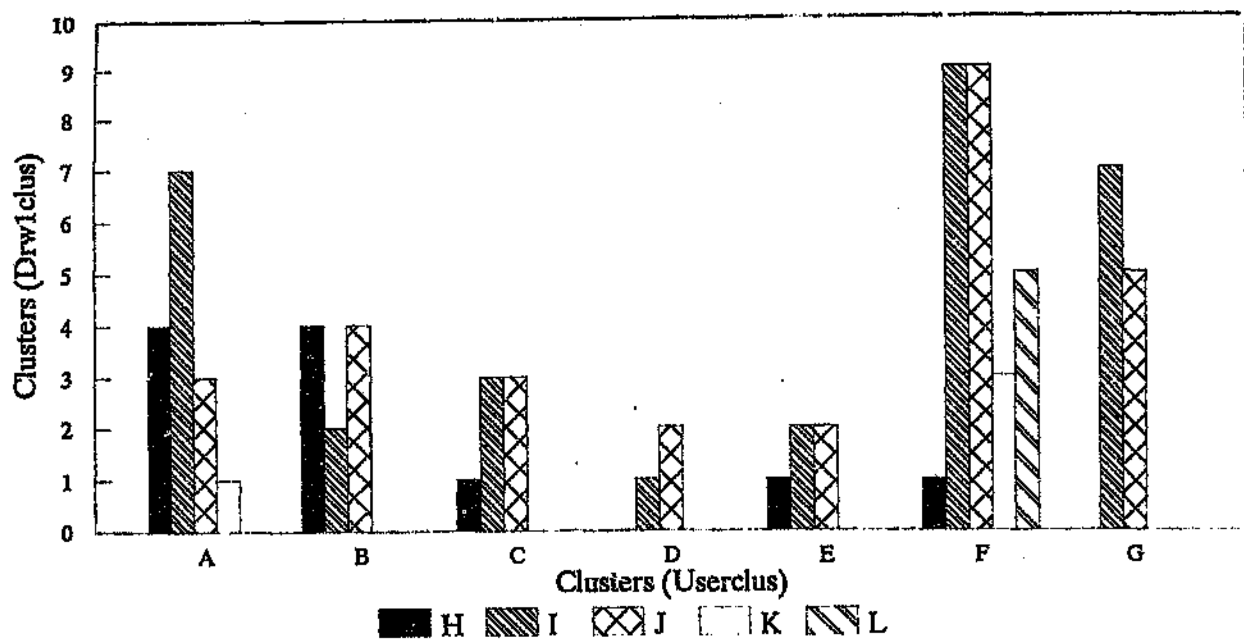


FIGURE 14.
DIAGRAMMATICAL PRESENTATION OF THE FREQUENCIES WITH WHICH SUBJECTS IN THIS STUDY FELL INTO EACH DUAL MEMBERSHIP CATEGORY IN THE USERCLUS AND DRW1CLUS CLUSTER SOLUTIONS.

*8.2.a. USERCLUS * DRW1CLUS*

Table 34 shows the number of subjects falling into each cluster combination from the USERCLUS and DRW1CLUS cluster solutions. Interestingly, the largest cluster dual-membership overlaps for members of Cluster H (who used the human metaphor in their mental models) were with Clusters A and B. These subjects were situated on the second most experienced position on the two-dimensional conceptual space, yet their sketches were the least 'computer-related'.

Members of Cluster A, who had received a high level of training and had a reasonably substantial amount of experience, predominantly used abstract sketches which implied that they had been exposed to the inside of a technical device, but had no functional or ordered mental model of what a computer 'does' at this stage. Cluster B, whose members were slightly less expert than those of Cluster A, had most of its members in Clusters H and J, rather than I - showing a knowledge of detail and functionality, explained either in technical or human analogies. The majority of Cluster A's members, and all of Cluster B, C and E's members fell into Clusters H, I and J.

In contrast, the least experienced users who belonged to Clusters F and G had the highest frequencies of overlap with Clusters I and J which were characterised by abstract and detailed computer-based mental models. Similarly, Cluster D and G's subjects, who were not very experienced with computers, all fell into Clusters I and J. Eight members of Cluster F constituted the majority of the subjects in Cluster K and L. They used distinct 'light' and 'letter' metaphors.

Past research (eg. Detienne, 1991) shows that the more expert the subjects, the more realistic the model is. This was apparent in the 'most expert' cluster in the sample - Cluster D. This cluster's members, who wrote computer programmes, were generally also members of Cluster J - signifying the most advanced sketches. The two other Clusters which were situated at the second highest level of expertise in this cluster were Clusters A and F. In contrast to the expected technicality and accuracy of the models, there were still several of these subjects who, as discussed previously, were members of Clusters H, K and L. One possible explanation is that the subjects falling into these clusters were the few who did not receive the additional training which the other members of Clusters A and F received, or, that the training unsettled the existing mental models of subjects, and they had moved away from computer analogies to redress the 'confusion'. It must be noted, however, that these subjects were only slightly more expert than the remaining clusters in the USERCLUS solution, and Cluster D was far more advanced on the naive-expert scale. As such, the deviation from the expected behaviour by the few subjects may not be significant.

These findings intimate that in this sample, the users who used few application systems had developed very distinct, clear metaphors of what the inside of a computer looks like, while the users who used more application systems had mental models which were either abstract, or were 'non-mechanical'. This may be explained in terms of Halasz and Moran's (1982) discussion regarding metaphors. They suggest that a metaphor only refers to part of an unknown system, and if the metaphors differ vastly for different applications, the novice may not know which aspects of the models are applicable to other situations, and may thus resort to a very broad model. Unfortunately, no quantitative analysis of the relationship between these cluster solutions was available to substantiate this qualitative assessment due to the limited memory and CPU time necessary for the Fisher's exact test.

*8.2.b. USERCLUS * FILECLUS*

Analysis of dual membership in clusters from the USERCLUS and FILECLUS cluster solutions were also considered. The frequency of subjects falling into each category is presented in TABLE 35 and diagrammatically in FIGURE 15.

_ ABLE 35.
THE FREQUENCIES WITH WHICH SUBJECTS IN THIS STUDY FELL INTO EACH DUAL MEMBERSHIP CATEGORY IN THE USERCLUS AND FILECLUS CLUSTER SOLUTIONS.

	A	B	C	D	E	F	G
M	4	2	1	1	1	1	1
N			2			1	2
O	7	2	2	1	3	13	5
P						3	

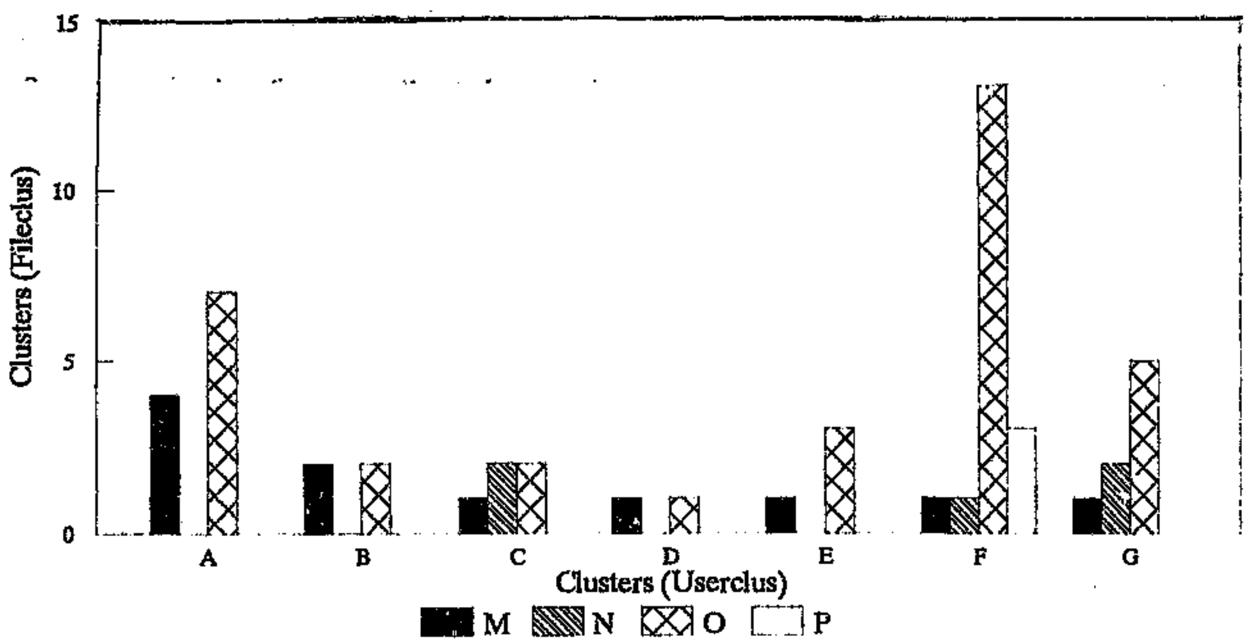


FIGURE 15.
DIAGRAMMATICAL PRESENTATION OF THE FREQUENCIES WITH WHICH SUBJECTS IN THIS STUDY FELL INTO EACH DUAL MEMBERSHIP CATEGORY IN THE USERCLUS AND FILECLUS CLUSTER SOLUTIONS.

It can be seen in TABLE 35 that most of the subjects fell into Clusters M and O for the second stage of sketches. More specifically, all members of Clusters A, B, D and E were clustered into the M (record player and filing cabinet analogies in sketches which bore no resemblance to these subjects' previous sketches) and O (Technical/mechanical analogies which resembled sketches of these subjects in the previous stage) Clusters, with more subjects falling into Cluster O.

All of the subjects who belonged to Cluster P were members of Cluster F. These subjects who were confident, although they were relatively naive users with limited training and experience, referred to a menu which has a save key option.

In accordance with the results in the USERCLUS * DRW1CLUS section, again the sketches of Clusters A and B who were situated on the most experienced position on the two-dimensional conceptual space, constituted the majority of the least 'computer-related' sketches, drawing on record-player and cabinet metaphors. Large frequencies were also apparent in the dual-memberships between Cluster O and Clusters F and G who were the least experienced users, but used the most mechanical and advanced metaphors. The members of Clusters F and G also used very specific metaphors as occurred before, as they only used one application system, and the operation of these application systems were apparent in their mental models (for example, a save key and menus were mentioned).

Fisher's exact test for USERCLUS * FILECLUS solutions showed that there were no significant differences (prob = 0.243) between these dual-membership categories. This shows that the clustering solutions for the usership data and the second sketch cluster solutions did not cluster the people with similar usership background into the same clusters, based on their sketches. This may be attributed to the different ways in which files were saved - for example on a personal computer (PC), as compared to the main-frame - as subjects generally referred to the application and operating systems with which they were most familiar. Subjects were not homogenous in this respect, and this contributed to the study by showing the effect of *type* of experience of subjects.

*8.2.c. DRW1CLUS * FILECLUS*

Analysis of dual-memberships in clusters from the DRW1CLUS and FILECLUS solutions revealed interesting cognitive behavioural changes in response to the tasks. The discussion which follows deals with the dual-memberships as illustrated in TABLE 36 and FIGURE 16.

In the first sketches by the eighty subjects, only twenty-two (27% of the sample) included communication, and twenty-seven displayed functional mental models. In the second sketches, 34% of the sample included communication. In the previous stage, twenty-five of the eighty subjects included the external features in their sketches. In this stage, twenty-one of the fifty-two subjects referred to external features. This may be attributed to coincidence as the same subjects who referred to external features may all have participated in the second sketches, but this seems an unlikely explanation as 42% of the sketches now differed from the original ones. A more likely explanation was that the idea of 'what goes on inside the computer when a file is moved' was difficult to conceptualise, and as such they drew what they emphasised in their interaction with the computer while thinking about it. They took a 'when I do X, the computer must do Y' perspective - resulting in the need for the inclusion of the keys which were used in the interaction process. This explanation was substantiated by comments made by the subjects.

In the second stage of the research, during which subjects were asked to sketch the inside of a computer, seventy of the eighty subjects included wires in their sketches and only half of the subjects included wires in the third stage - sketches of a computer saving a file. The apparent decrease in reference to wires may have been escalated if the subjects who did not participate in this stage were those who had used wires in the previous stage. This is possibly due to a change in emphasis of the drawings from a 'what a computer is' to a 'what a computer does' perspective, as twenty-three of the subjects changed their sketches completely from the previous stage. This indicates the importance of questions asked in determining mental models that are produced. As the point of reference changes, so do models as different functions are considered.

TABLE 36.

THE FREQUENCIES WITH WHICH SUBJECTS IN THIS STUDY FELL INTO EACH DUAL MEMBERSHIP CATEGORY IN THE DRW1CLUS AND FILECLUS CLUSTER SOLUTIONS.

	H	I	J	K	L
M	1	6	4		
N		2	2		1
O	4	12	12	2	3
1 P		2	1		

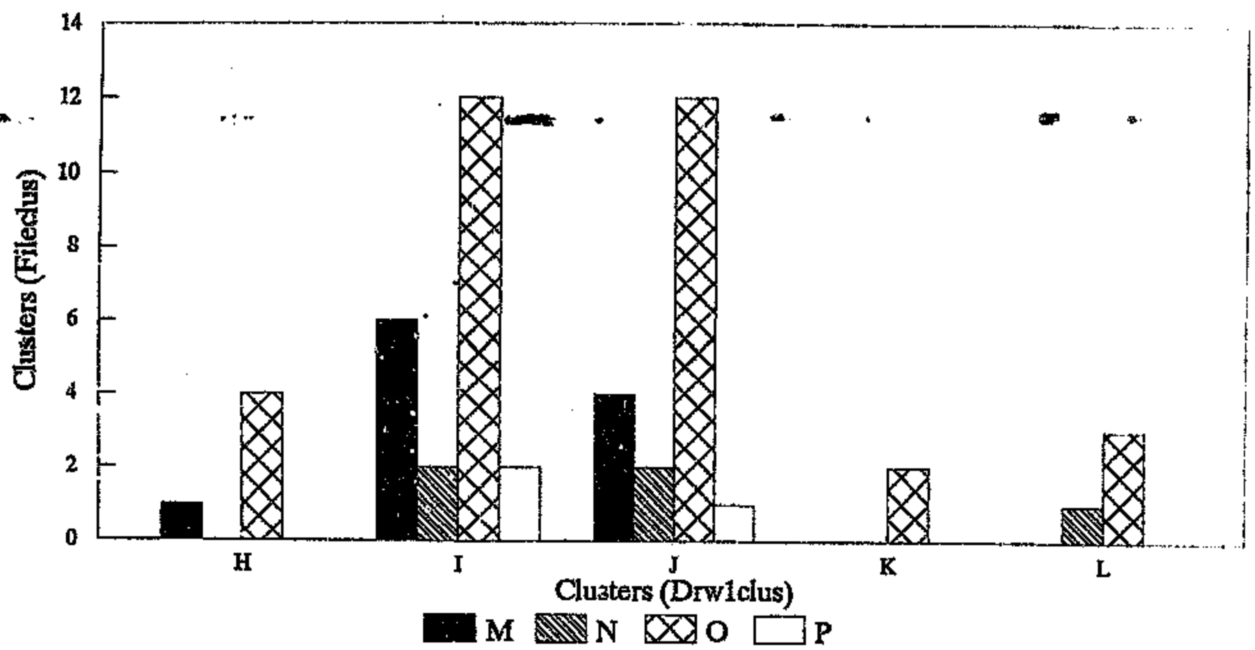


FIGURE 16.

DIAGRAMMATICAL PRESENTATION OF THE FREQUENCIES WITH WHICH SUBJECTS IN THIS STUDY FELL INTO EACH DUAL MEMBERSHIP CATEGORY IN THE DRW1CLUS AND FILECLUS CLUSTER SOLUTIONS.

This transition is explicit if one considers the dual membership in the DRW1CLUS and FILECLUS clusters shown in TABLE 36. More specifically, the functional perspectives in the DRW1CLUS solution were all members of Clusters H and J. The majority of the members from these clusters fell into Cluster O (the most mechanical/technical solution) in the FILECLUS solution. The subjects who previously sketched abstract diagrams of what the computer looks like inside (members of Cluster I) appear to have had deficient metaphors that could not be extended to the function of saving a file. The majority fell into Cluster O, showing that they did possess knowledge of more detail and technical aspects of the computer than they used in the first sketches. The second largest group of Cluster I's members chose new, unrelated metaphors (filing cabinet and record-player metaphors). Similarly, members of Clusters K and L who had used very specific, limited metaphors in the previous stage (lights and letters) also had to change their metaphors, and they tended to adopt the more mechanical technical view, thus having dual-membership in their usership cluster and Cluster O. These findings affirmed Denham's (1993) assertion that the perspective of what a computer 'is' compared to what it 'does' in the previous stage would impact on the extent to which the models change.

Fisher's exact test for DRW1CLUS * FILECLUS showed that there was no significant differences (prob = 0.981) between the categories. This shows that the clustering solutions for the two stages were not significantly associated. As organisational membership significantly influenced the cluster solutions in both of these stages, a likely explanation is that the metaphors used differed due to filing applications. For example, the option of a menu may have been used in one department within the company and a functional key in another.

As could be seen from the above discussion, the task at hand - the selected operating and application system(s) and the training used - impacted strongly on the mental models adopted to explain the dynamic computer processes. This is supported by the fact that the only variable which was significantly different between the clusters in both Cluster solutions, was organisational membership. The significance of any other background variables in the dual categories of DRW1CLUS and FILECLUS were not considered here as they were not notably significant within each cluster solution. Consideration of these variables may have confounded the discussion of the issue which was more pertinent, namely, the change of metaphor application when the task at hand changed.

Due to the common themes which emerged - irrespective of drawing level - in both the second and third stages' sketches, sketching can be seen as a valuable method of establishing mental models. Also, the lack of relation between the themes and the socio-cultural background variables implies that socio-cultural factors do not impact on mental models to the extent that knowledge, in terms of experience and expertise with the computer, do.

Although the extent of acculturation of the subjects in the sample could be used in defense of the past research, which advocates that culture impacts heavily on the way people model ideas and concepts, it is more likely that the more current researchers' (eg. Deregowski, 1984) views are correct. They maintain that human perceptual mechanisms are essentially the same throughout the species. Cultural influences shape the mechanisms by accentuating certain characteristics so that different skills result, but the overall message is still relayed effectively, despite the slight idiosyncrasies common to the group (none of which could be identified in this study). It is also interesting that where idiosyncrasies associated with background variables did exist, they impacted on the simpler tasks such as describing the inside of the computer. The more complex task (describing how a file is saved) was impacted on by training, rather than background. As such, when reduction of errors in complex tasks is considered, the training rather than background factors, is the variable which is pertinent. The positive practical implication of this finding is substantial. It shows that the variable which has a more profound impact (training) can be controlled, although culture, which impacts on less critical tasks which do not bear the risk of the possibility of incurring many grave errors, cannot (and probably need not) be managed.

CHAPTER 9 : CONCLUSIONS, LIMITATIONS AND IMPLICATIONS OF THE PRESENT RESEARCH

This study established similarities and differences between mental models, and their association with socio-cultural background variables. Sketches were used as the measuring instrument to ascertain their feasibility as a technique for assessing mental models. Due to the exploratory nature of this research, and its non-specificity (as there is no single variable or hypothesis which is under study), the quantity of relevant emerging information may at first appear to be perplexing. Despite this, various interesting conclusions emerged. They are summarised below.

Usership, in terms of knowledge and experience with computers, was strongly associated with organisational membership. This can be attributed to clerical level employees having certain levels of training pertinent to the use of the operating and application systems chosen by the organisation. Knowledge and experience are therefore influenced by the tasks at hand and the preference of the subjects' superior(s). Race also impacted on the usership categories. This may be due to the past Apartheid era which influenced employment and educational opportunities for different race groups.

The sample in this study was not homogenous as subjects differed from each other in terms of the combination of socio-cultural background variables. Cultural background variables (nationality, race group and home language) were more distinct between groups of subjects than were social class variables (education level, marital status and number of people living in the subject's residence). This could, however, be anticipated as socio-economic class is generally associated with vocational choice (Kohn, 1970). Despite this, the subjects were from easily differentiable backgrounds within the 'range' of levels of variables applicable to this vocational choice. The exploration of the impact of these factors on mental models was, therefore, possible.

This research had the advantage of analysing the mental models of the individual respondents, rather than those of pre-determined groups of subjects. This was achieved by not having any preconceived ideas of which independent variables should be used to assess the similarities and differences between the individual drawings. The clustering enabled an assessment of each sketch on a non-a-priori basis. By adopting this approach, similarities and differences in metaphors and analogies used to explain unencountered computational dynamics were identified in two tasks. Firstly, in terms of **'what a computer is'**,members of the different clusters used human; abstract technical; detailed techno-mechanical; illuminating light; and alphabet-based metaphors to explain **what exists inside the computer, 'under the lid'**. Secondly, when illustrating how a **file is saved**, necessitating a **'what a computer does'** perspective, mental models were expressed in terms of recordplayer/filing cabinet; 'save key'-based; techno-mechanical and menu-based metaphors.

In both stages which entailed sketching, it was found that subjects who used few (usually one) application and operating system(s) used explicit, detailed metaphors in their mental models. In contrast, those who used many application systems adopted broadly applicable, non-explicit models, showing a combination of features derived from the various systems. Halasz and Moran (1982) note that a metaphor only refers to part of an unknown system. They explain that if the metaphors differ vastly for different applications, the novice may not know which aspects of the models are applicable to other situations, and may thus resort to the use of a very broad model. The impact of the adopted operating and application systems on mental models was further confirmed in the third stage. Here subjects sketched what they encountered in their interaction with the computer while thinking about it - taking a 'when I do X, the computer must do Y' perspective. This evoked the need for the inclusion of keys or menus (which were used in the interaction process) in their mental models. The results regarding expertise concur with those of past researchers -as subjects' expertise increased, so did the accuracy and applicability of their models.

There was a significant shift of approximately half of the subjects to the use of new metaphors when conceptualisation of the inside of an inactive computer had to be extended to include the simple operations of saving a file. The two sets of metaphors differed substancially from each other. This implies that, as speculated by Denham (1993), subjects generally found their abstract views of what a computer 'is', to be inadequate when describing what it 'does'.

It is of interest to note that where idiosyncrasies associated with background variables did exist, they impacted on the simpler tasks such as describing the inside of the computer. It appears that for the development of mental models applicable to this task, the subjects used two sources. The first - culture (race) - seems to have been used to form the basis of the models. The second source, namely training received in the organisation, appears to have modified their existing mental models, thus impacting on them, but to a lesser degree than race did. In contrast, the more complex task (describing how a file is saved) was impacted on predominantly by training rather than background. As such, training, rather than background factors, is pertinent when considering areas of concern for error reduction in complex tasks. This use of training-engendered metaphors indicates that the industrial psychologist or trainer can influence usability of systems by optimising training offered. Fortunately, socio-cultural background, which cannot be changed by organisations, does not impact on critical tasks.

When analysing cluster solutions, the threat always exists of clustering occurring as an artifact of the scoring methods used, rather than of the actual attributes being measured. In the present research, themes and overall trends were easily identifiable. Also, similarities and differences between the clusters in each cluster solution were clearly distinguishable in terms of mental model metaphors. This implies that the former did not distort the findings. The ease with which these themes could be identified by the three raters implies the usefulness of sketches as a measuring instrument for the investigation of mental models. It is, however, suggested that a descriptive paragraph be included in the instrument, as in the present research, because these descriptions played a vital role in clarifying issues and elaborating on the reasoning behind the inclusion of the annotated features of the sketches.

The results of this study do concur with those of past research and emerging associations between background and mental models can be easily explained. However, as in all research, several **LIMITATIONS** exist in this study.

This study is limited in that its findings are only generalisable to South African, urban, clerical level workers. Also, as social class appears to impact on an individual's vocational choice (Kohn, 1970), the levels of the socio-economic variables were broadly distributed within a limited range of values applicable to a working-class (as opposed to middle or upper-class) sample. Further research is necessary to establish whether socio-economic variables beyond this limited range are associated with mental model formation.

A more critical limitation is the exploratory nature of this research which prevents the investigation of specific hypotheses. This is due to the vast number of variable levels which were considered. As such, more accurate data analysis was not possible - more specifically, the Fisher's exact test - the most appropriate statistical analysis technique for the present research - could not be conducted on several background variables due to the limited CPU time and memory available. Although the chi-square test overcomes these problems, it could not be implemented due to the heterogeneity of the sample (which decreased the frequency of subjects per cell). A further limitation of this study, which also prevented the use of chi-square procedures, was the use of volunteers who did not participate in the final stage (STAGE 3) of the research. Their reasons for not participating in this stage included absenteeism, leave, turnover and organisational deadlines. The positive **IMPLICATIONS** of this study attest to the need for further research aimed at establishing the extent to which these limitations may have distorted its findings.

Kerlinger (1986) notes three broader implications of most field studies that apply to this research. These are to discover significant variables in the field situation and relations among them and to lay the groundwork for later, more systematic testing of the hypotheses which can be determined from this study.

One possible hypothesis which emerged from this study is 'word usage and understanding impact on mental model formation and application'. As culture, race and language are closely related, the impact of race on mental models implies that language may also impact on the models. Limitations of this research, such as omission to establish 'extent of multi-lingualism' of subjects (a factor not pertinent in the present research), coupled with the inability of Fisher's exact test to establish the significance of the relationship between home language and mental model application, intimate that research in this area is viable. Another hypothesis which deserves further attention is one explored here, within a limited range, namely 'social class impacts on mental model formation'.

The findings of this research should benefit computer-users and writers of computer training packages in their understanding of the users' needs regarding programmes. The finding that training impacts on mental models regarding complex computational dynamics, which are conducive to users erring, has important implications.

The present study has served to advocate the generalisability of past findings relating to mental models of computer dynamics for complex tasks. Despite this, it disputes the past view of generalisability of findings regarding mental models of simple tasks (for example, describing the inside of a computer) as background variables such as race do impact on these models. Further, it reveals that generalisability of mental models cannot be assumed across tasks, as metaphors which are adopted are specific to the task to which they are applied. This study also has important implications for further research conducted on mental models, using sketches as the measuring instrument. It substantiates the validity and reliability of this technique.

These conclusions should broaden the spectrum of ideas which researchers, ergonomists and computer system and software designers can use. Due to the qualitative, EXPLORATORY nature of this research, emerging themes should be further investigated, while attempting to overcome the limitations of the present research. "The secret of success," said Disraeli, "is constancy to purpose." Similarly, Rogers humorously remarked "Even if you're on the right track, you'll get run over if you just sit there." (in Brown, 1988, p157).

APPENDIX 1

INDIVIDUAL DIFFERENCES WHICH AFFECT HUMAN-COMPUTER INTERACTIONS.

Stable Personality Characteristics :

Another factor is introversion-extroversion, which can further be divided into sociability and stress tolerance. Extroverted people have a higher stress tolerance, and are more able to accept a computer system with threatening error messages than an introvert is. Also related is the fear of failure, which can cause individuals to underachieve. In the classroom, competition amongst peers increases this problem. (Waern, 1989)

Cognitive and Learning Styles :

Barber (1988) notes that novices at computer systems perceive their own working memory capacity as very small. They have to process each new item separately. At first, even the logon procedure may exceed their working memory capacity. Experts differ from novices in terms of their declarative knowledge (knowledge of facts in the world) and their procedural knowledge (what they can do in the world). Declarative knowledge can be transformed into procedural knowledge through learning. (Barber, 1988)

The difference between ***procedural and declarative knowledge*** should be considered in the design of the computer and its instructions. Declarative knowledge is necessary for learning new concepts, but it is slow to use when action is required. Procedural knowledge can be applied quickly since the user need not attend to each single automated procedure. Systems should therefore facilitate the acquisition of procedural knowledge as far as pure system handling is concerned. Some declarative knowledge is important to allow the user to compare different methods for different situations, and to approach new tasks.(Barber, 1988)

Field (in)dependence refers to people's susceptibility to contextual clues. Field dependent people are generally affected by context. another area is 'visualizers' (preference for direct manipulation of icons) and 'verbalizers' (preference for verbal commands). The final difference which Waern (1989) discusses is a tendency towards reflective or impulsive behaviour. A reflective person will evaluate the problem more than an impulsive person. The former therefore may make fewer errors, but will take longer to solve simple problems. It is, however, preferable for complex tasks in which several alternatives must be considered before action can be taken.

Selective attention occurs when one attends to the immediate problem, but forgets the other relevant factors.(Norman, 1988) Barber (1988) explains that the user has two subtasks with which to contend. One is the task to be performed, and the second is handling the computer system. If both these tasks require attention, performance on one is likely to suffer - particularly if the person is stressed, unmotivated or anxious. In such a case, the computer may help the user with reminders or checks of details that may be easily forgotten. Norman (1988, p180) states that "the best computer programmes are the ones in which the computer itself 'disappears', in which you work directly on the problem without having to be aware of the computer." If people user help lines, the slight interruption may result in "cognitive disappearance" of the figure the user is working on. A good system should allow for a quick refreshing of the screen without help lines, or the user will lose track of his construction. Alternatively, the help lines could be displayed on one section of the screen, with the figure in another.

People learn by doing by means of either ***'systematic' or 'heuristic' problem-solving styles***. Systematic people use abstract logical models, whereas heuristic learners use past intuition. It is, however, important to note that tasks may differ : well-structured tasks are best handled by a systematic approach, whereas decision making tasks in an uncertain, ill-structured environment are best handled with a heuristic approach. She states that "people of a more intuitive or heuristic bent may be at a disadvantage in handling computer systems." (Waern, 1989, p116) Barber (1988) states that the first impression a novice has of the computer will determine both the goal he sets for himself and the efforts he will expend on his first attempt. This is related to 'metacognition' - the way one perceives ones cognitive capacity. It is not always effective since the feedback obtained from a situation is often inadequate. People who believe themselves to be good at problem solving will pursue a single approach to a problem, and will tackle the problem more systematically than people with lower estimations of their cognitive capacities.

APPENDIX 2

TABLES SHOWING THE COMPOSITION OF THE SAMPLE IN TERMS OF THE LEVELS WITHIN VARIOUS SOCIO-CULTURAL BACKGROUND VARIABLES.

ORGANISATION	ORG I	ORG II	ORG III

NATIONALITY

SOUTH AFRICAN	32	31	8
BRITISH	2	0	1
PORTUGUESE	2	0	0
SWAZI	2	0	0
ITALIAN	0	1	1

HOME LANGUAGE

ENGLISH	14	5	9
AFRIKAANS	4	21	1
BILINGUAL E/A	1	0	0
ZULU	6	0	0
SOTHO	4	2	0
BILINGUAL E/P	2	1	0
TSWANA	3	3	0
XHOSA	1	0	0
VENDA	1	0	0
PEDI	1	0	0
SWAZI	1	0	0

GENDER

FEMALE	34	27	9
MALE	3	5	1

EDUCATION

STD 8	6	6	2
STD 9	3	4	0
MATRIC	18	10	5
8 + DIPLOMA	3	3	0
10 + DIPLOMA	5	2	2
10 + DEGREE	3	7	1

APPENDIX 2 (Cont.)

ORGANISATION	ORG I	ORG II	ORG III
MARITAL			
MARRIED	25	11	6
SINGLE	6	18	2
DIVORCED	3	2	2
WIDOWED	2	1	0
SEPARATED	2	0	0
FAMNUM			
1	2	4	1
2	7	6	4
3	5	8	1
4	13	10	2
5	5	2	1
6	3	1	1
7	2	0	0
11	1	0	0

NATION	SOUTH AFRICAN	BRITISH	PORTUGUESE	SWAZI	ITALIAN
RACE					
WHITE	45	3	2	0	2
BLACK	20	0	0	2	0
INDIAN	5	0	0	0	0
COLOURED	1	0	0	0	0
LANGUAGE					
ENGLISH	24	3	0	0	1
AFRIKAANS	26	0	0	0	0
BILINGUAL	1	0	0	0	0
ZULU	1	0	0	1	0
SOTHO	6	0	0	0	0
BILINGUAL (E/P)	0	0	2	0	1
TSWANA	6	0	0	0	0
XHOSA	1	0	0	0	0
VENDA	1	0	0	0	0
PEDI	1	0	0	0	0
SWAZI	0	0	0	1	0

APPENDIX 2 (Cont.)

NATION	SOUTH AFRICAN	BRITISH	PORTUGUESE	SWAZI	ITALIAN

EDUCATION

STD 8	11	0	1	1	1
STD 9	7	0	0	0	0
MATRIC	28	3	1	1	0
8+DIPLOMA	6	0	0	0	0
10+DIPLOMA	9	0	0	0	0
10+DEGREE	10	0	0	0	1

FAMNUM

1	6	1	0	0	0
2	14	1	1	0	1
3	13	0	1	0	0
4	22	1	0	1	1
5	8	0	0	0	0
6	6	0	0	0	0
7	1	0	0	1	0
11	1	0	0	0	0

RACE	WHITE	BLACK	INDIAN	COLOURED

LANGUAGE

ENGLISH	22	1	5	0
AFRIKAANS	25	0	0	1
BILINGUAL E/A	1	0	0	0
ZULU	0	6	0	0
SOTHO	0	6	0	0
BILINGUAL E/P	3	0	0	0
TSWANA	0	6	0	0
XHOSA	0	1	0	0
VENDA	0	1	0	0
PEDI	0	1	0	0
SWAZI	0	1	0	[illegible]

GENDER

MALE	3	4	2	0
FEMALE	49	18	3	1

APPENDIX 2 (Cont.)

RACE	WHITE	BLACK	INDIAN	COLOURED
EDUCATION				
STD 8	11	2	0	1
STD 9	6	1	0	0
MATRIC	20	9	4	0
8 + DIPLOMA	4	1	1	0
10 + DIPLOMA	6	3	0	0
10 + DEGREE	5	6	0	0
MARITAL STATUS				
MARRIED	26	12	4	0
SINGLE	16	8	1	1
DIVORCED	6	1	0	0
WIDOW	3	0	0	0
SEPARATED	1	1	0	0
FAMNUM				
1	5	2	0	0
2	12	3	2	0
3	11	1	1	1
4	18	7	0	0
5	4	2	2	0
6	2	4	0	0
7	0	2	0	0
11	0	1	0	0

EDUCATION	STD 8	STD 9	MATRIC	8 + DIPLOMA	10 + DIPLOMA	10 + DEGREE
LANGUAGE						
ENGLISH	3	3	13	2	4	3
AFRIKAANS	6	4	10	2	2	2
BILINGUAL E/A	1	0	0	0	0	0
ZULU	0	0	4	0	2	0
SOTHO	0	0	3	1	1	1
BILINGUAL E/P	2	0	1	0	0	0
TSWANA	1	0	1	0	0	3
XHOSA	0	0	0	1	0	0
VENDA	0	0	0	0	0	1
PEDI	0	0	0	0	0	1
SWAZI	1	0	0	0	0	0

APPENDIX 2 (Cont.)

FAMNUM

EDUCATION	STD 8	STD 9	MATRIC	8 + DIPLOMA	10 + DIPLOMA	10 + DEGREE
1	1	0	1	2	2	1
2	5	2	7	0	0	3
3	3	0	7	1	1	2
4	3	5	11	1	4	1
5	0	0	4	1	1	2
6	1	0	2	0	1	2
7	1	0	0	1	0	0
11	0	0	1	0	0	0

LANGUAGE

FAMNUM	1	2	3	4	5	6	7	11
ENGLISH	3	10	4	7	3	1	0	0
AFRIKAANS	2	4	7	9	3	1	0	0
BILINGUAL E/A	0	0	0	1	0	0	0	0
ZULU	1	0	0	4	1	0	0	0
SOTHO	0	0	1	2	0	1	1	1
BILINGUAL E/P	0	1	1	1	0	0	0	0
TSWANA	1	1	0	1	1	1	0	0
XHOSA	0	0	1	0	0	0	0	0
VENDA	0	1	0	0	0	0	0	0
PEDI	0	0	0	0	0	1	0	0
SWAZI	0	0	0	0	0	0	1	0

APPENDIX 3

TABLE SHOWING FREQUENCY OF THE DIFFERENT SOCIO-CULTURAL BACKGROUND VARIABLE LEVELS OCCURRING IN EACH CLUSTER.

CLUSTER	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
NATION																
SA	13	11	5	3	5	23	11	12	25	25	4	5	10	5	28	5
BRITISH	0	0	1	0	0	2	0	0	0	3	0	0	0	0	3	0
PORTUGUESE	0	0	0	0	0	1	1	0	2	0	0	0	0	0	1	0
SWAZI	1	0	0	0	0	1	0	0	2	0	0	0	0	0	0	0
ITALIAN	1	0	1	0	0	0	0	0	2	0	0	0	1	0	1	0
MARITAL STATUS																
MARRIED	5	6	5	2	3	14	7	7	17	10	4	4	3	3	17	2
SINGLE	7	5	1	1	2	7	3	3	10	12	0	1	8	1	8	1
DIVORCED	2	0	1	0	0	2	2	0	3	4	0	0	0	1	5	0
WIDOW	1	0	0	0	0	2	0	2	1	0	0	0	0	0	1	0
SEPARATED	0	0	0	0	0	2	0	0	0	2	0	0	0	0	2	0
RACE																
WHITE	12	9	6	1	3	10	11	10	23	18	1	0	6	4	21	2
BLACK	3	2	0	1	2	13	1	2	4	9	2	5	4	1	8	0
INDIAN	0	0	1	1	0	3	0	0	3	1	1	0	1	0	3	1
COLOURED	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0
GENDER																
FEMALE	13	9	7	1	4	25	12	10	30	24	2	5	8	5	31	3
MALE	2	2	0	2	1	2	0	2	1	4	2	0	3	0	2	0
LANGUAGE																
ENGLISH	5	3	4	2	3	10	1	5	10	11	2	0	1	1	18	3
AFRIKAANS	7	6	1	0	0	3	9	5	14	7	0	0	5	3	6	0
BILINGUAL	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0
(E/A)	1	0	0	0	0	5	0	0	1	2	1	2	0	0	2	0
ZULU	1	1	0	0	1	2	1	0	2	3	0	1	1	1	2	0
SOTHO	0	0	1	0	0	1	1	0	3	0	0	0	1	0	1	0
BILINGUAL (E/P)	1	1	0	0	1	3	0	2	0	2	1	1	[illegible]	0	2	0
TSWANA	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0
XHOSA	0	0	0	0	0	1	0	0	0	0	0	1	0	[illegible]	1	0
VENDA	0	0	0	1	0	0	0	0	0	1	0	0	1	0	0	0
PEDI	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0
SWAZI																

APPENDIX 3 (Cont.)

CLUSTER	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
EDUCATION																
STD. 8	1	1	3	0	0	5	4	3	6	3	2	0	2	1	3	0
STD. 9	2	1	0	0	0	1	3	2	2	3	0	0	0	1	3	0
STD. 10	5	3	3	0	1	16	5	1	16	11	1	4	3	2	16	3
STD 8 + DIPLOMA	0	3	0	1	1	1	0	1	2	3	0	0	1	0	3	0
MATRIC + DIPLOMA	4	0	1	0	1	3	0	2	3	3	1	0	1	1	4	0
MATRIC + DEGREE	3	3	0	2	2	1	0	3	2	5	0	1	4	0	4	0
FAMNUM																
1	1	2	0	0	1	3	0	3	1	3	0	0	1	0	3	0
2	4	2	3	0	0	5	3	3	5	7	1	1	1	0	8	2
3	4	2	0	0	1	4	3	2	9	3	0	0	5	0	4	1
4	5	2	3	1	1	10	3	3	8	10	0	4	3	4	8	0
5	1	1	0	1	1	2	2	1	3	2	2	0	0	0	6	0
6	0	2	1	1	0	2	0	0	2	3	1	0	1	1	2	0
7	0	0	0	0	1	1	0	0	2	0	0	0	0	0	1	0
11	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0
ORG																
I	4	2	2	2	4	20	4	3	14	[illegible]	[illegible]	5	1	2	20	3
II	8	9	2	1	1	3	8	9	11	12	0	0	10	2	4	0
III	3	0	3	0	0	4	0	0	6	2	2	0	0	1	9	0

APPENDIX 4

QUESTIONNAIRE TO DETERMINE BACKGROUND AND POSITION OF THE SUBJECT ON THE TWO DIMENSIONAL CONCEPTUAL SPACE (novice-experienced, naive-expert):

DEMOGRAPHIC DATA.

Subject Name____________________ Race____________

Subject Number____________________ Gender____________

Age__________________________ Nationality__________

Home Language________________________________

Education____

Marital Status______________________________________

Living Conditions (number of people staying together)________________

USERSHIP DATA:

1] Over what time period (please specify if stated in years or months) have you used a computer ?
2] How frequently did you use the computer in the above mentioned time period?
3] Roughly how much time do you spend in each session of computer use?
4] Do you feel confident about using computers (1 = most conf; 10 = least)?
5] How many application systems and operating systems have you used ? What type were they ?
6] How flexible are the task goals in the tasks you experienced? (Were they fixed, routine tasks, or did they allow for flexible, creative input?)
7] Have you received any prior training in Computer Science? If yes, please state what the training was, and whether it was formal or informal.
8] Have you written any programmes on the computer ? If yes, in what language?
9] What computer training did you receive in this company and When?

(NOTE : the Questionnaires Shown in Appendix 5 and 6 were Produced both in English and in Afrikaans, and subjects could Answer in the Language of their Choice.)

APPENDIX 5

INSTRUCTIONS GIVEN TO SUBJECTS TO OBTAIN ANNOTATED SKETCHES, ACCOMPANIED BY A DESCRIPTIVE PARAGRAPH, DEPICTING THEIR MENTAL MODELS OF 'WHAT IS UNDER THE LID OF A COMPUTER' (STAGE 2).

NAME :

1] Do NOT discuss what you are sketching with anybody.

2] **SKETCH** : Draw the 'inside of a computer' (the part which is responsible for 'communicating' between the keyboard and the screen) in a way that 'a stranger would recognise it'. There is no 'right' or 'wrong' answer. Sketch what you believe 'exists under the lid' of the computer.

3] **ANNOTATE** : Label your sketches where possible.

4] **EXPLAIN** : At the back of this sheet of paper there is a block with lines. In this space, please write a paragraph explaining what you have sketched.

SKETCH AND ANNOTATE (label)

WRITE A PARAGRAPH EXPLAINING YOUR SKETCH :
Say what the different things that you have drawn do.

APPENDIX 6

INSTRUCTIONS GIVEN TO SUBJECTS TO OBTAIN ANNOTATED SKETCHES, ACCOMPANIED BY A DESCRIPTIVE PARAGRAPH, DEPICTING THEIR MENTAL MODELS OF 'WHAT HAPPENS INSIDE THE COMPUTER WHEN A FILE IS SAVED' (STAGE 3).

NAME :

1] Do NOT discuss what you are sketching with anybody.

2] **SKETCH** : Think back to your previous sketch of the 'inside of a computer' (the part which is responsible for 'communicating' between the keyboard and the screen). Based on that sketch, sketch what you think the inside of the computer would look if it was saving a file called XXX. Remember, there is no 'right' or 'wrong'

3] **ANNOTATE:** Label your sketch.

4] **EXPLAIN** : At the back of this sheet of paper there is a block with lines. In this space, please write a paragraph explaining what you have sketched.

SKETCH AND ANNOTATE (label)

WRITE A PARAGRAPH EXPLAINING YOUR SKETCH :

Say what the different things that you have drawn do.

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