THE ROLE OF HUMAN MEMORY IN THE EXTERNAL STORAGE AND RETRIEVAL OF INFORMATION: VOL 1.

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1. INTRODUCTION

Since the advent of the printing press the storage of paper-based information has reached unimaginable proportions. In contemporary society paper provides the information medium without which the worlds' various economies and cultures would collapse. However, over the last ten years we have reached another important milestone in the history of communication and the evolution of society. With the development of the microprocessor and the corresponding decrease in the cost of associated technology, the days of the world's paper-based information store and communications media could be numbered.

Micro-computers will potentially be available to everyone, especially in their working environments, and thus threaten to change the whole face of society. There is an increasing emphasis on skilled information handling tasks, and less on non-skilled, repetitive manual tasks. The potential market for computer technology is no longer limited to data processing centres, it is now encroaching upon offices, workshops, small businesses and workplaces in general.

The impact of micro-computer technology will probably be greatest, initially, in the office information handling environment. This point is aptly summarised by B.R. Gaines (1979) in the context of the commercial potential of improved man-computer interaction:

> "The size of the new markets required to give continuing scope for expansion .... forces us out of specialist applications into semi-professional and consumer markets. In the next decade it is the office and office-like environments that provide the scope for expansion, and in the following decade it will be the home and home-like environments (for later decades only the more far-out science fiction literature provides any reasonable projections!)."

However, the introduction of computer systems into these markets will not be without its problems. The source of these problems lies in the fact that the vast majority of systems require some kind of computer skills. Many of the potential markets are characterised by non-computer professional, or naive users. Again Gaines (1979) summarises the relevant points:

> "In these new environments we cannot expect to find specialist staff with computer knowledge or training - we cannot expect the person to adapt to the idiosyncracies of the computer - we cannot expect sympathy or tolerance for the artificial barriers to communication that have existed around our venerable computers. At the ever increasing rate at which we must install systems we do not have time for elaborate training programs, even to write elaborate user manuals - they will not be read. We need systems that are simple to use, self explanatory, natural, and so on - this is where interaction must turn into communication and where it will pay off."

Gaines has hit the nail on the head; people with no computer training need to interact with a computer in terms of concepts with which they are already familiar, and understand. To design computers that allow this kind of interaction there is a corresponding need for the computer systems designers to understand fully the needs of the potential users. Nicholls (1979) points out that this will involve a fundamental re-orientation in thinking, to see the user as the centre of a computer system instead of a mere peripheral.

To provide conceptual compatibility between naive users and computer systems, it is necessary to discover what peoples' conceptual needs are. The way that users conceptualise the functions, operations, and the 'logical' information flow of computers is dependent upon their own cognitive processes. The bases of the cognitive processes are the concepts, rules, and strategies stored in memory. It is this stored information which contributes to the formation of the cognitive model upon which each individual's interaction with a computer system is based. The appropriateness and compatibility of a particular cognitive model depends upon how people perceive the respective features of the system, which, in turn, depends upon the concepts already stored in memory. It logically follows that compatibility between system functions and operations and the concepts previously attained by an individual will result in the formation of an appropriate cognitive model. Thus, interaction with the system would be facilitated.

For the naive user, this would serve to reduce the difficulty encountered in understanding how to use a computer effectively. Therefore, an understanding of the way that information is stored and organised in human memory would contribute guidelines which might partially bridge the conceptual mismatch between the computer and the naive user.

It is the aim of the research discussed in this thesis to provide an understanding of some of the conceptual processes and cognitive models involved in information storage and retrieval, especially with respect to the long term storage of information in memory. The context is one of making recommendations which can contribute to the future development of computerised information storage and retrieval systems for use by the non-computer professional in the office environment.

Chapter 2 surveys the literature relevant to research subsequently described in the thesis. The discussion is aimed at a relatively non-specific level, this is so for four reasons: first, the context of the research incorporates a wide range of issues; second, the whole area of memory research, a major consideration in cognitive model formation, is too large to deal with in any great detail; third, at a specific level the context of much previous memory research is incompatible with the applied bias of the following experiments; fourth, specifically relevant material is dealt with in conjunction with each individual experiment, or series of experiments, subsequently described.

The survey begins with an introduction to the human concepts relating to the use of computer systems. Thereafter, the important cognitive processes are summarised, and emphasis is placed upon their relationship with the task environment. The context of the survey then becomes more specifically oriented in terms of information storage and retrieval; it is first discussed as a problem solving behaviour, then emphasis is placed upon the organisation and processes of memory which are relevant. Finally, a theoretical memory model is discussed in conjunction with a preliminary study of office filing systems in order to clarify thinking in the appropriate context.

Chapter 3 deals with a field study of office filing systems, in the form of a structured interview survey, in which the main objective was to examine the way that people organised information in their 'real world' office environments. Of major importance was the way in which they conceptualised their information and represented it in their memory. The study was aimed at the information storage behaviour of the individual rather than with collective storage. Moreover, it was hoped that the study would provide a fresh context within which to study the relevant literature, which had not been fruitful in providing ideas for subsequent research at that time. All of the subsequent experiments arose as a direct result of specific survey findings.

The results suggest that information organisation depends upon three separate considerations; task demands, user needs and conceptual characteristics of the users. The importance of spatial memory, in addition to information identity memory (categorical memory), is emphasised; this point forms the basis for the experimental work in chapters 4 to 6.

Chapter 4 deals with the first period of experimental work, an investigation into the characteristics of the cognitive model arising from the filing of information into a simulated conventional filing system; namely, an array of labelled pigeon holes, whose organisation could be varied. The aspects of memory found to be important are discussed. Special consideration is given to whether external information organisation is dependent upon internal memory structure, or whether internal memory structure is dependent upon external information organisation. Also, attention is paid to the relationship between the major cues, category identity and spatial location, used to conceptualise the external storage and retrieval of information.

Chapter 5 is a progression from chapter 4 in that it deals with the formation of memory models of filing using categorically and spatially organised lists of progressively increasing and more defined structure. The purpose of the experiments was to simulate the lists of files by which information is generally displayed by computers. The data are treated in much the same way as in the first experiment in chapter 4. In addition the results of the pigeon hole filing and the list filing are contrasted in order to discover any major difference.

Chapter 6 describes a short series of experiments which determine the reasons for the difference in memory models arising from pigeon hole and list filing.

In chapter 7 the emphasis changes, the experiment described was undertaken to answer a specific question arising from the office filing system survey; namely, were two levels of information classification most compatible with the inherent conceptual processes of most people. The use of a 2-level index was compared with that of a 4-level index. The resultant cognitive models were characterised using both time and error measures of index use, and the decision time and accuracy of a subsequent recognition task.

In chapter 8, the previous seven chapters are discussed within the context of a framework of user acceptability relevant to improved man-computer interaction. First the various measures of user acceptability are summarised, then the implications of the various experimental findings are examined in relation to them and also to any other relevant research. As a result a number of tentative guidelines are expounded. Finally, suggestions are made for future research: this includes the verification of guidelines and two specific additional areas which could be profitably exploited.

2. LITERATURE SURVEY

2.1 Users and their needs

As a prerequisite for the predicted growth in the use of computers, we must note the different needs of new users. Earlier users were committed to the use of computers either because of personal interest or job requirements. It is true that many users of future computer systems will be dedicated to a task. They will be highly trained, and the computer display terminal will be the focus of their work. By virtue of their backgrounds these users will have the appropriate conceptual knowledge to draw from, to enable them to interact efficiently and easily with their respective systems. Now, in addition, new classes of people are becoming potential users of computers. These 'discretionary' users, according to Bennett (1978), "will work with computers by choice, using the computer as a tool rather than the hub of their task. These people, for example, managers, physicians, lawyers, scientists, are professionals in their approach to work and in the kind of work that they do. But they are not computer professionals, and they must find computers appropriate to their needs and useful in practice. They must not be required to have the specialised knowledge familiar to computer professionals. For them the terminal through which they work 'is' the computer. To maintain their interest, and willingness to use the computer, they must be provided with information directly relevant to them in their work. They must have active control over their interaction with the terminal, and it must be in terms of concepts that they understand".

Bennett (1978) maintains that display terminals, as contrasted with typewriter terminals, are particularly useful in supporting discretionary users. High speed lines to displays permit the computer software to put two-dimensional information on the screen in familiar forms, such as tables of data, graphs, and formatted text. Two-dimensional information can have a powerful effect in guiding user action. Because the computer program has generated the presented information, the terminals can support, as inputs to the computer, user's selection of information elements, for example, commands and data items on the screen. This allows much closer coupling of user thinking and computer processing than is typically available with a typewriter terminal. The typewritten paper record of past interactions does provide a helpful context for the user but there is no convenient way for the user to 'point to' data on the paper.

It is much easier for users to 'recognise' information presented in a familiar format than it is to 'recall' the same information accurately from their memory (Kintsch, 1970). Thus, the capability of the display terminal to create a context for interaction meaningful to persons carrying out tasks can increase the usability of the computer in terms of efficient complimentation of cognitive processes.

In discussing the user role within a computer system, therefore, we clearly must take into account not only the physical attributes which affect the person's capability to interact with the equipment but also the cognitive attributes. Much work has already been done concerning physical interaction with computers, it is only comparatively recently that the emphasis has shifted towards cognitive interaction. Figure 2.1 contrasts in schematic form differences between physical and cognitive human factors (Bennett, 1979).

Physical human factors	Cognitive human factors
Auditory, visual stimulus	Recognise displayed information
Layout of control	Understand commands
Ease of keying	Construct results
Headache from glare	Mental strain from system use

Figure 2.1 - Comparison of human physical and cognitive factors (Bennett, 1979)

Probably the most important requirement, from a cognitive viewpoint, for effective user interaction with computers is that they must have an appropriate conceptual framework from which to work. Naive users will not have concepts gained by extensive computer training at their disposal. Therefore, it logically follows that interaction with a computer must be in terms of concepts that they already have available from their previous information handling experience. Furthermore, these concepts must be applicable to the new context of computer use. The only way that this can be achieved is by gaining a greater insight into human conceptual processes, and then applying this knowledge to future computer design.

2.2 The user conceptual framework

What are the important concepts relevant to user interaction with computer information systems? Siegfried Treu (1971) asserts that designers of interactive information search systems, in purposely planning for an effective searcher-system interface, must deliberately take into account that the human searcher has a sense of (or need for):

1) Spatial reference (or perspective)
2) Order (or file arrangement)
3) Completeness (or comprehensiveness)
4) Association (or connectedness)
5) Simplicity (or clarity)
6) Accessibility (or convenient access)
7) Responsiveness (or prompt reaction)
8) Control (or manageability)
9) Versatility (or variety in means and modes of access)
10) Compatibility (or harmony among means and modes of access)
11) Reliability (or confidence)
12) Support (or advice and assistance on demand)

A number of these assertions remain subject to empirical confirmation or rebuttal. Some of them relate to system capabilities which have already been realised; others point out areas requiring considerable improvements; still others may be missing. All of them, however, seem to be very interdependent and essential components for the conceptual framework presented to the searcher.

We can further refine Treu's conceptual framework by summarising certain important aspects of the cognitive interface between man and computer. The basis of this summary is the chapter concerning the cognitive interface in the Infotech State of the Art Report entitled 'Man/Computer Communication' (vol. 1) (Shackel, 1979).

The user conception of a computer would seem to depend on two broad sets of design aspects. The first can be defined as the software interface, which covers the dynamic interaction of the user with the computer software or program. Essentially, it includes the features of user communication with the computer. The second is concerned with the structure and presentation of computer-based information, which is of a more static nature. Nonetheless, this aspect is equally as important as and intimately connected with the software interface.

2.2.1 <u>Software interface</u>

A useful review of this area can be found in Stewart (1976). He proposes that there are two main requirements for a successful software interface: first, it should fit the function it serves in the design of the total system; secondly, the structure of the interface should be such that it can fulfil its functions, suiting the purpose of the system, the user job types, and the interaction modes.

To a great extent the function of the interface is dependent upon the nature and purpose of the system, e.g. stock control, and also the type of job the user is performing. A general purpose software interface seldom suits all users and consequently can be incompatible with their conceptual model of their job functions. The interface must therefore be geared to the specific needs of the various tasks which comprise the user's job. In addition, the function depends on the interaction mode, and the range of facilities available to the user.

Not only do users need a conceptual model of the functions of the computer within the context of their job, they also need a conceptual model of the dialogue structure; this is necessary for effective man-computer communication. There are three basic structural features: the language through which man and computer communicate; the procedures and operations through which the user interacts with the system; and the time base of the interaction.

i) Language.
Stewart (1976) lists several aspects of the language of communication which are important. These include such factors as the power of the language, the size of the vocabulary, the richness of expression and precision and the relationship between the man-computer language and natural language. One problem experienced by the naive user in understanding computer orientated languages is that they are often of necessity terse, coded and abbreviated. Human language, on the other hand, is highly redundant (in information theory terms) and missed items can often be inferred from the context of the communication. Lastly, there is the grammar of the language itself (for the internal organisation) which should be such that unambiguous communications can both be easily constructed and easily interpreted by the user.

ii) Operations and Procedures.
Secondly, there is the organisation of the language into operations and procedures. Operations include the various functional capabilities of the computer which interact with and act upon data and instructions input by the user. Procedures are specific combinations of operations needed to achieve some high level goal; for instance, logging on or inputting data.

iii) Time base.

The time base includes such factors as the delay of the system in responding to terminal enquiries, the frequency at which the data base or input is updated, the speed with which the system can be modified to suit new task needs and the susceptibility of the system to breakdowns and maintenance delays (Stewart, 1976).

The time base is an important factor in that the perception and conception of all other aspects of the cognitive interface, between man and computer, are dependent upon it. For example, if text is being edited, results must be apparent immediately so that the editor can keep track of what has been done. This is important because editing not only affects content but also format, and can change the whole appearance of the text.

2.2.2 <u>Structure and Presentation of computerised information</u>

It is important to organise data in some meaningful way, if people are to make any sense of it; a sentence displayed as a string of its constituent letters makes far less sense than when these letters are grouped into constituent words. Shackel puts this succinctly on page 134, volume 1 of the Infotech's "Man/Computer Communication" (Shackel, 1979):

> "Data are not information; information is not knowledge. In each case the transformation is made by processes of organisation".

Two levels of structuring the information at the interface will be reviewed; formatting and coding, and database structure/knowledge structure.

2.2.2.1 <u>Formatting the information</u>

The formatting of information can best be considered in the context of displays; the principles apply in general also for inputting the information. The way in which information is organised and presented may determine the way in which it is used and conclusions are drawn from it.

Again, it is the paper by Stewart (1976) which provides appropriate guidelines. He identifies seven features which contribute to good format design: these are logical sequencing, spaciousness, relevance, consistency, grouping, simplicity and partitioning.

i) Logical sequencing - the sequence in which the information is presented should be logical both in terms of the display itself and in terms of the user's task or other information sources being used; but primarily the sequence must be logical to the user.

ii) Spaciousness - clutter on a display greatly increases search time and increases the likelihood of missing or overlooking items, misreading items, and other errors.

iii) Relevance - the display of redundant and irrelevant information should be avoided; not only does it contribute to clutter, it can also mislead the user.

iv) Consistency - through the use of computers, users develop certain expectations with respect to procedures and operations, and the form and location of data. If the latter aspects of the system are consistent then it will be easier to use and interpret; an unfamiliar or new output, especially, can be more readily and accurately interpreted.

v) Grouping - the display can be improved by grouping together interrelated items. There is also evidence that grouped displays can be more rapidly and accurately searched.

vi) Simplicity - the overriding factor should be to present the appropriate quantity and level of information in the simplest way. For example, graphs are suitable for displaying information trends, tables are suitable for the accurate reading of data.

vii) Partitioning - an especially effective and high level form of formatting is partitioning. Independent of coding by character variations, the screen can be partitioned into separate areas, each being exclusively reserved for a specific aspect of the man-computer interaction.

2.2.2.2 Coding the information

The coding of information is especially useful to help discriminate among different classes of information simultaneously present on a display. Stewart (1976) discusses six main coding dimensions available; alphanumeric coding, colour coding, brightness coding, spatial coding, shape and size coding, and flashing.

i) Alphanumeric coding - the language may be abbreviated or coded so that the words used are shortened. Abbreviations, being part of the original word, can be quite meaningful. Numerical codes, though not particularly meaningful, can become associated in memory to certain items. In addition, a descriptor could be formed by joining an abbreviated word with a numerical code.

ii) Colour coding - colour coding can be particularly useful in terms of grouping data. Also, certain colours can be readily associated with particular messages, e.g. red for danger.

iii) Brightness coding - two or three levels of brightness can be easily distinguished on a VDU and selective brightening of parts of the screen clearly indicates critical or interesting items of information.

iv) Spatial coding - basically the same as formatting, allows particular classes or types of information or the relationships between items of information to be emphasised by their respective positions.

v) Shape and size - shaped symbols are useful as an addition to normal alphanumeric characters, particularly if they can be easily associated with the objects they represent. The size of the character can also be varied to indicate relative importance or different status (e.g. headings and text).

vi) Flashing - particularly urgent or important information can be distinguished from other parts of a VDU display if the appropriate lines or characters are made to flash (typically at 2-4 Hz).

2.2.2.3 Database structure

The previous sections on formatting and coding deal with the considerations and principles which contribute to enhancing the conceptualisation of displayed information. However, users also develop a conceptual model of the database as a whole by virtue of storing and retrieving information. The fundamental problem is how to organise the co-ordinated storage of and access to the data so as to enable subsequent retrieval to be both efficient and meaningful. In other words, how do we organise a database so that the interaction with it can be in terms of concepts which are meaningful to the user? Although there have been few fundamental studies on this subject, there is some relevant work available.

Durding et al (1977) reached three tentative conclusions:

First, the conceptual structure of the database should conform to the semantic relationships between the elements.

Second, the language used to interrogate the database should allow for the direct expression of the different types of relationships.

Finally, having the user fill in some physical form or skeleton which is consistent with the general type of organisation found in the data may have an advantage over free-form entry.

A major second question is whether one, or a limited number of types of system can satisfactorily and economically meet user requirements. Each specific user group, sharing a common type of job, are likely to have similar conceptual models of that job and the nature of the information used. It therefore seems logical that information should be organised in a manner compatible to these models. This would require many user-specific systems, rather than a few general and flexible systems. This is upheld by work done by Eason et al (1974).

Both of the latter two points lead to a final question with regard to database conceptualisation. Is the solution to design more flexible systems? For each particular type of user with his particular needs, the flexibility to do many other things than necessary may only cause confusion. Shackel (p.143, Infotech State of the Art Report, Vol. 1; Shackel, 1979) suggests a possible solution:

> "With regard to flexibility, we would expect the essential question to be whether the human user has to cope with and ignore various flexible features of the system that are not relevant to his particular task, which is likely to be less satisfactory and impede his performance; or whether the system is designed to cope with and respond to one of the natural forms of human flexibility, which would be expected to provide a much better man-machine communication".

One obvious solution is natural language systems. However, they encompass problems of ambiguity and users assuming too much "intelligence" of the machine.

2.2.2.4 Knowledge structure

The discussion of database structure indicates that present solutions are by no means generally successful. More promising is a user-specific approach which acknowledges the existence of well developed knowledge structures, evolved by human professionals by working in various fields. In essence, it seeks to implement that pre-developed knowledge structure in a computer system framework. For example, van Melle (1978) describes the MYCIN programme to assist doctors in the diagnosis and treatment of bacterial infections; the programme implements existing medical knowledge and also contains an extension system to justify its advice or educate users.

2.2.3 Summary of the user conceptual framework

To summarise: there are many different types of concepts that users must attain for efficient man-computer interaction. The more compatible these concepts are with user's cognitive processes, the more easily they will be attained and the easier the system will be to use. The general types of concepts should not be considered mutually exclusive, they are as follows:

i) Verbal concepts: this section includes the language of interaction and can be further divided into semantic concepts (meaning), such as natural language, and the more abstract concepts, such as alphanumeric descriptions and other codes.

ii) Spatial concepts: there are both dynamic and static spatial characteristics of systems; dynamic include, for example, some conception of the "spatiality" of information flow within the system, static concepts refer to the spatial characteristics of displayed information. Both aspects are somewhat interdependent.

iii) Temporal concepts: it is important that users have an accurate conception of the sequence of the interaction so that the correct actions can be taken at the appropriate times.

iv) Task specific concepts: the user must have a conceptual model not only of his job, but also the projection of that job structure on to the organisation of the computer system.

v) Abstract functional concepts: included here are all the functions that a computer has available for manipulating data; that is, input functions, data transformation functions, and output functions. The previous types of concepts all contribute to this to an extent; e.g. sequential knowledge is required when combining functions.

Although it is important to have some knowledge of how users conceptualise the functions and operations of a computer, it is not all we need to know. We also need to know, in general terms, how these concepts interact with the users' mental processes, and how these mental processes interact with the system environment; this will allow us to be judicious in terms of which concepts to concentrate on. Without this knowledge it is possible that, in trying to fulfil all the previous conceptual conditions, we may end up with a system which is too unwieldy to use.

The following section deals with the formation and storage of concepts, and the mechanisms which interpret them, in the human component of a systems environment.

2.3 The human as a system component

Human concepts are formed by the cognitive processes, stored in memory and are manipulated in terms of certain objectives in a particular task context. It is evident, therefore, that memory plays an important role in providing information to achieve a prescribed goal; for instance, undertaking a task on a computer. Shackel (1979) reinforces this view:

"One of many important issues about human performance in relation to man-computer interaction is memory. How does it function and what are the necessary cues in relation to the longer term storage and retrieval of reference material? What is meant here is not the esoteric psychological research on memory nor the specialised computer programming work on filing structures nor the librarian/information specialist's approach, although probably some proportion of their understanding may help towards the answer. I mean the basic fact that if you go into the offices of many people (like mine), you will find various piles of papers, reports and so on; but it is a constructive clutter, a creative chaos (at least I think so). Ask the user of the office for something borrowed from you three months ago, and he will say, "oh yes, it's that yellow paper with the peculiar arrow symbol on the top, isn't it?" and he will find it in one of his piles of papers within a few seconds. Now computer files at present are not structured and represented to the user at all like this. The stored papers, letters, memoranda and reports all reappear on the screen in a uniform white-on-black or the equivalent, and will certainly require a longer time to search through. What we really do not know is the extent of the loss and consequential cost, and how to compensate for it. Perhaps humans can learn to compensate for the shape and colour cues which are lost by means of other types of coding which are easier and cheaper to display; but so far there has been little or no research on this global problem".

It is evident that there is more to memory than a collection of abstract identity concepts. All manner of cues can be and are used, but many are unavailable when interacting with computers.

Plainly, however, memory cannot function independently of the other cognitive processes. There must be mechanisms for coding incoming stimulus material into meaningful informational 'chunks', for storing this information in and retrieving it from memory, and for generating and co-ordinating action sequences. These processes, in turn, must communicate with the environment which provides stimulus information and is consequently changed by resultant actions. To gain a better understanding of the relationship between the various cognitive processes and their relationship with the environment, we will first consider a rather elegant model depicting human information processing in general terms. Secondly, to put this model in context we will summarise a generalised task sequence. This serves to highlight the dynamic interaction of the cognitive processes with the systems environment when actively performing a task. The intention is that these reviews will serve as a general base within which subsequent material of a more specific nature can be assessed. Both are based upon a paper by Rasmussen (1980) which gives an excellent review of the human as a systems component.

2.3.1 A model of human information processing in a systems context (After Rasmussen, 1980)

"A human operator receives information on the operational state of a system, transforms it and as a result performs some physical actions upon the system. An operator is basically an extremely adaptive information data processor. When human performance in a uniform and well defined task condition is modelled, for example in manual control, the limiting properties of his/her inner mechanisms can be properly identified and described in terms of referring to external task concepts. If however, the model is to be useful for work situations where tasks vary widely and where different types of task may interfere and compete for the operator's resources, the limiting properties of operators must be identified and described in terms referring to internal human functions or mechanisms at a level which is reasonably task independent. Even though such models may be rather qualitative and ambiguous, they can serve as efficient guides to the design of work situations in which the operator can adapt efficiently, and the adaptability of the operator will often, though not always, serve to compensate for inaccuracies of the model. In the present context some features of the human data processor which have been found to be important from the analysis of the behaviour of control room operators can be seen in figure 2.2."

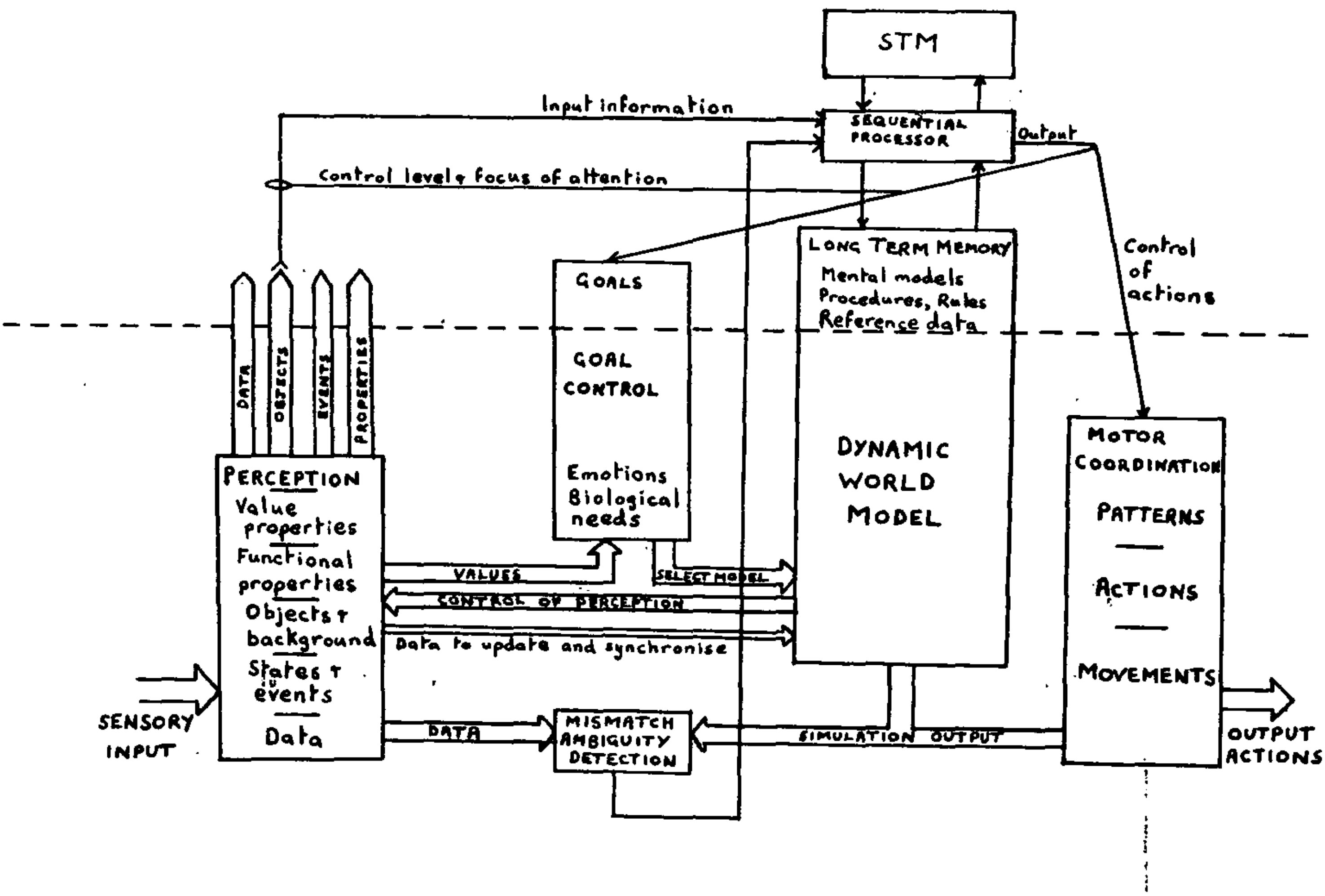


Figure 2.2: Model of Human Information Processing (Rasmussen, 1980)

The model illustrated in figure 2.2 is at a sufficiently general level to describe interaction with most data handling systems. The broad requirements of such a model are summarised by Rasmussen, thus:

> "First of all, since manual actions are almost always the output of human data processing, bodily skills are important elements of the human function. To be useful in the present context, a model of the human data processor must represent sensorimotor functions as well as higher level cognitive processes. Secondly, a model must consider the observations stressed in Miller's (1956) classic paper, where he points out that an individual's data processing capacity in certain situations is very low, even though one is able to recognise faces immediately and to drive a car in crowded traffic. Such behaviour can be accounted for by considering human data processing as a co-operation between a high capacity, parallel processing system, which functions subconsciously, and a sequential conscious processor of limited capacity. The subconscious processor takes care of routine well practiced tasks, and only in unfamiliar environments and tasks is there need for higher level control of the processing by the versatile, but slow sequential processor".

The previous processes are most readily apparent in the learning of complex tasks; in the initial stages an individual cannot cope with all the various elements of the task at once. In later stages when the tasks have been well learnt they become "second nature"; less conscious attention is paid to them and monitoring takes place at a more subconscious level. In relation to the model shown in figure 2.2, we will first discuss the subconscious processor and then the conscious processor.

i) The subconscious processor (Rasmussen, 1980):
There are several functions of the subconscious processing system which are important in the present context; a dynamic world model, some type of mismatch detection, a mechanism for perceiving the external environment, a monitor of the approach to set goals or objectives, and some form of motor co-ordination.

According to Rasmussen: "The possession of an efficient internal dynamic model of the world must be assumed if several features of human behaviour are to be accounted for. In familiar situations, complex and precise sequences of actions can be released by simple cues and performed at a pace too fast for simple sensory feedback control. Furthermore, human attention is very selective. An operator does not continuously scan the environment in order to obtain information; attention is selective and is focussed to where the important action is taking place. In highly trained situations it can be extremely difficult to predict the information which is used to synchronise the internal model. Often it can be secondary sources, utilising auditory feedback, such as relay clicks, or visual feedback, such as flashing cursor on a screen; anticipation is a major feature of skilled performance".

The internal, dynamic world model is the basis of how we conceptualise the world. If this model is not well developed, as with the naive computer user for instance, interaction with the system breaks down. To overcome this we either have to train individuals or design a system which matches the dynamic concepts that they do have available.

Rasmussen continues: "What are the elements of the internal, dynamic model? The model is apparently formed by extracting and storing dynamic patterns from the input information, therefore in some sense it stores a time-space representation of the behaviour of the environment. The precision of fast movements and the efficient transfer between similar environments almost suggests an internal world structure similar to an analogue model with generic types of objects and object behaviour. These 'Objects' refer to time-space data patterns representing physical objects, as well as artefacts such as signs and symbols on paper and displays."

An analogue model would make sense in light of the fact that people would transfer certain expectations from one system to a similar one, a situation which frequently occurs in practice; for example using two forms of the "BASIC" programming language.

Further: "Closely connected to the internal world model is a mis-match detection system which alerts conscious attention and control if the input information deviates from the predictions of the internal model. This occurs if/when the internal model loses synchronisation or is not properly updated due to unfamiliar or unexpected behaviour of the environment.

"Because of the great variety of stimulus information available in the environment, the human data processor must structure the environment into manageable higher level elements. Thus, the perceptive system aggregates data sources into familiar objects separated from the background and assigns to these objects a conceptual identity, and functional and value properties relevant to the particular situation. The level of activation of objects and the respective properties depends on the context of the situation and the immediate goal. Therefore, observed selectivity must be based on an internal model, otherwise one would need to be perpetually scanning and sorting information from the environment. This leads us to the important conclusion that the human is not an unbiased, neutral observer. Instead, information selection proceeds by asking those questions of the environment which are needed to update the internal model and verify its predictions. The necessary feature extraction in the perceptive system appears to rely upon parallel processing in a high capacity network preconditioned by the dynamic world model. Its efficiency depends upon the simultaneous presence of items of information which are correlated with, and can be structured in terms of, familiar time-space patterns. Overload of the input system is not directly related to the amount of information; but rather to masking effects from irrelevant information. Therefore, irrelevant information should be avoided.

"In a given task environment proper initiation and activation of the relevant dynamic world model depends upon the immediate goal and intention. In real-life work situations, a large degree of freedom is left to the human even though the general goal is stated unambiguously. This means that the subjective performance criteria and emotional preferences are important factors which, depending upon value properties assigned to the situation, will control initiation and activation of the internal world model."

ii) The conscious processor (Rasmussen, 1980):

"The high capacity of the subconscious sensorimotor functions protects the low capacity of the higher level conscious cognitive functions from overload in familiar routine tasks. Conscious attention may be considered as a single channel function which has to be switched between different items, objects, or tasks. Therefore, the conscious data processor may be thought of as a sequential processor which normally runs different tasks on a time sharing basis. The limiting properties of the conscious data processor are related to the capacity of its short-term buffer memory, which is generally accepted to be seven plus or minus two items of information (Miller, 1956). The effectiveness of the conscious processor, in spite of these limitations, is due both to its ability to operate on efficient information codes at high levels of abstraction and to its large repertoire of data processing models and strategies. In other words, a large amount of related data can be represented by just a few codes by virtue of models or strategies which direct attention to the various relationships.

"The role of the conscious processor varies widely. It can be used for passive monitoring of the performance of the subconscious processor in routine tasks. When a mismatch between the dynamic world model and the perceived situation is detected, the conscious processor intervenes. It first categorises the input data set and adds verbal labels to the situations; thereby altering the 'state' of the dynamic world model to suit the new conditions. It can also perform problem solving in unique situations by evaluating alternatives and by making decisions and formulating plans based on predictions relating to system procedures, operations and constraints".

In order to fully understand the model of the human as an information processor, it is necessary to understand how it operates in relation to the task environment.

2.3.2 Structure of task sequences

The human operator usually interacts with a specific task environment by undertaking a specific task. However, our context is one of providing guidelines for computer information systems in general. Therefore reference can only be made to a generalised description of typical task sequences.

From the analysis of operator's verbal protocols (Rasmussen, 1980): "it seems that the efficiency of skilled performance results from the ability to compose the process needed for a specific task as a sequence of familiar subroutines that are useful in different contexts. This implies the existence of links in the sequence, standard key points, or 'states of knowledge', which are characteristic of a specific skill. The data process stops at such links, the mode of processing and frequently the level of abstraction changes; to study and identify the processes, the activity must be structured according to such key points". In familiar situations, the subroutines depend upon subconscious or non-verbal processes. In unfamiliar task situations operators have to improvise and generate new subroutines. Here data processing involves conscious verbal processes. The verbal 'statements' of the task sequence reflect 'states of knowledge' in different categories representing plain observations, properties of the environment, goal, plans, etc.; i.e. knowledge at different levels of abstraction and associated with different roles in task strategies. It follows that the type of data process needed to derive one state of knowledge from the preceding one depends upon the categories of these states.

It is apparent that: "In a situation where the operator uses rational data processes based on knowledge of the operational sequence needed to attain a particular objective, the different states of knowledge follow each other in apparently logical order", (Rasmussen, 1980).

So far we have considered the human information processor in general terms in relation to a general systems environment. However, the context of the research described in subsequent chapters is specifically directed to the investigation of the role of memory in information storage and retrieval. Therefore, it logically follows that we should now outline the relevant specific characteristics of human memory. But first it would be sensible to summarise what is meant by information storage and retrieval, and try formally to characterise the behaviour associated with it.

2.4 The role of memory in information storage and retrieval

In today's society enormous quantities of information are generated, circulated and stored. Information is externally stored so that it can be used at a later date, if necessary, for purposes ranging from supplying details specific to certain enquiries, to forming the basis for generation of new information. This external storage of information is necessary in order to supplement our internal memory for the contextual details contained in the information; human memory alone cannot possibly store all the details necessary to deal with all future demands on it. However, enough information must be stored in memory for a person to be sensitive to the organisation of the externally stored information, otherwise access of particular items would be impossible.

Most work has been done in conjunction with computer database and library information storage and retrieval, and so this forms the basis of our knowledge of how people utilise an organised store of information. In line with the context of this thesis, however, more emphasis will be placed upon computer-aided information storage and retrieval.

2.4.1 Summary of the information retrieval task

Perhaps the best way of thinking about information retrieval is to: ".... consider retrieval systems as communication systems. Unlike television, which is one-to-many, or telephone, which is one-to-one, retrieval systems are few-to-few. The contributor to a computer information system knows that he/she is addressing some set of people, but does not know who they are. The user suspects that in a gigantic mass of irrelevant information there are a few that meet his/her interests. Both the contributor and user must share some coding scheme that allows the user to find the contributor's record", (Martin, 1980).

There are many forms that the coding schemes can take, ranging from relatively unique identifiers, to predefined categories, to naturally occurring terms.

In addition, records may pass from contribution to retrieval unchanged or may go through substantial conversion. A possible ranking of retrieval tasks, according to complexity is shown in Figure 2.3 (Martin, 1980).

	TASK	CODING	MESSAGE	PROCESS
TABLE LOOKUP	What is the telephone no. of the Golden Bull restaurant?	The name Golden Bull serves as a relatively unique identifier	A single record(name, address, number) is required	The record retrieved is the record contributed
DOCUMENT RETRIEVAL	What reports deal with higher education in Australia?	Descriptors like Australia & Universities narrow the description	A number of records(title, author, book location) are desired	The record retrieved is the record contributed
DECISION SUPPORT	What % of students have grade point averages above 3.0?	The category grade point average is used to order student records	An answer is constructed from information in the record	Information from the database is retrieved
QUESTION-ANSWERING	What route do I take from my hotel to the restaurant?	Knowledge about the situation is used to determine which hotel, which restaurant, and which means of travel are implied	An answer is constructed from a map of the city	Many different types of information from multiple databases are combined

Figure 2.3: Retrieval tasks ranked by complexity (Martin, 1980)

Selected paragraphs from Martin's paper serve to highlight the levels of complexity in the context of information storage and retrieval.

"Even in the most limited domains the quantities of information necessary for answering questions are vast. It is hard to anticipate the variety of ways in which things can be said or implied. The full power of context, goals and assumptions has to be brought to bear upon the task of deducing what is being asked and why. The more well-structured the topic, the easier it is for meaningful retrieval to take place.

"The query in figure 2.3 about student grades is an example of a well-structured task. The categories of information (grades students, classes) are known beforehand so data can be gathered and organised in advance. These systems have been called decision support systems, management information systems, and data base management systems. Users are typically expected to express categories, values and relationships in formal notation rather than in natural language. Items entered into the database are also specified using category names and values. As items are entered they can be split up and merged with other items so that storage responds to query patterns rather than contribution patterns. It is important that the structure inherent in the system matches the structure inherent in the minds of the users (Stabell, 1975).

"Document retrieval systems require less shared understanding. There are few categories, and relationships are limited to co-occurrence and sometimes word proximity. Users specify sets of words or phrases that characterise concepts. Concepts can be combined or intersected. The query in figure 2.3 about higher education illustrates both combining (universities, colleges, higher education) and intersecting (in Australia). Yet words and phrases often have multiple meanings, the resultant ambiguity can lead to lack of communication.

"The most simple type of retrieval is table lookup. Since identifiers are relatively unique and single items require no specification of relationships, thus the potential for misunderstanding is minimised. It is likely that most data bases offered for public use will be of this form."

Storage and retrieval of information in computer databases can be mediated in a number of ways; via natural language descriptions, via coded descriptions, via structured indexes, or via menu selection. The closest real world analogue to database storage and retrieval is obtaining information from libraries. Here again, information is stored according to a formal structure; based on the Dewey Decimal System (Vickery, 1970). Access can be via several descriptors, author, subject, and classification number, and many of the characteristics outlined in figure 2.3 apply; much reliance is placed upon a formal cross-classified index incorporating these features.

There is one major difference between computer database access and library information access. Whereas in computers it is necessary to enter an appropriate set of descriptors to access required information, in the library situation the descriptors have to be converted into a classification number, which is in turn converted into a spatial location containing constituent items in alphabetical order. Therefore, in the library, users develop a spatial model of information in addition to one based on the relationships between information descriptors. This means that if the location of the desired section of information can be remembered, a user can go straight to it, without index mediation, and scan for the required book.

However, both data base and library organisation is complex, due to the amount and nature of the information they contain. Rather than being easily accessible to the occasional untrained user, storage and retrieval often has to be mediated by a fully-trained information specialist. When computer retrieval systems were being developed, it was assumed that the end users would search for themselves. This has not happened in practice. Over seventy-five per cent of all searches carried out as of 1975, were carried out by information specialists (Wanger et al., 1976). Also, we know from our own experience that in libraries it is often necessary to gain the assistance of a professional librarian to exploit the available information to the full.

We can learn much from data base and library information organisation which might be useful to the development of computerised office filing systems. However, the office situation deals with smaller amounts of unpredictable, less clearly defined information. Also it is much more likely that the user will want to store and access information for themselves and not want to use a trained information specialist. Consequently, emphasis should be placed on investigating how information is stored and retrieved in the non-computer office situation, so that we can approach the problem in the correct context (see survey of office filing systems in chapter 3). But first we must consider the specific aspects of user information storage and retrieval behaviour and the subsequent storage and organisation of the relevant concepts in memory.

In essence we can view the storage and retrieval of information as a special kind of problem solving behaviour. Typically, in a job we must achieve some goal, but there is a state of uncertainty as to how to go about it. It is often necessary to retrieve a document from the filing system to assist us; the problem is, which information is relevant and where is it? We must interpret our mental model of the filing system in order to answer these questions; this mental model can be considered as part of the dynamic world model (figure 2.2) residing in long-term memory.

2.4.2 Mental Models in Problem Solving

Until recently, no precise definition has been forthcoming concerning problems of internal mental models. Previously psychologists investigated images, anticipations, and pictures of the environment, to name a few. It is now generally recognised that people form representations which are not a mere copy, but a transformation of reality. Miller, Galanter and Pribram (1960) were amongst the first to attempt to unify this area with their conception of image and plan. By image we understand an organised concept held by people of themselves and the world. A plan is a hierarchical process in the person which may determine the order in which an operational sequence is to be carried out.

According to these authors behaviour could be divided into TOTE (Test Operate Test Exit) units whereby each action is compared to some preconceived goal, or sub-goal. If the objective is met then action progresses to the next stage. If not, other actions are undertaken until a satisfactory outcome is achieved. Consequently, very complex plans can ensue from the individual units of behaviour.

It is evident, however, that this must be a two-way process. A general plan of goals and sub-goals to be achieved must be present. Also there must be some level of stored experience whereby it can be predicted which actions may, or may not, contribute to the achievement of the desired goal. On the other hand, any discrepancy which occurs in this process should add to the general experience which guides the initial action.

Newell (Newell and Simon, 1972) in his conception of information processing by man, deals in detail with inner representation of the task being solved. He calls the space where problem solving takes place the problem space. He captures not only the present situation, but also the possibility of its being changed and transformed during solving process. The subject's problem space need not conform to the 'objective' description of the environment delimited by the experimenter. However, the overall environmental structure of the task determines the possible structures of the problem space. Newell distiguishes two types of structure: set and search representation. The structure of the problem space determines possible programmes that may be used in the solution.

The essence of representation has so far been little studied and Newell also avoids to devote attention to it. And yet, in some problems the whole difficulty resides in finding the right representation (the solution itself is then relatively simple). Newell calls the initial process in the general organisation of the solution process an input translation, in whibh an inner representation of the external environment is being formed in the problem solver and simultaneously the problem space is being chosen.

The problem solution then proceeds within the framework of the inner representation thus created. The fundamental structures enabling representation are list structures (comprising sets of objects) and associations (relations among objects). In his studies, Newell made uee of various games, anagrams, and chess; however, he did not verify this theory experimentally.

A detailed survey of the mental representation process has been dealt with by Hoc (1972). He presumes the simultaneous presence in man of several systems of representation and processing that are hierarchically organised according to their level of generalisation. The relevant activity consists of coding the representations and processings to be expressed in another system. Under the effect of professional training, new systems of representation and processing are formed in man and become integrated into the existing hierarchy of systems. The author experimented with programmers (analysts).

According to Kozielecki (1975) a subjective task representation depends on the task structure, but is formed by an active organising of incoming information. It is a dynamic picture and the process of task solving depends considerably on the type of representation (i.e. geometrical, algebraic). In certain tasks one type of representation is more suitable while others fail to arrive at the correct solution. The difference in representation is affected by the type of task, instruction in the experiment and also the standard of general knowledge. In his experiments, the author focused his attention particularly on diagnostic tasks, experimental games and the like.

In an information storage and retrieval situation the previous literature would tend to delineate three stages in developing a cognitive model conducive to the problem solving involved in storing and retrieving information. These are as follows:

a) Information translation - an input stage where the input is translated in terms of important coding attributes for internal representation.
b) Information representation - this stage involves the formation of a cognitive model of information. It is important to realise that this may not be purely developed according to internal organisation criteria, unless the external representation is a true reflection of internal organisation. The relationship between internal and external organisation is an important one.
c) Storage and retrieval plan - this incorporates some strategy, based on internal representation of information, to either store or access information externally. The success of this will depend upon the compatability between internal organisation and external organisation.

The actions of storing and retrieving items from an information system are wholly dependent on the translation of the internal representation of information into some action via a relevant strategy. A comment on the work of Newell (Newell and Simon, 1972), that not much attention has been paid to the actual representation of information, exposes a weakness in the understanding of the development of the cognitive model of a specific environment. We will now consider information concerning the organisation of long-term memory in order to try to remedy this situation.

2.5 Organisation of Long term Memory (LTM)

All stimulus information reeeived by an individual is organised, at progressive levels, in order to make 'sense' of it. At low levels stimulus information is organised in terms of physical attributes or spatial orientation. At higher levels the information is organised in terms of more abstract concepts, coding meaning (Herriot, 1974).

The everyday information of the world we live in is organised in terms of various conceptual 'labels', and also in terms of the conceptual 'labels' of other information items, both by virtue of meaning (semantics) and often by its relative position in time and space. Information handled every day (except for perhaps previously learnt factual knowledge) is rarely independent of location and time.

Consequently, without the knowledge that we had received a particular item at some time, and without a 'cognitive map' of where we put it in relation to other items, we could not find it. Conversely, without a concept of identity we would not 'know' what we were looking for. Any theory of cognition in relation to information handling must give due consideration to these points.

Before considering the organisation of long-term memory, there are a number of things to note. One point is that current models are quite complex, although we will only be dealing with their general features here. This is dictated by the complexities of long-term memory itself, some of which have already been noted: 1) The uses of long-term memory information include problem solving, logical deduction, question answering, recall of facts and many others. 2) The amount of information in long-term memory is astounding. 3) Its organisation is orderly, not haphazard. In attempting to account for the many uses to which long-term memory information is put, the mass of information, and its organisation, no model of long-term memory, however complete, is at present totally adequate. However, models are constantly undergoing modification to enable them to account for more data.

A second point is one that may seem to compound the complexities of long-term memory. It is in fact useful to talk not only about one long-term memory, but maybe several. A two-long term memory idea has been suggested by Tulving (1972), who makes a distinction between semantic memory and episodic memory. Both memories are long-term stores for information; however, the kind of information they hold differs.

Semantic memory holds all the concepts that we need in order to define things in terms of language. It includes not only words and the symbols for them, their meaning and their referents (what they represent), but also the rules for manipulating them. Semantic memory holds such things as the rules of English grammar, chemical formulas, rules for adding and multiplying, knowledge that autumn follows summer; facts that do not depend on a particular time or place, but are just facts.

Episodic memory, in contrast, holds temporally coded information and events, information about how things appeared and when they occurred. It is our memory for autobiographical information, such as "last week I went to the dentist".

Although Tulving's (1972) distinction between semantic and episodic long-term memory is useful, it does not take into account another form of long-term information storage, namely, mental imagery. It seems useful to distinguish between two types of imagery; that connected with concepts in semantic memory, and that connected with cognitive models of the environment. Pavio (1971) discusses evidence for the presence imagery in connection with verbal processes. It seems that people can generate images or concrete verbal concepts, such as 'cat', or 'dog', and also use images to mediate more abstract verbal concepts, such as 'love' or 'hate'. Ulric Neisser (1976) discusses imagery in terms of the formation of cognitive models of our environments, for example, we can 'visualise' the layout of a room.

It might help to illustrate these different long-term memory systems if we consider an example from everyday life. The health inspector of a local authority might receive a telephone call from a Mr. Jones, the leader of a local action group, to ask what action has been taken in response to his letter of July 30th, calling for control of stray dogs in the community. Semantic memory is immediately in operation, interpreting and generating speech in the two-way flow of language. The health inspector can summon an image associated with the major concept of 'dogs'. Subsequent to the basic understanding of speech, episodic memory is consulted for information connected with receiving the initial letter, what was done with the letter, and whether any further action was taken. If the health inspector was unsure of the content of the letter, and whether action had been taken, he would need to retrieve it and related information from his filing system. It would therefore be necessary for him to have a mental model of his filing system. For successful retrieval the mental model would need some basic information identity classification scheme, and also a model of the locations of information in his office environment.

It is evident that there is a close interplay between the different types of LTM information in the problem solving situation just illustrated, where an enquiry necessitates some form of action. This interplay must proceed in a logical manner, so, as previously stated, there must be some higher order control over the interpretation of the available information. Therefore, any consideration of LTM should not only apply to the internal organisation and structure of information, but also to the executive processes directing the dynamic interpretation of this information.

Figure 2.4 illustrates one plausible (but not proven) analysis of several levels of processing that analyse sensory input and control motor output. Many levels of the different input and output modalities have been left out, but there are enough present to stress some important points.

N.B. The various types of memory have been depicted as separate systems. This is for ease of conceptualisation, not because this type of organisation is advocated.

First, there is a strong vertical, hierarchical organisation to the mind, hence levels of processing. Second, there are three basic types of levels; sensory (which only receives input), motor (which only produces output), and cognitive (which both receives input and produces output). Sensory levels represent stimuli, motor levels represent responses, cognitive levels attempt to represent the world. In between stimulus and response for human beings is an abstract cognitive model of the world that is neither purely sensory or purely motor in its function. Third, each cognitive level is superceded by a more abstract cognitive level.

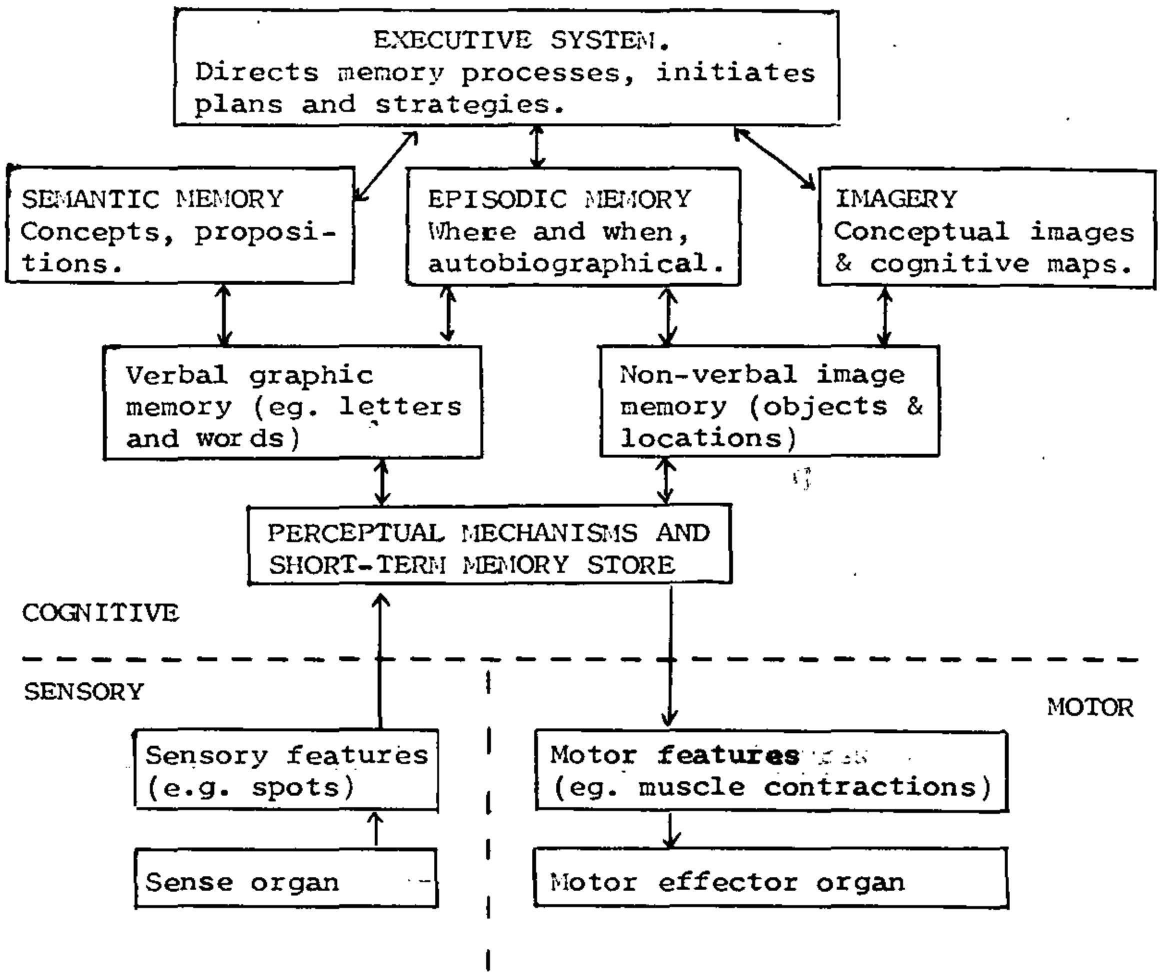


Figure 2.4: Levels of processing of the cognitive system.

In discussing the organisation of information in memory we will restrict our consideration to a fairly high level, namely, semantic, episodic and image memory. However, the organisation of the various memories is not fully meaningful without due consideration of the executive system which directs the processes involved in the organised storage and subsequent retrieval of information. Consequently, the executive system will be dealt with later.

2.5.1 Semantic structure in Long Term Memory

Brown and McNeill (1966) demonstrated and attempted to describe some of the regularities in LTM storage in an experiment that dealt with the tip-of-the-tongue phenomenon (TOT). The TOT phenomenon is when a person can almost, but not quite, remember a word or a name. Subjects were given definitions of words and then asked to say what these words were. What Brown and McNeill were looking for was the "TOT state", in which a subject felt he knew the word but could not recall it. When the state occurred it had a number of characteristics: the subject felt he knew the word, he could sometimes report the number of syllables, or the initial sound, or where the accent occurred. Often the subject knew that certain words recalled were not correct and could give words of related meaning. This type of recall, in which the subjects can identify the general characteristic of the word, is called generic recall.

In accounting for the existence of generic recall, Brown and McNeill described some aspects of LTM structure. They suggested that a word is stored in LTM at some location. Its representation there includes auditory information (its sound) as well as semantic information (its meaning). In the TOT state, total retrieval by meaning has failed, but a subject has partially retrieved the word. He has some knowledge of its sound but apparently does not have a complete acoustic representation. The previous facts tend to indicate that there is insufficient data for recall of the word. The authors also suggested that stored with each word were associations, or marked pathways, to other words in LTM, so that the subject could come up with words that meant almost the same thing. Thus, Brown and McNeill depicted LTM as a large set of interconnected storage locations, each holding a complex collection of information related to a single word or fact.

There are many more recent models of LTM with various approaches evident. These models can be roughly classified as network models, set models, and semantic-feature models. None of these categories is totally distinct from the others; all are closely related, which is not surprising in view of the fact that all attempt to account for the same human abilities.

2.5.1.1 Network models of Semantic Memory

Network models of semantic memory, like the theory of Brown and McNeill (1966), depict long-term memory as a vast network of associated concepts; not unlike the S-R conception of memory as a bundle of associations. However, these models differ from traditional association in some fundamental ways. For one thing, most such models assume that different kinds of associations can be formed; that not all associations are the same. This means that when two concepts are associated, the relationship between the two is known; the association is more than a simple bond. This approach has been called 'neo-associationism' (Anderson and Bower, 1973). This view of LTM also includes the idea that the associative network is as orderly and compact as possible.

Things that are close together conceptually may be expected to be closely associated in the LTM network. A useful analogue is the structure of a thesaurus where items are grouped by meaning and cross-referenced.

In considering network models it is important to bear two things in mind. The first is that the connections amongst concepts are circular; that is, concept A can be defined by its relationship with concept B and vice versa. The second is that the language associated with the models is in terms of English grammatical relationships. The reason for the latter characteristic is that current models of the structure of semantic LTM place primary emphasis on how they represent the kind of knowledge that is transmitted by language.

i) Quillians TLC:
The first network model of LTM, in which language and associative networks played an important part, was suggested by Quillian (Collins and Quillian, 1969). This model was called TLC, which stood for 'Teachable Language Comprehender'.

According to Quillian, the format of factual information in LTM is made up of three types of structures - units, properties and pointers (see figure 2.5).

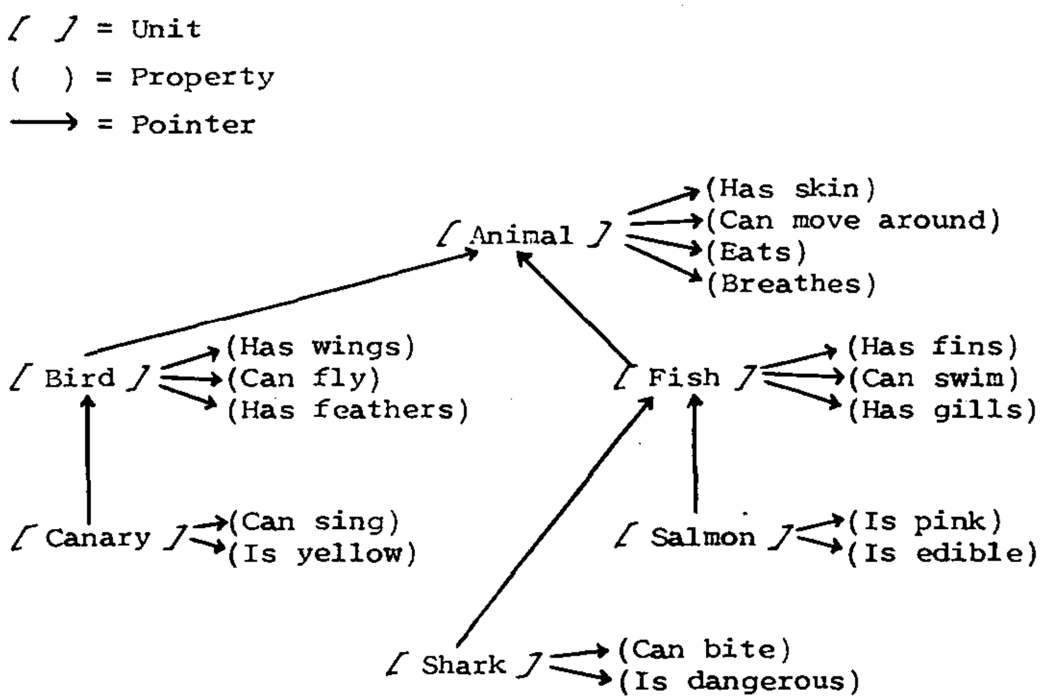


Figure 2.5: Quillian's TLC

The first two we can think of as locations, in Brown and McNeill's sense: units and properties are places in LTM that correspond to information about concepts. The difference between units and properties lies in the kind of concept that they represent. A unit corresponds to an object which would be described by a noun in the English language, or, if sufficiently complex, a sentence (e.g. 'fish' in figure 2.5). In contrast a property is a structure which describes a particular characteristic of a unit (e.g. 'can swim' in figure 2.5). The relationships between units, and units and properties are defined by pointers. There are, however, rules governing the connections that can be made. The first pointer of each unit must define the immediate superordinate unit; for example, animal is the immediate superordinate of fish in figure 2.5. The remaining pointers of the unit point to its properties, for example, 'has fins' has a pointer from fish in figure 2.5. In this way each unit can be defined in terms of higher order concepts and a list of properties. There are also rules for constructing properties. Each property has a pointer to an attribute and a value. In figure 2.5, 'is pink' is a good example to illustrate this; the attribute is colour, and the value is pink.

In summary, the structure that evolves is a potentially huge network of concepts. They are two types, units and properties, and the pattern of interconnections serves to give them meaning. Units are defined by other units and properties; properties are defined by other properties and units. It should also be noted that this associative network is essentially hierarchically organised through the superordinate conceptual associations.

ii) Anderson and Bower's HAM:
To expand the network idea, it will be useful to consider another model along the same lines as that proposed by Quillian. Developed by Anderson and Bower (1973) it is called 'HAM' (for Human Associative Memory).

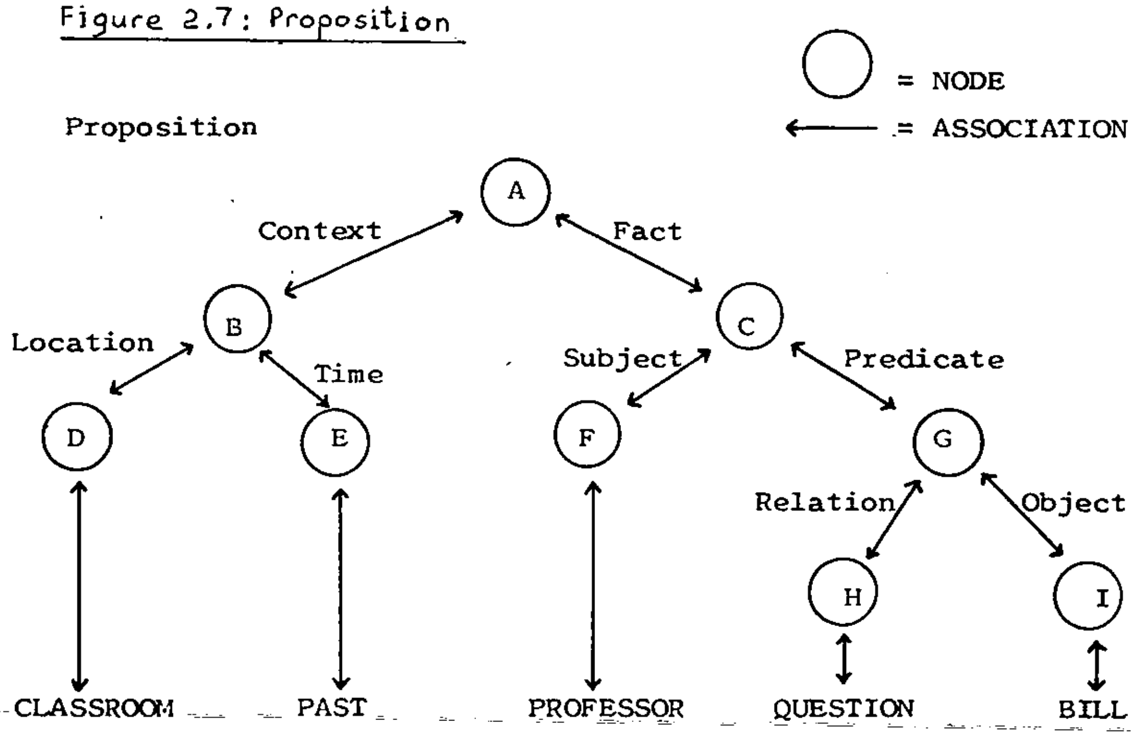
Although HAM bears a general resemblance to Quillian's TLC, it is quite different in the detailed structure it proposes for LTM. Of course, as a network model, HAM describes LTM as a vast collection of locations and labelled associations. In HAM, however, the basic component is called a proposition. HAM's propositions resemble English sentences, except that they are more abstract. That is, a proposition can represent a linguistic structure such as a sentence, but it is not that sentence itself, rather the related concepts represented by that sentence. However, propositions do not just represent linguistic information, they can also represent non-linguistic information such as visual scenes.

In general a proposition is a small set of associations and locations, its equivalent in TLC would be a small set of units and properties sufficient to represent a meaningful interpretation of some event. Each association is binary, which means that it combines, or associates, two concepts. The associations are of several types and the ways in which they combine to form a proposition are illustrated in figures 2.6 and 2.7.

Association	Examples	
Context-Fact	yesterday at school	John cried
	at home	we eat
Location-Time	Paris	1942
	school	yesterday
Subject-Predicate	Caesar	is dead
	my aunt	is a teacher
Relation-Object	is taller than	Bill
	likes	soup

Figure 2.6: Associations of HAM

Figure 2.7: Proposition



"IN THE CLASSROOM THE PROFESSOR QUESTIONNED BILL"

There are four basic types of proposition (see figure 2.6). The main proposition is represented by a context-fact association, the other three types of associations are subordinately related to this. Figure 2.7 shows how the proposition, "in the classroom the professor questionned Bill", can be hierarchically divided into the four types of the associations of figure 2.6. Each labelled circle in figure 2.7 represents a 'node' where two associated entities combine. The proposition node A is actually the result of a binary association between a context and a fact. If a proposition does not have a context, for example, "mice eat cheese", then the highest node would be C. The proposition would then be expressed in terms of subject-predicate, and relation-object associations only.

iii) Processes of TLC and HAM:
So far, we have learned that network models have an associonistic structure proposed for LTM, but that is only part of the picture. In order to simulate human behaviour, or to make predictions about experimental data (discussed shortly), a model must also stipulate processes. Processes act on the structure and work with it to encode, store, and retrieve information.

In Quillian's model, for example, it is necessary to explain how TLC acquires new information, comprehends linguistic inputs, and answers questions. The most important process used in these tasks is called the "intersection search". Suppose TLC is trying to comprehend a sentence such as "a wolf can bite". In the sentence, certain concepts are named (such as "wolf" and "bite"). The search process simultaneously enters LTM at the location of each concept named, then proceeds outwards from those concepts along the pointers or paths leading from them. Each time a pointer leads the search to a new concept, that concept is given a mark to indicate it has been passed in the search and from what concept it was reached. At some point, it is probable that a pathway being followed will lead to a concept that has been already marked (that is, has been reached previously in the search). At that point we have an intersection. Finding an intersection means that the same point (the intersection) has been reached from two concepts. Thus, it indicates that the two concepts are related. By checking the marker at the point, and tracing back the steps leading to the intersection, the process determines just which concepts in LTM are compatible with the relation in the input sentence, the sentence can be said to be comprehended as a true statement. With a non-sense sentence, such as "a wolf can talk", the two concepts are incompatible in terms of relations, and so the sentence will be comprehended as a false statement.

HAM's process corresponding to TLC's intersection search is called a "Match" process. The process is designed to connect input information with memory, thus enabling HAM to interpret the information. First, HAM attempts to encode the input (e.g. a sentence) into a proposition tree; "professor questionned Bill" in figure 2.7. This encoding process is called "parsing" the input. Then, it matches the terminal, bottom-most nodes of the tree (professor, question, and Bill) with their corresponding locations in LTM. (If an unfamiliar word is in the input, however, it cannot be matched with the LTM location. Instead, a new node representing the word will be formed in LTM, and information will begin being collected about that node, such as the words spelling, and what words it was associated with in the sentence, and in what manner.) Next, the match process attempts to find in LTM a tree that looks like the input tree. It does so by starting a search from each LTM location corresponding to a word in the sentence - a search for pathways through the LTM network that connect terminal nodes in the same way as they were connected in the input. Once this is accomplished there is a match between the input and the LTM network, and the sentence is comprehended.

At this point it seems appropriate to quickly summarise some of the data that these models attempt to explain.

iv) The category-size effect:

Perhaps the most important single phenomenon of semantic memory is what we call the category-size effect. Typically the subject is asked to verify sentences of the form "A (subject) is a (predicate); e.g. A canary is a bird. The independent variable is the category-size of the predicate, for instance, the category "animal" contains more members than the category "bird"; a bird is a member of the animal category. The principal result of these verification experiments is that reaction time for responding "true" increases as the predicate category-size increases. For example, it takes longer to verify "A canary is an animal" than to verify "A canary is a bird" (Collins and Quillian, 1969; Meyer, 1970). Generally, the reaction time to respond "false" to statements, such as "A daisy is a fish", also increases with an increase in predicate category size (Meyer, 1970).

The explanation for this, in Quillian's model, is that the bigger the predicate category the further removed it is from the subject category and the greater the number of pointers that intervene; therefore the longer the intersection search takes (see figure 2.5). the category size effects for "false" statements are harder to explain, however. From the previous logical explanation it would seem to be easier to relate daisy to higher order categories such as "living things" than to "fish". This is not so, and no acceptable explanation has yet been found. In addition, this is not the only problem faced by semantic network models.

v) Effects of semantic relatedness:

In typical studies of this phenomenon, subjects are first presented a set of word pairs. Each pair has one word that is a category instance and one that is the name of the category; for example, "robin" is an instance and "bird" is a category. For example, "robin" is judged much more typical of the category "bird" than is "chicken". Not only this, but reaction times are also quicker for the verification of more 'typical' members of a superordinate category.

It is very difficult to account for this effect in TLC, because the same one-pointer distance separates all category members from a category name. Anderson and Bower's HAM can better account for it, through the operation of the search (Match) process in LTM. Searches from the locations of the concepts from the bottom-most nodes of the input tree are started in parallel; however, from a given location only one pathway can be followed at a time. Since there are usually many pathways leading from any one location in LTM it is assumed that those pathways are given a priority ordering; which gives an order in which the paths from given locations are searched. The most important ones will be given high priority. This enables HAM to account for the effect of relatedness on true reaction times, for relatedness can be equated with the priorities. By assuming that judgements of relatedness are based on the priority list, it is easy for this model to account for those judgements.

There are alternatives to network models, however, and these will now be considered.

2.5.1.2 A Set-theoretic model of LTM

The "set-theoretic" approach was advocated by Meyer (1970). It assumes that semantic categories are represented in LTM as sets, or collections of information. They can include sets of instances of a category (for example, the category "bird" includes such instances as robins, sparrows, etc.). They can also include sets of attributes or properties of the category (for example, "birds" have wings, have feathers, can fly etc.). In other words, a category is represented in LTM as a set of information.

Meyer used the model to account for the time it took subjects to verify or disconfirm sentences of the form "All (subject) are (predicate)" or "Some (subject) are (predicate)". To account for reaction time data, he proposed a two-stage model describing the processes used in the task. The first stage involves the examination of all the sets that overlap (have members in common with) the predicate category. If the search through these sets finds an overlap with the subject category, then the first stage ends with a match; if not the outcome is a negative response.

Given a match in the first stage of the verification process, it is known that subject and predicate have some members in common. That would be enough to verify, for instance, "some stones are rubies", but not enough if the sentence was "all rubies are stones". For the latter, a second stage must be executed, the comparison of all predicate attributes with subject attributes. If every attribute of the predicate is also an attribute of the subject, then the sentence can be verified. If not, the subject makes a negative response.

This model can account for category-size effects, but not those of semantic relatedness. The next model is derived from the set-theoretic model, and also takes semantic relatedness into account.

2.5.1.3 A Semantic-feature model of LTM

The semantic feature model (Rips, et al., 1973) assumes that a semantic category can be represented in LTM as a set of attributes, or features. Moreover, the set of features is very broad, including features that are essential in defining the category and some that are relatively unimportant; varying along a continuum of importance.

In general, on such a continuum of features, we can select an arbitrary cut-off point to separate the more important features (called "defining features") from less important features (called "characteristic features"). In the feature model, defining features are given greater emphasis in verification tasks than are characteristic features. The processes involved in verification of an "all (subject) are (predicate)" sentence is similar to that in the set-theoretic model. However, the first stage results in a measure of similarity of the two sets of defining and characteristic features. If this measure is above a certain criterion then the two terms are so similar that a quick "true" response can be produced. If the value is neither high nor low, a second stage is executed.

In the second stage, only defining features of subject and predicate are used. If the defining features of the predicate agree with those of the subject, then a positive response can be made; otherwise there is a negative response. The advantage of the feature model is that it readily accounts for effects of typicality, or relatedness, on reaction time, in addition to the category-size effect. The more typical an instance is of a category, the more features they share and the greater the likelihood of a quick stage one decision.

The aforementioned models of semantic memory all deal with the comprehension of language concepts. However, we also have the ability to form mental images of certain concepts, external objects, and our environment. Therefore, we also need to discuss this ability if we are to understand the generation and storage of our various conceptual models.

2.5.2 Imagery: concepts, external stimuli, and spatial cognition

If someone asks you what a typewriter looks like you can immediately summon the appropriate conceptual image in your mind. Similarly, you could tell them what your office looks like, what objects are in it, what they look like, and where they are in the office relative to each other. However, there is a subtle difference between these examples. In the former, the image relates to 'typewriter' as a language concept, in the latter the images relate to objects and situations in our personal experience; that is, respectively independent of and dependent on our personal environment. Attneave (1974) goes further, he suggests that our image of our environment may be separated into 'what' (image) and 'where' (spatial systems). Attneave also observes that the what and where systems must be closely interconnected, since we are capable of perceiving specific objects in specific locations. In any event, we must somehow distinguish between images of language concepts (Paivio, 1971), of the form properties of objects, people and pictures we encounter (Paivio, 1971; Wicklegren, 1979), and their location in the world (Neisser, 1976).

2.5.2.1 Image mediation of verbal concepts

One of the prime examples of the role of imagery in conjunction with language concepts, is in its use as an aid to the verbal learning of words and paired associates.

Paivio (1965) discovered a high correlation between imagery and the concreteness of words; subjects rated sixteen concrete and sixteen abstract nouns on a five-point imagery scale. On the assumption that the usefulness of stimulus evoked imagery as a mediator of verbal associations would depend on how readily an image is aroused, imagery was defined in terms of the ease or difficulty with which the word arouses a mental image. He later confirmed these results with larger samples of single words and paired associates (Paivio, et al., 1968). It has also been found that concrete words are more meaningful than abstract ones (Spreen and Schulz, 1966; Paivio, et al., 1968; Frincke, 1968), and that more meaningful material is more easily learnt (see review in Woodworth and Schlosberg, 1954). Therefore, it follows that image mediation can enhance verbal learning.

Another example of the enhancement of verbal learning by imagery is demonstrated by Bower (1972). He gave subjects concrete-noun pairs and asked them to image a scene of the two objects interacting in some way. An example is that "dog" and "bicycle" can be imagined as a dog riding a bicycle. He found that this caused cued recall to increase highly significantly.

It logically follows, from the previous work, that imagery can make an important contribution to verbal learning; a result repeatedly noted by Paivio (Paivio, 1971). To make the optimum use of imagery in connection with language, however, it is necessary to assess the relationship between the relevant verbal and imagery processes.

2.5.2.2 The Dual-coding hypothesis

The history of the concept of visual imagery has given rise to the idea that images may serve as an alternative to verbal codes as a means of representing information; thus imagery may be a medium for representing information that could readily be described by words. And, imaginal representations may be as useful or even more useful than verbal representations in LTM when they are used in tasks involving learning and memory.

Paivio (1969; 1971) proposes a dual-coding hypothesis. Essentially, the dual-ooding hypothesis assumes that there are really two basic ways of representing information in memory; that is, two coding systems. One is word, or verbal, or linguistic representation, an area which has borne the emphasis of past research. The other is non-verbal; it may be called imaginal, and it includes (although it is not restricted to) the visual images we have just been discussing. The two systems are strongly connected, so that we can derive an image from a verbal label, or vice versa. However, the two systems of representation also differ in some fundamental ways.

For one thing, the imaginal system can deal better with picturable concrete entities, like "dog" or "bicycle"; how could we picture something abstract like "truth"? What this means is that we can think of certain psychological entities as best represented by words, whereas others can be represented either verbally or non-verbally. Another way in which the two systems differ is in the way they process information. In the verbal system, it seems that serial order is of primary importance. When words are perceived in speech, for example, the sounds come in a sequence, and the meaning assigned to those sounds largely depends on their order. However, we can contrast this with the way that we deal with visual inputs, which seem to be handled in a "spatially parallel" manner. That is, we process all the information in an area of space at once. In viewing the letter A, for example, we can simultaneously process the whole thing, rather than viewing it as / \ -.

One of the implications of the dual-coding view of memory is that information that can be held in both verbal and imaginal systems should be more accessible than information held in just one system; because we should be able to get at the information by either verbal or non-verbal retrieval processes. In a sense, there is twice as much information about a twice-coded item than about an item which exists in only one form. Thus, it should be easier to remember concrete words than abstract words. Concrete words can be represented either imaginally or verbally; abstract words can be represented only verbally. This prediction is supported and the amount of psychological data can be interpreted in terms of the dual-coding hypothesis is considerable (Paivio, 1971).

However, there are other aspects of imagery, other than those connected with verbal concepts, which will now be considered.

2.5.2.3 Imagery and external stimuli

The previous two sections dealt with internally generated images in response to verbal concepts. This section deals with images generated in response to encounter with items in our environment; that is, our internal images of external objects.

Shepard (1967) discovered that subjects could recognise a large number of pictures they had seen just once. Standing et al (1970) carried this sort of demonstration even further. They showed subjects 2,500 slides for 10 seconds each. Later, on a recognition test of a subset of those slides, subjects scored 90%; it seems that subjects must have something more than verbal descriptions of the slides in memory.

There is substantial evidence to support the proposition that visual perception of a complex picture involves successive eye fixations on different informationally rich portions of the picture. People do not stare at the centre of a picture and build up an image by prolonged fixation focussed on a single point (Kolers, 1970). Thus, images are undoubtedly associative traces rather than non-associative activity traces. This conclusion is also supported by the fact that image memory can persist as long as verbal memory; sometimes for a lifetime.

Loftus (1972) has demonstrated that recognition memory for pictures increases as a function of the number of fixations on a picture during learning, and that it is independent of exposure time when the number of fixations is held constant. Initial learning of a complex picture generally depends primarily upon the number of fixations, provided study time per fixation is at least a few hundred milliseconds.

Retrieval also appears to involve a revival of the image by means of successive generation of the parts. Several investigations have demonstrated that recall of complex visual material is often accompanied by eye movements (Marks, 1972; Kahneman, 1973; Bower, 1972; Hall, 1974). Furthermore, Hall showed that image recall is better when eye movements are permitted than when the subject is required to fixate a single point during the retrieval of the image. Wicklegren (1979) makes four points in relation to this evidence. First, if an image is simple enough to be generated all at once with maximum clarity, there is no need to generate it in parts via shifts of attentional focus. Second, shifts of attention across a mental image would not appear logically to require an eye movement, nor is it obvious why eye movements should benefit image retrieval. Miniature or even full-blown eye movements may often occur as an irrelevant "down-stream" consequence of mental scanning. Third, it is doubtless possible to retrieve part of a scene "on centre stage in the mind's eye" directly, rather than first retrieving the entire scene and then focussing on one part. Fourth, Marks's correlation data (which show that good imagers make fewer eye movements than poor imagers in recall of pictures) seem best interpreted to indicate that good imagers can generate more complex images in a single focus than poor imagers. These correlational individual difference data do not oppose the hypothesis that retrieval of complex images often involves piecemeal generation of its parts.

Moreover, the image modality does not consist of a passive collection of images arranged like so many paintings on a wall. The range of operations that can be performed on images is an equally important component of the image modality.

2.5.2.4 <u>Image operations</u>

Image operations can conveniently be classified as non-destructive or destructive. Non-destructive operations may include initial generation of a mental image from some retrieval cue or cues, subsequent scanning (focussing attention on some part of the image), and zooming (retrieving more detailed constituents of some part of the image to achieve something like a photographic blow-up), (Kosslyn, 1973 and 1975). Destructive operations include deletion, rotation, reflection, translation, magnification, minification, squashing, stretching, and tearing of visual images (Wicklegren, 1979).

Shepard and Metzler (1971) provide one of the best demonstrations of operations upon an internal image with their studies of image rotation. They showed subjects pairs of pictures of three-dimensional shapes, some of which were the same. However, the shapes were shown in differing spatial orientation. The time required to judge whether they were the same was measured. Subjects reported that in order to make this judgement they had to imagine one of the objects rotated into the same orientation as the other. The time to make the judgements was found to increase linearly with difference in angle between the two objects. This would seem to suggest that "rotation" is a transformation that can be applied to a memory activation. This conclusion is even more strongly supported by a later experiment by Cooper and Shepard (1973) using two-dimensional letter images. The speed of rotation of these images was considerably faster than the speed of rotation of the three-dimensional images studied by Shepard and Metzler. Since Shepard and Metzler had already demonstrated that rotation of three-dimensional images in the picture plane is not intrinsically faster than rotation in depth, the essential difference appears to be whether the image is itself two- or three-dimensional.

Finally, we will deal with more global imagery.

2.5.2.5 Spatial memory

How do we find our way around our environment? How do we give people directions of how to get to a place? There must be some representation of our spatial environment in memory in order to fulfil this kind of informational need.

The term 'cognitive map' was coined long ago by Tolman (1948). It has gained new currency in the last few years, as psychologists, geographers, planners, and other professionals have become increasingly interested in problems of spatial orientation. Cognitive maps are often discussed as if they were, "mental pictures of the environment that could be examined at leisure by the mind's eye while the mind's owner reclined in his armchair" (Boulding, 1961). However, Neisser (1976) believes that it is unwise to define cognitive maps by the ability to give such descriptions or to have such images. He coins the term "orienting schema" as a synonym for 'cognitive map' to emphasise that it is an active, information-seeking structure. Instead of defining a cognitive map as a kind of an image he proposes that spatial imagery (the cognitive map) itself is just an aspect of the functioning of orienting schemata. Like other schemata, they accept information and direct action (see section 2.4.8.4).

Cognitive maps are ubiquitous. We all know what to expect around the corner on the way home; we can all plan trips to a hundred destinations, and check our expectations along the way if we undertake one; we can all take new short cuts with some idea of where they lead. These abilities are common place, but they are by no means uninteresting. A particularly good account of them appears in Kevin Lynch's book 'The Image of the City' (Lynch, 1960). He identified features of the cognitive map such as landmarks, pathways, and boundaries, as important orienting points. There is evidence that we store our knowledge of the physical surroundings by converting our experience into relatively simple geometric forms. An elliptical railway system may well be thought of as a circular one (Canter and Tagg, 1975). Although two crossroads may meet each other at oblique angles, they may well be thought of as having the neater, right angle cruciform arrangement (Pocock, 1973).

More specifically, human beings code and remember, the spatial positions of significant objects. They also appear to encode and remember certain characteristics of the changes of positions of objects (movements). These characteristics include speed, acceleration, duration, and extent of movement. Knowledge of position and movements that are not part of the body or in contact with parts of the body can only be given by vision or hearing. We derive information regarding position and movement of our body parts or of objects in contact with our body from visual, auditory, tactile, and kinesthetic sensory systems. We also derive information concerning the position of body parts from central motor representatives (motor overflow) that control the position of these parts (Wicklegren, 1979). The integration of spatial information from different sensory and motor modalities, and the fact that interference appears to be specific to the type of information (rather than to the sensory or motor modality from which it was obtained), argue for a common cognitive representation of position and movement independent of input node (Laabs, 1973).

To complete our picture of the information stored in memory, we shall deal with episodic memory.

2.5.3 Episodic memory

Episodic memory receives and stores information about temporally dated episodes or events, and temporal-spatial relations among these events (Tulving, 1972). A perceptual event can be stored in the episodic system solely in terms of its perceptible properties or attributes, and it is always stored in terms of its autobiographical reference to already existing contents of the episodic memory store. The act of retrieval of information from the episodic memory store, in addition to making the retrieved contents accessible to inspection, also serves as a special type of input into episodic memory and this changes the contents of the episodic memory store. The system is probably quite susceptible to transformation and loss of information. The specific form in which perceptual input is registered into the episodic memory can at times be strongly influenced by information in semantic memory and image memory, because both verbal and imaginal ooncepts can be part of an event, it is also possible for the episodic system to operate relatively independently of the semantic system.

In some ways episodic memory is more closely associated to image memory than semantic memory, because events and objects can be 'visualised' whereas semantic memory is the memory necessary for the use of language. Semantic memory does not register perceptible properties of inputs, but rather the cognitive referents of input signals. Alternatively, there are similarities between semantic memory and image memory; they both permit retrieval of information not directly stored in them, and retrieval from both systems leaves their contents unchanged, although any act of retrieval constitutes an input into episodic memory. However, episodic memory is involved in setting the context of an event, a fact which is provided for by a high-level context-fact association in Anderson and Bowers HAM model (1973); this allows for description of facts and autobiographical information, such as where we put something. But what of the organisation of episodic memory?

The most primitive form of organisation is based on temporal and spatial proximity of elements in perceptual input. Organisation carries the implication of changes in the memory trace of an event that is influenced by the presence of certain other traces in the episodic memory store. The temporal date of a stored event may be determined by its organisation in relation to other events with their temporal dates (Tulving, 1972). Similarly, semantic organisation refers to the grouping of items in a given set that somehow reflects the semantic relations among corresponding concepts. In other words, temporal co-ordinates of an event and its representation in episodic memory need not be specified in terms of the clock or calendar. They could be recorded in terms of temporal occurrences of other events in some as yet little understood manner.

2.5.4 Summary of memory organisation

To summarise, there are three basic types of memory organisation; semantic, imaginal, and episodic. This does not mean, however, that there are three distinctly separate memory systems, rather that there are three types of information stored in memory with a strong interaction between them.

First, we previously discussed three kinds of models of semantic memory; network models, a set model, and a semantic-feature model. Each were considered in the context of two major areas of research, category-size and relatedness effects. It is clear that in many ways the models are similar. All of them present a theory of meaning, for example, in which a concept derives its semantic content from its relations with others; whether by virtue of associations, by containing the other concepts as subsets in its definition, or by having those concepts as features. However, it should be clear that network and set models differ in some fundamental ways. One of the most important differences is that set models are designed to deal with data collected in specific semantic memory experiments, whereas network models are capable of handling a larger body of data. The HAM model, for example, attempts to deal with such varied topics as linguistic ability, forgetting, perception, pattern recognition, learning, and more. Because of their greater scope, the network models are relevant to many of the phenomena of episodic memory, as well as semantic memory.

Secondly, it seems that a strong case can be made for the existence of images; although there is opposition also. Despite the controversy, some basic points can be made about image memory. One is that the world is not represented in LTM in full pictorial detail; that seems to be ruled out on both logical and experimental grounds. Another point is that there must be stored in LTM information about visual events, for such information is needed in order to recognise patterns and remember things previously seen. What is uncertain is just how much the visual information in LTM, or the images generated from that information, resemble mental "pictures". What is certain, however, is that imagery can have a profound effect on the way we conceptualise information.

Third, concerning episodic memory, Tulving (1972) proposes that most studies of human memory and verbal learning have almost exclusively been concerned with this phenomenon. The large majority of typical memory tasks require that the subject remember what particular perceptual event occurred in what temporal (sometimes also spatial) relation to other events. The relatively scant literature on semantic memory consists primarily of studies of free association to, and classification of, word stimuli, as well as studies of retrieval times of semantic information.

In general, we have to be careful how we view these different types of memory organisation. Tulving (1972) points out that a collection of essays by Norman (1970) referenced some twenty-five or so categories of memory, from "active memory" at the beginning of the alphabet, to "working memory" at the end. So again it is important to note that the previous discussion was more concerned with highlighting the storage of different kinds of information, rather than advocating separate and independent memory systems. In fact there is strong interaction between these types of memories; a fact illustrated by the example in section 2.5.

Finally, there is one important point to note when discussing LTM in the context of an information processing model. The contemporary view of information storage and retrieval from memory no longer distinguishes a separate short- and long-term memory system. Rather, it advocates short- and long-term information storage in terms of depth, or level of coding. Short-term storage puts a greater emphasis on coding the physical characteristics of information. Long-term storage, on the other hand, is more concerned with meaningful concepts (Herriot, 1974).

We have discovered that human memory can organise and store much information, concerning the state of our environment, via various inherent cognitive processes. It is necessary, in addition, to conceive of some form of executive system which initiates and monitors the relevant processes.

2.6 The Executive system

An executive system is necessary for initiating the perception of information from the environment; for organising the storage of information in memory; for directing the retrieval of information from memory; for formulating and interpreting plans, strategies and rules in the light of objectives and intentions; and for initiating and directing sequences of responses to achieve a desired goal.

For example, M.W. Eysenck (1977) proposed that recall of information from memory involves at least five different stages or processes, which are assumed to occur serially:

i) Perception of a retrieval cue,

ii) Rule or strategy formulation, including a determination of the size of the search set to be used,

iii) Item search, in which the search process operates on the specified search set and produces one or more items,

iv) Evaluation, in which any responses generated by the search process are evaluated in terms of the current rule or strategy and perceived goal,

v) Emission, in which items positively evaluated are produced.

In short, the executive system directs thought and behaviour on the basis of both information in the memory systems and its own goals. It is important to consider the concept of direction in understanding the executive system.

2.6.1 Direction of thought

It is necessary at the outset to distinguish between directed and undirected thought. Undirected thought consists simply of the idle wanderings of the mind, as in dreams and daydreams. Directed thought tends toward a particular end, a goal as in problem solving. It is directed thought which most clearly engages the executive system.

One of the simplest examples of undirected thought is free association, in contrast with the simplest example of directed thought, controlled association. In a free association test, a person is given a list of words and asked to write down next to each the first word that it brings to mind. In a controlled association test, a person is asked to give for each of several words a word that stands in a particular relation to it (e.g. the opposite).

It can be demonstrated that directed thought requires additional, executive mechanisms. B.F. Anderson (1975) shows that free association with the words 'cold' and 'ebony' produced a number of different words. Cold produced hot 35% of the time, winter 6%, sick 6%, and warm 4%. Ebony produced black 58% of the time, wood 8%, magazine 6%, ivory 4%, and white 4%. Subsequent controlled association using these words, with direction to provide 'the opposite of', provided some subtly different results. The opposite of cold was hot on 91% of occasions, the opposite of ebony was white on 74% of occasions and ivory on 10%. The first thing to notice is that association does not necessarily produce one word, it does, however, produce some words more frequently than others. Such frequencies are assumed to reflect associative strength (Osgood, 1968), a concept in keeping with a semantic network theory of memory representation (Anderson and Bower, 1973; Collins and Quillian, 1969). The second thing to notice is more crucial to the demonstration of the presence of executive mechanisms. In free association and controlled association hot is the word most strongly associated with cold. When ebony is used as the stimulus in free association the strongest association is that of black with 58%. In controlled association white, with 4% in free association, becomes dominant with 74%, and black is excluded altogether. Thus the response which has the highest associative strength to ebony is never given. The reason is that it does not fulfil the requirement of being opposite ebony. Such a requirement, or direction, supplements associations in directed thinking. This is demonstrated in the last example where the direction restricted the acceptable responses to those which would in some sense be considered to be the opposite of ebony, but this still permitted two responses, namely white and ivory which differed in associative strength. The associative strength of white was supplemented more than that of ivory, maybe due to differing associative strengths in the directed context. Maier (1970) proposes that both direction and association act as selecting mechanisms in directed thinking.

2.6.2 Organisation of the Executive system

The executive system is organised on at least two levels; what we might call a superordinate executive system and one or more subordinate systems. Perhaps the best way to characterise these two levels is in terms of direct comparison between the two.

The superordinate executive system is the control centre of the executive system, often referred to as the central processor (CP). Under certain conditions, at least, the capacity of CP seems to be a single item; that is, CP appears to be capable of doing only one thing at a time, to be strictly serial (Sternberg, 1966). The subordinate system, however, seems to be a parallel associative mechanism that is capable of doing more than one thing at a time (Neisser, 1976). In conjunction with this, the superordinate system seems to operate at a conscious, intentional level, whereas the subordinate system seems to involve subconscious processes and operates automatically. Fitts (1964) has identified three stages of skill learning: a cognitive stage, an associative stage, and an automatisation stage. The cognitive stage seems to involve the superordinate executive system. It is during this stage that instructions and demonstrations are the most helpful; and, during this stage, the best performers seem to be those who are good at visualising spatial relations. The associative stage seems to be a transitional one, where TOTE representation (Miller, Gallanter, Pribram, 1960) is being translated into an associative representation; that is, the correct response to a certain stimulus situation. The automatisation stage seems to involve primarily the subordinate system. Here, errors are seldom made, and further practice serves mainly to make performance smoother and faster. Sequences of actions are pre-programmed, and the best performers seem to be those with the fastest reaction times.

The concepts of superordinate and subordinate executive systems compare favourably with that of human information processing taking place via conscious and subconscious processes (see figure 2.2, section 2.3.1). The superordinate executive system corresponds to the sequential processor. The subordinate executive systems relate to the various aspects of subsconscious processing.

The distinction between superordinate and subordinate levels corresponds to Miller, Gallanter, and Pribram's (1960) distinction between strategies and tactics and seems to be what Newell and Simon (1972) had in mind in distinguishing between goal-directed behaviour, which seems to require maintenance of a goal in short-term memory, and behaviour that is directed only in the sense of being a translation into associative terms of stimulus - response sequences that were originally components of goal-directed behaviour. In other words, the superordinate executive system determines the intermediate states which should be reached in achieving a certain goal; that is, it formulates high-level plans or strategies. The subordinate executive systems deal with the information concerning appropriate actions required to reach the next stage after achieving the previous one. Both must rely on the internal representation of relevant information in memory.

2.6.3 Plans and procedural knowledge

Control of our information-processing capacities is more organised than simple stimulus-induced activation of responses. Such organised control processes are called plans.

Plans are something akin to small computer programs that 'program' the mind to perform certain cognitive tasks; e.g. locating desired information, or generating a sentence. Like propositions, simple plans can be embedded in more complex plans to produce a hierarchical control system (p.357, Wicklegren, 1980).

A search strategy for solving a problem is a plan which directs the subject from the initial representation to a final goal state. The development of such a plan may come as a whole, or more likely, result from attempts to test simpler plans. As a person tries various approaches, he begins to understand the information he needs in order to move from his present representation to one which comes nearer the solution of the problem. Such plans can be thought of as consisting of simpler TOTE units (see section 2.4.2). The individual formulates a sub-goal which might move him closer to the solution, and then tries out various mental operations which may move him toward that goal.

Such plans are very much akin to retrieval cues or hypotheses, but operate on a higher level; that is, a plan can incorporate retrieval cues and hypotheses. They tell the subject where to look in memory or what to examine in the external world in order to advance toward a solution. To assemble a plan, a person must take account of the initial representation, the likely organising principles of his own long-term memory, and the mental operations he can perform. In some sense plans are central to problem solving and yet we know very little about their development. The plan provides the dimensions by which ideas[3] and experiences stored in long-term memory can be collected. In a real sense the plan provides the cues for retrieval from memory. The essence of its role in problem solving is to select items in memory which are alike in the way a particular sub-goal requires. The plan becomes an executive or organising scheme providing the key dimensions which relate possible solutions. This appears to be a function of consciousness in that the subject can often report the process verbally (Duncker, 1945).

There is an important alternative way of conceiving of the action of the executive system on external and internal information, that of schemata.

2.6.4 Schemata

One of the most important, but variously defined, concepts is the schema; especially used in connection with semantic memory (Bartlett, 1932; Minsky, 1975). A schema can be thought of as an attentional set that includes the stored information more or less directly associated to what is currently consciously on your mind.

A comprehensive account of schemata can be found in 'Cognition and Reality' by Ulric Neisser (Neisser, 1976). He defines the schema as that portion of the entire perceptual cycle which is internal to the perceiver, modifiable by experience, and somehow specific to what is being perceived. The schema accepts information as it becomes available at the sensory organs and is changed by that information; it directs movements and exploratory activities that make more information available, by which it is further modified.

The functions of schemata may be clarified by some analogies. In one sense, when it is viewed as an information-accepting system, a schema is like a format in a computer program language. Formats specify that information must be of a certain sort if it is to be interpreted coherently. Other information will be ignored or lead to meaningless results; however, the limitation does not have to be too sharp as schema can operate at various levels of generality.

A schema is not merely like a format; it also functions as a plan, like the TOTE paradigm (Miller, Gallanter and Pribram, 1960). Perceptual schemata are plans for finding out about objects and events, for obtaining more information to fill in the format. Information can be picked up only if there is a developing format ready to accept it, and any that does not fit such a format goes unused; perception is inherently selective.

The analogy between schemata and formats and plans is not complete. Real formats and plans incorporate a sharp distinction between form and content, but this is not true of schemata. The information that fills in the format at one moment in the cyclic process becomes a part of the format for the next, determining how further information is accepted. The schema is not only the plan but also executive of the plan. It is the pattern of action as well as the pattern for action.

It is important to stress that schemata are not a final, constructed product in the perceiver's mind. For instance, by constructing an anticipatory schema, the perceiver engages in an act that involves information from the environment as well as his own cognitive mechanisms. He is changed by the information he picks up. The change is not a matter of making an inner replica where none existed before, but of altering the perceptual schema so that the next act will run a different course. Because of these changes, and because the world offers an infinitely rich texture of information to the skilled perceiver, no two perceptual acts can be identical.

In addition, schema are overlapping; for instance, the 'going to a restaurant' schema and the 'going to a grocer's shop' schema overlap because they both contain the 'obtaining food' schema. It is certainly inadequate to think of schemata as a moderate number of large, non-overlapping, general frames or contexts in which specific knowledge is stored. Schemata include every possible pattern of attentional expectations and inferences from presented information. These patterns range from the highly specific to the very general, and the schemata expand, contract, and merge continually into different schemata, which in turn overlap their predecessors to varying degrees (Anderson, 1976, pp.444-46). Anderson's description is perhaps more aesthetic than scientific, but nothing less does justice to the capacity of the human mind.

We have discussed how people conceptualise information, some contemporary approaches to computer and real world information storage and retrieval, how information storage and retrieval is a form of problem solving based on memory, and how information is organised and interpreted in memory. However, the research subsequently described in this thesis examines the role of memory in information storage and retrieval applicable to the office. In light of this aim it is useful to draw parallels between a model of retrieval of information from memory (Shiffrin, 1970) and retrieval of information from a filing system.

2.7 'Memory Search' by R.M. Shiffrin: A preliminary comparison with initial field work

The conception of the memory search model to be presented here is along the lines of that of the earliest psychologists, that items of information can be represented by a certain probability of being retrieved from among the many items presented in a memory store. This model is quite close to our own introspections as to the nature of the act. It is thought that this type of memory search will provide a useful comparison with that involved in retrieval of information from filing systems and serve to organise thinking in this latter area. The model used in this case is R.M. Shiffrin's (1970) model of memory search. The comparison with filing behaviour is based upon a pilot survey of filing systems used to orientate thinking prior to the survey work described in chapter 3.

A prerequisite for any search is a collection of objects through which the search is to be made; in the present instance, the memory traces. These memory traces can be traditionally defined as a set of images or codes, where the structure of the images is a function of the current task being utilized. Each one of these images is assumed to be made up of sub-sets of items of information. The difficulty with this approach is that it is dependent upon the specific task and type of memory test being used; it would be preferable to define the search upon a collection of objects that would not have to be altered with changes in the task and type of memory test. The items of information making up an image are presumably inter-associated to some degree; it is these items of information which are considered as the objects upon which the search should be defined. These items of information could include all sorts of features of the image; its physical appearance, its context, its location temporally and spatially, and categorization and association with other images or information previously stored. These units of information which are stored together tend to be closely associated, so that they are usually recalled together - it is in this sense that they are termed an image. It is proposed for the Shiffrin model, however, that the search be based upon individual information pieces. To be precise, the search is defined upon some sub-set of informational units called the search-set. This search-set consists of smaller sub-sets of information which are the images, made up of closely associated informational units. The selection phase of the search process consists of selecting randomly one unit of information from the search-set, and then examining the image containing the unit drawn. Suppose there are n units of information in the search-set, and n1, of these units make up image A. Then the probability of examining A on the first search attempt is n1/n, the number of units in the image divided by the total number of information units in the set being searched. Thus the individual units of information are the objects through which the search is made, and not the images per se. Nevertheless, in practice it will often be convenient to talk of searching through a particular set of images, with each image having a 'strength' proportional to the number of informational units of which it is constituted. The probability of examining a particular image on a particular search is thus the strength of that image divided by the summed strengths of all the images in the set being searched; the rationale for this assumption should remain clear as long as the underlying model is kept in mind.

The units of information through which the search is made will be called 'I-units' and are presumed to have the same sort of existence as the stimulus elements in stimulus sampling theory (Estes, 1959). That is, it is not implied that all I-units are necessarily sampled with equal probability; however, if some I-units is twice as likely to be sampled as the others, we will conceive of it as two smaller I-units closely connected. The set of information through which the search is to be made is called the search-set and will have a strengh S = Si, where the sum ranges over all the images making up the search-set. The term 'draw' will be used to denote the choice of an I-unit from the search-set at a particular point in the search, while the term 'search' will refer to the recursive process in which many draws may be made.

A filing system can be thought of in a similar way. The whole filing system is analogous to human memory in that it contains many items of information. The so-called images, or traces, can be likened to the component files which make up the filing system, though the variety of information which they contain may not be as much as in the images of memory. This analogy of memory images and component files of a filing system is important.

When we want to find a certain piece of information in the filing systems we may well, by means of structural rules, narrow down the search area to a 'search-set'. At this level the naive user would probably sample individual items of information on a random basis to ascertain whether the file which contained it was appropriate to his needs, although he would have a rough idea from file titles. With the naive user the access of information from a filing system is similar to Shiffrin's proposed memory search model.

An experienced user of a filing system, however, develops certain rules of storage and retrieval, for example, chronological order, which provides him with certain cues for more efficient access of the required information. Here Shiffrin's model falls down, because a decision process leads the accessor to the appropriate file (image) which contains the required information. Again, within this file, there is likely to be some sort of structure providing cues to the access of the appropriate information item. Shiffrin's model suggests that items of information are selected at random from the search-set and then that the image which contains them is examined. This purely random sampling, would take a longer time than that apparent when we extract information from memory. It seems logical that memory structure must reach to a far deeper level than proposed by Shiffrin's model and that this structure is negotiated more easily the more familiar we are with a certain area of information. There is in filing systems, and must also be in human memory, some kind of meaningful structure whose various levels are accessed by a formal decision process, or algorithm. This decision process could be 'by-passed' in certain ways, especially with familiar information, to cut short the time involved in information retrieval. An example would be the role of spatial memory where the position of a familiar file is remembered, thus cutting short the formal decision process which would ordinarily be involved if information was being accessed via some hierarchical category structure.

As with the memory model, where the structure of the images making up the 'search-set' are determined by the current task objectives, the analogous group of files making up the 'search-set' of the filing system depend on the task objectives and the kind of information needed to fulfil these objectives. As with memory images the files are always chainging as more information is added.

In memory certain information is associated, to a certain extent, with other information, maybe in a temporal, semantic, or spatial context, amongst many others. In a filing system information is also associated with certain other information relevant to the same task objectives, or the same temporal situation: the file may contain very closely associated information in some kind of temporal sequence; a file containing an alphabetic list of employees has association between these employees by virtue of the fact that they all work for the same firm.

It is true that if an image is made up of more pieces of information than another it will have more 'strength' on a random sampling basis. Does an image have greater strength because it has more items of information, or is it that the strength is a function of how frequently the information is used? If an image is accessed more frequently there would be a well defined by-pass of the decision process involved during retrieval and the strength of the image could result from ease of access and not necessarily from the amount of information it contains. It is likely, however, that the more an image is accessed the more information it will contain, but this is not necessarily always the case. These points are directly relevant to filing systems. If a file is frequently used a person can, so to speak, put their hand straight on it due to their familiarity with the file and what it contains.

If information is dealt with as Shiffrin proposes in his model, the narrowing down of the search to the 'search-set' could be represented by an algorithmic decision process through the storage structure. Could it be, on the other hand, that we could define the 'search-set' straight away for familiar information due to some contextual association with incoming stimulus information, thus by-passing the information storage decision process?

Shiffrin then proposes that within this search set items of information are picked out at random and the image which contains them is reviewed to see whether it is relevant to the task objectives. The criterion for how much relevant information is needed is set by comparing the stimulus information with the task objectives; if the information accessed in memory fulfills this it is then retrieved, if not the memory search continues. This approach is similar to Miller, Gallanter and Pribram's (1970) TOTE unit theory, where information is tested against a criterion and more information is added until this criterion is fulfilled. This process seems too long-winded, however, compared to the speed and efficiency with which memory can operate. It seems probable that there is a very complex structured organisation of information in human memory. From our own introspection we can realise that familiar information is much more quickly retrieved than unfamiliar information, where we sometimes have to go through a conscious cuing and decision process to retrieve it from the storage structure. As with filing systems, there must be a way of by-passing the decision process defined by the storage structure in human memory for fast retrieval of familiar information.

It is conceivable that if information is stored hierarchically in memory then we must reach an end point in this hierarchy where the structure goes no further, whether this is at the category level where many items of information are contained or at the level of individual items of information remains to be seen. If the storage structure does end at the category level then random sampling for the relevant information within this category is conceivable, but this seems a very inefficient process and nature is not noted for its inefficiency.

Another question for debate is, how rigidly structured is the information store in human memory? It is possible that the whole of memory is a massively complex structure where all information is associated, ranging from strongly to hardly at all, in a vast network. On this network we could then impose our own structure depending on the demands of the task, so that imposed structure is envisaged as a function of information likely to be needed and anything vaguely related. This approach not only considers storage structure but it also puts an emphasis on retrieval structure imposed on information, and so it doesn't assume that the retrieval process is necessarily a function of storage structure. This approach accounts adequately for the difficulty in retrieval of certain types of information not often used. The reason for this could be due to the lack of a well-defined retrieval structure or 'action plan', and therefore the subsequent difficulty of accessing the desired information by a structurally defined decision process. If, however, we used certain information a great deal, a well defined retrieval plan would be available to impose on the stored information. The more a certain retrieval structure was used the less the number of decisions that would be necessary due to others being by-passed, enabling a more direct access to the information.

It is important to consider storage and retrieval structure separately because they are not necessarily the same. Bousfield (1953) showed that clustering appears in free recall and Tulving (1962) hypothesized that words are output according to the storage structure of long-term memory store, but this evidence only highlights retrieval structure, storage structure should not be determined from this. We can't determine storage structure without physically looking into the brain. Maybe it is the difference between storage structure and retrieval structure which causes the difficulty with access to certain information.

The reason we use filing systems is to compensate for our own inadequacy in retrieving large quantities of information from memory. As with memory we can easily retrieve familiar information, but with unfamiliar information we have to have a rigid retrieval structure to enable us to negotiate the storage structure and access the required information. In this situation the storage structure is well defined and is actually open to view and therefore easier to use, with information access more reliable than is the case with memory.

In imposing a structure on information in our memory we form categories; these categories will depend on the context in which information is sought which tends to bias thinking towards retrieval structure rather than storage structure. Although in filing systems we impose a basic storage structure which doesn't change, the retrieval strategy for particular information will depend on the context under which it is being sought. This difference between storage and retrieval structure will be dealt with later. To illustrate the effect of context; if we wanted information about a particular student we might well go to his/her personal file, but if we wanted information of students on a particular course we might go to the course file which would contain details of students taking part, including, maybe, the one formerly mentioned. This point is well illustrated in 'Zen and the Art off Motorcycle Maintenance' by R. Persig. Persig says that in categorizing things in a certain way we apply an analytic 'knife' and that the way this 'knife' cuts up reality determines how we view a situation. For example, a motorcycle can be viewed in terms of its components or in terms of the functions which these components carry out. When a person creates a filing system he is, in effect, 'cutting up' reality in his own particular way; and when he imposes a certain retrieval structure it depends on the context of the search as to the nature of this structure.

Just how much a personal filing system represents the structure of human memory is debatable, because a filing system compensates for the inadequacy of retrieval of certain information from human memory. Tulving and Pearlstone (1966) discovered that there is a lot more memorized material available at the time of recall than is actually accessible, although this was found in experiments using only words. It is a possibility that every sensory experience that we have ever had is locked away in the dark depths of memory but unable to be retrieved until particular cues unlock them, otherwise they are in effect forgotten. However, the conventional view of sensory register, short-term memory, long-term memory, implies that some selection of information to be transferred to short-term memory operates, and so not all sensory experience is stored. This short-term, long-term memory approach should be compared with the approach in 'Attributes of Memory' by Peter Herriot. Herriot proposes that all information is coded and that this occurs to different depths or levels of coding. This approach puts emphasis on the processes of memory rather than the structure as in the former case (see Herriot, 1974, pages 6 and 7), and so it is better to talk about long-term and short-term storage and not memory. Of interest to us here, is the comparison between long-term storage in memory and long-term storage in filing systems.

In Shiffrin and Atkinson (1969) it was proposed that long-term storage in memory was indeed a permanent repository and that information once stored is never lost. This fits with Tulving and Pearlstone's (1966) availability versus accessibility argument without favouring the argument that all sensory experience is stored. Shiffrin and Atkinson ascribed the observed decrements of performance over time and intervening items to failure in the retrieval system (search process). Shiffrin (1970) later says that the retrieval process is likely to be the same whether or not permanent forgetting occurs, however, and that decrements are due to retrieval failures and forgetting. The latter part of this argument is credible, but to say that retrieval processes are the same whether forgetting does or does not occur is too much of a sweeping statement in the light of such a lack of evidence. When we want to remember something that has been partially forgotten we think harder and try to throw up associated cues to lead us to the information we seek. It can't be said that in a filing system, for instance, the retrieval process is the same for information whose location is not well known, although the structure may be the same in both cases.

2.7.1 Stages of retrieval

The term retrieval shall be used to describe the entire process of information recovery and possible response production, from the inception of the test to the end of the allowable response period. This process shall include initial decisions concerning which memory store to examine, whether to guess without any search whatever, and where in the memory store to begin the search. If a decision is made to initiate a search, a recursive procedure then begins, shown in figure 2.8.

First a search-set is selected on the basis of such factors as the stimuli or cues provided in the test, the overall task, and the strategies of the subject. From the search-set an I-unit is randomly selected and considered; this random selection is one of the weaknesses of the model because it is more likely that some strategic decision or certain cues leads to the appropriate image. If appropriate the information is recovered and is used in any other series of decisions; these include, whether to respond, what response to give, and whether to continue the search. If the search is continued, then the recursion loops back to the executive decision maker for possible selection of a new search-set and continuation of the process. This basic model is quite useful to compare with the process of retrieval of information from a filing system.

1) This recursive step lies between perception and response.

2) Similar approach to Miller, Gallanter and Pribram's response selection.

3) It could be that the less well known information requires more recursive steps.

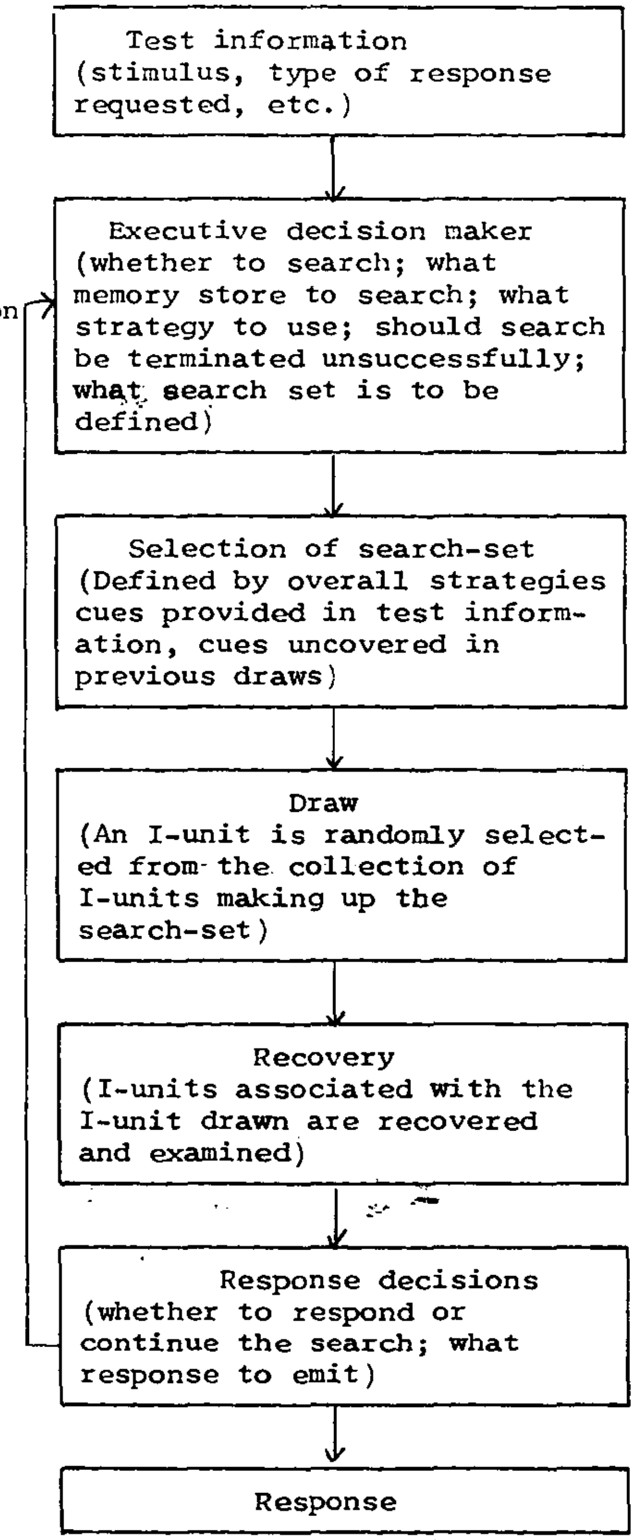


Figure 2.8: Shiffrin's recursive model of memory retrieval

The search scheme described here is quite obviously sequential, or serial, rather than parallel; just one image is examined at a time. The primary justification for adopting this view, apart from quantitative comparison of specific models, lies in the nature of the input and output systems. Information input to and output from the system is monitored primarily by short-term store which at this time was considered verbal-auditory in character, and our verbal-auditory system seems to operate in an intrinsically sequential manner. This is not a good reason for serial search, however, because the memory search is primarily of the long-term store (deeper forms of coding as opposed to a structural approach is favoured). Although input and output may be sequential it does not necessarily follow that search through the long-term store must be sequential; it would be more efficient if it was parallel because of the potentially unlimited amount of information available in long-term storage compared to short-term storage. This argument is taken up at a semantic level with visual recognition of letters, between proponents of parallel (e.g. Neisser, 1967) and serial (e.g. Sternberg, 1966) processing (see Herriot, p.144 and Norman, p.383). However, the sequential model is appropriate for comparison with filing systems because storage and retrieval of information in them is a sequential process.

2.7.2 The Executive Decision Process and response decisions

The decision phases of retrieval are treated under a single heading because response decisions are actually a particular subset of various executive decisions. The response decisions refer to some sort of comparison of the currently recovered information with a standard, a comparison on the basis of which the subject decides two things: whether he has recovered sufficient information to give the desired response, and what response to give.

The executive decision routine initializes the search recursion by choosing whether to search memory, and then choosing the appropriate memory store. In this case, because of comparison with filing systems, only information stored in the long-term store will be considered.

Another initial decision to be made is what the overall strategy of the search will be. These strategies all involve decisions to alter the search-set during the retrieval recursion in a pre-set and systematic manner. Other strategies could be adopted by determining how many draws to make in a particular search-set, or in general, what stopping rule to use. The most apparent factors governing termination of search are the expiration of the allowable response time, decay of the information in the memory stores, and recovery of the desired information. The first two are self-explanatory, but the final one depends on some criterion as to what is desired information: if, for instance, information is needed very quickly then the criterion is likely to be set lower, thus increasing the error probability.

The concept of an executive decision maker can be applied to the retrieval of information from filing systems also; we need to know whether to search, where to search, what strategy to use, and whether to terminate the search unsuccessfully and search somewhere else. It is necessary, however, that we obtain the desired information from a filing system with as close to 100% accuracy as possible, because the information may be crucial to the efficient running of an establishment and mistakes may cost a lot of money.

The strategy adopted in searching a filing system is of importance, whether it be an algorithmic decision process working through the formal structure of the system, or whether this be bypassed in some way by using memory of locations within a system, it must lead successfully to the required information.

The termination of search within a filing system depends on matching the retrieved information with a set criterion which in turn depends on the requirements set by the stimulus situation as to how much information is needed to formulate an appropriate response.

2.7.3 Selection of the Search-set

A search-set is selected at the start of each loop of the search recursion. The selection of the search-set lies at the heart of the retrieval process; this selection depends on certain factors:

1) The task set for the subject.
2) The response required.
3) The clues or stimulus information given in the test.
4) Information previously recovered in the search.
5) And overall strategies and biasses by which the search-set is systematically altered from one loop to the next.

These factors apply to filing systems in much the same way as they do for memory. The task set for the subject defines the search-set in terms of the overall objectives of a retrieval situation; within these objectives the required response in relation to given stimulus information further defines the search-set. If information previously recovered is similar to that required then this will provide clues as to the definition of the appropriate search-set depending on the amount of association between that previously obtained and that required. This latter factor is also important in contributing to the bypassing of certain levels in the algorithmic decision process associated with filing structure; in other words, the more experienced someone is with a filing system the quicker the search-set will be defined with few decisions, thus speeding up access to the required information. Speed and efficiency of information access will also depend on the overall strategies and any biasses that these or the person using them have towards the stored information. The strategy used by someone who is inexperienced with a certain system is likely to be different from that of an experienced person. The strategy of the inexperienced person is likely to be defined to a great extent by the filing system structure, whereas with an experienced person their strategy is likely to promote as much bypassing of levels of decision as possible. With experience, however, there is likely to be more bias towards certain types and locations of information. It is important, when designing a filing system to bear in mind the main type of information likely to be handled.

An extremely important mechanism governing the selection of search-sets in memory is based on temporal cues, that is, the search-set is defined so as to be delimited in time. Temporal cues do operate in filing systems but not usually at the search-set level. If we take our analogy where the images that make up the search-set are the individual files, then often within these files, items of information are stored in chronological order, usually that of being received. At this level temporal cues can be considered in relation to the spatial order of information and can thus act to reduce the amount of searching needed within a file. In memory the older the information the more difficult is its retrieval and also retrieving it in its original form. This does not necessarily apply to filing systems as the information, once stored, does not alter with time. What does change with time is the spatial memory associated with that information, unless the information is used a lot, and this makes retrieval more difficult. If spatial memory fails then a decision process takes place to narrow the search down to possible logical locations of the information.

The decision process involved in locating a piece of information is mostly located in the 'executive decision maker'; testing of the stimulus information takes place prior to this stage, and the actual selection of the search-set takes place after. It is within the 'executive decision maker' that I propose short cuts between stages of the decision process takes place, mainly due to spatial memory.

2.7.4 Application of the memory search model to a practical example

It is useful to have an example of actual retrieval from a personal filing system so that the proposed model can be fully understood.

A memo could be received, for example, requesting information on how much money was allocated to a particular project at a particular financial meeting. Stimulus information would include; the title of the meeting, the date on which it took place, the name of the project, and possibly the people involved, who wanted the information, and for what reason it was wanted. From this information the person involved could decide on the desired response and how urgent it was. For the naive user the decision process would be something akin to the following:

Question: Where is the information recorded?
Answer: In the minutes of the meeting on .... date.
Question: What general location are these likely to be in?
Answer: Probably in the administrative section of the filing system.
Action: Locate Administrative section.
Question: What file is the information in?
Answer: Financial meetings file (found by either looking through an index or by scanning the files in the administrative section).
Note: The strategy adopted to locate this file would depend on whether the files were arranged alphabetically or just in any order. If arranged alphabetically the general location of the file could be narrowed down by considering the title of the file and comparing our internal model of the alphabet with the spatial layout of the files.
Action: Locate and remove file if title found from index, or remove if found from scanning files.
Question: What is the location of the relevant minutes of the meeting within the file?
Note: Assuming the minutes of the meetings in the file were arranged in chronological order between

certain dates, then cues as to the spatial location of the relevant minutes would be provided by consideration of the relative position of the date of the desired meeting to the range of dates covered by the file.

Answer: At location Y (may be approximate).

Action: Retrieve (if inappropriate a recursion back to the 'executive decision maker' would then take place and the procedure would be repeated until the right information was obtained).

The experienced user would know which file the relevant document was in and its precise location, and so he could, so to speak, put his hand right on it. He would still have to employ the search strategy, within the file, however. This illustrates how certain levels of the decision process can be bypassed through the use of spatial memory, once the nature of the desired information has been decided upon. The 'executive decision maker' is involved in the decisions between deciding what information is required and the selection of its precise location (this could involve recursive steps if the precise location is not found straight away).

2.8 Discussion

2.8.1 A framework

The aim of the literature survey has not been to provide an in-depth survey of the cognitive ergonomics of man-computer interaction, or information storage and retrieval, or human memory. Rather, it is intended to provide a framework of understanding within which the subsequent experimental rationales, experimental designs, results, and discussions can be fully understood. Furthermore, it relates findings to the more general context of human conceptualisation of computerised office information storage and retrieval systems; the main emphasis being placed on the memory models upon which human conceptualisation is based. Therefore, the progression moves from a general appraisal of a conceptual framework of typical computer interaction, followed by an outline of the relevant cognitive processes and their interaction with the environment, to a more specific review of human memory within the information storage and retrieval context. The survey culminates with a detailed assessment of a model of human memory search in conjunction with findings from a precursory survey of office filing systems; the aim being to reinforce the contextual link between the two.

Probably the most important point which arises from the survey is that the storage and retrieval of concepts by the memory processes is highly organised in a hierarchical manner; concepts within concepts, words within sentences, images embedded within images. Also, the processes of internal storage and retrieval of information operate in a systematic manner according to stored strategies, plans, and rules; hierarchic control being much evident. It is of major interest to discover how this internal organisation of information is related to the way in which we perceive the world.

However, care has been taken not to become too specific with the discussion of relevant literature. The reason for this is that much psychological research provides theories which are very similar in general terms, but often in considerable conflict concerning specific details. If we were to review all the various debates about unresolved inconsistencies in experimental data we would totally confuse the issue and not fulfill our primary objectives. Where necessary, however, specific detail has been dealt with in the literature reviews accompanying the experimental work subsequently discussed. Two large areas which have been left out for the sake of clarity are short-term memory storage and attributes of encoding.

2.8.2 Short-term memory storage

In any theory of memory we must account for the short-term storage of information (Broadbent, 1958). However, we have paid scant attention to this aspect of memory, except as part of the conscious sequential processor of the cognitive processes (see figure 2.2). This is because subsequent experimental work is more specifically concerned with the long-term storage of conceptual models. For our purposes, short-term storage will be regarded as an 'action memory' (Posner, 1973). Action memory fulfills the functional need to consciously bring together stimulus information from the environment, and relevant information from long-term memory storage, to be 'worked on' by the cognitive processes to achieve some aim.

2.8.3 Attributes of encoding

Although we have dealt with the many different concepts stored in memory, we did not specifically review the many attributes by which these concepts are encoded. A very useful review of the attributes of encoding is provided by Herriot (1974), who deals with the physical attributes of short-term storage through to the more abstract attributes of long-term storage.

The general issues discussed in the literature survey deal with conceptual implications pertaining to man-computer interaction. However, the more specific appraisal of memory does not, thus necessitating further discussion.

2.8.4 The implication of memory characteristics relating to computer interaction

i) Semantic memory:

Computer information systems can be based upon databases and language structures (section 2.2.2.3) similar to the structure of semantic memory previously discussed (section 2.5.1). If system data organisation is compatible with that of conceptual organisation in semantic memory, it may serve to enhance the conceptual interaction between man and computer. Some form of semantially structured index could be useful here, so that users are explicitly aware of the global semantic organisation.

ii) Imagery (section 2.5.2):

Image mediation of verbal concepts carries many implications for the development of an effective software interface. In addition to language and formatting considerations, simulations and analogues of traditional information systems could be an important aid to the conceptualisation of computer functions and processes for naive users. Also, the dual coding hypothesis implies that we could reduce the computer user's verbal processing load by displaying pictoral or graphic representations of information. We would do well to remember the adage that "a picture is worth a thousand words".

Spatial imagery obviously plays an important part in our conceptual model of our real world information environment. On a computer, however, this is reduced to a partial view of the information environment through the two dimensional "window" of the VDU. Consequently, people find it difficult to "navigate" about the database, especially as they do this in terms of abstract modified verbal codes. If ways could be found to reproduce a simulated "spatial environment" on a computer, it might be of benefit to naive users in terms of accessing information; they would have a concept of "where" instead of trying to remember appropriate verbal codes.

iii) Episodic memory (section 2.5.3):
Episodic memory stores information about the fact that we, for instance, stored a piece of information in a particular file. This information source could be enhanced by storage and retrieval aids which keep a log of instances of information storage and retrieval. However, this raises as many design issues as the database storage and retrieval of information.

2.8.5 Implications for further research

With respect to the literature review, it is evident that memory plays a central role in formulating a conceptual model of computer interaction. It is important to understand the relationship between internal and external organisation of information, and what effects they have on each other. Only by doing this can we arrive at a computerised filing system optimally organised to suit the naive users conceptual apparatus.

However, it is also apparent that the way we conceptualise information is also dependent on the task it facilitates. Therefore, the immediate priority, within our context of office filing systems, must be to investigate the nature of information organisation in the office. This is necessary so that we do not overlook present conceptual needs with respect to office information organisation and thus direct thought within an inappropriate context.

3. A SURVEY OF ASPECTS OF INFORMATION HANDLING IN THE OFFICE ENVIRONMENT

47 pages
nuo = 23

3.1 Introduction

The aim of this first stage of the research programme was to examine the role played by human memory in the filing of information in a practical context; these results could then be used to form the basis of recommendations for the development of future computerised filing systems.

As a precursor to the literature review in chapter 2, a study of previous research in the area of human memory was undertaken. Due to the lack of context at this stage, however, it was very difficult to relate findings to conventional information storage and retrieval; the real issues relevant to the office filing environment were not appreciated. It was evident, therefore, that a field survey of information handling in the office environment should be made.

The primary objective of the survey was to provide a broad base of information relevant to office filing practice. It was important to discover how people organised their information in a 'real world' environment. Also, the survey was needed to provide a fresh and relevant context for reviewing the previous laboratory research concerned with human memory and to generate ideas for subsequent research.

A prime consideration at this point was the specific technique that was to be used for collecting the desired information.

3.2 Formulation of an appropriate survey technique

The initial step in gaining the required type and amount of information, from a survey of office information organisation behaviour, was to decide upon, and develop, the appropriate tool, a structured form of asking questions.

This required first the generation of valid questions, and second a decision as to the form in which these questions were to be put to the people surveyed. However, these stages could not be carried out independently of the appropriate context. Therefore the correct approach necessitated an initial familiarisation with the office environment and the type of storage and retrieval of information which took place. For this reason an initial observation period was decided upon, followed by the generation of appropriate questions. The form in which these questions were to be put to filing system users could then be finalised by means of a pilot study.

3.2.1 Observation period

The observation period procedure consisted of informal conversation concerned with how people stored and retrieved information. Of particular interest was the type of job that each person was doing, the type of information they handled, and the strategies employed in storing and retrieving information. A note was taken of any important points. The people involved were various members of the Human Sciences Department of Loughborough University.

3.2.2 Question generation and initial formatting

From information gathered during the observation period, as many valid questions as possible were generated and written down. Broadly speaking, the questions were concerned with filing system use, the type of information, the organisation of information, and storage and retrieval behaviour. These questions were then reviewed and simplified: duplications and minor items were eliminated, and closely related topics were combined.

The original intention was to combine the questions in a structured questionnaire requiring yes/no answers. However, it soon became apparent that it was perhaps not the best way to obtain fundamental information concerning personal filing systems. A questionnaire of this type is very constraining, especially in a hitherto unexplored area, by putting pressure on people to make a choice between limited alternatives without being able to qualify their choice.

The acquisition of information in line with the objectives previously stated, would be facilitated by open-ended questions rather than those requiring yes/no answers. It was important, however, to have a structured approach to the collecting of information, because people would only be willing to give up a certain amount of their time to answer the questions.

Therefore, a structured interview approach was decided upon, this would involve the interviewer putting a number of preconceived questions to each respondent. Each question, though being designed to elicit the desired information from the respondent, would also act as a prompt to the interviewer in steering the answer along the desired path. Another point in favour of this technique is that it is much more personal, putting the respondent at ease, and likely to maximise the amount of information elicited.

Initially, the format of the questions was such that those of similar context were grouped together. The next stage was to undertake a pilot study to finalise the form of the structured interview and smooth out any problems that might arise.

3.2.3 The pilot study

The pilot study was carried out using a diverse group of six people. The group consisted of a university administration assistant, a university professor, two university lecturers, a secretary, and a woman in charge of a citizens advice bureau. The object was to try out the structured interview on people using a range of different job types. An indication of the appropriateness of the structured interview approach could then be obtained, with a view to a subsequent full-scale survey.

Based upon general advice in the literature, a number of guidelines were established for the interviews of the pilot study. These guidelines were considered to be important both for acceptance of the interview by the people involved, and with respect to the validity and reliability of questions. The guidelines adopted were as follows:

1) The order in which the questions were asked was of importance because the interviewee must be able to see the logic in the progression of questioning.
2) The questions had to be valid with respect to the research context.
3) Questions had to be as unambiguous as possible, and seen to be relevant and to the point. Involvement of the interviewer in clarifying certain points is a useful feature of the structured interview technique.
4) Some consistency in the type of answer obtained had to be achieved; answers should not be too limited by the question, neither should they be totally open to interpretation. Here again the interviewer can play an important part.
5) If the interviewees were given a choice of alternatives they should also be given the chance to elaborate upon the choice made.
6) The whole interview should not be too long, not only would this cause boredom it would also impose upon peoples' working time to too great an extent.
7) People should not feel threatened by the questions. They would not respond well to a situation where they felt they were being assessed on whether they were doing things correctly or not. A certain amount of this type of question was inevitable, but the phrasing and delivery could make a difference to the way in which people reacted.

As a result of the pilot study, with due consideration of the above guidelines, questions were deleted or changed, and the format of the structured interview was finalised.

It was considered that, in addition to the structured interview, a standard task undertaken by the interviewees, using their own filing system, might be a useful way of stimulating them to think of their storage and retrieval strategies, common errors made, and any idiosyncracies that were a part of their filing system. This, however, was soon found to be infeasible. The diversity of peoples' filing systems, both in structure and degree of complexity, was such that this approach was rendered impossible. The interview period would also have been extended. It was therefore decided that people would have to answer questions on their strategy of storage and retrieval by means of their own introspections during the interview.

Therefore, it was concluded that the survey should be conducted by means of a structured interview alone, the details of which are discussed in the following section.

3.3 The structured interview survey

3.3.1 Format

The final format of the structured interview can be seen in appendix 3.1. The interview can be broadly divided into two: the first part deals with basic considerations and general structure apparent in a filing system; the second part deals with aspects of information storage and retrieval. This format presents the most logical progression of questionning, from filing system structural considerations to functional considerations.

3.3.2 Subjects

The subjects consisted of 15 computer professionals and 15 non-computer professionals. The former were all drawn from a large computer corporation, whereas the latter all held posts in various local government departments. A representative cross-section of occupations were surveyed in each group.

Computer professionals are specifically trained to think in a logical and structured manner compared to the non-computer professionals used in the survey. Also, the nature of their employment differs. The computer professionals tended to work fairly independently on specific projects, whereas the non-computer professionals were part of a highly structured organisation (the local authority) with well-defined responsibilities. How these differences affect the way in which the two groups structure and use their personal filing systems is of major interest.

3.3.3 Approach to the subjects

The computer professional subjects were obtained through close contacts working for the large computer corporation concerned. Each person was given a typed sheet explaining the objectives of the research and the reason for the interviews. It was stressed to each subject that each interview would be treated as confidential and that no names would be mentioned.

The non-computer professionals subjects were obtained by writing to the personnel officers of two local government establishments. In each case, the letter outlined the research being done, the time involved, and the fact that interest was not in specific information but how it was organised. Again, confidentiality of information was stressed.

The approach used to subjects of both groups aimed to gain their confidence and allay any suspicions that they were being assessed.

3.3.4 Results collection

The interviews took place during the period of December 1978 to March 1979. There were various delays due to fluctuations in the workloads of interviewees, which tended to extend the period somewhat. Each interview was planned to take about half an hour, but in practice this was found to vary greatly. Different people were stimulated into discussions of differing lengths, in fact some interviews went on for an hour and a half.

3.4 Discussion of results - the aims

In discussing the results of the structured interviews, each question will be dealt with separately. Firstly, the reason for asking the question will be discussed, followed by the answers given. Finally, these answers will be considered in the light of what people do in the 'real world', their implications for the design of computerised personal filing systems (emphasis being on the design for non-computer professionals), and in relation to any other relevant questions in the interview. It should be noted that the results of the survey are intended to provide a broad basis of information from which more specific questions can arise, not to provide a definitive appraisal of personal filing systems behaviour. The results of the interview survey, and the discussions of them, will now be dealt with in this context.

3.5 Stage 1 - Basic considerations and general structure

3.5.1 Job description

The type, quantity, and complexity of information that a person has to handle is related to the nature of their job. Someone who is responsible for many projects, with the accompanying financial aspects and the people working under him, is obviously going to have a greater need for information organisation than someone involved with one aspect of a project. In asking for a description of someone's job one can obtain some idea of the information load. It is not possible, however, to make definitive correlations between job description and other information generated by the survey; this is due to difficulty in quantifying respective correlates. What is possible is a general appraisal in this sphere.

The 15 non-computer professionals, with comments made on the type and complexity of their information usage, are listed as follows:

a) Chief conveyancing assistant - responsible for supervising other conveyancers in dealing with the legal aspects of land transactions. Much reference must be made to legal books, many legal documents and correspondence has to be stored. Keeps own files and interacts with central filing. Though he does not keep a great quantity of information it is fairly complex.

b) Administration assistant to the entertainment manager - mostly administrative and advertising information is kept.

c) Chief auditor - keeps many files on the finances of all departments. The files are coded. A complex system.

d) Safety Officer - responsible for all safety issues and so has to keep many details of all aspects of safety arising in the local authority. A fairly complex system.

e) Training officer - has to keep details of all training courses available and staff that undertaken them. A moderate personal system.

f) Manager of O & M and work study - has to keep many details of all aspects of the work of local authority employees. Tries to keep as many as possible on a moderately large departmental filing system.

g) Assistant county personnel officer - especially responsible for training. He interacts with his own small filing system and a large departmental system.

h) Chief quantity surveyor - in charge of a section of approximately 20 people and deals with the financial and legal aspects of projects. Has own moderate filing system and also interacts with central filing.

i) Waste disposal officer - responsible for all aspects of county waste disposal. Has a moderate filing system of his own and also interacts with central filing.

j) Manager of O & M for county - does much gathering of facts. Interacts with own small filing system and a large departmental one.

k) Chief administration officer of country secretaries department - is a legal adviser to the county council and is responsible for taking information at meetings. Keeps some information of his own, but also frequently interacts with central filing.

l) Principle assistant administrator - keeps a large amount of information mostly on a large formal departmental filing system of his own design.

m) Divisional planning officer - apart from the usual type of information she had to keep chests of maps and plans. The filing system was not particularly elaborate and of moderate size.

n) Deputy health and safety officer - much factual information has to be kept on a fairly large indexed system.

o) Manager of a leisure centre - had a mostly administrative role. Used a moderately sized filing system.

N.B. Much local government information is kept upon a very organised central filing system, or on departmental filing systems. The reason for this is that many peoples' work overlap, and also information has to be kept because local authority is publicly accountable. Interaction with these additional formal systems is slightly different that takes place with personal files, due to more structuring of information being evident.

The fifteen computer professionals and the type and complexity of the information they handle are as follows:

a) A writer of hardware and software customer manuals - used a moderately sized filing system, however, the information contained was very com[illegible]

b) Manager of product publications - also involved in writing manuals. Kept some technical information but most of the administrative information was filed by his secretary in her office.

c) Computer system researcher - had a fairly small filing system characteristic of someone responsible to a project chief and does not get involved in administration.

d) Support line manager (personnel) - had to keep much information concerning people. Information was kept and dealt with through a secretary.

e) Secondment to management development running courses for managers on site - a moderate filing system with information concerning people and their training.
f) Hardware product engineering manager - mainly project progress and technical information kept in a moderately sized filing system.
g) Systems evaluator - much measurement and technical information kept in a fairly large system.
h) Research professional - used a fairly small filing system, mainly due to the specific nature of work and lack of communication needed with other people.
i) Administration manager - the filing system was not very large but it contained a wide variety of information. A secretary helped with the filing.
j) Project leader for software development - used a moderately sized filing system.
k) Manager of scientific centre - had a large filing system containing complex information. A secretary helped with the filing.
l) Systems evaluator - used a moderately sized filing system.
m) Senior scientific centre staff assistant - again a fairly moderate size of filing system.
n) Manager of product development - had a fairly large and complex filing system maintained by himself and a secretary.
o) Financial analyst - had a filing system of moderate size, containing mostly financial information.

N.B. In addition to their personal systems, the computer professionals also had access to an archive system and computer storage facilities.

One of the major problems encountered when surveying filing systems was that it proved impossible to establish criteria for objectively describing and comparing their size and complexity. The reason for this was not only the large variation in these parameters, but also because there was a large variation in the type of information and the tasks to which it contributed. As a rough guide, however, a moderately sized system can be thought of as a desk, with draws, a filing cabinet, and perhaps some shelves for miscellaneous items.

3.5.2 Why is it necessary to keep information?

This question was asked to discover peoples' conceptions of why they kept information, and to gain an insight into their view of the role that the information played in their job.

Listed are typical reasons for keeping information along with the number of times that each was given. Also listed are typical comments that were made.

Reason	Occurrences NCP/CP*
Records kept for reference, to see what has happened, to see what should happen, to enable follow-up, or to enable future planning.	12/16
To make information available to other bodies, other departments, or other people.	5/3
To enable report writing.	2/2

* NCP = Non-computer professional
  CP = Computer professional

Typical comments made by non-computer professionals were: 'I need to keep information to assist my job'; 'I cannot remember all the information needed to carry out my job'; 'If I was off ill someone else could do my job'.

Typical comments made by computer professionals were: 'my filing system serves as a memory aid'; 'there is a need to organise complex information'; 'need information for a back-up'; 'can learn from information and build up a basis of knowledge'; 'need to have access to the information'; 'need information to keep the system running'; 'need to produce reports for other people'.

Approximately 63 per cent of the comments made by the non-computer professionals, and 76 per cent of those made by the computer professionals, saw their filing systems primarily as a source of information for personal references. This is interesting as most of the people interviewed had to make information available to others in some form. Only approximately 36 per cent and 23 per cent, for the non-computer and computer professionals respectively, saw their filing systems as a basis for supplying others with information. The computer professionals seem to view their filing systems as more for their personal use than the non-computer professionals; this might be because local authority employees are more accountable to the public, through bureaucratic channels, than are the computer corporation employees. In the design of personal computer information systems, the amount of required communication needs to be given much thought along with all the confidentiality issues raised by it.

From some of the comments made it seems that filing systems are seen as an external extension of internal memory, concomitant with this is the need for information organisation. This raises the question of whether the external information is organised in a similar way to our internal memory, or whether the external information organisation is imposed upon internal memory organisation. Obviously the latter case would give more scope to any computerised information storage schemes, because we can, within reason, expect internal memory to adapt. By 'within reason' I mean giving consideration to the individuals available set of conceptions; these will be different for computer professionals than for non-computer professionals.

3.5.3 Basic considerations

i) Is certain 'action' information kept outside the filing system for matters being dealt with or to be dealt with? Where is it kept?

Although people keep information in a filing system, while it is in there they cannot work with it. It was of interest to find out whether they kept some information separate to their filing system and where it was kept. All the computer and the non-computer professionals kept information being worked on outside their filing system in numerous ways. A list of methods observed follows; it should be noted that often combinations of these were apparent.

a) In tray (sometimes with an out tray) - usually in the form of a wire basket.
b) Piles of information - information being dealt with or to be dealt with was often kept in drawers, piles on desks, tables, chairs and even floors.
c) Notes on pieces of paper or notice board - often people would make a list of things to be undertaken in the near future.
d) Diaries and year planners - these were used to make notes on things that had to be undertaken in the near and far future.

There was a wide variation in the amount of 'action' information kept outside the filing system. The range varied from a list of jobs to do next day, to piles of information in locations all over the office. The main point to be considered is that all this information, or its relative location is present in the 'real' environment at the same time and can be directly related to. The interviewees could, frequently, remember that a particular piece of information was approximately half way down a certain pile, even if we only had a vague idea of its context rather than its exact content.

An 'action' information facility could easily be provided in a computer filing system. In this situation, though, information is kept inside a 'black box' which is viewed through a VDU 'window'. Only part of the information can be seen at any one time and so it is hard to relate to it as a whole. In 'real world' terms the computer storage provides an inadequate cognitive model of the information and its relationships. This point is important because it is unlikely that the 'action' information would have been arranged in the formal structure of the main filing system and so would have no cognitive relational model, thus making retrieval difficult. An 'action' information facility on a computer would also have to be very flexible in terms of capacity; there are differing tendencies amongst people to keep 'action' information and different work load demands from day to day.

ii) If 'action' information is kept, is it material just received or is it mixed with relevant documents retrieved from the system?

The relationship that 'action' information has with the main filing system is important. Is a two-way flow of information required or just a one-way flow into the system? Of the 15 non-computer professionals 11 said that their 'action' information was mixed with information retrieved from the system, compared with 6 out of 15 computer professionals. This reflected a tendency for computer professionals not to leave information lying around. In fact the computer corporation involved operated a 'clear-desk' policy for security reasons, which was a reason for only keeping out of the system that information not yet filed.

It seems apparent that a two-way link between incoming information and that already filed would be necessary for efficient computer information system use.

iii) What are the important factors dictating the amount of time spent filing?

It is important to know the factors that dictate the amount of time spent filing. With this knowledge a system can be tailored to the needs of a specific person. The various types of answers obtained, and the number of times encountered, are as follows:

a) Filing depends on the priority of the work, some can be left (routine unimportant items).
NCP = 2 CP = 2

b) As little time as possible is spent filing.
NCP = 5 CP = 7

c) Constantly updating the filing system (varying from as work is finished, to a regular spot each day).
NCP = 6 CP = 2

d) Depends on the quantity of accumulated information.
NCP = 2 CP = 1

Only a small proportion of non-computer and computer professionals seemed to assign priorities to work with respect to need for filing. This suggested that the importance of work was not a criteria often considered in whether filing should take place. A third of non-computer professionals, and almost one half of the computer professionals, felt that they wanted to spend as little time filing as possible, probably because filing is usually considered to be boring. Time availability becomes even more important when a person is busy and has little spare time. Following on from this, it seemed that the non-computer professionals had a greater need to constantly update their filing systems compared to the computer professionals. This difference is likely to be due to the fact that it is much more important for local government employees to keep records than the computer professionals, as they are publicly accountable. A small number of computer and non-computer professionals said that they only filed information when it built up to a certain level, in some cases this meant when there was little room to store any more outside the filing system.

There was a general impression that filing information was unpopular and that the less time spent involved in it the better. Time seemed to be an important constraint. Usually the time spent filing was indicative of the amount of organisation apparent in the system; the less time spent the less the organisation. The amount of filing of information also seemed to be related to the demands of the job; a manager handling much information usually had more filing demands compared to someone carrying out research.

When designing a computerised filing system it would seem valuable to have the computer do as much of the filing as possible, or to have a quick, non-laborious method of entering information. Care would have to be taken, however, that these considerations did not cause the user to lose track of the information and consequently find it difficult to relate to and retrieve. It would also make sense either to tailor systems to job demands or to have them flexible enough to cater for many different types of demands.

iv) Does a secretary help with the filing?

If a secretary helps with the filing another mediating step is introduced between dealing with information and storing and consequently retrieving it. A person's cognitive model of the filing system would not be as extensive in this situation unless, as sometimes happens, they interacted with the system also. The more a person acts through a secretary the more remote they become in relation to the storage and retrieval of the information. Ideally both secretary and manager should be as efficient in retrieving information.

Four non-computer professionals and six computer professionals either had a secretary or had access to one. Usually managers had their own. The usual procedure in using a secretary was to identify the file to which a piece of information belonged and let the secretary put it away. In the extreme this could result in the boss knowing which files were needed but not where they were; the secretary would always have to be present in this case. In practice people using a secretary had at least a partial cognitive model of where the information desired was located. This could be achieved either by using the filing system in the same way as the secretary did, or by working through some systematised plan of the system. Confusion arose when the secretary's and the manager's cognitive models of the system were different, especially where files were similar in context.

Any computer system used by a secretary should be duplicated for her manager. Their storage and retrieval strategies should ideally be the same, otherwise information might go astray.

v) Do other people need to use any, or part, of the information and is the filing system, or relevant part, designed with this in mind?

The user of a personal filing system will be well acquainted with its basic structure, layout, and idiosyncracies. However, if someone else needed to use the information it would be very difficult for them to retrieve information unless the storage strategy was readily apparent.

Of the non-computer professionals, 11 said that other people needed to use their information, but only 7 said that they designed the system with this in mind. Of the computer professionals 8 said that other people needed to use their information, but only 4 said that they designed the system with this in mind. It can be seen that in a significant number of cases other people needed to use some of the information in someone else's personal filing system. This is more apparent with the non-computer professionals because jobs in the local authority overlap to a greater extent. It can also be seen that users do not always design their filing systems with others in mind. In these cases people either have to search around for the required information (perhaps making guesses as to the storage strategy) or mediate through the owner of the filing system who can locate the information.

If others have to use a computerised filing system, apart from security considerations it is better not to have a system so personally organised that information cannot be retrieved by them. Ideally, the strategy of storage should be readily apparent for efficient use by other people.

vi) Is the filing system design with a specific retrieval plan or retrieval plans, in mind?

This particular question was designed to discover to what extent people consciously organised their filing systems, and whether the organisation had to be elaborate to make the system workable.

A significant proportion of those interviewed, 13 non-computer and 12 computer professionals said that they designed their systems with a specific retrieval plan in mind. The amount of organisation varied from simply putting information in an appropriately labelled pile, to numerically indexed systems. The most organised systems were those of people with fairly high level managerial responsibilities. Their systems were divided up into general areas dealt with, and within these areas each file was given a number and a title. On the corresponding index files were listed in numerical order, but not alphabetical order. This made it easy to add new files but meant scanning the index for the number of a desired file so that it could be retrieved. The lowest level systems merely consisted of putting information into a labelled file and this into a location. Retrieval in this case meant either scanning for or remembering the location of a file. In between the previous extreme types of filing system there were systems where related files were organised into clusters without any formal index. The clustering served to narrow down search, but memory for a particular location was still useful for immediate access.

Contemporary computer system design requires a greater degree of information organisation than is apparent in the 'real world'. Office type information does not lend itself to ease of categorisation, but in the real world this is overcome to some extent by being able to relate directly to the information via a cognitive model in a three dimensional environment. It is possible that this 'real world' feature may prove to be an important aspect of future thinking in the development of computerised information systems. Organisation for the sake of it could be counter-productive; this can be illustrated by a quote from one of the interviewees: '... my files are activity related. If they were broken down into too much detail then relevant documents could become spread across many files. It would be very difficult in this case to maintain an overview of the particular activity, especially with large time gaps between documents'. In this case it is better to have all the documents involved related by activity in the same location.

3.5.4 Structural considerations

i) What general types of information are stored, e.g. administrative (personnel etc.), teaching, project progress (technical/research)?

Different types of information need handling in different ways. Financial information is stored in a different form than a technical report, for instance. Whereas much information can be obtained from glancing at a page of figures, to get the most out of a report you have to read all of it. Types of information stored and how they are related to job type is therefore an important consideration in filing system design. Results are as follows:-

	NCP	CP
a) Project progress (records etc.)	8	12
b) Administrative (including financial and personnel information)	10	12
c) Meeting records (usually kept under project progress)	4	1

	NCP	CP
d) Policy, organisational, professional, and procedural information	10	2
e) Technical information	5	11

The results show that the relative proportions of different types of information dealt with depends on the particular emphasis within the type of job. For instance, more computer professionals deal with project progress type information than non-computer professionals. The possible reason for this is that there is more emphasis on project-type work for computer professionals. On the other hand, non-computer professionals (local authority employees) keep significantly more policy and procedural type information. As government employees this emphasis would seem logical. It is also evident that computer professionals keep more technical information in line with their involvement with developing technology.

When designing a computerised information storage and retrieval system, on the basis of the preceding evidence, it would seem to be very useful to assess job demands in terms of the amount and type of information dealt with. Varying amounts of storage capacity will be necessary for different types of information.

ii) Are some general information types used more than others? Why? Is more structure evident? (tie up with type of job)

Not all the information in a filing system is used **equally**, some areas are used more than others. It is important to ascertain what factors are responsible for this differential use. Which of the general information types are used most is not as important as why. For this reason quantification has been avoided; rather the statements made by users were examined.

The information used at any time depended on job demands; these could vary from day to day or during different periods of the year. Broadly speaking information could be divided into that which was constantly interacted with, and that which was stored as back up information for occasional reference purposes. For example, over a period work might be concentrated on project progress and all aspects of it. This might include only occasional reference to technical information, although there could possibly be a great deal of it stored. Question i) stressed that the quantity and type of information were important computer information systems design considerations. The differential use of information allied to job demands must be added to this. It is possible that different strategies of storage and retrieval could be considered depending on the type of interaction with different types of information. Another factor relevant here is that users remembered best all aspects of that information with which they were either dealing at the time, or with which they dealt very frequently. No greater structure was apparent in the organisation of this information, the users were just more cognitively aware of it. It might therefore be useful to have a low structure, direct access, action information store incorporated into a computer information system. This would be analogous to the office situation, where 'action' information and relevant files are brought together into a common readily available location.

iii) Within these broad categories are files created based on:

a) Origin of information?
b) The common function that the information might be called upon to facilitate although it might be from different origins?
c) The origin of the information and the function the information facilitates?

It is evident that in organising their information people invariably categorise it in some way. Their conceptual model of this categorisation and the relationships between the categories depends on the type of categorisation that takes place. Categories can either be job oriented on the basis of common function the information facilitates, or origin oriented, based on the source of the information. The results are as follows:-

	NCP	CP
a)	1	1
b)	10	10
a) & b)	2	1
c)	1	1
a) & b) & c)	1	2

Two thirds of both the non-computer and the computer professionals chose b) as the basis for categorisation. The rest were divided amongst the other possibilities. The significance of this result is that people tend to conceptualise their information in terms of functional divisions of their jobs. The functional structure of their job is usually strongly represented in most people as it is something they are always involved in. Very rarely is origin of information alone used as a basis for categorisation, and this usually in a personnel context. More often origin categorisations are mixed with functional categorisations in a filing system. It seems, therefore, that a person's mental model of their filing system is usually functionally oriented.

It is useful to consider some comments made in conjunction with choices made by individuals:-

a) 'Does it not depend on whether you deal with the job or people'.

b) 'Origin does not matter'.

a&b) 'Function is not always obvious when received'.

a&b&c) 'It depends on what you need from the information'.

In developing a software system for an organisation, which has to incorporate information storage and retrieval facilities, it might be useful to base it on the functional structure of that organisation as most of the employees will have a cognitive model of at least part of it.

iv) Are these broad categories of files laid out in any logical order?

In a filing system the first level of organisation is dependent on the distribution of the files. This question attempts to discover whether users organise files in any strategic way. The results were as follows:

	NCP	CP
Clustered	11	9
Chronological	1	0
Alphabetic	2	0
Numerical index	0	1
None	1	5

From the results, for both non-computer and computer professionals, it seems that a clustered approach was the most popular. This approach involved the grouping of files of a similar context together. Other than this one non-computer professional chose a chronological approach, and two tried an alphabetic order. Only one non-computer professional did not group files under a strategy; this possibly reflects the more structured nature of the local authority jobs. Of the other computer professionals one used a numerical index, but this was a reflection of the large and complex nature of the information to be organised. Significantly five computer professionals used no broad category grouping strategy. In this case any strategy would have to start at the level of relationships between individual files. This lack of broad category grouping could also reflect less of a need for organisation amongst computer professionals who tend to have less structured jobs and more frequently only work on one aspect at a time.

v) Are the files appropriately titled?

To distinguish between files, to facilitate storage and retrieval, a person can use their differing spatial position. However, to make this meaningful each file must have an identity, some descriptor relating to the information contained which is meaningful to the user. Each file could be considered as a category of information, so it is of interest to determine whether users give each file some kind of categorical title. The results were as follows:-

NCP : 12 said that all files were titled; 2 said that most were titled; 1 said that none were titled.

CP : 12 said that all files were titled; 1 said that most were titled; 2 said there were not titles on their files.

It can be seen that most people, computer and non-computer professionals, identified their files with some kind of categorical descriptor. These varied from alpha-numeric indexes, to names or their abbreviations. Three people said that they titled most of their files and three said that they did not title files. In the latter two cases there must be an association between the context of information a file contained and its physical appearance and/or its spatial position. In cases where these cues were not strong enough to identify individual files, scanning of file contents had to take place.

It is in the interests of developing an efficient cognitive model of a filing system to identify clearly each file categorically and, ideally, spatially. To a certain extent this point would apply to computer filing systems, which at the moment rely more on categorical identification than spatial. Whether spatial cues are important is a question that needs consideration.

vi) Are the files stored in:-

a) Alphabetical order?

b) Chronological order depending on when created?

c) No particular order, reliance being upon memory of their location?

d) No particular order, reliance being on scanning files to find the relevant one?

e) Colour coding?

f) Any combinations of the previous?

g) None of these.

Still following the theme that organisation of information is the basis of cognitive models, and bearing in mind that general information areas tend to be clustered, it is of interest to examine the strategy by which files are added to a filing system. Results were as follows:-

	NCP	CP
a)	1	2
b)	14	15
c)	1	2
d)	3	1
e)	0	0
f)	0	0
g)	0	0

From the results it can be seen that by far the most popular file storage strategy, for both computer and non-computer professionals, was a chronological one based on when a file was created within each cluster. I suspect that this was mainly due to convenience rather than by design. For example, within, say, the administration drawer of a filing cabinet the new files might be added at the front. This result does not mean, however, that this strategy creates the strongest cognitive model, just the most convenient. In a computer information can be automatically arranged in any order, for example, alphabetical. It might be the case that other strategies facilitate stronger cognitive models of the systems, providing they maintain a high level of convenience with respect to storage.

vii) Is there overlapping between categories?

Office type information is not as easily categorisable as, for instance, library type information. There tends to be different amounts of overlap between categories; for instance, a letter in a correspondence file might apply to some aspect of a project file. In this case it would be better to create a functional file combining the information under a common heading. In some cases, however, the overlap is more subtle. Results obtained on whether there was overlapping in systems involved in the survey are as follows:-

NCP	8 said yes
	2 said there was a small amount of overlapping
	5 said no
CP	9 said yes
	2 said there was a small amount of overlapping
	4 said no

Approximately twice as many of both non-computer and computer professionals said there was overlapping compared to those who said there was none. A small proportion said that there was a small amount of overlap. Part of the overlap was almost certainly due to the type, complexity and amount of information dealt with. Some, however, was due to the strategy of storage, which tended to vary in two major ways. Some people purposely left their categories large and fuzzy at the edges. In this case it was fairly easy to store information but hard to retrieve it from amongst a mass of other information. Some people, alternatively, subdivided categories, here ambiguous information was harder to store due to having to decide upon precise categories. Also, this latter strategy did not seem to enhance retrieval significantly, because with more categories it was often difficult to decide which was the appropriate category. However, as most peoples systems seemed to be workable there must be other cues, in addition to categorical ones, which were important associates with the information sought. The spatial position would seem an obvious choice (see section 3.6.2), but there are many other types of cues available which can serve to distinguish one piece of information from another (e.g. colour, shape, format, size, etc.).

I feel that the number and type of cues available on a VDU, in a computerised information storage and retrieval system, will be a major issue in the future. At present information tends to be presented as a homogenous green mass of file names and codes, which, ostensibly, only caters for categorical type relationships. Bearing in mind the difficulties with categorical classification of information previously mentioned, there may be a case for enriching the cues available for storage and retrieval purposes.

viii) What types of documents are stored in the files?

- a) Memos
- b) Letters
- c) Assorted personnel records
- d) Progress reports
- e) Paperwork concerning employment of staff
- f) Various financial statements and evaluations
- g) Notes and minutes of meetings
- h) General information concerning established systems
- i) Factual information (technical/research)
- j) Other types

As well as the type of information dealt with (i), it is also important to know the form which the information takes. When considering computer storage and retrieval, storage space and standard formats are an important consideration. The results are as follows:-

	NCP	CP
a)	12	14
b)	12	14
c)	8	8
d)	10	13
e)	5	7
f)	12	12
g)	14	15
h)	14	13
i)	14	14
j)	2 (1 forms)	0

The proportions of document types handled by non-computer and computer professionals are remarkably similar. Although there is a differing emphasis on the type and quantity of information dealt with due to job demands (question i), both groups receive information on documents of similar form. There is therefore a case for investigating standard document format facilities in computer information storage and retrieval systems. However, the sample surveyed is relatively small and cannot be treated as representative of the population at too specific a level. It is more likely that document types and formats will be user group specific.

ix) Are these documents stored in:-

a) Alphabetical order?

b) Chronological order?

c) No particular order, reliance being on the memory of location?

d) No particular order, reliance being on scanning to find?

e) Any combination of these? Explain.

f) None of these? Explain.

To store or retrieve a document from a particular file, a person must have a cognitive model, or at least a cognitive strategy, upon which to act. This question attempts to discover which strategy is most commonly used. The results are as follows:-

	NCP	CP
a)	1	2
b)	14	15
c)	1	2
d)	3	1
e)	0	0
f)	0	0
g)	0	0

As with the strategy of file storage in question vi), it can be seen that chronological order was by far the most popular.

Here again it must be realised that this strategy is the most convenient, and does not necessarily have to be the best strategy for developing an efficient cognitive model. The small incidence of other strategies were mainly for cases where the information either lent itself to alphabetical order, or where there was not enough retrieval information to preclude scanning. Even with chronological order in a sheaf of documents, a person is only going to have a rough idea of position of a document from knowledge of the exact or approximate date received.

Both this question and question vi) show that there may well have to be a compromise between conveniency of storage and the efficiency of the cognitive model upon which retrieval is based in computer information systems. Computers can do much of the work in arranging information in different ways, but for efficient retrieval the users cognitive model of the information storage has to correspond to the strategy the computer has employed. When users become too alienated from this process a possible mismatch may occur. Consideration needs to be given to how a cognitive model of a filing system is developed.

x) Was the system:

a) Consciously organised bearing in mind what might be asked of it?
b) Evolved by allowing the nature of information received, or generated, to dictate the organisation?
c) Evolved by putting files in the first handy place available?
d) Any combination of these?

When dealing with a filing system the user must have a cognitive model containing sufficient information to enable successful storage and retrieval. It is interesting to speculate how this cognitive model is developed. A first possibility is that the user anticipates the nature of the information he will have to handle and the relationships inherent in it. Information could then be arranged externally in accordance with the users preconceived internal organisation. The second possibility is that the external system organisation is evolved as the information is received and that the internal representation is built up from this in a corresponding manner. The above questions attempt to give an insight into this problem. The results are as follows:-

	NCP	CP
a)	10	8
b)	5	5
c)	1	4
d)	0	0

Two thirds of the non-computer professionals said that they consciously organised the system in anticipation of what might be asked of it, whilst only approximately half of the computer professionals reported likewise. One reason for this might be that the jobs of local authority employees are more clearly defined and therefore the information dealt with can be more easily anticipated. The jobs of the computer professionals, however, have a much more unpredictable input and are less clearly defined. This is reflected by the high proportion that chose b) and/or c).

It is possible that human memory is very flexible. Where there is a clearly defined preconceived model use could be made of it in organising information externally. Alternatively, where preconception is not possible the external organisation of information might evolve and at the same time alter the internal cognitive model appropriately. Whether it is more efficient with respect to storage and retrieval to give people a preconceived model of information relations, or to let them evolve their own, is a matter for debate.

Also of relevance here is the fact that the majority of both non-computer professionals (12) and computer professionals (13) kept paper-based indexes of their filing systems. However, the indexes tended to be used fairly infrequently, generally as a back-up. Users were usually familiar with the location of relevant files and so did not have to work via the index. Index use tended to occur more frequently with the larger, more complex filing systems. It is evident, therefore, that cues other than categorical ones are an important part of users' cognitive models in the 'real world'.

xi) Are there problems in categorising certain documents?

If a difficulty arose would:
a) New files be created rather than filing inadequately in existing categories?
b) Documents put in a vaguely related file and their location remembered?

In question vii) a significant proportion of both computer and non-computer professionals reported overlapping between categories. If information was filed purely on a categorical basis we would expect there to be a corresponding amount of difficulty in categorising the documents. In the case of a preconceived defined job, in terms of information, we would expect new files to be generated rather than tolerating 'fuzzy' storage. In the case of a less well defined job, cues other than categorical ones would have to be available to promote the efficient use of filing systems. The above questions attempt to resolve this problem. Results and discussions are as follows:-

	NCP	CP
Any problem	Yes = 6	Yes = 10
	No = 9	No = 5

The above results probably reflect the nature of the job definitions. The non-computer professionals tend to have better job definition in terms of information handled. This is reflected in that they have less problems categorising information compared to the computer professionals. Following from this:-

	NCP	CP
a)	6	0
b)	4	12
a) & b)	4	2

The a) & b) condition consisted of a new file created if it was thought that more information on the subject would occur, or fuzzily categorising if little similar information was expected.

In condition a) identification of information for retrieval could be done on a purely categorical basis and the file then located. This condition made for harder storage and not necessarily easy retrieval. Non-computer professionals, due to more job definition, tended to favour a) when compared with computer professionals. Computer professionals, however, with their less well-defined job, significantly favoured b) when compared against the non-computer professionals. Condition b) made for easy storage, but again, not necessarily easy retrieval. In this case, cues other than categorical ones must be used to differentiate between relevant pieces of information fuzzily stored. Maybe spatial cues (see section 3.6.2), for instance, serve to reduce the ambiguity of certain information by tagging it with a spatial identity. This point might be important for computer design as computers at the moment generally only work on categorical relationships.

xii) Is there any cross referencing within the system?

Question vii) showed that there was an overlapping of categories in some filing systems, and question xi) showed that classifying information was not always an easy task. Within any filing system it is possible that a piece of information could be relevant to more than one category, and ideally we would want reference to the information in each one.

If this occurs then the information is said to be cross-referenced. Cross-referencing increases the complexity of information relations within a filing system, and thus increases the complexity of the users cognitive model of that system. This question attempts to discover whether people try to organise their system fully by means of cross-referencing, or whether they try to keep it as simple as possible. The results are as follows:-

a)	NCP	Yes = 6	No = 9
b)	CP	Yes = 2	No = 13

Both the non-computer professionals and, to a greater extent, the computer professionals tended to not cross-reference information. Whether this is due to lack of time, motivation, or trying to keep filing systems as simple as possible is not clear. The lack of cross-referencing is more marked in the computer professionals. A possible reason for this is that the type of information they handled was not as intra-related as that generated in a local authority where information can serve a multitude of purposes. Also, local authority employees are encouraged to keep comprehensive records to a much greater extent than the computer professionals. Generally cross-referencing is more likely to occur in large complex systems, in fact, some large and complex systems have copies of the same document filed in the various relevant locations.

Some form of cross-referencing could be a useful feature of computer information systems. There is a consideration, however, that over complication might cause the system to become unmanageable. People, on the whole, like to keep their filing systems as simple as possible.

xiii) Is the system hierarchically organised to any extent?

Most information can be broken down into smaller and smaller categories, each of which is more specific than its derivation. This 'branching' organisation is called a hierarchy. The number of people reporting hierarchical organisations are as follows:

NCP = 6
CP = 7

All but two of the computer professionals reported hierarchical organisation when it was, in fact, only a two level breakdown. In effect, a two level breakdown is the clustering together of files of similar context. That file clustering is a significant phenomenon has already been reported in question iv). In question iv), 20 people reported clustering, whereas 11 people reported a two level organisation, here, as a hierarchy. Therefore, 9 people do not consider two levels of organisation a hierarchy whereas 11 people do. Only 2 people (CP's) went further and organised some of their information to a third level. To avoid confusion it seems logical to classify any organisation beyond 2 levels a hierarchy, and classify a 2 level organisation as clustering. From the results it can be seen that people are reluctant to organise information beyond 2 levels, and that they would rather locate information in clusters; this is in keeping with the response to question iv).

xiv) Could benefit be gained from a more structured filing system? What are the reasons for the lack of structure?

The reason for this question was to find out whether users thought that their filing systems were sufficiently structured, and if not, why not. Amongst the non-computer professionals 6 thought that some benefit could be gained from more structure, whilst 9 thought not. The corresponding figures for the computer professionals were 8 and 7. These results show that computer professionals were slightly more prone to thinking that more structure would be a benefit. However, this could be due to the less structured nature of their jobs.

Of those, generally, who thought more structure would be a benefit, the reason given for their lack of structure were similar to those of question 3.5.3 iii). Typical comments were: 'Yes, but I do not have time'; 'Yes, but I cannot see a way of maintaining the system without it affecting the amount of time available for work'; 'Yes, providing it was maintained by someone else'. The main constraints seemed to be motivation, and time availability. Filing was considered a necessary evil. Also, in question vii), it was observed that more structure often made storage more difficult and did not necessarily enhance retrieval.

Of those who did not think that more structure would be of benefit, the general concensus was that this was because their system of storage and retrieval was satisfactory in its present form. Typical comments were: 'No, I have never had any problem finding anything'; 'No, it is workable as it is'. This suggests that individuals had a good working knowledge of their information and its location.

The implications of this question, and the previous one, is that if you give people the facility for elaborate information organisation, they will not necessarily use it. This, however, could be dependent upon the amount and complexity of information dealt with. It is conceivable that a computer might automatically organise information for the user, thus alleviating the time and motivation constraints. The problem in this case, though, is that the user would be further alienated from the information. The results of this could be an increased cognitive mismatch due to possible unfamiliarity with the particular concepts needed for information retrieval.

Also, office type information is not always sympathetic to the rationalising approach of computer categorisation. Users might therefore be much happier with a system that includes facilities for a much more direct relationship with the information, and which cuts filing down to a minimum.

3.6 Stage 2 - Storage and retrieval

The questions asked are as follows:

i) To what extent did the memory of a particular file and/or document location play a part in the storage/retrieval of items of information?

When considering this question it must be realised that there is a certain amount of implicit spatial memory in storing and retrieving information from any personal filing system. There is no way that anyone who interacts with their own filing system cannot have some kind of spatial model of the information. Only if the user never physically interacts with his system will there be no spatial model available to him. The use of a secretary might deplete a user's spatial memory concerning information location, but even in this case it is unlikely that a user will be totally unfamiliar with the spatiality of his system. It was considered important, in this survey, to find out how important a part the user considered his spatial memory played. It is obvious, however, that a particular file should be identified categorically before its location could be considered. The question tries to gain an insight into how dominant the users considered their spatial memory to be; did the location of certain information immediately spring to mind, or did they have to translate the categorical structure in some way to elicit the required spatial information? The results are as follows:

NCP 13 of the fifteen people interviewed thought that memory of information location played a large part in the use of their filing system. Typical answers were= 'Very high', '75%', '100%', 'a large part'. Only 2 people did not think that spatial memory always played a large part., One of these said that it did, depending on the accuracy and exclusiveness of the original decision of where to put particular information. The other person said that he had a poor memory; his system, however, was laid out based on departmental structure within the local authority, which acted as a kind of Mnemonic enabling translation into spatial position.

CP 12 of the fifteen people interviewed thought that memory of information location played a large part in the use of their filing system. Again a range of typical answers reflects this; they included 'totally', '100%', 'all'. The 3 people who were not so openly spatially orientated tended to structure their files reflecting indexes of the information kept. Here it was a case of translating their index into spatial terms. One user made an interesting point, that is, he thought it important that the context of retrieval should be the same as that of storage for immediate association.

There is no doubt that spatial cues are extremely important in the retrieval of information from a personal filing system. It should be noted, however, that people are usually very familiar with their own filing systems through constant use. Of particular interest is the relationship between categorical and spatial aspects of filing systems. The results show that a few people translated their formal categorical index into spatial terms; these, however, tended to be the larger more complex systems. On the whole, in the rest of the filing systems, the spatial layout did not reflect the categorical relationships within the information stored. Here, retrieval tended to be reported as very spatially orientated, though information must have been categorically identified first. Some kind of associative translation must have taken place between the categorical identity and the location of a particular information item. Are spatial and categorical type memories separate systems or are they closely related cues reflecting the flexibility of memory as a whole? From comments made during the interviews there are four possible parameters which could affect the spatial/categorical relationship; these are, the amount, and complexity of the information, the amount of familiarity a user had with it, and the motivation to organise the information to varying degrees.

The relationship between categorical and spatial cues could be important in terms of computer information system design. For instance, would a spatial representation of information categories enhance storage and retrieval efficiency?

ii) For files:-
    Did they remember:-
    a) Location of certain files?
    b) Title of a file, then rely on scanning the cabinet to find it?
    c) Physical characteristics of a file, then rely on scanning the cabinet to find it?

Although previous results emphasised the importance of spatial cues in using filing systems, the possibility of other cues being available was not overlooked. The result of this thinking was the above question. Results obtained are as follows:-

	NCP	CP
a)	14	10
b)	5	9
c)	7	5

Both non-computer and computer professionals tended, most frequently, to remember the location of a certain file. This was especially evident for the non-computer professionals. Conversely more computer professionals tended to identify the file needed and scan for it. Physical characteristics of a file (e.g. colour, shape, size, etc.) were also used as memory cues for its retrieval. It seems likely, however, that physical characteristics play a secondary, back-up role in file retrieval. The predominance of location memory amongst the non-computer professionals could be due to the fact that there was generally more inherent categorical structure in the information with which they dealt compared to the other group, where more scanning was evident. This scanning was, however, usually directed to a relevant part of the filing system, showing that some spatial cuing was still taking place. Perhaps a spatial arrangement closely adhering to categorical structure would be the most efficient type of organisation to promote efficient retrieval. This would reduce the amount of translation needed from the categorical identification of a file into its spatial position in the filing system. Again the stress is that the relationship between categorical and spatial type memory could be an important one with regards to design of computer systems. Advantage might also be gained from an enriching of the physical characteristics of displays.

For documents:-

Did they remember:-

a) Appropriate location in the file?

b) Deduce the approximate location from knowledge of the document and the strategy of document storage?

c) Remember the physical features and scan for it?

The rationale behind this part of the question is similar to that of the first part, in that it attempts to discover the part that spatial memory plays in relation to other cues. From this we can get an idea of how deep into the system spatiality is important. Results are as follows:-

	NCP	CP
a)	3	1
b)	14	12
c)	10	10

As can be seen, memory for spatial location was not as important in retrieving documents from the file, compared to file retrieval. Users did, however, frequently translate the strategy of storage, usually chronological, into a rough spatial search strategy. For example, if a user was searching for a document received a long time ago, he would look towards the back of the folder, if new documents were always put at the front. So temporal cues can be seen to be used if available. Again, physical characteristics, this time of documents, were an important factor.

Although spatiality did not seem as important at the document level, due to documents being in an amorphous wad, it could be possible to enhance spatial cues in a computer system at document level. This might contribute to more efficient retrieval. As speculated in the first part of the question, there is a case for incorporating a variety of extra cues into computer information systems.

The decision process involved in the 'real world' retrieval of an item of information, at the most basic level, would have to follow the structure of information storage. For example, if information was represented on a hierarchical index, there would be a decision point at each branch in the hierarchy. This identification would then have to be translated into the location information for the particular item. If the filing system was laid out reflecting the index, then the user could work through the system, as he would the index, and narrow search down to the appropriate file. However, in practice the spatial layout of a filing system does not always reflect the formal categorical relationships, but often people can put their hand straight on the appropriate file. In this case cues other than categorical ones must be providing 'short cuts' to the information. Even at the identification level people often know from an enquiry the piece of information they require and associate this immediately with the appropriate file. It is evident, therefore, that retrieval is a complex interaction of cues and does not necessarily follow the formal procedures based on categorical relationships between information. The formal procedures that have to be followed during retrieval from a computer information system may not be necessary except as a back-up system, if the information was spatially displayed.

Generally it can be seen that human memory is very flexible and can make use of a whole range of different types of cues. Why, then, do we restrict the amount of information displayed and the number and type of cues available in computer systems? Could this restriction be a source of cognitive mismatch between computer systems and the non-computer professional? Is the lack of cues the reason why it is harder to relate to information in a computer compared to that of a 'real-world' filing system (see chapter 2).

iii) Is information thrown away? What criteria are employed in either keeping or throwing away information?

In any information storage and retrieval system it is necessary to throw information away. To do this criteria have to be employed in deciding whether information should be kept or not. The results from the above question attempt to identify these.

13 non-computer professionals and 13 computer professionals said they eliminated information from their systems. This could take the form of destruction; however, other alternatives were open. The non-computer professionals could send their information to a central registry, or put it in a common departmental filing system. The computer professionals could send theirs to archives. The individuals who tended not to throw information away were natural hoarders. (One was chief auditor of the local authority and had to keep information by law for 7 years.) In fact, man as a whole has a tendency to hoard information and has great difficulty in deciding which should go and which should stay. In both groups the main criterion employed, in the decision for removing information from their systems, was whether the information was past its usefulness and would not be of any use in the future. Some people employed a time limit, either arbitrary or statutory, and guidelines were available from the organisations. Sometimes information had to be eliminated to create space for more, although subject to the above considerations. The criteria employed are not as straightforward as they seem,

however. For instance, how do you decide when a piece of information is not going to be relevant in the future, without knowing the demands that will be put on you?

In designing computer information systems, the issue of criteria employed in removing information from a user's immediate personal access deserves much thought. Should the capability be an automatic feature of the system, or should the user be aware of it?

iv) What common difficulties are encountered with storage and retrieval, and what common errors are made?

Knowledge of errors and difficulties encountered in storing and retrieving information, in the 'real world' situation, can provide an insight into the weaknesses of peoples' filing behaviour. This knowledge can then be taken into account when designing future systems and features can be included to smooth out likely problems.

It is difficult to talk of errors and difficulties encountered separately because, to a certain extent, they are interdependent. Any difficulty encountered in a system might well result in an error of some kind. The following discussion will deal with categories of difficulties and errors and try to preconceive the implications to computer information systems design. The problems seem to fall into three general categories; physical constraints, cognitive inconsistencies, and difficulties caused by other people.

A major physical constraint encountered in offices is a lack of space, and the availability of the physical components of a filing system, for instance, filing cabinets. The result is an accumulation of information and nowhere to put it. Files become bulky and so piles of unfiled information accumulate around the room. One answer is to throw information away, but it is difficult to decide which information should be kept and which should not. Rule of thumb criteria often result in relevant information being thrown away, whereas judging each item of information independently can result in information hoarding. Eventually bulky files have to be split up and the filing system rearranged. The decision on the manner in which the files should be split is difficult, and information which would be better kept together can be separated. Failure to file at all is creating difficulties in that it is hard to retrieve information that is lying around in piles. A person may have a good idea of location, but can still spend much time searching. Finally, difficulties can arise from the form in which information is presented, papers can come adrift, or get soiled and torn.

A computer based filing system design would need to give the 'real world' physical difficulties much consideration. No computer, for instance, has unlimited capacity, whereas some filing systems have to cope with a prodigious amount of information. Built in systems criteria for disposing of information might be an answer; however, question v) discusses the difficulties with this idea. One point in favour of computers, however, is that they do not deal with information in a physical form within the system and so soiling or damaging does not occur; though if a piece of information did go astray no visual search of the computer is possible.

Many cognitive inconsistencies arise from the fact that office-type information is often very difficult to categorise. If there are several possible categories in which an item of information could be stored, it is possible that the one chosen for storage may be different from the one chosen when subsequent retrieval of the item is necessary. This can be compounded if the information being dealt with is ambiguous, or if the context of retrieval is different from tnat of storage. The consequence is that information is not immediately accessible, and, in the extreme, not accessed at all. In computers storage and retrieval decisions are usually made on a purely categorical basis; this results in the system being very susceptible to storage and retrieval misinterpretations. Misinterpretation might be reduced if extra cues, for instance spatial ones, were associated with the information. It is logical that increasing the number of cues by which information can be identified would result in easier identification of it.

Cognitive inconsistencies can also occur due to simply forgetting. It is possible that all types of cues, spatial, categorical, temporal and physical may be forgotten. Here again the answer would logically seem to be to increase the number of cues by which a piece of information could be identified, then if one was forgotten retrieval could be based on others. However, I am not advocating that the categorical type of storage and retrieval in computers should be discontinued, this could still remain as a back-up. Rather we should increase the number of cues available for use in the system. Systems operations and procedures should also be kept simple and compatible with peoples' real world conceptions. The reason for this is that all or part of these can be forgotten and they should be as easy to remember and meaningful as possible.

The interference of other people with filing systems can also cause information to go astray. People sometimes borrow information without telling the owner. Often when they return the information they put it in the wrong place, either due to lack of knowledge of the owner's strategies or because they cannot be bothered to find the correct place. Computer systems could have built in security and other safeguards to prevent this type of occurrence.

3.7 Summary and conclusions

The purpose of the survey was to provide a foundation of information concerned with the principles employed by users of filing systems in an applied, 'real world' situation. The survey was not designed to be definitive in its approach, but merely instrumental in generating information which could elicit further issues for research.

The limitations of the survey should be borne in mind: Firstly, the people interviewed covered a restricted range of users; secondly, the number of people interviewed was not as large as it might have been, although it is adequate. There were a number of constraints contributing to the limitations: it was difficult to find an organisation willing to have its staff interviewed; as the interview was fairly lengthy, the number interviewed had to be fairly restricted or too many man-hours would be lost; finally, the mobility of the interviewer was restricted through lack of transport. However, the survey did provide some useful results.

Particular reference has been made to the development and nature of cognitive interaction between the user and the information concerned. The following summary and conclusions of the survey highlight some of the important considerations thought to be especially relevant to computer information systems design. There are three main areas of discussion: firstly, the demands put on the users by the characteristics of their jobs; secondly, the needs of the users in the context of carrying out their job; and finally, the way that users tend to conceptualise the information with which they interact.

3.7.1 Job Demands

Different jobs place different demands on each individual with respect to the type of information received and the filing and retrieving thereof. A person with an administrative type of job might have to interact constantly with incoming and previously stored administrative information. This type of information is fairly dynamic. A person formulating ideas on a research project, on the other hand, may only occasionally need to reference stored technical information; consequently the interaction is less dynamic. Different types of information demand would also dictate the form in which the information was received. An auditor, for example, would receive relatively more standard format financial declarations, whereas a public relations officer might receive a relatively greater proportion of letters. Computer systems design, therefore, not only needs to consider the type of interaction, but also the form in which relative proportions of the information is received. Two final factors are relevant at this point, namely the volume and the complexity of information received. A large amount of complex information would need more organising than a small amount of non-complex information. It is no use designing a computer information system with facility for a large amount of complex information, when the prospective user only deals with small quantities of non-complex information. Ideally, computer information systems design needs to cater for the needs of each individual. In practice, however, this is not possible for economic reasons. Therefore, consideration needs to be given to ranges of job types and important characteristics, along with the corresponding information characteristics. In this way at least the specific needs of different user groups could be catered for.

3.7.2 User needs

All the people surveyed seemed to interact with three levels of filed information, namely, 'action information', 'personal work files', and long term, 'archive storage'. 'Action information' consisted of that being dealt with or to be dealt with in the near future. It could usually be found lying around in in-trays, on desks, and even on chairs or the floor. 'Action information' was usually immediately accessible. However, if it was allowed to build up into large quantities, it was often necessary to search painstakingly through piles of information for a desired item. 'Action information' could only be used efficiently if the quantity was manageable with respect to remembering the items and their locations.

'Personal work files' refers to information that had been filed, according to some strategy, in the immediate office environment. This could be located in files in filing cabinets, cupboards, or in the user's desk. The information was relevant to the user's present work schedule. Retrieval of information would ideally correspond to the strategy of storage to be most efficient.

Long term, 'archive storage' applied to information that was of no direct relevance in the user's predicted work schedule. Archive stores were usually structured systems, away from users' offices, where many users can send information suitable for archiving. It would seem sensible to give full consideration to these levels of interaction in the design of computer information storage and retrieval systems. This point is especially important when one considers 'action' information. Items need to be worked on, and have to be kept somewhere during this period. Without this facility information use will be fragmented, especially if information has to be accessed one item at a time.

On the whole people tend not to categorise their information in their filing systems in elaborate ways, the tendency being to keep them as simple as possible. However, people often start off with the good intentions of constructing complex filing systems, including the use of colour coding and hierarchical classification of information, but this usually falls by the wayside. The result is that filing systems end up with all manner of idiosyncracies. People can vary considerably in the way they organise information; some systems can be very disorganised, whereas some can be relatively fairly organised. The size of the system seems to be an important factor, the large systems being generally more organised. These, however, are the exception rather than the rule.

The average user of a personal filing system does not seem to be motivated toward developing an elaborate filing system. In fact the less time spent on actual filing the better. There are two main reasons for this. The first is that most people do not have time to undertake large amounts of filing; it is usually done during the working schedule, or in spare moments. Secondly, most people find filing boring and wish to do as little as possible. A secretary often undertakes the filing if a person has a lot of responsibility and/or a heavy workload; this usually applies to the larger more complex systems. However, this can result in an extra stage of user removal from contact with the system, and unfamiliarity with its workings. It would seem logical, therefore, that a computerised filing system should require as little storage and retrieval effort as possible. Conceivably, filing could be carried out automatically by the system, but this would result in the user's cognitive model of the information in the system becoming inadequate. Consequently, when retrieval of information was desired the user might be at a loss to know how to proceed.

The usual lack of formal information organisation, and the range of variation, are incompatible with the organisation demanded by contemporary computer information systems. Users of most computer systems have to follow quite rigid formal procedures to store and access information. Computer systems should be designed to overcome this incompatibility by including operating procedures which are more in line with people's 'real world' concepts and behaviour. However, these systems should always guarantee a high probability of retrieving a desired piece of information.

3.7.3 Conceptual considerations

A feature of man-computer interaction which, until recently, has not been given enough consideration is the development, and subsequent compatibility, of an efficient cognitive model by the computer user. To interact efficiently with a computer information system the user must be able to conceptualise the information stored in the system. He should also be able to conceptualise the operations the system is capable of carrying out on that information in response to all the possible actions that the user might take. A trained computer professional will have at his disposal a cognitive model of the system which allows virtually total interaction with the stored information. However, a non-computer professional has a cognitive model more receptive to 'real world' concepts, especially that of 'whereness'. He is used to relating directly to information in a 3-D environment. As a result, when complex operational procedures mediate information access, a mismatch occurs between the user's concepts and those necessary to operate the computer system. Also, due to the limited visual access to computerised information (via the customary VDU), it is difficult for the user to relate all the information in his mind. It follows that if we are going to design computer information storage and retrieval systems for use by the non-computer professional, we should discover what important 'real world' concepts are apparent in office filing systems.

The frequency of interaction with information, and the extent and type of its organisation, play an important part in the development of a person's conceptual model of that information. The three levels of information storage previously mentioned exhibit differing amounts of formal organisation and varying frequencies of user interaction:

1) 'Action information' is usually least formally organised and interacted with most frequently. Interaction consists of deciding upon the item of information desired and then locating it, either directly or by means of scanning. The cognitive model in this case is predominantly spatial; however, we intuitively know that interaction has to be of sufficient frequency to prevent our spatial awareness of information items becoming indistinct.
2) 'Personal work file' interaction is usually based upon a mixture of categorical and spatial relations with respect to the stored information. More formal structure of the information is apparent, being used to access information when the spatial awareness of particular information items is not so clear; interaction being less frequent and over longer periods of time.

3) 'Archive storage' is the most formally organised level of interaction. Here, knowledge of spatial location of information is not as well developed due to infrequent use over very long periods. However, because the system is usually extensively structured in categories, the strategy of storage or retrieval can be based upon knowledge of the particular categorical structure.

Present computer information storage and retrieval is most closely allied to archive storage, in that the strategy of interaction is based upon categorical relations in the information. However, many micro- and mini-computer file indexes are chronologically arranged. This usually involves much scanning as chronological awareness is not sufficiently highly developed to serve as the basis for an efficient list search strategy, except in broad terms. To incorporate 'action' and 'personal file' levels into a computer with the respective amounts of organisation, we have to assume that the spatial awareness prevalent in the 'real world' will also apply to computers. Further research is needed to test the validity of this assumption.

It is interesting to note in the survey that action and personal file information is usually placed in categories which reflect the user's concepts of the functions within their job content. It is also interesting to note that information is only usually organised to two levels (i.e. grouped or clustered). This raises two questions for future research. First, is information organised to two levels because of user's functional concept of it - for example, an administration section containing files of administrative information? Second, do people naturally tend to conceptualise all information in terms of two levels? In addition, there are major questions concerning the extent of information organisation in computer systems, and also the type of information retrieval aids (i.e. indexes) needed: if information is extensively organised, will it confer any advantage over a two-level organisation? If an elaborate indexing system is present, will it be used effectively, or help to consolidate the user's conceptual model?

It is clear, however, that categorical aspects of information are not the sole consideration when storing and retrieving information in 'real world' office filing systems. Spatial cues seem to play an important part, especially in enabling people to relate to information directly, without any mediation process. This is apparent by the fact that although many people kept paper-based indexes of their filing systems, they were only used infrequently as a back-up when people could not recall the spatial location of a file.

It is important to discover the relationship between categorical and spatial memory. In the 'real world' spatial cues seem to play a part in compensating for a general lack of categorical organisation of people's personal filing systems. The location of the filing system in the 3-D space of the office provides a framework containing many points of reference with respect to the stored information. On the computer, however, there is not a 3-D framework within which to relate to information. Even the computer professional, at best, only has schematic models of computer processes obtained by virtue of extensive training. Perhaps some way could be found of imposing a meaningful spatial framework on computerised information, and on allied storage and retrieval procedures. This would serve to enhance informational inter-relationships and facilitate the development of an effective cognitive model in the user with respect to information storage and retrieval. If it were not possible to impose an effective spatial framework on computer information systems, then some form of paper- or computer-based index would become an important consideration. There is, however, a similar range of conceptual considerations as to what constitutes an effective index.

The relationship between categorical and spatial cues needs to be examined closely in a 'real world' and a computer context, in order to provide some answers to the question of what is conceptually compatible to information storage and retrieval needs.

Interest should not be confined solely to spatial and categorical memory. This sort of blinkered approach has led to context specific research in the past. People also tend to use temporal and physical cues (i.e. date and aspects such as colour, size, shape, etc.). It seems that human memory is a very flexible entity which can relate to information in many different ways. All the different cues contribute to different ways of conceptualising the information, and are instrumental in the formation of a cognitive model of a filing system. If we could understand how these cues relate to each other within a particular cognitive model, we could design computer information systems to function in ways compatible with the users' own cognitive models. Or, conversely, we could discover how much training would be necessary if total compatibility could not be achieved. Both of these approaches attempt to eliminate cognitive mismatch between man and computer, and consequently make systems more acceptable to, and easily used by, the non-computer professional user. Even without going to these lengths, there is a case for 'cue enrichment' in computer information systems.

Finally, the way in which cues are incorporated into cognitive models could help in the assessment of how adaptable these models are, with respect to the nature of the information system. If cognitive model development is dependent upon the information relations already stored in human memory, then people will be fairly inflexible as regards a range of different information systems. If, however, the emphasis is on internal memory organisation being dependent on the development of the external information system, people will be quite flexible as regards a range of different filing systems. In reality, the answer could be a combination of these two situations. If the implications are that users are quite flexible, a greater range of possible computer information systems will be acceptable.

In conclusion, it is evident that the design of a user-compatible, computer-based information storage and retrieval system must take into account:

1) The demands that the users' various tasks place upon them;
2) the needs of the users within the task context; and
3) the way that users conceptualise their interaction with information.

The survey has provided a broad base of understanding from which many issues for future research arise. However, the main emphasis of research subsequently described is in terms of conceptual considerations in information storage and retrieval. For instance, what is the relationship between categorical and spatial cues? Is the well developed spatial awareness of the 'real world' apparent in computer simulation? Why are two levels of organisation prevalent in moderately sized filing systems? How extensively organised should a filing system be?

4. EXPERIMENT 1 - THE ROLE OF CATEGORICAL AND SPATIAL MEMORY IN THE FILING OF INFORMATION

4.1 Introduction

From the structured interview survey of the individual filing systems of computer and non-computer professionals (see chapter 3) it seems that information is grouped into logical, or not so logical, categories of one type or another. The information is then stored in the filing system according to these categories. There is, however, more to the storage and retrieval of information than just deciding on the appropriate category it belongs to and remembering or recording this. It is important to know the spatial location of the desired information to retrieve it; it is also important to know where to locate information when storing. Categorical relationships are implicit in any information handled by an individual but dependent upon prior knowledge and interpretation. The amount of spatiality associated with the information depends on the design of the filing system.

The aspects of memory involved when using a filing system are crucial in that they dictate the strategy used to either store or retrieve information, both in memory and the system. Most research into memory, to date, has been of a laboratory type with contrived tasks not compatible with the 'real world' situation. Laboratory research on human memory tends to favour theories of memory which hinge on one important aspect; this is probably due to the 'unreal' and specific nature of the tasks used, and also to the controlling of all variables except the one being studied (see literature survey chapter 2). The results of many of these experiments are dictated directly by the experimental design; in other words, the subjects' behaviour is confined by what the experimenter is looking for and reflects the experimental design. This means that many results are valid only within the context of the experiment and should not be extrapolated to form general principles defining memory in relation to practical contexts. In fact, it could be said that all theories of memory are correct, but only within their experimental context. Perhaps memory is very flexible and adaptable and uses cues and storage strategy peculiar to specific situations.

There seems to have been a great reluctance to study memory in any applied situation which, admittedly, is a very difficult task due to the variety of possible situations and lack of control of independent variables. Consequently, within the applied context of this Ph.D research it is very difficult to relate work done in the past on memory to an every-day type of information handling situation. There are few established experimental techniques which can be wholly adapted to the applied situation with any degree of success. Probably the only answer is field survey work, as has been carried out, followed by experimentation upon simulated 'real' tasks in the laboratory. This approach does not limit research, as in the past, because it first identifies important memory aspects in the 'real' situation; the characteristics of these can then be examined in an experimental situation in the right kind of context. This approach may sacrifice the rigid control of previous laboratory research, but it does provide a good basis for highlighting important general features of an applied situation. The ways in which people conceptualise information in the office filing situation is of far more use to the future development of computerised information systems than is, for instance, how people memorise nonsense syllables.

The two most important aspects of filing arising from the structured interview survey were the categorisation of information and the locating of the information within the system. These considerations, in turn, generate three fundamental questions in the relationship between memory and the filing system. Firstly, is the organisation of the filing system dependent on perceived categorical relations developed from some pre-defined memory model (e.g. factual knowledge) similar to the network models of long-term memory (Anderson and Bower, 1973; Collins and Quillian, 1969)? Secondly, do we organise our memory model as a reflection of the external organisation of the filing system? Or, finally, is it possible that the answer is a combination of these two?

An experimental design has been formulated to investigate the nature of spatial and categorical memory and the relationship between them. From this comparison inferences can also be made about the relationship between memory model and filing system organisation. A short review of some relevant literature will help to set out the context of the experiment, before discussing its aims.

4.2 Literature review

Some models of memory favour a semantic organisation, such as Human Associative Memory (HAM) (Anderson and Bower, 1973), and Teachable Language Comprehender (TLC) (Collins and Quillian, 1969). These models, and memory model research in general, propose an associative network type of storage in long-term memory; this, however, takes into account only non-episodic memory, or that knowledge which exists independently of time or place it was acquired. The storage of factual information is of this type. Usually, we not only store factual information in long-term memory but also physically handle information in the spatial dimensions of our everyday environment. There are many proponents who take these episodic and spatial components of information handling into account (e.g. Tulving, 1970 and Neisser, 1976, respectively) and support temporal and visual representation in long-term memory. The question of whether we have visual images in memory has been debated in the past, but one only has to consider our ability to remember faces and scenes to realise that important considerations must be given to this aspect of human memory. These capacities have been investigated experimentally, for example, in Shepard's (1967) demonstration of our ability to remember common objects. We can also usually remember, with varying degrees of accuracy, when we did something.

Most research has been done either with items having semantic attributes, such as lists of words, etc., or with items with visual characteristics, such as pictures. This immediately imposes a dual theory of memory approach, that there is a semantically represented and a visually represented storage of items, as well as creating a rather false representation of items we handle in everyday life. Each day we handle all types of items whether it be books, letters or memos, or an electric food mixer; they are all handled in three dimensional space and information about that event is stored in memory. G.A. Miller (1968) argues that spatial localization is a feature of considerable importance in the organisation of an information user's memory, and has been largely overlooked in the automation of information systems. Mandler (1977) was interested in the incidental learning of locations of objects. He found, however, that people often consciously used spatial location as an aid to memory. Subsequently he designed an experiment where learning was truly incidental in that subjects did not expect to recall the objects and their locations. There was only a small loss in recall of objects and their locations. It was concluded that a great deal of location information is automatically coded in long term memory storage in the sense that active processing is not required. If this is the case, it suggests that there is a good deal of 'on-going' mental processing related to spatial location that people ordinarily do that is not utilized or exploited, especially in such situations as the storage of information in information storage and retrieval systems.

Information about 'location' seems to be part of human information processing even at the sensory level. There is evidence of distinct localisation mechanisms embedded in the auditory and visual systems (Deutsch and Roll, 1976). On a higher, more central cognitive level, we not only store a great deal of information about our spatial surround (cf, for example, Tolman, 1948), but can use vivid spatial mental images or organise memory for complex material as in 'The Method of Loci' a mnemonic procedure whereby one associates items to be learned with waystops on an imaginary journey through a familiar area (Neisser, 1976, Chap. 7).

Kinchla and his colleagues have studied memory for the position of visual dots (Kinchla and Allan, 1969; Kinchla, 1971). They distinguish between knowledge of absolute position, which is the position of a dot within the same unchanging frame of reference, and relative position, which is the position of a dot in relation to some other dot, object, or moveable frame of reference. Moreover, it was clear that encoding of the spatial position of an object was in relation to one or more frames of reference. If these frames move with respect to one another we can, to some extent, make separate judgements concerning the remembered position of an object with respect to each frame. Furthermore, we can remember a number of different locations for the same object at different times. It is not known whether this encoding of temporally or contextually specific associations between objects and locations occurs strictly within the spatial modality or involves associations between the spatial and verbal propositional modality.

Are semantic memory and imagery separate cognitive systems or are they just the coding of different attributes in the same system? Lindsay and Norman (1977), in their book 'Human Information Processing', propose a semantic network type memory where 'visual images' are used as prototypes to facilitate semantic definitions at a generic information level, e.g. dog, cat, etc. This supposes that semantic and spatial memories may be intimately related. Both types of memory provide cues for the successful storage and retrieval of items of information not only in memory but also in the 'real' world in conjunction with memory.

Alternatively, Salthouse (1974) has reported a particularly interesting study, in which subjects had to perform two tasks. The recall task involved remembering either the positions or the identities of several target items in a 25-item array. During the retention interval of the recall task, subjects were given a recognition task for either aeroplanes or words. On the recall test, position information was more detrimentally affected by the aeroplane recognition task than by the word recognition task, with the opposite result for identity information. On the recognition task, aeroplane recognition was more affected by the position information recall task than by the identity-information task, with the opposite result for word recognition. Salthouse concluded that the position-recall and aeroplane-recognition tasks were mutually interfering because they both involved imaginal processing, whereas the identity-recall and word-recognition tasks were mutually interfering because they both involved verbal processing. This result is in accordance with Paivio's (1971) dual-coding model for verbal and imaginal processes; both maintain the differential independence of these processes.

Storage and retrieval from a personal filing system depends on a strategy based on a working memory model of the system. To understand the part the strategy plays in retrieving information from memory to lead to successful external storage or retrieval of information, it is useful to consider R.M. Shiffrin's (1970) model for recursive retrieval of information from memory (see discussion and figure 2.8, section 2.5 of the literature survey). This model can be used to illustrate the decision, based upon information in memory, of where to look for an item of information, assuming that the relevant information category is equivalent to search-set. The two important boxes are the Executive Decision Maker (EDM) and the selection of a search-set. The EDM makes the decision on whether to search or not; if the search is made then the general area of memory, in long term or short term, is defined, probably depending on the context set by the stimulus. The search strategy depends on how information is stored and by what type of cues; the search strategy will only be wholly successful if it follows the strategy of storage. Any strategy involves decisions to alter the search-set during the retrieval recursion in a pre-set and systematic manner. The executive decision maker also decides on the criteria for termination of search, whether successful or unsuccessful. The processes involved in the executive decision maker should lead to the definition of the appropriate search set, unless the relevant criteria involved dictate otherwise, and logically progress to selection of it.

Selection of the search-set depends on certain factors. The task set for the subject defines the search-set in terms of general objectives of a retrieval situation; within these objectives the type of information required to formulate the appropriate response in relation to given stimulus information is further defined. The response may require factual information, information about when something was undertaken, or where something was put. If information previously recovered is similar to that required then this will provide clues as to the definition of the appropriate search-set depending on the amount of association between information previously obtained and that required. This latter factor is also important in modifying the strategy, used to define the search-set; in other words, the more experienced someone is with a situation the quicker the search-set will be defined with fewer decisions, thus speeding up access to required information.

Although I do not necessarily agree that the draw and recovery stages are randomly based, the fact that search is recursive and is based on some strategy brings it in line with Miller, Gallanter and Pribram's (1970) TOTE unit paradigm (see section 2.4.2 of the literature survey). The TOTE unit (Test Operate Test Exit) is a recursive decision process, proposed as underlying behaviour, based on a 'plan' which varies with experience. Plans for remembering are amongst those proposed in explaining behaviour.

Within the context of filing system storage and retrieval, a useful theory to note is proposed by Ulric Neisser (1976, Chap. 6). He talks of cognitive maps, or better orienting schema, as a basis for a memory model, and links this with imagery. Neisser goes further and says that images are not pictures in the head, but plans for obtaining information from potential environments. Imagery is obviously important; without it we would not be able to decide on the location of any desired information in the 'real world', for example, in a filing system. In retrieving information from a filing system we would also have to have a knowledge of the information categories, the information they contain, and the relationship between categories, so that we can decide which is the appropriate category.

So we return to the question previously posed; is categorical memory a separate system from spatial memory and dependent upon different orienting schema; or are they both part of the same plan or orienting schema in memory, the purpose of which is to direct access to the appropriate information? This, in turn, raises the question of how much each contributes to the orienting schema, and at what stage in the decision process each is predominant.

4.3 Experimental design

4.3.1 Basic considerations

If a stimulus provokes a situation where there is a need to retrieve information from a filing system, we must:

i) have a memory for types of information and the relevant categories into which they fall (categorical memory), along with relations between the categories (this assumed that each category is fairly exclusive and that there is a logical relation with the information it contains).

ii) have a memory of the location of relevant categories of information so that the information sought can be retrieved.

These considerations in turn generate two questions, do we;

a) first decide which type of or category of information is relevant and then decide on its likely location? (The latter decision is not needed at present when using a computer system.)

b) decide on category and location simultaneously because these associated cues are stored together. (Important here is how closely associated the spatial and categorical relations are in the memory system, i.e. whether related categories are represented spatially together, or have implicit spatial cues combined with them.

It is logical that decisions on the spatial aspects of information cannot be made until information has been defined categorically, or there would be no way of knowing which information was being considered. However, if spatial and categorical information were stored separately it would seem likely that the decision process involved in retrieval would progress as in (a). On the other hand, if spatial and categorical information were stored in an intimately related form it would seem likely that decision process (b) would be the more appropriate. Memory of spatial and categorical aspects, of the information in a filing system, provides the basis for the development of an appropriate cognitive model of that system. It is by means of this cognitive model that we conceptualise the information and its relationships, and can consequently develop the strategies for subsequent storage and later retrieval. These strategies will be more efficient if either the two types of memory cues are independent or they complement each other. If, however, there is a conflict between the two types of memory cues and they are closely related, the resulting storage or retrieval strategy could be expected to be inefficient. Not only is this consideration important in the 'real world' situation, it is also of importance to the development of computer information systems. The storage and retrieval strategy, especially for the non-computer professional or naive user, will presumably be less efficient if based on purely categorical access. The results of the interview survey (chapter 3) indicated the importance of spatial cues in storage and retrieval of information in filing systems. If spatial cues were built into a computer system, however, it would be important to know how they interacted in a user's cognitive model. If the two types of cues were closely related and there was a conflict in the system, then no advantage would be gained.

It should be noted at this point, that I do not advocate that categorical and spatial cues are the only form of information encoding in memory, only that these seem to be the dominant ones. It is intended that this experiment should be flexible enough to be sensitive to other forms of coding used by the subjects.

4.3.2 Experimental aims

The main aim of this experiment was to find out just how closely connected spatial and categorical cues are in memory, whether they belong to two separate systems or schemata or whether they are closely associated in the same schema. Also of importance was the predominance of each type of cue in a certain situation. This leads to the second aim of the experiment which was to find out whether the inherent categorical memory proposed in the literature imposes relationships on external information for the purpose of internal storage, or whether the arrangement of external information dictates relations in the memory schema which is then represented in the filing system.

A useful comparison can be made between the results of this experiment and the results of the structured interviews (see Chapter 3). From this comparison much can be said about initial organisation of memory when involved with filing; as compared to the behaviour of people involved with filing in the 'real world' where they each have their own developed system and interact constantly with it. Each of the experimental aims are based on questions posed by the structured interview survey (see summary and conclusions of chapter 3).

4.3.3 Experimental rationale

One of the problems in investigating the mental processes behind the filing of information was to investigate the nature of the representation of information in memory. To do this, a technique had to be created whereby the information stored in memory, and the attributes by which it was coded, could be reflected. However, the desire was not to create a false situation by divorcing the experimental task from what happens in a 'real world' filing situation. Control had to be gained over certain aspects of any representative filing task, such as the nature and categorical relationships of the information dealt with, and the spatiality of the system. This control could not be accomplished using individuals' different filing systems as the information each individual deals with is different from that which another deals with. The spatial aspects of their environment also vary. Therefore, it was decided that a filing procedure must be simulated, to achieve the necessary amount of control over independent variables, and make the results obtained reliable. The categorical relationship of the information could be kept constant, and the effect of different spatial arrangements examined. In any filing system there is always categorization irrespective of spatiality.

The basic task involved in the experimentation was the presentation, to the subjects, of a number of pieces of information similar to those used in an office filing situation. They were subsequently asked to file the information into various relevant categories. The type of information that was chosen had to be equally relevant to all subjects used, so that no bias from familiarity was incurred. The requirement was that certain pieces of information should be categorically related, in other words, they could be categorized together under a more general heading. It was valid for the categories to be decided already, because it meant that each subject had the same categorical relations available. However, it was important that the information belonging to the various categories could be flexibly interpreted so that subjects were not totally constrained to experimenter-defined relations as in much of previous memory research.

It was necessary to build a simulation of a filing system into which the information could be filed, and that this should take the form of an arrangement of labelled spatial locations. Here again, the requirement was for the labels to be pre-defined corresponding to the flexibly defined categorization of the information. The main reason for this was that it would be necessary to pre-arrange the categories spatially, a procedure that would have been impossible had the subjects generated their own categories. Also, it would have been highly unlikely for each subject to generate sufficient numbers, and similar numbers of categories in each case. The categorical relationships decided upon had to be in keeping with semantic relationships with which the subjects would already be familiar. It was necessary for the subjects already to have the categorical relationships, prior to the experiment, so that the experimental aims could be met. The main aim of the experiment was to look at the relationship between categorical and spatial memory, not how subjects generated categories. It must be noted, however, that subjects retrieve desired material better when using descriptors they themselves have assigned to an item of information, rather than those applied by others (Broadbent, 1978).

It was proposed that there be three experimental conditions; one in which there was a close relationship between categorical and spatial aspects of the filing task; and two in which there was no relationship, but a conflict, between the categorical and spatial aspects. In the close categorical-spatial relation condition, and in one conflict condition, it was proposed that categorical recall should be examined first followed by spatial recall. The effect of the two conditions on the two types of recall, and the relationship between the two sets of cues, could then be ascertained. In the second conflicting categorical-spatial relation condition, it was proposed that only spatial recall be tested. A comparison of results would then show if prior categorical recall was having any effect on subsequent spatial recall. An important consideration however, was how do we elicit categorical and spatial memory recall in a form that could be analysed? Categorical recall must reflect any categorizations of items in memory, whereas spatial recall must reflect spatial relations between items stored in memory.

Work by W.A. Bousfield (1953) showed that semantically related items (words of the same or similar semantic category) are recalled in clusters, because items are stored coded by their semantic attributes and related items cue each others recall. This phenomenon is called the free-recall paradigm. If categorical memory was predominent then the free recall lists in the first two experimental conditions should reflect categorized storage of information in memory. However, where information has been physically handled and placed in a spatial location, there is an inherent spatiality, concerning the whereabouts of items, which is incidentally learned by subjects (Mandler, 1977). If subjects store information in memory in conjunction with a mental image of the filing system, this will show up in the order of free recall as they mentally search through each location in turn for an information category.

To demonstrate retrieval from spatial memory it was proposed that subjects are asked to fill in a schematic diagram of the spatial locations labelling each location with the appropriate category. To do this the subjects would have to generate a spatial model of the system from memory.

The time between the experimental task and subsequent recall was crucial, the concern being with the type of coding of information undertaken in the subjects memory. Interaction with a filing system is usually based on a long term memory model of the information, although it is possible that short term memory interactions might take place. To assess the initial long term storage of the filed information, the period between the task and recall should be of sufficient length. It should not be so long, however, that extensive forgetting occurs. A person is rarely out of contact with their office filing system for more than half an hour. It was also important that the subject was unaware of the recall that would be required. This would prevent rehearsal of the information categories, and thus reflect the type of coding that naturally occurs. A break of half an hour before recall was thought to be adequate to make sure that the results were a reflection of initial long term memory storage.

By analysing the results from the three experimental conditions it should be possible to gain an insight into the relationship between categorical and spatial memory. If a categorical memory plan is found to be predominant it seems more likely that categories are filed externally in a manner sympathetic to contemporary semantic memory structure theories (Collins and Quillian, 1969; Anderson and Bower, 1973). If spatial memory is found to be predominant, it would seem logical that an internal memory model of a system is built up, and organized, based on the physical organization of external elements of the system. If both spatial and categorical memory are closely related then it seems likely that the proposed inherent semantic memory structure (network), and a memory image of the external system, both contribute to an overall orienting schema of the system (this could be why filing systems are in general not extensively categorically organized - similar categories tending to be spatially clustered. See questions 4 iv) and 4 xiii) in the interview survey of filing systems).

4.4 Experimental procedure

4.4.1 Apparatus and location

The main piece of apparatus used in the experiment was an array of 36 pigeon holes. They were arranged in a 5 x 6 matrix, the dimensions of which can be seen in figure 4.2. Each pigeon-hole had a detachable black plastic clip, to which a black plastic dymo-tape label could be affixed. This enabled any desired label to be placed on, or re-located from, any pigeon-hole in the array (see figure 4.1).

There were 180 pieces of information available for filing into the appropriate labelled pigeon-holes. The information and its characteristics are discussed in section 4.4.4.

A stop-watch, fixed to a work study board, was used for timing experimental periods. On the work study board, for each subject, were the recording sheets necessary for free recall, spatial recall, the recording of misfiles, problems, and experimenter comments for each subject, and finally for recording the subjects comments on aspects of the experiment, (the latter two documents can be seen in appendix 4.1).

FIGURE 4.1

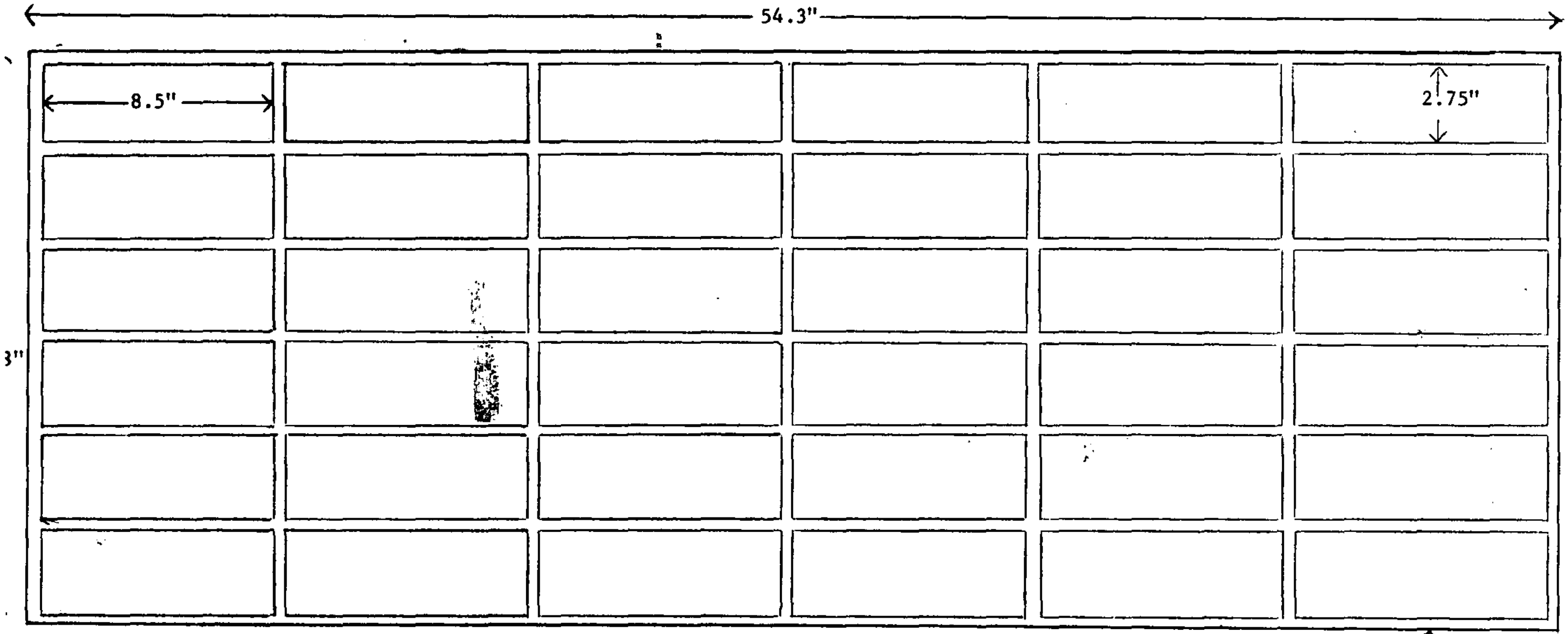


Figure 4.2 - Dimensions of the pigeon hole array.

This row is unused in the experiment.

4.4.2 Pilot study

The objective of the pilot study was to test the feasibility of the experimental design and to see how it could be improved, both by elaboration of and elimination of certain aspects.

Initially, three people were asked to sort the one hundred and eighty items of information into the appropriate randomised categories of the pigeon-hole array, each mistake they made was corrected. During these trials the experimenter could obtain a feel for the experiment and also see how the subjects coped with the task. With the first subject, it was obvious that an initial training period would be necessary to familiarise subsequent subjects with the available categories before each experimental run. Using the other two subjects two training runs were found to be adequate; each run consisted of a different random list of categories being read out and the subject touching the appropriate pigeon-hole. After each experimental run the subjects were asked to remember as many of the categories as they could by free recall and spatial recall.

As a result of these three trial runs, it was evident that certain considerations were necessary in the pilot study, these were as follows:-

1) Did the information provide four clear experimenter defined major categories and a more vague one?
2) What kind of problems did the subjects encounter and were there any important general features of their experimental behaviour?
3) Were there too few or too many categories for the achievement of the experimental aims?
4) Were the results obtained in a form conducive to the proposed analysis techniques?
5) What were the important subject strategies and considerations in the experiment?

Nine people (university technicians and students) took part in the pilot study. They had to file information into the pigeon-hole array, and then after half an hour had to free recall and spatially recall the job categories according to the experimental conditions to which they were assigned; three subjects were assigned to each condition. On completion the subjects were questionned on their strategies, problems, interaction with the information and any other points that they considered relevant.

Two problems were discovered in relation to the information used, although on the whole it seemed to provide clear major categories along with one which was not so clear. The items of information for 'buying', in the 'industrial' major category, were being more strongly associated with the 'commerce' major category. To overcome this the key word in each was changed from 'purchasing' to 'industrial purchasing' so that the industrial context was stressed. It was also found that the information category of university 'technicians', in the 'academic' major category, was being associated with an industrial-type context. This category was scrapped and replaced with a category of 'part-time education'.

During the pilot study many mis-files were made and had to be corrected. It was decided that it would be useful to record these to gain an insight into the kind of mis-interpretations that could occur. Also a provision for experimenter comments was thought useful.

When the subjects were asked to recall, it was found that they could not easily remember all the categories and often forgot a few. They were remembering enough, however, to make analysis worthwhile. Measurement of categorical recall by counting cluster pairs from the same major category and dividing by the number of pairs was found to be adequate. However, the measurement of spatial recall, that is, counting the number of squares by which each recalled category was discrepant and adding them up was found to be inadequate. This measure of total error was very crude and did not take into account the different numbers of categories recalled by different subjects. A more specific measure was that of percentage nought (%O); each time a recalled job category oorresponded with its position in the pigeon-hole array a nought was scored. If the total number of noughts was expressed as a percentage of the total number of job categories recalled, it was found to provide a good measure of the accuracy of spatial recall. These measures of categorical and spatial recall could then provide the basis for t-test and analysis of variance techniques.

After talking to all the subjects, on completion of each of their experimental runs, four main areas for subjective comment were identified. These were:-

a) Whether they were aware of the major categories of information.
b) The strategy adopted for reading each information item.
c) The strategy employed for free recall.
d) The strategy employed for spatial recall.

It was realised that much useful information could be gained from questioning subjects concerning these areas.

The appropriate changes, based on the pilot study, were made to the experimental procedure. The finalised aspects contributing to the experimental design, and the experimental method, are detailed in the following sections.

4.4.3 Subjects

In the past much experimental work has been undertaken using students as subjects, because in most academic establishments they are the most numerous and easily accessed population. The context of this research, however, precludes the use of students; the results should be representative of a wide range of filing system users. The subjects used were representative of three basic groups, non-computer professionals, computer professionals, and secretaries. The non-computer professionals were made up of university administrative assistants, they dealt with a great deal of information but were not involved with computers. The computer professionals comprised the staff of the university computer centre who were responsible for the day-to-day running of the computers. The secretaries were drawn from departments around the university.

In using three distinct groups of subjects it could have been possible for subject bias to manifest itself when comparing the three conditions. For this reason, it was necessary to balance the allocation of subjects across the conditions. Nine subjects were allotted to each condition; three non-computer professionals, three computer professionals and three secretaries.

4.4.4 Information used in the experiment

It was necessary to use information in the experiment which was categorically related in some way. Research in the literature, concerning categorical clustering in free recall, used very distinct categories of words, for example, types of fish or types of birds. In an office situation, however, although some major categories are clear cut, some may be more vaguely defined by the components which make them up. The major categories used in the experiment concerned job opportunities and were public service, industrial, academic, commerce, and a vague, miscellaneous one relating leisure and non-government public services. These major categories were sub-divided as follows:-

Armed forces	
Local authority	
Civil service	PUBLIC SERVICES
Public transport	
Medical	
Social work	
Management services	
Engineering	
Industrial administration	INDUSTRY
Management training	
Buying	
Quality control	
Accountancy	
Stockbroking and investment analysis	
Insurance	COMMERCE
Banking	
Retailing	
Advertising	

MSc courses - Social sciences
Teacher training
MA courses - arts ACADEMIC
PhD research
MSc courses - Physical sciences
Part-time education

Environmental control and design
Tourism
Hotel management and catering MISCELLANEOUS
Journalism
Legal work
Entertainment

Each job category was represented by a descriptor, or key word (e.g. Banking). Much memory research has been done using key words, but little effort has been made to provide a 'task context' within which the key words could be efficiently related. Lack of appropriate context is perhaps why it is so difficult to relate previous work with what actually occurs in a 'real world' applied research situation. To overcome this problem, rather than have subjects associate a 'sterile' key word with the appropriate pigeon-hole, the task involved placing items of information which had to be read and interpreted into the correct pigeon-hole. This was much more representative of an office filing situation. Each of the thirty job categories had six items of information associated with it, each concerning an opportunity for a graduate in that particular job. Each item of information consisted of a heading (a company or type of work), text (frequently containing a key word), and an address to write to at the bottom. For a detailed description of the information see appendix 4.2.

In sorting the information into the various job categories, it was hoped that the subjects would develop a categorical model as well as a spatial one. The available categories were designed to impose a measurable amount of categorization upon the subjects, whilst remaining flexible enough to allow some freedom in the subjects' interpretation. This flexibility, along with the inclusion of a vague major category, attempted to make the simulated office filing task used in the experiment more realistic. Some information categories encountered in filing systems are distinctly fuzzy, consequently the filed information cannot be as strongly associated as in the case of a clearly defined category.

4.4.5 Independent variables

The independent variable for the three conditions of the experiment was the variation in arrangement of the categorical labels on the spatial array of pigeon holes. There were thirty labelled pigeon holes arranged in a 5 x 6 array each with a removable job category label. The job category labels each corresponded to the appropriate 6 items of the information to be filed. The arrangement of labels in condition 1 was different from the arrangement in conditions 2 and 3.

In condition 1 each major category of labels was randomly assigned to each of the five columns used in the pigeon-hole array. The six labels of each major category were then randomly assigned to the pigeon-holes in the appropriate column. Consequently, the spatial arrangement and the categorical relationships between the job categories corresponded.

In conditions 2 and 3 the thirty job category labels were randomly assigned to each of the thirty pigeon-holes in the array. Consequently, the spatial arrangement was in conflict with the inherent categorical relations between the job categories.

Random assignation in condition one was accomplished using random number tables. In conditions 2 and 3 the distribution of the labels was accomplished by the computer generation of nine random assortments of the numbers 1 to 30, each number corresponding to a particular label (see appendix 4.3 for the program and the nine random lists).

One list of the nine was chosen at random for each subject who undertook conditions 2 and 3 by using random number tables.

The resultant arrangement of labels in the 5 x 6 array of pigeon-holes in conditions 1, 2 and 3, was termed the 'experimental order'. It was important that the experimental order be different in each case, so that there was no chance of order effects biassing the results.

4.4.6 Pre-experimental procedure

The 180 items of information were randomised to prevent any order effects, namely the consistent associations between particular items of information by each subject. Each subject was randomly assigned to an experimental order and the numbers of two random job category lists different from the experimental order to be used in the training periods. The job category labels were then arranged in the chosen experimental order on the pigeon-hole array; this was then copied onto a schematic diagram of the pigeon-holes. The documents necessary for experimentation on each subject, namely those for free and spatial recall, and those for recording experimenter and subject comments, were attached to the work study board. The stop-watch, which was also attached to the board, was wound and reset.

4.4.7 Experimental method

Prior to the main experiment each subject undertook two training periods. They were required to sit in front of the covered pigeon-hole array, the experimenter sat to the right and slightly behind. They were then read the training instructions appropriate to the experimental condition that they were undertaking (see appendix 4.4 for subject instructions). When the experimenter was satisfied that the instructions had been understood the training procedure went ahead. The cover was taken off the pigeon-hole array and the stop-watch was started. The subject was instructed to look at the pigeon-holes and they were then read the first of the random training lists prescribed by the experimental plan. As each job category was read the subject touched the appropriate labelled pigeon-hole.

Upon completion of the first list the stop-watch was stopped and the subject was instructed to look away from the experimental rig. The time taken by the subject to touch all the pigeon-holes was recorded. This procedure was then repeated for the second random training list order from the experimental plan. The pigeon-holes were then covered up and the subject was read the instructions necessary to undertake the main experiment. The 180 items of information on student job opportunities were placed up-side down on the small table attached to the chair in front of the subject. When the experimenter was satisfied that the subject understood the procedure, the main experiment was initiated.

The cover was taken off the pigeon-hole array and the stop-watch was started. The subjects were aware of being timed; this was to provide motivation to work fairly quickly. The subject turned over the first piece of information, read it, and decided which was the most appropriate job category. The piece of information was then placed in the corresponding labelled pigeon-hole. If the subject filed the information in a wrong pigeon-hole the experimenter said 'no', the subject then had to place it in another appropriate pigeon-hole. Each misfile was noted. This procedure continued until the information item was correctly filed, whereupon the experimenter would remain silent. Each of the 180 information items were filed in this way. On completion the stop-watch was stopped, the pigeon-holes were covered up, and the time taken noted. The stop-watch was then re-set and started to time the half hour break in the experiment. During the experiment, communication between experimenter and subject was kept to a minimum in order not to provide any extra cues for recalling the information being dealt with at that time.

During the half hour break most subjects accompanied the experimenter to a coffee lounge for a drink. Any discussion of the experiment was discouraged and conversation was always steered towards subjects entirely unconnected with previous proceedings. A few subjects went back to their office to continue with their work. The rest break and lack of knowledge of what was to come were both precautionary measures to prevent rehearsal of the job categories. Consequently, recall would elicit the sort of uncontrived organisation present in the office information interaction situation.

Towards the end of the half hour the subjects were taken back and situated, as before, in front of the experimental rig. Upon completion of the half hour the stop-watch was stopped and reset, each subject was then read the instructions for the next stage (see appendix 4.4). For conditions 1 and 2 the first of these instructions were for the free recall situation, in condition 3, however, they were for spatial recall. The subjects were allowed approximately ten minutes for each recall. After this, subjects undertaking conditions 1 and 2 were read the instructions for spatial recall, and then allowed approximately ten minutes to accomplish this. In the free recall situation each subject had to write down all the job categories remembered in any order, drawing a line between periods of continuous recall. In the spatial recall situation the subjects had to write the appropriate job category in the correct position on a schematic diagram of the pigeon-hole array.

The experiment was concluded by asking the subjects questions about certain aspects of the experiment, for instance, their strategy of recall in each of the conditions. For more detail on the collection of results during the experiment, see the results collection, section 4.4.9.

4.4.8 <u>Dependent variable</u>

The major dependent variables concerned in this experiment were:-

a) The number of job categories recalled in each condition; this reflected the efficiency of recall.
b) A measure of the categorical dependence of free recall in conditions 1 and 2.
c) A measure of spatial dependence of free and spatial recall in conditions 1, 2 and 3.

Other dependent variables of interest were:-

d) The time taken to complete the training periods and the main experiment.

e) Subjective comments concerning the strategies of recall employed in the experiment and observations about the information used.

A detailed account of the quantification of the dependent variables follows in the next section concerned with results collection.

4.4.9 Results collection

The results of the three major dependent variables were obtained from free and spatial recall undertaken by the subject.

4.4.9.1 Number of categories recalled

The categories written down during free and spatial recall were checked against their respective master list and schematic diagram respectively, in order to eliminate duplications and discover the categories missing. The number of categories recalled were then simply counted.

4.4.9.2 Measurement of categorical recall

The method of results collection, to reflect categorical recall, can be followed in conjunction with documents A and C in appendix 4.5. Document C shows the actual pigeon-hole arrangement for subject 8 undertaking condition 2. Document A shows the subsequent free-recall of job categories as prescribed by the subject instructions.

The first step in analysis was to ascertain the number of recalled category pairs. Only the pairs within each period of continuous recall were counted; the association of the category immediately before a drawn line and the category immediately after was not a pair. Each job category pair was now examined in turn. If each member of the pair were of the same major category the pair were counted as a categorical association. Categorical associations are denoted by the numbers on the left of the recalled list on document A in appendix 4.5. The proportion of categorical associations compared with the total number of pairs was then expressed as a percentage, in this case 57.9%.

It should be noted that this technique has two weaknesses. Firstly, it is not sensitive to the association of a recalled category with another category more than one space removed in the recalled list. Any of the categories previously recalled, when scanned, might have cued the recall of a related category. Secondly, the scoring of the associations only takes into account experimenter defined categorical associations. Many other associations are possible, for example, two words beginning with S, both words being short, or some alternative major category imposition (e.g. Tourism, and Public Transport might be associated together under travel, although from different experimental major categories). The first weakness cannot be compensated for. The proportion of the second however, can be estimated from a critical review of each free recall list and the noting of other possible associations. Even without compensation for other associations the measure of categorical recall employed provided a reliable index of whether categorisation was occurring.

4.4.9.3 Measurement of spatial recall

If the information categories were stored in memory by means of a spatial model, then it was possible for this to be reflected in both the free recall list and the filling in of the schematic diagram. Therefore some measurement of spatial recall was needed for both contingencies.

For the free-recall list the number of pairs in each block of recalled categories were counted as previously in 4.4.9.2. Each of the pairs was then examined in turn and each of the pairs located on the master diagram of that particular experimental order (see document C of appendix 4.5). If the two categories concerned were adjacent to each other in any direction, including diagonally, then this was counted as a spatial cluster. The spatial clusters are noted on the right hand side of the free-recall list. The logic behind this technique was that if someone was scanning a spatial memory image to effect recall, then adjacent categories would be associated together on the free recall list. On document A of appendix 4.5 the amount of spatial clustering can be seen to be 26.3%.

The weakness of this technique is that it is quite possible for certain categories to stand out visually in one's mind, and others not to be visualised at all. The result in this case might show no spatial clustering even though the recall was via a mental image. However, if this effect was marked it would be reflected in the placing of categories in the schematic diagram of the pigeon-holes. If the free recall list showed marked categorical groupings and insignificant spatial groupings, and the schematic diagram showed a similar number of categories recalled and correctly placed, we could conclude that categorical cues and relationships are dominant in free recall; this would be in spite of accurate spatial cues being available. Spatial cues used in spatial recall would have to be at least as strong as the categorical associations for accurate placement of job categories to take place in conditions 2 and 3.

Analysis of the accuracy of spatial recall was undertaken by comparing the diagram of the pigeon-holes completed by each subject with the master diagram of the relevant experimental order. In appendix 4.5, document B is the recall of spatial positions by subject 8 in condition 2, document C is the corresponding master diagram of the actual experimental order. The category written in each location of the diagram by the subject was compared with its position on the master diagram. If the two positions corresponded a nought was scored. If the two positions were in the same row or column it was simply a matter of counting the number of squares between them, either horizontally or vertically. If the two positions were in a different row and column the number of squares between were obtained by either counting down and across, or across and down (see figure 4.3).

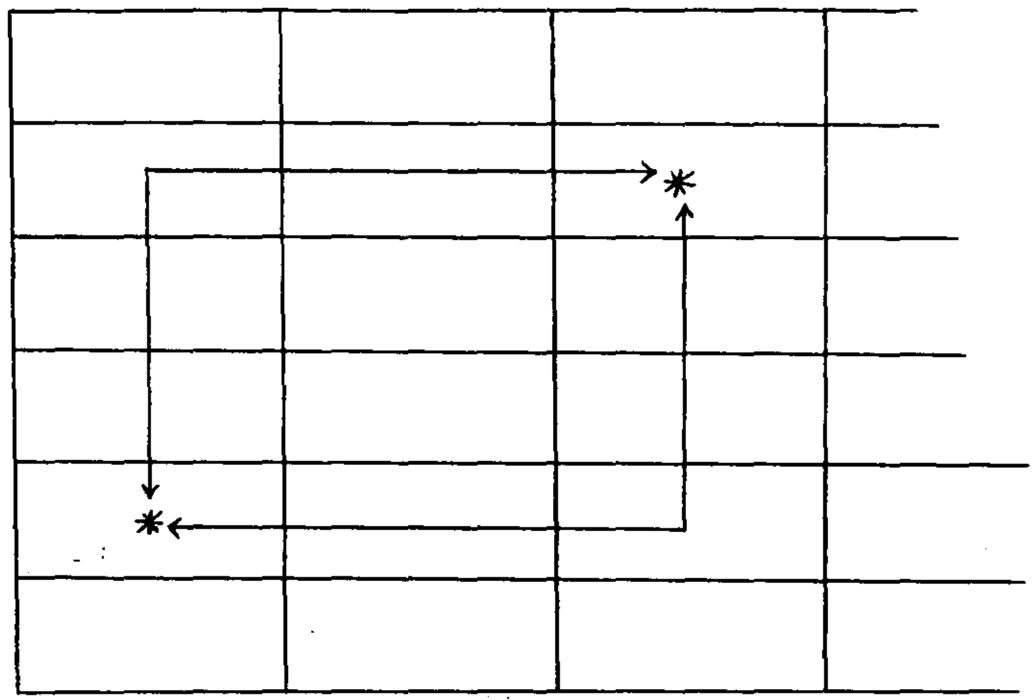


Figure 4.3: Determination of total error

The number of squares difference, for each of the comparisons, were added for each subjects' spatial recall. This score, the total error score, was a rough reflection of the accuracy of spatial recall. However, it did not reflect whether the total error was due to many categories being recalled in positions only slightly discrepant from the master experimental order, or whether just a few categories were recalled a long way out of position. For this reason total error was converted to average total error by dividing by the number of job categories recalled. Also the number of noughts scored, denoting correct placements of job categories, were added and expressed as a percentage of the total number of categories recalled. The '%0' score was independent of the number of categories recalled and thus showed the accuracy of placement to a greater degree than the total error score.

The score profile can be seen at the bottom of document B, appendix 4.5, the corresponding total was 8 and the % noughts was 75.86%. A high % noughts and a high total error would mean that a few recalled categories were a long way out compared with the experimental order, and vice versa.

4.4.9.4 Time taken to complete stages of the experiment

Each of the training periods, and the main experimental period, were timed by means of a stop-watch. The results were recorded on the experimenter problems and comments document.

4.4.9.5 Subjective comments and experimenter observations

At the end of each experiment, after the subjects had completed their recall, questions were asked concerning certain aspects of the experiment. These, plus observations made by the experimenter during the experiment, will be dealt with separately in section 4.6.

4.5 Experimental Analysis

4.5.1 Comparison with chance

The main aim of the experiment was to discover the effects of the three experimental conditions on the free and spatial recall of thirty job categories. A conclusion could then be reached concerning the nature and relationship between categorical and spatial memory. The measures of categorical and spatial memory, however, both assume that there was significant categorical and spatial organisation taking place as a result of internal memory processes. Therefore, before the effects of the experimental conditions can be assessed, some method of determining that significant categorical and spatial organisation is taking place must be applied.

If no internal organisation of information was taking place, and there was no formal strategy of retrieval, we could assume that information was being retrieved according to the laws of random chance (it is not advocated that this happens in practice). Therefore the measures of categorical and spatial recall in the experiment could be compared with the values of those same measures occurring by random chance, thus ascertaining whether any significant categorical or spatial organisation was apparent. There were three measures of random chance needed to test the significance of the experimental results; firstly, the chance occurrence of categorical clusters in free recall; secondly, the chance occurrence of spatial clusters in free recall; thirdly, the chance occurrence of placing the correct category in the correct pigeon-hole in the spatial recall diagram.

A measure of the chance occurrence of categorical clustering in free recall was obtained by scoring thirty six different random lists generated by the computer program in appendix 4.3. However, the measures of clustering in the experiment were based on differing numbers of recalled pairs of job categories. Therefore, the chance scores had to be calculated for the corresponding pair numbers on the random list. This was achieved in a systematic manner by counting down from the top of each list for the required number of pairs and then obtaining a score for the number of spatial clusters obtained within those pairs counted. The result was that each value of categorical clustering in the experiment had a corresponding value, for chance occurrence based on the appropriate numberof pairs. A table of results for chance scores could then be constructed (see results and analysis, section 4.5.3).

The chance values for spatial clusters in free recall were obtained by the comparison of the nine random lists of job categories (see appendix 4.3), with these same lists converted into schematic diagrams of the pigeon-holes. Thirty six different comparisons of lists and diagrams were possible. Again, the appropriate numbers of pairs of job categories, corresponding to numbers recalled in the experiment were used. The scoring of chance comparisons followed the same procedure as that for spatial clustering in free recall in section 4.4.9.3 (see section 4.5.3 for chance results for spatial clustering in free recall).

The chance values for spatial recall of the job categories were achieved by the comparison of each of the nine random experimental order diagrams with the others. Thirty six different comparisons could be made, and each was scored according to the procedure for the experimental spatial recalls (see section 4.4.9.3). The percentage noughts, and the error totals, however, had to be calculated corresponding to the number of job categories recalled in the main experiment. Each comparison between random experimental order diagrams resulted in a row of thirty scores of nought upwards, depending on how far out of position the corresponding job categories were. Therefore, to achieve the random score for the different numbers recalled in the experiment, each random comparison was evaluated from the left until the score was based on the appropriate number of recalls. The results for the amount of chance spatial correspondence can be seen in section 4.5.3.

4.5.2 Statistics

4.5.2.1 Tests for homogeneity of data

To test for homogeneity of data, and thus ascertain the validity of using parametric statistics, the F-distribution was used. The procedure for comparison of two samples is documented on pages 198-200 of Runyon and Haber (1973). The procedure for three samples is documented on pages 124-125 of Meddis (1977).

4.5.2.2 Principle parametric tests for analysis of experimental data

A student's t-test for independent samples was used for comparison of two samples, as prescribed on pages 194-198 of Runyon and Haber (1973). An analysis of variance was used for the comparison of three samples, see pages 215-225 of Runyon and Haber (1973). The method used for comparing sample parameters with a population mean can be seen on page 180 of Runyon and Haber (1973). The latter was used for comparison with chance.

The measure of correlation between average error total and %Q scores, both measures of spatial recall, was carried out using a Commodore S-61 calculator. The procedure was documented in the handbook.

4.5.3 Results and analysis

4.5.3.1 Number of categories recalled

Results can be seen in Table 4.2.

	C1		C2		C3	
	CAT	SPAT	CAT	SPAT	CAT	SPAT
S1	29	28	28	26		21
S2	28	26	24	23		28
S3	30	30	29	25		27
S4	24	23	25	23		29
S5	26	27	28	28		27
S6	28	28	27	28		25
S7	29	29	29	27		29
S8	29	29	29	28		28
S9	30	29	29	28		24
$\bar{x}$	28.1	27.7	27.6	26.2		26.4
Σx	253	249	248	236		238
Σx^2	7143	6925	6862	6224		6350

Table 4.1

A t-test for two independent samples was applied to the numbers of categories remembered during free recall in conditions 1 and 2.

Ho: There was no difference in the number of categories recalled between conditions 1 and 2.

Test for homogeneity of variance: df = 8/8

F = 1.09

Therefore there was no significance between variances ($p > 0.05$)

t = o.613, df = 16.

Therefore there was no significant difference between the number of categories remembered by free recall in conditions 1 and 2 ($p > 0.05$).

An analysis of variance for three independent samples was applied to the numbers of categories remembered during spatial recall in conditions 1, 2 and 3.

Ho: There was no significant difference in the number of categories recalled between conditions 1, 2 and 3.

Test for homogeneity of variance: Ave, df = 8.
F = 1.58.
Therefore there was no significant difference between variances ($p > 0.05$).
ANOVA: F = 0.94, df = 2/24.
Therefore there was no significant difference between the number of categories remembered by spatial recall in conditions 1, 2 and 3 ($p > 0.05$).

A t-test for two independent samples was applied to the comparison of numbers free and spatially recalled within conditions 1 and 2.

Condition 1: t = 0.46, df = 16.
Condition 2: t = 1.42, df = 16.

Therefore there was no significant difference between the number of categories elicited by free recall compared with spatial recall in each of conditions 1 and 2 ($p > 0.05$).

4.5.3.2 Measurement of categorical recall

Table 4.2 shows the experimental results for measures of categorical recall, and Table 4.3 shows the corresponding results that we would expect if recall was based on random chance.

To ascertain whether the amount of categorical clustering was significantly greater than that occurring by chance, a comparison was made between the average amounts of clustering in Table 4.2 with that due to random chance in Table 4.3. The average value due to chance, in each condition, was regarded as a representative population mean. The comparison was made between chance and experimental mean in each condition by the use of the t-statistic for comparing a sample with population parameters. Although the variance of results in conditions 2 and 3 of Table 4.3 is very small compared with Table 4.2, it should be remembered that these values are the representative mean values of thirty-six separate comparisons. The results upon which these values were based, for appropriate pair numbers, were roughly normally distributed. The results in conditions 1 and 2 of Table 4.2 are from the experiment and not averages, thus the variance is much higher. The mean values of the results in conditions 1 and 2 of the experiment, in Table 4.2, correspond to the means of mean values for appropriate recalled pair numbers in Table 4.3.

	C1	C2
S1	73.9%	42.9%
S2	56.5%	31.6%
S3	34.6%	26.3%
S4	60.0%	47.4%
S5	45.5%	61.1%
S6	52.6%	66.7%
S7	100.0%	52.2%
S8	73.1%	57.9%
S9	57.7%	41.7%
$\bar{x}$	61.5%	47.5%
Σx	553.9	427.8
Σx^2	36960.52	21775.66

Table 4.2

	C1	C2
S1	15.70%	13.76%
S2	15.70%	13.74%
S3	15.60%	13.74%
S4	13.70%	13.74%
S5	13.63%	13.73%
S6	13.74%	13.73%
S7	15.70%	15.70%
S8	15.60%	13.74%
S9	15.60%	15.51%
$\bar{x}$	14.997%	14.154%
Σx	134.97	127.39
Σx^2	2031.81	1808.56

Table 4.3

Clustering in condition 1 compared with chance:
$t = 7.36$, $df = 16$.
Clustering in condition 2 compared with chance:
$t = 7.45$, $df = 16$.

Therefore the amount of categorical clustering is very significantly greater than that occurring by random chance in both conditions 1 and 2 ($p < 0.05$).

A comparison between conditions 1 and 2 in the experiment was made using a student's t-test for independent samples.

Test for homogeneity of variance: $df = 8/8$.
$F = 1.99$
Therefore there was no significant difference between variances ($p > 0.05$).
Ho: there was no significant difference in the amount of categorical clustering for free recall in conditions 1 and 2
$t = 1.81$, $df = 16$.

Therefore there was no significant difference between conditions 1 and 2 in the amount of categorical clustering which occurred ($p > 0.05$).

4.5.3.3 Measures of spatial recall

Table 4.4 shows the amount of spatial clustering occurring during free recall in the experiment. Table 4.5 shows the corresponding random chance values.

A comparison of spatial clustering in free recall with that occurring by chance was undertaken in the same manner as previously documented with the categorical clustering scores.

Clustering in condition 1 compared with chance:
$t = 2.04$, $df = 16$.
Clustering in condition 2 compared with chance:
$t = 0.39$, $df = 16$.

	C1	C2
S1	39.1%	14.3%
S2	34.8%	21.1%
S3	23.1%	36.8%
S4	6.7%	0.0%
S5	22.7%	33.3%
S6	21.1%	26.9%
S7	39.1%	17.4%
S8	38.5%	26.3%
S9	34.5%	25.0%
$\bar{x}$	28.9%	22.3%
$\sum x$	259.7	201.1
$\sum x^2$	8487.07	5455.89

Table 4.4

	C1	C2
S1	21.14%	21.16%
S2	21.14%	20.76%
S3	21.15%	20.76%
S4	22.59%	20.76%
S5	21.21%	20.83%
S6	20.76%	20.83%
S7	21.14%	21.14%
S8	21.15%	20.76%
S9	21.15%	21.41%
$\bar{x}$	21.27%	20.93%
$\sum x$	191.43	188.41
$\sum x^2$	4073.82	3944.72

Table 4.5

Therefore there is no significant difference between the amount of spatial clustering that occurred in free recall and that occurring by chance (pr $>$ 0.05).

A comparison between conditions 1 and 2 in the experiment was made using a student's t-test for independent samples.
Ho: There was no significant difference in spatial clustering between free recall in conditions 1 and 2.

Test for homogeneity of variance: df = 8/8.
F = 1.032
Therefore there was no significant difference between variances ($p > 0.05$).
t = 1.25, df = 16.
Therefore there was no significant difference between conditions 1 and 2 in the amount of spatial clustering which took place.

Table 4.6 shows the error totals and %O, scores for spatial recall in conditions 1, 2 and 3 in the experiment. Table 4.7 shows the corresponding values due to chance. No measures of spatial clustering are recorded for spatial recall; this is because the spatial recall template precludes this type of scoring.

Table 4.6

	C1		C2		C3	
	AVE. TOTAL ERROR	%O	AVE. TOTAL ERROR	%O	AVE. TOTAL ERROR	%O
S1	0.11	89.3	0.54	69.2	0.24	76.2
S2	0.27	84.6	0.87	56.5	0.61	78.6
S3	0.07	93.3	0.20	84.0	0.37	44.1
S4	0.65	59.1	0.04	95.7	0.00	100.0
S5	0.82	73.1	0.18	82.1	0.33	70.4
S6	0.19	82.1	0.29	75.0	0.44	72.0
S7	0.35	75.9	0.59	66.7	1.17	51.7
S8	0.28	75.9	0.93	64.3	0.71	57.1
S9	0.28	72.4	0.29	82.1	0.96	41.7
$\bar{X}$	0.34	78.41	0.43	75.07	0.54	65.76
Σx	3.12	705.7	3.93	675.6	3.83	591.8
Σx^2	1.50	56176.75	2.50	51884.54	3.66	41741.56

	C1		C2		C3	
	AVE. TOTAL ERROR	%O	AVE. TOTAL ERROR	%O	AVE. TOTAL ERROR	%O
S1	3.45	4.35	3.46	4.17	3.33	3.52
S2	3.46	4.17	3.29	3.61	3.46	4.35
S3	3.49	4.63	3.44	4.07	3.45	4.26
S4	3.29	3.61	3.29	3.61	3.46	4.35
S5	3.45	4.26	3.46	4.35	3.45	4.26
S6	3.46	4.35	3.46	4.35	3.44	4.07
S7	3.46	4.35	3.45	4.26	3.46	4.35
S8	3.46	4.35	3.46	4.35	3.46	4.35
S9	3.46	4.35	3.46	4.35	3.36	3.98
$\bar{x}$	3.44	4.268	3.42	4.124	3.43	4.166
Σx	30.98	38.42	30.37	37.12	30.87	37.49
Σx^2	106.94	164.62	105.12	153.86	105.82	156.78

Table 4.7

An analysis of error total and %O scores in each condition compared with their corresponding chance scores was undertaken.

Condition 1 compared with chance:
Error total $t = 36.77$ $df = 16$
%O $t = 21.67$ $df = 16$

Condition 2 compared with chance:
Error total $t = 27.76$ $df = 16$
%O $t = 17.60$ $df = 16$

Condition 3 compared with chance:
Error total $t = 23.50$ $df = 16$
%O $t = 9.85$ $df = 16$

There was a significant difference between chance and experimental scores, for error totals and %O, in each of the three conditions. The error totals were significantly greater in the chance situations, whereas the %O scores were significantly greater in the experimental situations ($p > 0.05$).

An analysis of variance, for three independent samples, was applied to the error totals and %O scores generated by spatial recall in conditions 1, 2 and 3.

Test for homogeneity of variance

Error total $F = 3.36$ Ave. $df = 8$

%O $F = 2.72$ Ave. $df = 8$

Therefore no significant differences between variances, in conditions 1, 2 and 3, for error total and %O ($p > 0.05$).

Error total $F = 0.18$ $df = 2/24$

%O $F = 2.64$ $df = 2/24$

Therefore there was no significant difference between conditions 1, 2 and 3 for measures of error total and %O ($pr > 0.05$).

The amount of correlation between the total error scores and %O scores was calculated (using a Commodore S-61) using the results from all three conditions

$$r = -0.7618$$

this was found to be significant ($pr < 0.05$) demonstrating that the lower the %O score the higher the error totals.

4.5.3.4 Time taken to complete stages of the experiment

The results of the training times can be seen in Table 4.8 and the results of the main experiment times can be seen in Table 4.9.

In Table 4.8, D is the amount of improvement in speed to complete the second training run compared with the first. An analysis of variance was carried out to decide whether there was any significant difference imposed by the different conditions on this measure.

	C1			C2			C3		
	Tr 1	Tr 2	D	Tr 1	Tr 2	D	Tr 1	Tr 2	D
S1	3.92	2.77	1.15	4.03	2.92	1.11	4.18	3.77	0.41
S2	4.45	2.82	1.63	3.03	2.48	0.55	3.22	2.72	0.50
S3	2.53	1.68	0.85	4.00	3.03	0.97	3.38	2.45	0.93
S4	3.93	2.83	1.10	4.50	4.17	0.33	3.63	2.97	0.66
S5	3.18	2.17	1.01	3.17	3.05	0.12	2.37	2.37	0.00
S6	3.87	3.30	0.57	3.42	2.78	0.64	3.03	2.60	0.43
S7	2.67	2.46	0.21	2.27	1.97	0.30	2.37	2.12	0.25
S8	2.68	2.52	0.16	3.32	2.90	0.43	3.38	3.22	0.16
S9	2.25	1.82	0.43	3.43	2.67	0.76	3.97	3.50	0.47
AVE	3.28	2.60	0.79	3.46	2.89	0.58	3.28	2.86	0.42

<u>Table 4.8</u>

	C1	C2	C3
S1	22.12	42.20	66.68
S2	42.48	48.03	40.68
S3	25.58	40.23	30.03
S4	51.62	42.70	30.00
S5	26.90	34.70	24.32
S6	24.27	24.23	42.40
S7	21.98	23.13	22.57
S8	23.23	27.65	34.60
S9	31.83	21.57	28.25
AVE	30.00	33.83	35.50

Test for homogeneity of variance:

$F = 3.159$ Ave. df $= 8$

Therefore there was no significant difference between variances ($p > 0.05$).

Ho: there was no significant difference in the improvement of speed, for Tr2 compared with Tr1, between conditions 1, 2 and 3. $F = 0.219$ df $= 2/24$.

Therefore there was no significant difference between conditions 1, 2 and 3 ($p > 0.05$).

A t-test for independent samples was applied to examine the difference between Tr1 and Tr2 in each condition.
Ho: there was no significant difference between Tr1 and Tr2 in conditions 1, 2 and 3.

C1	Tr1 v Tr2	$t = 2.13$	df = 16
C2	Tr1 v Tr2	$t = 1.97$	df = 16
C3	Tr1 v Tr2	$t = 1.52$	df = 16

Therefore there was no significant difference between Tr1 and Tr2 in any of the conditions.

An analysis of variance was carried out upon the data in Table 4.9, the aim being to detect any significant differences between conditions.
Test for homogeneity of variance
$F = 1.69$ ave. df = 8

Therefore there was no significant difference between variances ($p > 0.05$).

Ho: no significant difference in experiment time between conditions 1, 2 and 3 for the amount of time taken to complete the experiment ($p > 0.05$).

4.5.4 The nature of the spatial image

The previous spatial recall results give representative values for each subject on the general accuracy of spatial localisation. However, the specific nature of the typical spatial 'image' of the pigeon-holes cannot be characterised from these. To do this we must examine spatial recall parameters for each individual pigeon-hole. The parameters used were the numbers of categories recalled and %O.

4.5.4.1 Calculation of results

The number of job categories recalled per pigeon-hole were added up over the nine subjects in each spatial recall condition. Therefore, if each subject recalled the job category from a particular pigeon-hole, the total would be 9.

The %O scores per pigeon-hole were treated in a different way. The probability of obtaining an exact localisation of a job category was calculated for each pigeon-hole. First, the probability for the exact localisation of job categories in each column was calculated, then the same was done for the rows. For example, for a column, the number of O's scored in that column was totalled for the nine subjects in each condition. This total was then divided by the maximum total possible (i.e. 9 x 6 = 54), which gave the probability of getting at least one O in the column. To get a total for each pigeon-hole the probabilities for the rows and columns were multiplied together.

4.5.4.2 Results analysis

The results obtained for the numbers of categories recalled per pigeon-hole can be seen in tables 10-12. The probabilities of exact localisation for each pigeon-hole can be seen in tables 13-15. From a cursory look at the results it seems that the number of categories recalled per pigeon-hole is similar for all of them. The probability of exact localisation, however, seems to be higher for the outside pigeon-holes than the ones in the middle. The significance of these characteristics needs to be statistically assessed.

The statistical test used was a t-test comparison of the values of the eighteen outer pigeon-holes against the block of twelve in the middle (surrounded by the double lines in tables 10-15).

	C1	C2	C3	C4	C5
R1	9	9	9	8	8
R2	8	9	9	8	8
R3	9	8	8	7	8
R4	7	9	8	8	8
R5	9	7	9	9	9
R6	9	7	8	8	9

Table 10 - Condition 1

	C1	C2	C3	C4	C5
R1	9	7	8	8	9
R2	8	9	9	8	7
R3	6	7	7	7	7
R4	8	6	8	7	9
R5	7	8	7	8	9
R6	8	8	9	9	8

Table 11 - Condition 2

	C1	C2	C3	C4	C5
R1	9	8	8	9	8
R2	9	9	9	8	7
R3	7	9	9	6	7
R4	8	8	8	8	8
R5	8	5	8	7	7
R6	8	8	9	7	9

Table 12 - Condition 3

Numbers recalled:

Condition 1 $t = 0.33$ $df = 28$
not significant ($p > 0.05$)

Condition 2 $t = 1.236$ $df = 28$
not significant ($p > 0.05$)

Condition 3 $t = 0.45$ $df = 28$
not significant ($p > 0.05$)

Tables 13-15. The probabilities of correctly locating the various job categories for each of the pigeon holes

Row value		C1	C2	C3	C4	C5	
↓		0.77	0.75	0.78	0.73	0.79	←Column value
R1	0.89	0.69	0.67	0.69	0.65	0.70	
R2	0.79	0.61	0.59	0.62	0.58	0.62	
R3	0.72	0.55	0.54	0.56	0.53	0.57	
R4	0.65	0.50	0.49	0.51	0.47	0.51	
R5	0.77	0.57	0.56	0.58	0.54	0.58	
R6	0.93	0.72	0.70	0.73	0.68	0.73	

Table 13 - Condition 1

		C1	C2	C3	C4	C5
		0.88	0.77	0.66	0.61	0.82
R1	0.88	0.77	0.68	0.58	0.54	0.72
R2	0.66	0.58	0.51	0.44	0.40	0.54
R3	0.66	0.58	0.50	0.42	0.40	0.57
R4	0.71	0.62	0.54	0.45	0.43	0.62
R5	0.70	0.62	0.53	0.45	0.43	0.61
R6	0.84	0.74	0.64	0.54	0.51	0.73

Table 14 - Condition 2

		C1	C2	C3	C4	C5
		0.88	0.64	0.55	0.61	0.84
R1	0.82	0.72	0.52	0.45	0.50	0.69
R2	0.66	0.58	0.42	0.36	0.40	0.55
R3	0.52	0.46	0.33	0.29	0.32	0.44
R4	0.53	0.47	0.34	0.29	0.32	0.45
R5	0.70	0.62	0.45	0.39	0.43	0.59
R6	0.90	0.79	0.58	0.50	0.55	0.76

Table 15 - Condition 3

Probability of O:

Condition 1	$t = 3.72$	$df = 28$
	significant ($p < 0.001$)	
Condition 2	$t = 6.48$	$df = 28$
	significant ($p < 0.001$)	
Condition 3	$t = 5.99$	$df = 28$
	significant ($p < 0.001$)	

There is no significant difference between the numbers recalled for the outside pigeon-holes compared with the inner block. However, there is a very significant difference between the probability of accurately locating job categories in the outer pigeon-holes compared to the inner block; the outside ones give higher probabilities.

4.5.5 **Discussion**

The comparison of the results, for the various measures of free and spatial recall, with those that could have been obtained by random chance elicited two important findings. The first was that categorical cues were dominant in the free recall situation; the amount of spatial clustering was not significantly different from chance, whereas the amount of categorical clustering was very significantly greater (see section 4.5.3.2.). The second was that spatial cues were dominant in the spatial recall situation, the measures of recall, average total error and %O, being very significantly greater than chance (see section 4.5.3.3). The high %O scores preclude any significant categorical influence in placement of categories on the spatial recall diagram. This does not mean, however, that categories are not first identified via a categorical model, merely that placement is predominantly spatially cued.

The main experimental interest was in the relationship between categorical and spatial memories. It might be argued that because the general implicit categorisation of the information items was flexible, the measure of categorical recall was unrepresentative of subjective categorisation in absolute terms.

However, the relationship between categorical and spatial memory cannot be conceived in terms of absolute measures; rather, the differential effects of conditions 1, 2 and 3 upon the results is the important consideration. Any deviation of the measures of categorical and spatial recall from 100% can be accounted for in terms of chance, forgetting, inaccurate storage, or the use of other cues meaningful to each subject; an insight as to the nature of these factors can be gained from subjective comments. The results which are central to an understanding of the relationship between categorical and spatial memory are the number of categories recalled, the measures of categorical recall, and the measures of spatial recall.

The number of categories recalled reflects the efficiency of retrieval from memory. If categorical and spatial cues were closely and dependently related in memory, we would expect the efficiency of recall in condition 2 to be significantly less than that resulting from the explicit categorical organisation in condition 1. The reason for this is that the two types of cues are in conflict in condition 2, whereas they correspond in condition 1. However, if categorical and spatial memory were built up independently we would expect no decrease in efficiency of recall in condition 2 as compared with condition 1. The results suggest, therefore that categorical and spatial memory are independent systems. This conclusion is further supported by the comparison of the efficiency of spatial recall in each condition with prior free recall, and the comparison of these with condition 3 where there was no prior recall. A close relation in memory between spatial and categorical cues would lead to prior free recall interfering with subsequent spatial recall in condition 2 as compared with conditions 1 and 3. We would also expect the spatial recall of condition 1 to be more efficient than spatial recall in conditions 2 and 3. None of these comparisons showed any significant difference in efficiency of recall (see section 4.5.3.1), thus suggesting the two types of memory are independent. In turn, we must consider the possible presence of some form of 'executive' mechanism which differentially interprets categorical and spatial memory.

The measurement of categorical recall, percentage of categorical clusters, provided an index of the amount of categorical organisation taking place in memory. We would expect less categorical organisation to take place in condition 2, compared with condition 1, if the two types of cues were closely related. Appropriate analysis showed no significant difference, again suggesting independence of the two types of memory. The results also imply that the explicit categorical organisation of pigeon-holes in condition 1 did not promote a more structured categorical memory model in comparison to the use of randomly arranged pigeon-holes in condition 2, where the categorical relations were implicit.

The two measures of spatial recall, error total and %O, both give a measure of spatial recall accuracy. Of the two, %O is a better indicator of accuracy. We would expect that the lower the %O score the higher the average total error would be. This was confirmed by a correlation which produced a significant negative relation between the two.

As before we would expect a close relationship between categorical and spatial cues in memory to produce a less accurate spatial recall in conditions 2 and 3, as compared with condition 1. Also, we would expect accuracy of spatial recall in condition 3 to be better than condition 2 due to no prior free recall. This, however, was not the case, there was no significant difference between any of the conditions for average total error or %O, further evidence for the independence of the two types of memory. In addition, it is evident that a strong spatial memory model is formulated, irrespective of meaningful categorical organisation.

Finally, the analysis of the specific nature of the spatial image demonstrated an approximately equal probability of a job category being recalled for all pigeon-holes regardless of position. In terms of spatial location, however, the job categories of the outermost pigeon-holes had a significantly higher probability of being accurately located. Three things are apparent: final confirmation of the independence of categorical and spatial memory; job category identities must be established from categorical memory prior to location; and that the strategy of spatial location establishes reference points at the extremes of the information locations.

The implications of this experiment is that there are separate, independent systems for categorical and spatial memory; a 'memory system' is a set of common mechanisms for storing information (Posner, 1973). Within these systems information is coded in different ways. Categorical memory can be thought of as coded in terms of verbal processes, especially in terms of semantic relationships. Spatial memory coding can be considered in terms of a spatial 'image' made up of inherent spatial relations. This 'image', however, is not necessarily visual in nature; for instance, motor components might contribute to its coding. It is also evident that the 'image' is established via points of reference in the display, usually those parts at the extremes which provide a 'frame of reference'.

The independence of the categorical and spatial memory systems conflicts with previous work done in a similar context. Bower, et al. (1969) showed that the structural organisation of items to be recalled, into their common categories and sub-categories, resulted in a greatly superior recall. Broadbent et al. (1978) showed that the organisation of presented information items into hierarchical and matrix structures, based on semantic relations, gave better performance in recall. Clearly this would imply that categorical and spatial cues are closely associated, because the categorical relationships in the information and the spatial organisation of the information would seem to be complementing one another; thus contradicting the present experiment.

In the latter two experiments categorised lists of words were presented to the subjects, whereas the present experiment requires the semantic relations between job categories to be built up from the interpretation of information during a simulated filing task. The presentation of pre-structured categorised word lists provides very little 'task context' to act as a 'frame of reference', for the words. Broadbent et al. presented the structured word lists and asked for recall, the presentation was repeated as necessary. After the first presentation the subjects were expecting to have to remember the words and so could have used the word structure as a spatial mnemonic. The scanning of this spatial image would then produce categorical clustering in recall. The lack of task context and the building up of a purely spatial model of the words would cause retrieval to be better in the structured situation; a categorical word model need not be involved.

The simulated filing task in the present experiment provided a strong task context within which to relate the job categories. The task context was developed as a result of interpreting and sorting information into categories over a period of half an hour on average. This task context provided a strong frame of reference within which to relate the semantic aspects of the job categories. The job categories also had a spatial frame of reference by virtue of their positions on the spatial array of pigeon-holes. As in an office filing situation the spatial cues were incidental to the main task, and the use of them was more relevant to that occurring in most natural working environments.

It is feasible, therefore, for strong categorical and spatial models of information to be built up independently as present results suggest. A lack of 'real world' task context could be a major factor in the difficulty encountered in relating previous laboratory-type memory research with the role that memory plays in applied situations.

The times taken to complete the training periods, and the main experiment, were an index of how easily efficient cognitive models of the spatial and categorical aspects of the pigeon-hole array were built up. Relatively slow times would indicate difficulty in building appropriate cognitive models, and vice versa. If categorical and spatial memory were closely and dependently associated, it would be expected that the conflict situations, in conditions 2 and 3, would be associated with subjects taking longer to complete the experimental stages. If, however, categorical and spatial memory were independently built up, no significant difference in times would be expected. Therefore, as the experimental analysis of times taken to complete experimental stages showed no significant differences, it would seem that categorical and spatial recall memory are separate systems, separately built up.

The large variation in the times taken to complete the experiment suggests that people are not equally proficient in developing conceptual models. Some subjects adapted to the filing requirements very quickly, whilst others took much longer. This, and the variation present in the categorical and spatial recall results, suggests that the conceptual mechanism of some individuals are superior to those of others.

4.6 <u>Results of subjective comments and experimenter observations</u>

In addition to the main experimental results, certain non-quantitative information was available which was useful in qualifying the results obtained from the quantitative analysis. Subject introspection concerned with interpretation of the information and their strategies of recall was one source of information. Experimenter observations were the other.

Subject comments were elicited by five questions, these were:

1) Were you aware of any major categories of information? This question examined whether they had noticed that the job categories fell into five major categories.
2) What strategy did you adopt for the reading of each item of information? Concern here was with how each subject read each item of information in their attempt to interpret it correctly.
3) What strategy did you employ for the first part of recall? (show them the free recall list). Much could be learned from the strategy the subject employed during free recall, in addition to the quantitative analysis of the free recall lists.

4) What were the reasons for recalling the items after you had drawn a line?
   This question was concerned with trying to establish the types of cues which elicited another period of recall after a pause, during which the subject was trying to recall more job categories.
5) What strategy did you employ for the second period of recall? (show them the spatial diagram).
   As in 3), interest was in the strategy employed during this particular type of recall.

Questions 3) and 4) did not apply in condition 3 of the experiment.

Experimenter observations included any aspects of subject behaviour thought to be important within the context of the experiment. These included the noting of behaviour at different stages of the experiment, and searching through free recall lists for associations other than those defined by the major categories of information.

4.6.1 Subject comments

The introspection employed by the subjects, in response to the questions asked of them, was a useful method of investigating how they consciously interpreted and subsequently recalled information. It is, in effect, a technique for 'observing' unobservable thought processes. Thinking is not necessarily 'unobservable' to the thinker; he may be able to make his private awareness public by reporting on it.

The difficulties of dealing with introspective data are considerable. Introspective data are by their nature unverifiable; they can represent only those aspects of thinking of which the thinker is readily aware and therefore can offer no clues to the existenee or nature of 'unconscious' thinking; they are conveyed only by the verbal report of the thinker and this may not be sensitive enough to portray all the subtelties of experiences. Further, simply asking a subject to report on how a certain mental process operated might cause the actual process to be elaborated upon. Nevertheless introspection has been, and still is a valuable tool in psychological research. (For a fuller discussion of the use of introspection in the study of thinking, see Humphrey, 1951). In the present experiment the introspective element served to elaborate upon the quantitative data, thus giving a clearer picture of the interaction with categorical and spatial memory.

4.6.1.1 Awareness of the major categories of information

The five major categories of information used in the experiment were designed to be flexibly interpreted (i.e. buying in the industrial context could be related to retailing in a commercial context); in one case the job categories were purposely fairly vaguely related. The subjects' awareness of the major categories, in the different conditions of the experiment, was considered an indication of the nature of their categorical model of the information. Of particular interest was the relationship between the experimenter defined major categories and those developed by the subjects.

The first observation was that in some cases subjects were aware of all the experimenter defined major categories. Others were aware of only the more obvious major categories and consequently developed their own major categories to include the job categories that remained. The results can be seen in Table 4.10.

	C1 (frequency)	C2 (frequency)	C3 (frequency)
Aware of all experimenter defined categories	6	3	1
Aware of some experimenter defined categories	3	6	8

Table 4.10: Results for question 1

In condition 1, a greater number of subjects were aware of all the experimenter defined categories; this was in spite of not being sure what to call the vaguely defined category comprising leisure and non-government public service jobs. In condition 2 a greater number of subjects were aware of only the more clearly defined major categories. They defined their own major categories for the remaining information. Condition 3 showed the same type of result as condition 2 only more extremely so. The reason for this was probably that, because there was no initial free recall, the subjects did not have to access their categorical memory. Therefore, the categorical relations were not available in 'active memory', although present in categorical memory.

The experimental results of free recall in conditions 1 and 2 showed no significant difference in categorical or spatial clustering. Condition 2, however, showed a decrease in the realisation of all the experimenter defined categories. The reason for this could be that, although categorical and spatial memory seem to be independent, the spatial cues involved in the columnar grouping of experimenter defined major categories in condition 1 can aid the formation of a categorical model at the major category level. In condition 2, where job categories were randomised, subjects tended to generate their own major categories, based on categorical relations already stored in their categorical memory. It should be noted, however, that these were usually sub-divisions of experimenter defined major categories (e.g. Civil service, Local authority, and social work might be categorised under 'Government'). It seems that categorisation takes place irrespective of the spatial cues, although they can help to define the categories.

In all three conditions the subjects had trouble with the vague major category. In condition 1 half the subjects realised that major categories were assigned to columns, this caused them to have more difficulty classifying the vague category; they knew that it must be a major category but were unsure of how the individual job categories related together.

In conditions 2 and 3 the members of the vague category were related in smaller groups, for instance, tourism and hotel management and catering, or tourism and public transport. The former association would not affect the categorical clustering measure, whereas the latter would.

The previous evidence points to both spatial and categorical cues being used to build up categorical relations between the job categories. Sometimes the external model of information can contribute to the categorical storage of information relations. On other occasions pre-stored knowledge of categorical relations can contribute to the categorical storage of information irrespective of the spatial model developed. This suggests that there is definite communication between categorical and spatial memories.

4.6.1.2 What aspects of each item of information were looked at?

There seemed to be two main strategies for reading each item of information, and two others which were only used once, each by a particular subject. The four alternatives and frequency of use are as follows:-

Strategy	Frequency
Scan the text first for key words. Then look at the title to clarify if necessary.	12
Look at the title first. If not enough information was present, scan the text for key words.	13
Scan the text first for key words. Then look at the address to clarify, followed by the title if necessary.	1
Haphazard scanning.	1

It must be noted that in the early stages of many experiments, when subjects were less familiar with the information items, they often had to read and inwardly digest some of the information in order to file it.

V. However, task here was highly unrealistic.

The results demonstrate that most subjects adopted a systematic strategy for reading each item of information. Approximately half looked at the heading first and then scanned the text for an appropriate key word if this did not provide enough information. The others did the opposite. In some cases there was misleading information in the heading, in some cases there was misleading information in the text. The strategy adopted therefore caused misinterpretation of the information. These different strategies occurred even though the information was standard format. The standard format seemed to encourage expectations as to the information content of each item, consequently subjects scanned for key words which they expected to be there. If other unrelated key words are also present, or the heading could be interpreted under some other major category, misfiling could occur. Variation in information format might encourage more careful reading and interpretation of the document. Standard format documents might not be a good idea in computer systems.

4.6.1.3 <u>Free recall list - strategy and cues used. Also: Reasons for the after line associations.</u>

The choice of strategy and use of cues was investigated to give an insight into the use of categorical and spatial memory in free recall. Another consideration was how each burst of recall was cued, after a line had been drawn during the preceding pause. The categories of subject comments on these questions, along with the frequency of occurrence, can be seen in Table 4.11. Those categories with an asterisk at the side also served to sometimes cue periods of recall after a previous pause.

An important group of comments is provided by categories a), b) and c) in Table 4.11. a) shows that approximately equal numbers, 5 and 6, of subjects in conditions 1 and 2 thought of job categories in relation to the super-ordinate major categories. This suggests that subjects had categorical models available irrespective of the experimental condition. b) and c), however, show an interesting trade-off between conditions 1 and 2. In condition 1, a significantly greater number of subjects started by trying to visualise the array of pigeon-holes. The subsequent recall of a category, or categories, then caused the categorical model to take over and categorically related job categories were cued and elicited in recall. In condition 2, a significantly greater number of subjects visualised the spatial locations of categorically related job categories. A possible explanation is that when the information was interpreted in condition 2, it was first identified with a job category via categorical memory. It would then have been necessary to search for the location of the appropriate job category on the pigeon-hole array, which was not laid out in any logical order. The categorical model would therefore have a corresponding array image where common categories were associated in widely different locations.

	C1	C2
*a) Thought of related by major categories	5	6
b) Tried to visualise array and work systematically through, but categorical associations took over	8	2
*c) Thought of spatial associations between categorically related locations on array	1	6
d) Categories more relevant to past experience stood out	3	1
*e) Scanned those already written and tried to think of rest by process of elimination	3	3
f) Remembered because items easily filed into it	1	0
g) Remembered because had difficulty filing into it	2	1
*h) Tried to remember actual information items	3	3
*i) Tried to think of many possible jobs and then decide if present	0	1
j) Remembered because category descriptor was either long or short word	2	1
*k) Some came out of nowhere	1	1

Table 4.11: Results for question 3

In condition 1 subjects were not required to visualise the connections between common job categories to such a great extent. This was because the spatial layout of the job categories corresponded to a logically defined categorical model of the information. Therefore the visual scanning of the spatial positions was quickly taken over by the categorical model.

These results suggest three important conclusions. The first is that categorical memory is dominant in the free recall of categorised information. The second is that, although categorical memory is dominant in free recall, people naturally try to visualise information relations in memory if it has been interacted with in some kind of systematised task environment. Thirdly, there must be communication between the categorical and spatial memory systems. This could either take the form of a switching of attention between the two, or of parallel processing in the two memory systems.

Comment categories d) to k) demonstrate the many other subsidiary strategies and types of cues used as an aid to memory. Memory can again be seen to be flexible in using a variety of different cues and strategies in an effort to retrieve information.

4.6.1.4 Spatial recall list - what was your strategy of recall and what cues did you use?

This question attempted to discern how categorical and spatial memory were used during spatial recall, and how this affected the strategy and cues used. The results can be seen in Table 4.12.

Every subject in a) of Table 4.12 tried to visualise the pigeon-hole array. b) shows that certain parts of the array seemed to be established as points of reference. It was significant to note that in condition 1 the bottom and top of the array seemed important reference points, whereas in conditions 2 and 3 it seemed to have been the corners. In condition 1 the common categories were laid out in columns, it seems logical, therefore, that the top and bottom of these columns should be used as reference points. In conditions 2 and 3, however, the job categories were placed randomly, and so the corners of the array provide logical reference points. The sides of the array were used equally as reference points in all conditions. The middle areas, or individual random pigeon-holes, were used as reference points infrequently. c) in Table 4.12, as in Table 4.11, shows more use of a spatial image relation between common categories in the randomised conditions rather than in condition 1.

	C1	C2	C3
a) Tried to visualise the pigeon-hole array in mind	9	9	9
b) Certain points of reference were readily available in the image.			
i) Bottom and top	7	3	2
ii) Corners	1	6	5
iii) Sides	4	4	3
iv) Middle	2	2	0
v) Random locations	1	0	0
c) Visualised different locations of common major category members	1	3	3
d) Remembered information most relevant to self	2	0	4
e) Words had similar features (e.g. both began with A)	1	1	0
f) Thought of job category then its location	0	1	1
g) Thought of individual information items	1	0	0
h) Remembered categories that were troublesome	2	1	3

Table 4.12: Results for question 4

This again suggests interpretation and identification of information, via categorical memory, prior to location in the array, and also the natural tendency of people to visualise information relationships in the 'real world' environment. As in Table 4.11, d) to h) show that other strategies and cues were used to recall job categories, thus demonstrating the flexibility of memory. The results demonstrate that spatial cues play a much stronger part in spatial recall than they do in free recall. There also seems to be communication between categorical and spatial memory, though perhaps not quite as much as in free recall.

4.6.2 Experimenter observations

Experimenter observations arose from two sources. The first source was the noting of any general behavioural characteristics occurring during the main experiment. The second source was from the examination of the non-experimenter defined job category pairs in the free recall lists.

4.6.2.1 General behavioural characteristics during the main experiment

All subjects experienced initial difficulty in interpreting and correctly filing each information item. It was obvious, at this stage, that the subjects' cognitive models were under-developed and inefficient. Symptoms were indecision, much scanning of the array, and relatively more misfiles comparedto later stages of the experiment.

There was evidence that categorical memory was develpped faster than spatial memory. Often the subjects identified the necessary job category but then could not find it on the pigeon-hole array although they knew what they were looking for.

Filing efficiency progressively developed during the experiment as peoples cognitive models became more complete, and fewer mistakes were noted. Subjects often read a piece of information, identified it, and then automatically moved to the correct area of the display without looking. The correct pigeon-hole was then visually determined. This suggests that there was some form of enactive component contributing to the spatial image, and that it was not purely visual in nature.

In the later stages of the experiment the smooth running of the filing task was only interrupted by ambiguous items of information. At these points, the decision time concerning identification and location increased, as would be expected. Filing generally, however, was much faster than in earlier stages.

The performance of all the subjects plainly demonstrated that some individuals were much more conceptually competent than others. Where some people might have taken twenty five minutes to complete the experiment, others took over an hour. This aptitude might be peculiar to each individual, on the other hand, it might be specifically related to a particular user group. Whichever is the case, it is important to consider this variability, especially if the design of computer systems are to be compatible with users' conceptual mechanisms.

4.6.2.2 Examination of free recall for clusters not defined by the experimenter major categories

Although the index of categorical clustering in free recall was based on experimenter defined major categories, the flexibility of this definition was such that other subject orientated associations were possible. To gain an insight into the possible non-experimenter designed associative cues used by the subjects, a further review of the free recall lists was necessary. Each recall pair, that was not ascribed to one of the major categories, was examined for any other possible associative aspects. The result of this further investigation was that possible associations were classified into three broad categories. Some of the associations were obvious and easily classified, whereas some of the relationships were of a more speculative nature. The three categories included associative relations based on the subjects own interpretation of context, physical similarities between words, and those where there was no obvious association.

The subjects own interpretation of context was judged to occur when a pair of job categories could possibly be related in a context other than that defined by the experimenter. This does not necessarily mean that the subject used that particular different context, just that it was possible. The examples that follow will give some idea of the logic behind each classification.

Management training and accountancy - Accountancy could be related to management training by virtue of the accountants place in a management-type set-up.

Public transport and tourism - People might tour the country by public transport. Both involve travel.

Banking and buying, Buying and retailing - These categories were the most strongly associated outside experimenter defined major categories. There is a strong financial connection. This association might suggest that job category titles were being interpreted on face value with the subject supplying his/her own context. The context of buying was stressed as industrial in each relevant information item.

Banking and legal work - There is a strong legal aspect in banking.

Advertising and buying - Advertising is the mediating influence between manufacture and purchase.

Physical similarities between job categories include many different associations. For instance, each job category might start with the same letter, or they might have the word training in common (although this might be acceptable to a contextual association under training). The following examples illustrate possible physical associations.

Engineering and environmental control and design - Both begin with E (also might have a contextual association that engineers could be involved in environmental control and design).

Local authority and legal work - Both begin with L (also might have a contextual association that local authorities deal with legal matters).

Quality control and environmental control and design - Both have control in common.

It must be noted that distinctions between physical associations and contextual associations was somewhat arbitrary. However the subjective comments made it clear that physical similarities were sometimes used. In section 4.6.1.3 three subjects used the association between job categories of similar length to cue recall. In section 4.6.1.4 two subjects used the association of job categories beginning with the same letter to cue recall.

When no obvious association could be found between the members of a recalled category pair, they were classified into the final category, along with all the other similar pairs. This category was termed, 'no obvious connection found'. It is possible that pairs in this category might have been spatially related, however spatial clustering in free recall had been found not significantly greater than that occurring by chance. Also included in this category might be many recalls cued by task context information, similar to those reported in the subjective comments (section 4.6.1). Possible cues are as follows:-

1) Scanning items previously recalled and eliminating possibilities.
2) Job category associated with past experience.
3) Job category associated with ease of filing into it.
4) Job category associated with difficulty of filing into it.
5) The reviewing of all possible jobs known by the subject.
6) Job category remembered 'out of the blue'.

The frequency of recalled pairs in each of the three categories previously discussed is as follows:

	C1	C2
Personal interpretation of context	26	34
Physical similarities between words	9	12
No obvious connections found	40	48

These results tend to suggest that subjects were very flexible in their interpretation of information within a predefined task context, where the categorical structure of the information was not rigidly defined. It also seems that the subjects used many more cues to aid recall than purely categorical and spatial ones. This is demonstrated by association of physically similar job categories and the large proportion of associations where no obvious connection could be found.

4.6.3 Summary

The subjective comments reinforced the experimental results in suggesting that categorical and spatial memory were separate systems. In general comments either confirmed experimental results or formed a basis for the elaboration of processes involved in the use of categorical and spatial memory.

Results suggest that internal conceptualisation of an external filing system arises due to the influence of pre-stored categorical knowledge and the external organisation of information Subsequently, experimenter observations noted that an efficient cognitive model of the externally organised information did not develop particularly quickly; the time taken varied widely amongst individuals. There was evidence, however, that categorical memory developed quicker than did the concommitant spatial memory.

Recall of information from memory, concerning filed information, seemed to engender communication between categorical and spatial memory, taking the form of either attention switching or parallel processing. During free recall categorical memory was more dominant, whereas spatial mamory was more dominant during spatial recall. Any scanning of the spatial image, however, did not necessarily have to be spatially systematic; the scan could be determined by categorical relationships between external locations.

Subjects seemed naturally to try to visualise information, in both free recall and spatial recall, when that information had been interacted with in a 'task environment'. This tendency, however, was less pronounced in free recall. Any spatial image of the information system had established points of reference corresponding to certain areas of the structure containing information in the task environment. The use of 'visualise' and 'image' is not meant to advocate that the spatial cognitive model was purely visual in nature, however; there was also an enactive, or motor, component which possibly contributed to it. Evidence also showed that the use of this image, during storage or recall of information, was very likely preceded by categorical identification via categorical memory. This would seem logical because it is impossible to locate information that has not been identified. The categorical identification of a piece of information was largely dependent upon the strategy used to interpret it. The appropriateness and efficiency of the strategy could affect the efficiency of storage and subsequent retrieval of that item. Once a piece of information had been correctly identified, however, memory was very flexible in its use of strategy and cues to effect storage and recall. This flexibility was demonstrated by the subjects, much of this being provided by the strong task context of the experiment and the more realistic and flexible information used.

4.7 Conclusions

As a result of this experimentation a number of conclusions may be drawn:

1) Explicit spatial organisation of the labelled pigeon-holes, according to meaningful categories, does not enhance the categorical organisation of information in memory, as reflected by free recall.
2) A strong spatial model of the pigeon-holes is developed irrespective of their being externally arranged in a meaningful manner.
3) The points of reference upon which the spatial memory model is based are the outermost pigeon-holes.

4) Categorical and spatial memory are separate and independent systems; they may be interpreted differentially by some form of executive system.
5) Categorical memory is dominant in identifying information; identities are interpreted using categorical knowledge previously stored in memory. Spatial memory is dominant in locating information; the spatial model is built up using externally perceived positional relations. Therefore, the cognitive model is formed using both internally stored and externally perceived information.
6) Cues other than categorical and spatial can be incorporated into the cognitive model of a filing system. Episodic cues in particular were prevalent: these are concerned with the fact that a particular piece of information was filed, and also with the temporal context of filing. An example of an episodic cue is where a subject remembers that they made a mistake whilst filing into a particular job category. (Other cues, e.g. colour, were not prevalent because they were standardised in the experiment.)

However, we cannot be certain that these findings are appropriate for consideration in the design of computer filing systems. Therefore, we must consider them within the appropriate context by undertaking similar experimentation using a simulated computer filing task.

5. THE EFFECT OF LISTS OF PROGRESSIVE SPATIAL AND CATEGORICAL STRUCTURE ON THE FREE AND SPATIAL RECALL OF JOB CATEGORIES

5.1 Introduction

Experiment 1 demonstrated that categorical and spatial memory were interpreted independently. It also showed that both types of memory functioned efficiently irrespective of a random or logical organisation of pigeon-holes. The task in experiment 1 was designed to simulate a 'real world' filing situation; it involved a large, well defined array of spatial locations for the information, and gross movements involved in actually filing.

Having investigated the role of memory using a 'real world' simulation, the context of the research demanded a logical progression towards an investigation of a computer filing simulation. Most mini- and micro-computer systems allow information to be stored on discs in files. To retrieve information a person can either remember the correct file descriptor which enables access, or they can list all the files from the disc and search for the appropriate file and descriptor. It was the latter situation which was thought to offer the best opportunity for simulation. Therefore, a filing procedure using various list forms of the job categories used in experiment 1 was undertaken.

To gain the maximum amount of information from the proposed computer simulation the best approach was thought to be a series of experiments employing the same task as in experiment 1. In each experiment the same job categories would be listed in different ways; firstly the amount of spatial structure would be increased, this would then be followed by a concomitant increase in categorical structure.

Each experiment would incorporate both free and spatial recall. The free recall would provide an insight into the categorical model of information and simulate recall of category descriptors used in accessing information from a computer. Spatial recall would provide an insight into the spatial model, and simulate the recall of category descriptors and their relative position in a list. Anyone who has searched on a VDU screen through a homogeneous green mass of file listings unsuccessfully for an appropriate category descriptor can see the relevance of this approach.

If list structure does aid information localisation, then the cost of the extra software involved could be worthwhile in terms of making computer filing systems more 'friendly' and 'comfortable' to use.

5.2 Literature survey

5.2.1 Introduction

Much work has been done in the past to explore how individual items of information were coded by means of sundry different attributes. These items ranged from visually presented letters through words to sentences (Herriot, chapters 2 and 3, 1974). It is clear that such an approach can only partially describe how subjects code the presentation episode. For in a typical presentation phase of a memory experiment, several items are presented. There is no justification for the assumption that subjects code visual lists of items item by item. In other words, experimenter-defined and subject-defined units may differ (Tulving, 1968).

The nominal, or stimulus, units may differ from the functional, or coded, units in terms of their size. Also, the order of items as presented and as coded may differ (Rundus and Atkinson, 1970). For example, given a randomly ordered list of items, some of which are animals, the subjects may rehearse the animals together during the presentation (Rundus, 1971). However, as shown in experiment 1 of the present research, information that is not rigidly defined by the experimenter need not necessarily be organised by the subject according to experimenter expectations. Many items can be recalled with no obvious associational or organisational strategy discernible. We must therefore be very clear what we are analysing. If some absolute strategy of memory organisation is required then analysis of the whole subject-defined rather than the experimenter-defined order should be undertaken. For comparison of the effects of different experimental conditions on experimenter-defined relations in information, on the other hand, it is valid to analyse subject recall in terms of these relations. It will be of value to review some of the possible attributes by which information in the form of lists could be coded in memory.

5.2.2 Order attributes

Hintzman (1970) and Hintzman and Block (1971) have showed that a number of attributes of a list presentation situation are encoded. The position of an item in the list, the number of times an item is repeated within a list, or even the number of other items between two repetitions of an item can be reported by subjects, who, it must be stressed, were only given very general instructions at presentation.

Underwood (1969) has demonstrated that combinations of attributes are encoded, and that they will interact to decrease uncertainty as to the nature of an item. He also reports an experiment in which he shows that subjects do not necessarily remember the order of those items that they recall, and vice versa. Memory for order cannot therefore be explained in terms of any simple strength hypothesis, where the order information would be derived directly from the strength of the 'trace' of the item itself. Perhaps the executive process of memory has to refer to memory models, or systems, via some strategy, for the required information. One system would perhaps deal with the semantic identities of items, whereas another might store positional, or spatial, information.

However, most of the research on attributes such as order of items has employed the serial recall task. It is reviewed by Estes (1972) and the experimental situation is briefly as follows. A set of four letters is presented visually and sequentially at a fast rate (e.g. 2.5 per second) to subjects. They have to read these aloud. Then they have to read aloud a set of digits at the same rate. Finally, they have to recall the letters in the same order as they were presented. Experimenters seek to distinguish item and order properties in recall, treating certain errors as indicative of the loss of order information. These errors are where a letter which was presented at a particular position has been replaced in the subject's recall by a letter which had appeared at presentation in some other position in the same sequence.

Estes (1972) summarises the results in this area as demonstrating: a) high accuracy of recall for order, b) difference in the rates at which order and item information are lost (i.e. the former faster), c) differences in the positions in the sequence at which order and item information are lost (i.e. greater loss in the middle of lists or groups), d) effects concerning grouping.

The grouping effects are particularly important if any theoretical account is to be given of how subjects code order information. Wicklegren (1967) made subjects group items within strings of eight, nine or ten digits into units of from one to five digits. The size of these chunks did not affect the number of items recalled to any significant extent, but it did affect the probability that a digit from a string was recalled in the correct position if it was recalled at all. This probability reached is maximum when there were three items per chunk. Wicklegren (1969a) found that if one item within a chunk was correctly recalled, the next was highly likely to be correct also. However, there was a much higher probability of a transitional error if the next item was the beginning of a new chunk.

The implication of this work on grouping is that chunks are coded, and that the code of a chunk contains the item and order information relating to the member items. It appears to rule out any attempt to use sequential cueing as an explanatory device. This would suggest that the first item cues the second, the second the third, etc. That subjects can employ a sequential cueing device is clear from the results of probe experiments which ask for the recall of the item which succeeded the probe in the presentation sequence (Wallace, 1970). But the results of the grouping experiments indicate that there may be hierarchical as well as sequential modes of coding order.

There is one finding of N.F. Johnson's (1970) which suggests that sequential coding plays little part even within chunks. Johnson presented interfering material to subjects between the presentation of chunks and their recall. The material consisted of the to-be-recalled chunk with one of the three letters changed. It made no difference which one of the three letters was changed, the first, second or third. All had equally deleterious effects on the recall of the other letters in the chunk. If there were sequential cueing within each chunk, altering the first letter would have the most deleterious effect. For that would prevent the second letter being cued, and hence the third.

However, this approach still fails to specify how order information is coded. It merely suggests that coding of the order of a whole list is more hierarchical than sequential. But the form in which the order information is coded may be in terms of position tags. That is, the subject may assign an abstract representation of where the item is within a chunk to each item. This representation need not be in the form of a number (e.g. the seventh item). It might instead be represented spatially, with the items coded as a linear series. This might be best suited by short series, which would explain why order information is best with chunks of three items. Underwood (1969) quotes studies in which the spatial features of the presentation situation are coded, e.g. when different items are presented in different positions. But these are highly speculative suggestions.

5.2.3 Time and frequency attributes

There are other attributes of the presentation situation which might give additional information about order. Two of these are time and frequency.

Perhaps the most effective method of showing that subjects can use temporal codings is that of 'judgements of recency'. Subjects have been shown to be remarkably successful in stating how many items intervened between the first and second presentation of an item in a list (Hinricks, 1970). They have also been shown to be capable of deciding which of two items appeared first on a list (Yntema and Trask, 1963). However, difficulty lies in isolating temporal variables from other factors. For example, Yntema and Trask found that the shorter the interval between the occurrence of an item and the subject's recency judgement, the more accurate that judgement was. In other words, information about relative occurrence in time may be quickly lost over time. This could mean that the time information is closely connected with the other attributes of the item in memory. Moreover, when an item recurs several times in the list it is more likely to be judged more recent than when it does not recur (Morton, 1968), supporting the idea that temporal judgement is intimately tied in with strength of the coding of the item.

Another feature of item presentation which subjects use to code items is the frequency with which they have occurred in the list (Underwood, 1969). Subjects are very good at informing the experimenter of the number of repetitions of an item. However, as with demonstrating other forms of coding, to exhibit coding by frequency one has to hold constant the strength and extent of all other attributes of coding of the item in question. But if coding by frequency is one of the attributes by which an item is coded, then varying the frequency attribute will result in a general variation also in the strength and extent of coding.

5.2.4 Semantic attributes

In addition to the attributes concerning the physical structure of lists previously discussed, there are also the conceptual relations between the information items in the lists to be considered (Voss, 1972). If one says, for instance, that the relationship between 'cat' and 'dog' is coded, one implies that these attributes which the items have in common are coded as a unit. The remaining attributes which the items do not share will be coded separately, and will serve to distinguish the two items from each other and from other items for storage and retrieval purposes. This proposal satisfies the findings that related items are often recalled together and more effectively than unrelated items; and it explains how the right items are recalled. It allows, in other words, both for the reductive and for the elaborative functions of coding - the reduction of the load on the system and the need to identify carefully each item for retrieval purposes.

The two main approaches to the analysis of organisation in recall have concentrated on one function of coding largely to the exclusion of the other. The reductive function has been emphasised in experiments in which material is selected and results analysed in terms of the superordinate - subordinate hierarchical relationship. That is, it has been assumed that several items are coded by means of a single superordinate coding. This involves a very considerable degree of constraint of the situation by the experimenter; for by selecting the items on a categorical basis (e.g. four animals, four items of clothing, etc.) and by analysing the order of recall on the same basis, he effectively ignores all other possible methods of organisation the subject may employ. If he is to generalise from his experimental situation, he must assume that organisation is in neat and tidy units, with each item being coded only within one unit.

The second tradition in the study of organisational coding, stressing the elaborative function, is less constrained by the experimenter. It seeks to show how subjects code relations between nominally unrelated words. However, the explanations are couched in terms of associative networks of words. That is, it is assumed that the relation between two words presented in a list is coded by the number of word associates they have in common, while the number of word associates peculiar to each word in particular serves to individually identify it. The distinction between the reductive and elaborative traditions is that the latter supposes that words are coded by means of other words, the former by means of attributes. It can be argued that both the main traditions have under-estimated the difference between the nominal and the functional; the reductive tradition assumes the identity of the subject's coding and the experimenter's categories, while the associative tradition assumes that coding is in the same form as presentation, viz., verbal.

The form of the present experimentation, which includes the analysis of categorical clustering, emphasises the reductive tradition. This does not mean, however, that any elaborative coding will be ignored. In a 'real world' situation, where information is related to varying degrees, reductive coding might occur where explicit relationships are readily available. Where no explicit relationships are available it might be necessary to elaborate upon the available information in order to enhance storage and subsequent retrieval. A penetrating review of the whole field of organisation is provided by Postman (1972) and a thorough one by Wood (1972).

The mainstay of the reductive tradition is the use of free-recall, where recall is scored for the number of experimenter defined categorical clusters. Free recall has repeatedly shown that subjects employ the relations inherent in material to aid their recall. It has been found that, given random-order presentation, recall has been ordered in a non-random way; that the amount of principled ordering is correlated with the amount recalled; and that the values of both these variables increase over trials. Closer analysis of the recall protocols has revealed that it is an increase in the number of items per subjective unit that results in the general increase in items recalled; it is not the increase in the total number of subjective units. Mandler (1967) confirmed these findings in experimentation where subjects were required to sort nominally unrelated words into as many subsets as they wished. He found that the limitation on the number of items per unit, and the number of units remembered, was seven. Tulving and Pearlstone (1966) provided labels for units at recall, this resulted in an increase in the number of units recalled but not in the number of items per unit. Mandler (1967) concluded that the function of organisation is to chunk the presented material into any number of chunks up to the upper limit of immediate memory, that is, seven (Miller, 1956). As organisation proceeds over trials in a multi-trial free recall procedure, units become larger and better formed. Thus more items can be passed through the information processing system from short-term into long-term storage. This point of view is supported by the finding that although the number of unrelated items recalled is less than the number of categorically related items, the number of units is the same. In other words, categorizable items are easier to unitize, and so are better recalled. This is known as the 'strong' reductive hypothesis.

Postman (1972) reversed the Mandler procedure, such that the subjects' sorting criterion succeeded rather than preceded recall. No relation was found between the number of units sorted and number of items recalled. A relation was found, however, between number of units recalled and number of items recalled. This suggests that the locus of limitation may be at the retrieval rather than the storage phase. Further support for this finding results from the strong reductive hypotheses running into more difficulties. Postman showed that more units can be recalled when longer lists of items are presented, even though the size of the units remain constant. Moreover, it is conceivable that, given adequate practice, subjects could recall more than seven units in those task situations where this limit appears to operate. One may postulate 'superchunks'. However, it seems less risky to abandon the notion of strict upper limits to processing capacity in favour of organisation at retrieval.

Organisation at retrieval postulates limitations upon the number of stored units which can be retrieved from storage at recall. Tulving and Pearlstone (1966) demonstrated that more items were available at retrieval than were recalled; this was in terms of cued categories of items recalled only, not in terms of number of items per category. The conclusion was that although subjects had stored the items by means of category codings, they could not provide themselves with those codings at recall.

There is a considerable amount of other evidence which suggests that subjects employ codings of relations at retrieval. Firstly, interference occurs at the category rather than the item level (Tulving and Psotka, 1971). Secondly, items within a category cluster are recalled in short bursts, with little time between items. In comparison, there is a longer gap between the last item in one category and the first in another. This gap increases as the recall phase progresses from one category to another, implying that the later category codings are not so easily available to the subject (Pollio et al., 1969).

Finally, there is the interesting 'some or none' effect (Cohen, 1966). That is, if a category of items is recalled at all, then several of its member items are recalled. Single items from a category are seldom remembered. Further, when category labels are actually included among the items to be recalled, they are recalled at the head of the list of their category members.

All the previous findings suggest that relational codings are employed for retrieval purposes, and sometimes result in a greater number of items being recalled. The correlation of measures of clustering to amount recalled has been investigated frequently. Measures of clustering are based on a comparison between the number of occasions when any two items from the same category occur adjacently in recall, and the number of occasions when this would be expected to occur by chance. The greater the difference, the higher the degree of clustering. In general positive correlations have been found. Colle (1972), however, suggests caution with the following observations:

1) Positive correlations may be artefacts of the measures of clustering; with some measures the optimum possible level of clustering increases with number of items recalled.
2) The increase in degree of correlation which one would predict as a result of the provision of cues at recall as compared with their absence has not been reported.
3) Some evidence suggests that only very high levels of clustering result in increased recall.

The latter point has most relevance for the present research. Thompson et al. (1972), for example, found that only when subjects who clustered highest were compared with those who cluster lowest, with the middle range omitted, were any differences found in the amount recalled.

It is possible that only when subjects adopt in its entirety the neatly ordered set of categorized chunks, provided for them in the material by the experimenter, that recall of categorizable material is improved. Again, it is possible that when items are presented in a categorical sequence, serially or blocked, recall is better than in the situation in which the subject has to perceive the categorical relations in a randomly ordered set of items. Further, simultaneous as opposed to successive presentation of items may well result in increased recall, since it permits the relations between items to be more easily perceived (Puff and Bousfield, 1967).

It is evident that subjects can use obvious categorical aids; it does not show that they habitually do use this form of structure when they actively code material which is not so neatly packaged. The high degree of clustering evidenced in subjects' recall shows only that subjects had no alternative but to follow the experimenter's organisation. It is only when clustering is considerably less than maximal that the possibility arises that subjects were actively using other codings of relations not provided by the experimenter. Ironically, low clustering may point to greater active organisation.

Bousfield and Bousfield (1966) showed that subjects use many other features of material provided, for example: words each beginning with a different letter of the alphabet; items of similar visual shape; words which rhyme; words of different logical relationship to each other (e.g. subordinate, co-ordinate, super-ordinate); synonyms; and words with similar imagery components. Similar results were found in experiment 1 of the present research, where other cues in addition to categorical ones could mediate recall. Bousfield and Bousfield (1966) reached their conclusions by using a measure of inter-trial repetition (ITR), in addition to that of categorical clustering. The ITR measure is an index of the extent to which items are recalled in the same order on successive trials. It is obtained by subtracting from the observed repetitions the number which would be expected on the basis of chance alone. If the superordinate-subordinate relation were the only one being employed by the subject, there is no reason to predict a high ITR score. The subject would simply use the super-ordinate coding to retrieve the items which it subsumes in no particular order. It has been shown, however, that this is not the case. High clustering is accompanied by higher ITR scores, implying that the recall of one individual item can cue that of the next (Puff, 1970b).

Indeed, the presentation of the material in certain ways may result in the subject preferring a sequential strategy to a hierarchical one. For example, if items are presented in the same order on each trial, subjects tend to recall them in the same order; such presentation results in better recall than random order presentation (Mandler, 1969). Further, if an item is added to the presentation list on each trial, most subjects employ a sequential strategy, even when material is categorizable (Mandler and Dean, 1969).

We are left with the conclusion that the evidence for a simple reductive function of organisation of a superordinate-subordinate nature is an artefact of the material selected and measure employed (Herriot, 1974).

5.2.5 Summary

It seems, from the work reviewed, that there are a number of features of lists of information which can be used in the recall of that information. The different theories seem to fall into two distinct schools.

The first area concerns a sequential approach, incorporating a representation of aspects of the physical structure of the list in memory; for example, order, time and frequency information. It seems to contribute to a 'spatial' awareness, or image, of the lists.

The second area concerns semantic properties of the information contained in lists. Here information is organised in memory by means of categories (reductive tradition) or in relation to other information (elaborative tradition).

These theories should not, however, be considered a panacea with respect to how people organise list information in memory. They have also been shown to use many other types of cues.

Previous work, irrespective of its limitations, does provide a basis for the present assessment of memory in terms of recall of the items from lists used in a simulated filing task. It can be considered partly in the decision of what constitutes an optimum list, in terms of categorical and spatial structure, for use in a filing task. The following series of experiments, by emphasizing a more applied, 'real world' approach, can serve to clarify some of the points of contention evident in the literature.

5.3 Experimental design

5.3.1 Basic considerations

When information is stored on a computer it is often put in 'files' which need to be accessed according to some descriptor. The appropriate descriptor is usually found by scanning down a list of items. As in experiment 1 the 'what' and 'where' questions apply in locating the appropriate descriptor in a list in order to access required information. Unlike the pigeon-hole array in experiment 1 a VDU listing is uni-dimensional, flat, smaller, and has less space inbetween category descriptors. Therefore, the relatively efficient localisation of pigeon-holes, via a spatial 'image', irrespective of categorical or random arrangement, might not necessarily apply to lists. It is necessary to ask:

a) What are the effects of different amounts of categorical and spatial structuring on the categorical and spatial memory models?
b) What are the specific characteristics of categorical and spatial memory arising from list filing?
c) Do spatial and categorical memory models exhibit the same characteristics after list filing as compared to pigeon-hole filing, and if not, why not?

5.3.2 Experimental aims

The main aim of this series of experiments was to assess the optimum type of displayed information list, in terms of categorical and spatial structure. To facilitate this a number of lists of varying categorical and spatial structure would have to be assessed. In the design of computer systems for use by non-computer professionals, is it enough to list files in the order in which they were entered (essentially hardly any structure), or is it worth investing in extra software to structure files? Extra software could only be justified if it brought about a return in ease of use. Although this was the major aim it was also of interest to assess the effect of different list structures upon the formation of categorical and spatial memory models, and the subsequent interpretation of and recall from them.

5.3.3 Experimental rationale

In order to achieve the experimental aims, subjects would have to undertake a filing task using lists of differing spatial and categorical structure. The filing task would have to be essentially the same as that used in experiment 1 to enable valid comparison between simulated 'real world' and simulated 'computer' filing. This would again involve the use of experimental information which had an implicit categorical structure. It could be argued that pure spatial memory, independent of any categorical cues, should be examined. To a certain extent this is valid comment; however, filing would never take place using totally unrelated items of information. To counter any possible criticism it was decided that the use of each type of list should not only be followed by spatial recall, but also free recall. This would demonstrate any effects that the differing structures of the lists had on the categorical memory model, as well as the spatial. Separate subjects would be used for each of free and spatial recall, because one type of recall might affect the other if both were undertaken by one subject.

A separate experiment for each type of job category list was thought best, due to both free and spatial recall being used in each case, and to enable a more meaningful comparison between list types. The lists used would have to cover a range of spatial and categorical structure. One list would have to have neither spatial nor categorical structure, to act as a basis for comparison. Another list would need to have spatial structuring, but not in any meaningful categorical way, to assess the effect of spatial structure. The next list would logically have to exhibit categorical structuring. However, it is impossible for this to take place independently of spatial structuring, as it means grouping common job categories together in their major categories. Finally, it was decided that a list should be added which exhibited a maximum amount of spatial and categorical structure. This would include alphabetic order, and meaningful labels for each of the categorical groupings. To summarise the list types were as follows:

1) No overt spatial or categorical structure.
2) Overt spatial structure only.
3) Overt spatially organised categorical groupings.
4) Overt spatially organised list with a maximum of categorical structure, and cues.

(The lists are discussed in detail in the following section.)

Recall of list 1 would demonstrate the efficiency of categorical and spatial memory when no overt structure was apparent in the list. A comparison of the performance using list 2 with list 1 would demonstrate the effect of spatial cues on categorical and spatial memory. If both types of recall showed a spatial order influence we might conclude that spatial tags are attached to the job categories in memory. If only spatial recall showed an improvement, and categorical recall remained constant, it would tend to suggest that categorical and spatial memory were separate and interpreted according to different rules. Predominant categorical clustering in both types of recall would indicate the domination of categorical relationships in recall.

Recall of list 3 would demonstrate the effect of additional explicit categorical cues on categorical and spatial memory. Any increase in experimenter defined grouping in recall would suggest that categorical cues need to be explicit for them to be best used. Increase in accuracy of spatial recall would lead us to the conclusion that spatial interpretation of lists is better when there is an underlying categorical structure. If these findings were found to occur to a greater extent when using list 4, it would indicate that spatial localisation within a list is better with increased categorical structure.

Comparison of results with those of experiment 1 would possibly generate some tentative differences between 'real world' filing and 'computer' filing.

It should be noted that memory systems are interpreted by an executive system according to certain rules and strategies (Anderson, 1975). Any interdependence of different types of memory cues does not necessarily mean that cues are closely associated, being stored in the same memory system. It may be the case that two memory systems could be interpreted via the same, or similar, strategies by the executive system. If cues were closely associated in one memory system we would expect a certain resonance and common variation in both free and spatial recall. Any variance of one type of recall without the other would indicate executive interpretation of two separate systems. Further, it might be expected that separate systems of cues could be responsible for an additive effect in recall performance. With an executive interpretation of two systems, however, recall could consist of an either/or situation where a good performance during one type of recall is not necessarily followed by a good performance during the other. This would be dependent upon the comprehensiveness of either of the memory models.

5.3.4 Independent variable

The independent variable for the four experiments was the variation in spatial and categorical structure of the lists.

Experiment 2 used a different randomly ordered list of job categories for each subject. Experiment 3 used different randomly ordered lists of job categories spatially divided into five groups of six. The lists for experiment 4 were categorically grouped, the thirty job categories being divided into their five experimenter-defined major groupings (e.g. Industry). The major groupings were randomly organised on the page, and the job categories within the major groupings were randomly organised. Experiment 5 used the same list for each subject. It was divided into the five experimenter-defined major groupings, each one being meaningfully labelled according to experimenter definition (e.g. Industry, Academic, etc.). The major groups were arranged alphabetically, as were the job categories within the groups. Examples of the four types of experimental lists follow on subsequent pages.

In experiments 2 and 3 the job categories on the lists were randomised using the random number generator program used in experiment 1, run on a PDP11 computer. In experiment 4, the major categorical groupings and the job categories within the groupings were randomised using random number tables. The appropriate experimental plans by means of which the subjects could be allocated their appropriate training orders and experimental lists were also formulated using a PDP 11 computer.

Buying

Civil service

Legal work

MA courses - Arts

PhD research

Entertainment

MSc courses - Social sciences

Hotel management and catering

Accountancy

Management training

Medical

Social work

Local authority

Stockbroking and investment analysis

Tourism

Part-time education

Teacher training

Quality control

Management services

Environmental control and design

Advertising

Insurance

MSc courses - Physical sciences

Public transport

Engineering

Journalism

Banking

Armed forces

Industrial administration

Retailing

<u>List for experiment 2</u> - <u>No overt spatial or categorical structure (i.e. random arrangement)</u>

Entertainment

Social work

Advertising

Legal work

MSc courses - Physical sciences

Insurance

Mangement services

Tourism

Public transport

Journalism

Quality control

Engineering

Local authority

Buying

Stockbroking and investment analysis

Civil Service

Teacher training

Environmental control and design

Part-time education

Banking

Armed forces

Management training

Industrial administration

Medical

MSc courses - Social sciences

Retailing

Accountancy

Hotel management and catering

MA courses - Arts

PhD research

<u>List for experiment 3</u> - <u>Overt spatial structure only (i.e. grouping)</u>

Local Authority

Armed forces

Mecical

Public transport

Civil service

Social work

Advertising

Banking

Retailing

Accountancy

Stockbroking and investment analysis

Insurance

Entertainment

Legal work

Tourism

Environmental control and design

Hotel management and catering

Journalism

MSc courses - Physical sciences

Part-time education

MA courses - Arts

Teacher training

MSc courses - Social sciences

PhD

Buying

Industrial administration

Management services

Quality control

Management training

Engineering

<u>List for experiment 4 - Overt spatial and categorical structure</u>

MA courses - Arts	
MSc courses - Physical sciences	
MSc courses - Social sciences	ACADEMIC
Part-time education	
PhD research	
Teacher training	
Accountancy	
Advertising	
Banking	COMMERCE
Insurance	
Retailing	
Stockbroking and investment analysis	
Buying	
Engineering	
Industrial administration	INDUSTRY
Management services	
Management training	
Quality control	
Entertainment	
Environmental control and design	
Hotel management and catering	MISCELLANEOUS
Journalism	
Legal work	
Tourism	
Armed forces	
Civil service	
Local authority	PUBLIC SERVICES
Medical	
Public transport	
Social work	

List for experiment 5 - Overt spatial and categorical structure, plus alphabetical order and meaningful group labels

5.3.5 Dependent variables and the rationale of their use

As in experiment 1, the major dependent variables were classified into three major groups; the general efficiency of recall (i.e. the number of job categories remembered), measurement of the influence of categorical relationships on recall, and the measurement of the influence of spatial relationships on recall. The importance of these three groups lies in their specific reflection of the effect of progressive increase of list structure on the free and spatial recall of job categories.

Additionally, the time to complete stages of the experiment and subjective comments were noted.

5.3.5.1 Recall efficiency - number of job categories recalled

Again the number of job categories recalled by each subject was taken as a broad measure of the efficiency of recall in either free recall or directed spatial recall of the job categories from the experimental lists. As a broad measure it does not supply any information regarding the possible strategy of recall and as such should not be used in too definitive a way. However, it provides a useful comparison of the effects of list structures in experiments 2 to 5 on recall efficiency in general.

5.3.5.2 Measurement of categorical recall - categorical clustering

Measurement of categorical clustering attempts to demonstrate internal organisation of information, in this case job categories, in terms of the information's semantic properties. Information sharing the same or similar contexts would be logically grouped together in memory and consequently cue each other in recall; thus common categories would appear next to each other in recall. These assumptions form the basis for the free recall paradigm (Bousfield, 1953; Tulving and Donaldson, 1972) in which internal categorisation can be scored by quantifying categorical clustering in recall. In practice, however, the free recall paradigm is subject to many weaknesses (as outlined in experiment 1). Therefore categorical clustering should not be used as a definitive measure, but rather when comparing the effect of a variety of conditions of the independent variable within the same task framework

The implicit categorical relations in the stimulus material provide a model within which to quantify the amount of experimenter defined categorical clustering evident in the recalled job categories. The flexibility of this model, however, allows any significant deviation either towards or away from the experimenter classification to be recognised. This is especially important in comparing the recall of lists not categorically structured according to the model with those that are. It also allows the detection of any categorical memory influence on the spatial recall of uncategorised lists.

5.3.5.3 Measurement of spatial recall - spatial clustering

Spatial clustering measures the extent to which job categories are organised in memory using associations due to their adjacency on the stimulus list. The assumption is that job categories which are next to each other on the stimulus list, and are therefore associated in memory, will cue each other and be adjacent on the recall list. It should be stressed that this does not necessarily mean that a perfect copy of the stimulus list will be recalled, rather that certain adjacent pairs will remain adjacent when recalled. This measure does not score for the relative accuracy of placement of job categories in the whole of the recall list with respect to their position in the original stimulus list.

5.3.5.4 Average total error (ATE)

This measure attempts to quantify the amount of inaccuracy of the positions of the recalled job categories in comparison to their position in the stimulus list. Unlike spatial clustering this and the subsequent two measures progressively examine the accuracy of the spatial model of the stimulus list in memory. They all relate to the association of job categories to the stimulus list as a whole, rather than to each other.

5.3.5.5 Percentage sector score (%SS)

If a subject cannot remember the exact position of a job category during spatial recall, he might, nevertheless, be able to remember the section of the stimulus list in which it was. %SS quantifies the number of job categories which are recalled in the correct sector of the recall list as compared with the stimulus list. For this purpose each stimulus list is divided arbitrarily into five groups of six job categories.

5.3.5.6 <u>Percentage nought (%O)</u>

%O is a measure of absolute accuracy of job categories in the recall list with respect to their position in the stimulus list. A job category in the recall list only merits a 0 score if it is in the correct position in the recall list compared to its position in the stimulus list.

%O is a measure which reflects the association of each job category and its position relative to the whole representation of the stimulus list in memory. It does not, unlike ATE and %SS attempt to quantify any error in positional memory or any rough accuracy of placement.

ATE, %SS and %O scores enable us to determine the effect of stimulus lists of varying spatial and categorical structure on the spatial memory model of each list by assessing the positional recall to varying degrees of accuracy.

In experiment 1 a numerical profile of the spatial model of the pigeon-holes in each condition was formed using the probability of correct recall and other spatial measures.

It is possible to formulate similar profiles using ATE, %SS and %O for the lists in experiments 2 to 5. Because they are uni-dimensional it is a simple matter to obtain average values of these measures for each of the thirty locations of each list; no calculation of values for rows and columns separately is necessary.

5.3.5.7 <u>Training period and experiment times</u>

The timing of training and experimental periods were not classed as major measures. The reason for this was that any time differences could not be attributed to any specific cause and could be due to a combination of many factors causing indecision. These could include motivation, personality type, previous knowledge of the job categories etc. The times do, however, provide a rough guide to ease of use of each list rather than a definitive measure of any specific mental processes involved.

5.3.5.8 Subjective comments

It is possible to gain much information on the nature of subjects' memory models from a quantitative analysis of recall. However, it was also important to gain some insight into information organisation and recall strategies used at a conscious level. The inclusion of questions concerning perceived organisation of information, interpretation of information, and recall strategy, could fulfil these requirements.

5.3.6 Experimental procedure

5.3.6.1 Apparatus

The apparatus used in experiments 2 to 5 was identical to that used in experiment 1 except that, instead of an array of labelled pigeon-holes, four types of list exhibiting progressively increasing spatial and categorical structure were used.

5.3.6.2 Subjects

Again, the subjects used were non-computer professionals, computer professionals, and secretaries. Each experiment involved eighteen subjects, nine for each of free and spatial recall. The three subject types were balanced in each experiment, that is, three of each type per recall condition.

5.3.6.3 Method

The pre-experimental periods in experiments 2 to 5 were essentially the same as that in experiment 1. The difference was that instead of arranging the labels on the pigeon-holes in the appropriate order, the appropriate list of job categories was randomly allocated to each subject.

Prior to the main experiment each subject undertook two training periods. They were required to sit down at a desk with the appropriate experimental list face down in front of them. The experimenter then read the instructions appropriate to the training periods (see appendix 5.1 for subject instructions). When the experimenter was satisfied that the instructions had been understood the training procedure went ahead. The subject was instructed to turn the list over and the stopwatch was started. The experimenter then read the first of two different random lists of job categories as prescribed by the experimental plan. As each job category was read the subject pointed to it on the experimental list. Upon completion of the first list the stopwatch was topped and the subject instructed to turn over the experimental list. The time taken by the subject to point to all the job categories on the list was recorded. This procedure was then repeated for the second random training list order from the experimental plan. The subject was then read the instructions necessary to undertake the main experiment. The 180 items of information concerning student job opportunities were placed up-side down on the table adjacent to the experimental list. When the experimenter was satisfied that the subject understood the procedure, the main experiment was initiated.

The pile of 180 sheets of information was turned over, as was the experimental list, and the stopwatch was started. The subjects knew they were being timed; this was to provide motivation to work fairly quickly. The subject read the first piece of information, decided which of the job categories on the list was most appropriate and ticked it.

If the choice of job category was wrong the experimenter said 'no', the subject then crossed out the tick and chose another and ticked it, thus ensuring that the subject did not expect there to be six information items to each job category. This procedure continued until the information item was correctly filed, whereupon the experimenter would remain silent. Each of the 180 information items were filed in this way. During the experiment, communication between experimenter and subject was kept to a minimum in order not to provide any extra cues for recalling the information being dealt with at that time.

On completion the stopwatch was stopped, the list was turned over, and the time taken noted. The stopwatch was then re-set and started to time the half-hour break in the experiment.

The procedure during the coffee break was the same as in experiment 1. On resuming the experiment, each subject was read the instructions for the next stage (see appendix 5.1). For nine of the subjects in each experiment the instructions pertained to free recall, for the other nine spatial recall (see experiment 1). Subjects were allowed approximately ten minutes for each recall. In the free recall situation each subject had to write down all the job categories remembered in the order they came into their head, drawing a line between periods of continuous recall. In the spatial recall situation the subjects had to write the appropriate job category in the correct position on a template of the experimental list, lines represented the position of job categories (for example of free and spatial recall see appendix 5.2).

The experiment was concluded by asking the subjects questions about certain aspects of the experiment, for instance, their strategy of recall in each of the conditions. For more detail on the collection of results during the experiment see results collection and calculation, section 5.3.7.

5.3.7 Collection and calculation of results

An explanation of the calculation of the various experimental results for each subject follows:

5.3.7.1 Number of categories recalled

The categories written down during free and spatial recall were checked against their respective master list in each case, in order to eliminate duplications and discover the categories missing due to forgetting. The number of categories recalled were then counted.

5.3.7.2 Measurement of categorical characteristics of recall

The method of collection of the results reflecting categorical recall was the same as in experiment 1. Document A (appendix 5.2) is an example of free recall of job categories as prescribed by the subject instructions. Categorical associations are denoted by the numbers on the left of the recalled list in document A (appendix 5.2). A categorical association, or cluster pair, occurs when a pair of adjacently recalled job categories are from the same experimenter defined major category; for instance, social services and civil service both belong to the public services major category. The % categorical clustering, expressed in terms of the total number of pairs recalled, is 36.37 for free recall and 12 for spatial recall.

5.3.7.3 Measurement of spatial characteristics of recall

i) Spatial clustering - the measurement of spatial clustering was obtained in a similar manner to that of categorical clustering, in that each recalled pair was examined in turn. If the two members of each pair were adjacent on the master experimental list (document B, appendix 5.2), used to simulate filing, a spatial cluster pair was recorded (see document C, appendix 5.2; spatial clusters are on the right hand side). A measure of spatial clustering was also calculated for the free recall lists. This was in order to ascertain whether there was any spatial influence on free recall; if job categories were recalled due to associations based upon their juxtaposition on the master list, then spatial clustering would be significantly greater than chance.

For the next measurements of spatial recall, %O, % sector score (%SS), and average total error (ATE), the treatment of the spatial and free recall lists differed.

In the spatial recall list all positions on the recall template were important, even if left empty due to forgetting. It was the intention not only to assess spatial recall over the whole of each list but also in specific sections of each list. For this reason each master list and each recall list was divided into five sections of six. The positions on each list were then numbered 1 to 30.

In the free recall list there were no empty locations for forgotten job categories. Therefore, forgotten job categories were discounted on each master list, even thought it was divided into five sectors of six job categories as in spatial recall. The difference was that only the remembered categories were numbered on each master list. Each corresponding category on the corresponding free recall lists were numbered, and the sector division took place on the basis of the numbered job categories in each sector of the master list. For instance, if the first sector on the master list contained the numbers 1 to 5 with one job category forgotten, the corresponding first sector on the free recall list contained the first five categories. The weakness of this is, however, that all the job categories in a sector of the free recall list might not correspond with a period of continuous free recall. It might also seem irrelevant to spatially score free recall lists. The reason for it is to make sure that there is no spatial basis for free recall by comparing the spatial scores obtained with those due to chance (see documents A, B and C in appendix 5.2).

ii) ATE - each job category recalled was compared with its position on the corresponding master list. The difference between the positional numbers was then recorded adjacent to each category on the master list. The average total error was obtained by dividing the sum of the discrepancies by the number of job categories recalled.

iii) %SS - if, when each job category on the recall lists was checked, the sector that it was in corresponded with the same sector on the master, a tick was recorded on the master list. The total number of ticks were then expressed as a % of the total number of job categories recalled.

iv) %O - each job category recalled was compared with its position on the corresponding master list. If the assigned number, in each case, corresponded a O was scored. This denoted that the position of a recalled category corresponded exactly to its relative position on the master list. The number of O's were expressed as a % of the number of job categories remembered.

In addition to the aforementioned measures, relating to the whole recall list, measurements for each position of each list were generated. Consequently the spatial memory of different parts of the lists could be examined. It was realised, however, that if spatial measures concerning whole free recall lists did not prove significantly greater than those due to chance, it was worth comparing positional scores for free recall lists.

5.3.8 <u>The calculation of chance occurrence of experimental variables</u>

In order to assess that significant cognitive organisation was occurring, as measured by the various experimental variables, it was necessary to compare the results obtained with those that might occur by chance. It was assumed, as previously, that if no cognitive organisation occurred the results obtained would conform to chance values. This necessitated the calculation of chance values for each of the major variables of the experiment. Chance values assume no organisation at an information storage or retrieval stage.

It must be noted that chance values were calculated for a range of numbers of job categories recalled. For example, some people might only remember 23 job categories whereas others might remember 29. Categorical and spatial clustering measures were based on the number of clear pairs of job categories recalled, whereas the rest were based on the number of job categories recalled. It can therefore be appreciated that organising the list of job categories into groups of six effectively reduced the number of possible job category pairs. This also had to be taken into account. The procedures undertaken to calculate chance values will now be outlined.

5.3.8.1 Categorical clustering

Thirty random lists of the thirty job categories used in the experiment were scored for the amount of categorical clustering they contained. This was done by counting the number of job category pairs where both members belonged to the same experimenter defined major category (e.g. Public Services, Industry, etc.). However, the previous procedure only provided a figure for a list of thirty job categories. To calculate the value for different numbers of recalled pairs, each list was progressively shortened by reducing it by one job category at a time at random. If this action caused the destruction of a pair of categories constituting a cluster, one was subtracted from the previous number of category pairs scored for the whole list. If a new cluster pair was created one would be added to the previous value. Using the thirty lists, an average value for the number of cluster pairs could be calculated for each possible number of recalled job category pairs. The percentage of categorical clustering was then calculated, for each possible number of recalled job category pairs, by dividing the average number of counted cluster pairs, taken over the thirty random lists, by each required number of recalled job category pairs. A table was then constructed showing the appropriate chance value for each possible number of recalled job category pairs. Thus, if a person recalled 27 job categories, resulting in 23 pairings, the corresponding chance value would be opposite 23 pairs in the table.

5.3.8.2 Spatial clustering

The amount of spatial clustering due to random chance was calculated on the basis of the thirty six different possible comparisons of nine random lists of the thirty job categories (i.e. 1 and 2, 1 and 3 ..... 8 and 9). Each pair of job categories in turn from one list were compared with the two same job categories on a second list. If these same two categories were adjacent on the second list a spatial cluster was scored. A table was constructed with the two lists being compared in each case labelled down the side, and the comparison of each of the twenty nine job category pairs horizontally across the page. If a pair of job categories from one list did not correspond with the same pairing on the second list a X was scored. If there was a corresponding pairing a ✓ was scored (see figure 5.1).

1 and 2 XXXXXXXX✓XXX✓XXXXX.......
1 and 3 XXXXXXXXXX✓XX✓XX.........
etc.
8 and 9

Figure 5.1: The scoring of chance occurrence of spatial clustering

From the table of comparisons an average value for the amount of spatial clustering could be calculated for recall of twenty nine pairs of job categories by counting the total number of ticks and then dividing by thirty six (the number of list comparisons). A percentage value of chance spatial clustering could then be calculated by dividing by twenty nine and multiplying by one hundred. To calculate values for other numbers of recalled job category pairs, vertical lines were taken out of the table at random and the number of ticks contained subtracted from the total used in the previous calculation. This total could then be treated as previously to calculate a chance value for percentage spatial clustering, being careful to use an appropriately reduced number recalled job category pairs.

Initially an allowance was made for the fact that for experiments two onwards the job categories were organised into groups of six, with a concomitant reduction in the number of category pairs (by four). It was discovered, however, that calculating chance values from lists of thirty ungrouped categories gave values very similar to those when the allowance was made.

5.3.8.3 <u>Average total error and %O</u>

The chance value for average total error was calculated in a similar way to that used to calculate chance percentage spatial clustering. A table was constructed and instead of comparing pairs of job categories, each job category and its position in one list was compared with the same category and its position in the second. The difference in their positions gave a value of total error for each job category (see figure 5.2). Average total error was calculated for each list by dividing the sum of total errors for each list by thirty, the number of job categories.

1 and 2 2.3.27.11.4.0.3.1.10.7.7.0.3.8.14.....
1 and 3 28.1.24.7.12.6.8.2.10.10.6.10.3.12.1..
etc.
8 and 9

<u>Figure 5.2</u>: <u>The scoring of chance values for average total error and %O</u>

As with the spatial clustering table, vertical lines were taken out at random to enable the calculation of chance scores for occasions when fewer than thirty job categories were recalled.

It was also possible to calculate chance values for %O's from the total error table. When the position of a job category on one list coincided with its position on the second list the difference was 0. The chance %O value for thirty job categories recalled could be calculated by dividing the total number of O's in the table by 1180 (the number of list comparison X the number of job categories) and multiplying it by 100.

5.3.8.4 <u>%SS</u>

To calculate chance values for %SS a table was again constructed comprising of the 36 possible random list comparisons. For each job category on one list a tick was entered if on the second list it was in the corresponding sector of six job categories. If not a cross was entered. The procedure for working out the chance %SS for a list of job categories was as previously described.

5.3.9 Statistics

The data collected from the experiments were analysed for homogeneity of variance between samples. It was found that homogeneity of variance was not present in most cases, a factor which precluded the use of parametric statistics. There was, however, a very good general non-parametric statistical program available, called 'Omnibus' (Meddis, 1980). This was used to analyse the data.

First of all the computer program converts the data into ranks (low value scores get low ranks). The program prints out mean rank for the scores in each sample. The program next evaluates and prints out the statistic H which is a measure of how widely spaced the sample rank means are. When the sample rank means are widely spaced, H tends to be large. H also increases with the number of samples being compared. When only two samples are being considered the traditionally used Z is printed rather than H. Z is the square root of H and is asymptotically normally distributed (Meddis, 1980).

The program then goes on to assess whether the degree of spread could have occurred if the ranks had been assigned in a random manner (by chance). This is tackled by effectively (but not actually) looking at all the permutations of the ranks and computing a value of H for each of them. It then finds the frequency of permutations yielding a value of H greater than or equal to the value of H resulting from the data input. By dividing this frequency by the total number of permutations, we obtain a value for the probability (P) of getting, by chance alone, as large or larger a value of H than the one resulting from our data. If this probability is low (certainly less than 0.05), we might decide that chance factors alone cannot explain our results and we must seek some explanation in terms of systematic effects influencing the scores in our samples.

When there are only two groups, the test could be either one- or two-tailed. For experiments 2 to 5 a two-tailed value was used because comparison between samples was always non-directional (i.e. significant differences were being sought).

If we have only two samples and our result is statistically significant, then we simply conclude that the samples are different, or to put it more precisely, that there is at least one factor at work which is selectively influencing scores in one of the samples more than the other. However, if we have more than two groups (as in comparing scores across the four experiments), the situation is not so simple. To know that there is at least one factor influencing at least one sample more than the others is not very helpful, and we must resort to another set of computations to evaluate more specific hypotheses concerning what might be happening to the data. This is the evaluation of trends and contrasts (comparisons). It should be noted that a large value of P does not rule out the possibility of systematic influences being at work. Therefore, the next stage should be undertaken whenever there are more than two samples.

Ideally the researcher should have conducted his experiment with some hypothesis in mind concerning the outcome. For experiments 2 to 5, for example, one hypothesis would be that increasing list structure promotes better spatial memory for location of job categories. Four numbers expressing this hypothesis can now be generated, concerned with the order of sample rank means. These are simply:

1 2 3 4

The order of these numbers implies that spatial recall performance improves with increase in list structure. These values are called 'Lambda coefficients', or just 'coefficients'. Their job is simply to reflect the pattern of expected sample rank means. The computer takes these values and correlates them with the actual sample rank means. It then generates a statistic Z, which is large and positive when the correlation is good. A negative value of Z indicates that the coefficients would have correlated better in reverse order. A value for P is subsequently calculated, in a similar way to that used previously with the value for H.

5.4 Analysis and discussion of results

5.4.1 Critical assessment of previous work in comparison with the 'real world' context of the present experimentation

Before dealing with the results analysis it is useful to examine the relationship between previous studies specifically related to this area with the experiments described here.

One of the great difficulties encountered when trying to assess previous work done in the present applied context, is that laboratory tasks are usually unrealistic with respect to the 'real world'. Therefore it is dangerous to generalise from previous results without considering differences in task contexts.

Rarely do stimuli exist in the 'real world' by virtue of their spatial position alone. They usually have some meaningful concept identity. For this reason it was thought advisable to critically assess previous work concerning both spatial and categorical organisation in memory (see section 5.2) in relation to the experimental design used in experiments 2 - 5. There are a number of important features of the tasks used in previous work which differ from that used in experiments 2 - 5.

Previous work on characteristics which contribute to memory for order has used strings of letters or digits, either presented sequentially or simultaneously, of varying lengths and groupings. Such stimuli have very little meaning, other than physical identity, a factor which is accentuated by there being very little task context in which to relate the items. It is possible that semantic relations might provide quite important cues as to the order or spatial positions of stimuli relative to one another, if the ability to actually 'visualise' the positions of stimuli in mempry is lost. Fuchs (1969) use of four letter nouns in replicating earlier findings using letter and digit strings suffered from a similar lack of task context. Experiments 2 - 5 all use the same meaningfully related job categories, more so due to their interpretation within a realistic task context. The relations were either implicit or explicit depending on the experimental list used. In the 'real world' all mental models are developed within a meaningful context and incorporate both spatial and semantic information.

The tasks used in most previous work involved the rapid presentation of stimuli followed by random stimuli to prevent rehearsal during retention periods of varying lengths. This rarely happens in practice where people usually have a longer period over which to consolidate information, depending on the task being carried out. Experiments 2 - 5 involved each subject in scanning and classifying information at random into 30 spatially arranged job categories (a greater number than usual in previous work) over periods ranging from approximately 20 minutes to just over an hour. The half hour period before recall did not need rehearsal prevention mechanisms because subjects were not expecting to recall the categories. Therefore, any spatial or related order information stored in memory is incidental to the task and not the aim of the task itself. This is more in keeping with how people naturally interact with spatial aspects of information handling.

A final important difference is that previous work dealt with short term retention of information (i.e. generally 20 seconds or less) whereas the present experiments deal with longer term retention features (i.e. after 30 minutes). It is well known that so-called short and long term memories use different attributes of information for coding purposes. Short term memory seems to retain much of the features of the stimulus information, whereas long term memory tends to contain higher level more abstract representation of stimulus information (Herriot, 1974). Therefore, what has been discovered previously might not apply to the present experimentation.

Most experimentation concerning the coding of semantic attributes falls into two main approaches, reductive and elaborative coding. The former arises largely as a result of the imposition of highly structural information on the subject by the experimenter. The latter tends to favour the presentation of unrelated information to the subject. It is easy to see, therefore, how the dichotomy of theories arose. Neither approach allows for the grey area, in between extremes, where only partial or varying amounts of organisation are present (see section 5.2).

The present experiments use a set of job categories as the basic category units into which information is filed. Amongst the job categories there is a loose organisation into five major categories. These are flexible enough for the subjects to organise the information conceptually by means other than experimenter defined relations. Thus the possibility of both reductive and elaborative coding is catered for.

Again, it is important to stress the task context. Experiments 2 - 5 require the subjects to interpret information into the job categories over periods usually in excess of half an hour. In most previous experimentation subjects have been presented with related words and later asked to recall them. Usually these words are dealt with in unrealistic task contexts, and are not realistically processed at all. Some subjects were required to group items into meaningful categories, but even this is a somewhat 'sterile' task in terms of possible cues. If we look at this in more general terms and assess similar views held by other psychologists working in this area, it will help to put the previous criticisms of past work into a better perspective.

The episode of presentation is a source of attributes by which items may be encoded. Such attributes as frequency, order and time are difficult to distinguish in their effects, both from each other and from other attributes. The success of researchers in demonstrating their use, however, makes one wonder how many features of the situation subjects employ. Clearly, there are many potential features of the experimental situation which might either act as attributes for coding themselves, or might result in the use of some attributes rather than others. Bower (1972 a, pp.92-93) prefers the notion of 'context' defined as "the background external and interospective stimulation prevailing during presentation of the phasic experimental stimuli. Included here would be internal factors like posture, temperature, room and apparatus cues, and stray noises, as well as internal physiological stimuli such as dry throat, a pounding heartbeat, stomach gurgles, nausea, and boredom. But more significant than any of these is what the subject is thinking about, what his mental set is, at the time the experimental stimulus intrudes". Bower mentions such features as the subjects internal monologue, his conceptions of and associations to the instructions, the task, his own strategies, the experimenter and his purpose etc. He supposes that changes in these contextual features will result in the use of different attributes for encoding. If he guesses that the experimenter is going to ask him to recognise the material, he may code it by different attributes from those he would use if he thought he was going to have to recall it (see Frost, 1971). It would therefore seem more appropriate to use an experimental situation which is as realistic as possible, with respect to the 'real world', in order to discover the important features of how people naturally store information.

There is no doubt that the present experiments sacrifice a certain amount of control in order to gain a realistic task context. For instance, the number of times each job category is scanned on the filing list, and the time taken to complete the task, varies considerably. Some measure of the effect of this on the cognitive model resulting from the filing task may be calculated by correlating the time taken for the completion of each filing task and subsequent recall performance. However, although previous work has shown a relationship between short term retention of information items and the time taken to memorise them or the frequency of their presentation (see 5.2.3), this does not necessarily apply to long term retention.

5.4.2 Results of experiment 2

The following list of abbreviations are used in the subsequent results and analysis tables:-

S1.......Sn	-	Refers to the particular subjects involved.
CFR	-	Free recall condition.
CSR	-	Spatial recall condition.
No.Rec.	-	Number of job categories recalled.
%CC	-	% categorical clustering.
%SC	-	% spatial clustering.

TE and ATE	-	Total error and average total error.
%SS	-	% sector score.
%O	-	% O score.
Tr1 and Tr2	-	Training periods 1 and 2.

Experiment 2 involved filing using the randomly arranged, ungrouped list of job categories. The results obtained, and the corresponding values that could be expected due to chance, are listed in tables 1 to 13 of appendix 5.3. A summary of the results analysis for experiment 2 follows in table 5.1. The 'Omnibus' program was used in the analysis of this and following experiments.

5.4.2.1 CFR and CSR v. chance

The amount of categorical clustering in free recall is very significantly greater than that which could be expected due to chance. This indicates that subjects used predominantly categorical relations, with respect to the experimenter defined major categories, as cues in the free recall of job categories. It can be seen, however, from the raw data (Table 5.2, appendix 5.3) that the average amount of categorical clustering is only just above 40%. This means that subjects do not only use experimenter defined categorical relations to retrieve the job categories from memory, other types of cues must be used also. Because the information is fairly loosely structured it is possible that other categorical relations can be formed (see section 5.5.1.3). There is also evidence of some involvement of spatial cues in free recall. Both ATE and %SS measures show a significant influence when compared to chance. These are both measures of general spatial influence with respect to the total list. %SC and %O, on the other hand, measure a more specific influence of spatial cues with respect to particular spatial juxtaposition of categories and specific position in the lists respectively. The lack of significant difference, in comparing these measures with chance values, suggests that the spatial cuing is not strong and specific but of a more general nature.

Table 5.1. Experiment 2 - Summary and analysis of all measures: vs. chance; and free recall vs. spatial recall.

Table 5.1. Experiment 2 - Summary and analysis of all measures: vs. chance; and free recall vs. spatial recall.

	Cat. cluster	Spat. cluster	Average total error	Percentage SS	Percentage O
CFR v. chance	CFR > Chance Z=3.58 $p < 0.001$	NS	CFR < Chance Z=3.587 $p < 0.001$	CFR > Chance Z=2.009 $p < 0.05$	NS
CSR v. chance	NS	CSR > Chance Z=3.595 $p < 0.001$	CSR < Chance Z=3.597 $p < 0.001$	CSR > Chance Z=3.597 $p < 0.001$	CSR > Chance Z=3.597 $p < 0.001$

	Cat. cluster	Spat. cluster	Average total error	Percentage SS	Percentage O
CFR v. CSR	CFR > CSR Z=3.49 $p < 0.001$	CFR < CSR Z=2.783 $p < 0.005$	CFR > CSR Z=3.576 $p < 0.001$	CFR < CSR Z=3.576 $p < 0.001$	CFR < CSR Z=3.585 $p < 0.001$

	No. recalled	Tr 1	Tr 2	Exp. time
CFR v. CSR	NS	NS	NS	NS

	Tr1 > Tr2
CFR	$p < 0.05$
CSR	$p < 0.05$

Spatial recall shows no influence of categorical cues in recalling the positions of job categories. This does not mean that job category identities are not retrieved as in free recall prior to being positioned (see subjective comments, section 5.6). It does mean, however, that spatial cues are used independently of categorical cues, otherwise there would be conflict and some categorical clustering would be evident in spatial recall. All the measures of spatial recall are very significantly greater than those expected due to chance, indicating that spatial cues are predominantly involved in the recall of spatial positions. This may seem like stating the obvious, but nothing should be taken for granted in psychological research.

5.4.2.2 <u>CFR v. CSR</u>

The comparison of CFR and CSR further emphasises the predominance of different cues in free and spatial recall. There is significantly more categorical clustering in free recall than spatial recall. Alternatively, there is significant increase in spatial clustering, %SS, and %O, and a significant decrease in ATE, in spatial recall. Therefore, remembering category identities is specifically a function of categorical memory, whereas positioning them is specifically a function of spatial memory. This does not, however, make it clear whether job categories are visualised as part of the 'spatial model', in spatial recall, or whether categories are first recalled from categorical memory and then positioned via spatial memory. Whichever is the case, it seems likely that there is some higher level 'executive mechanism' which interprets categorical and/or spatial memory according to some predefined strategy.

It is interesting to note that there is no significant difference in the number of items recalled in CFR and CSR. This could mean that item identities are always recalled from categorical memory, even if subsequent location is desired; or, spatial and categorical cues could be involved in both types of recall; or, the internal 'spatial image' of the list of job categories is recalled from memory as efficiently as the categorical model of job categories.

There are no significant differences between training times and experiment times in comparing CFR and CSR. This is to be expected as prior to recall the task is the same. In both CFR and CSR the initial training periods always take significantly longer than the following ones. It is therefore clear that learning takes place between successive periods.

5.4.3 Results from experiment 3

The results from experiment 3, using the spatially grouped random list, show the same characteristics as those in experiment 2. The raw data for experiment 3 can be seen in appendix 5.3, tables 14 - 26. The analysis is summarised in table 5.2.

5.4.4 Results from experiment 4

The raw data for experiment 4, using the categorically grouped lists, can be seen in appendix 5.3, tables 27 - 39. The analysis is summarised in table 5.3.

Again, the characteristics observed in experiments 2 and 3 are present. There are, however, some differences which must be discussed. The amount of spatial clustering in CFR compared to chance is very significant. This would suggest a strong and specific spatial influence in free recall. However, the master lists used in experiments 4 and 5 were organised into the experimenter defined major categories. Therefore, there is bound to be a higher incidence of spatial clustering when comparing free recall with a categorically structured list as compared with chance. There are two reasons for not calculating chance values using successive comparisons of the structured master lists used in experiment 4: first, the basic assumption is made that no organisation of information in memory would result in completely random recall of the master list; second, a comparison of the structured lists would produce very high values for chance spatial clustering.

Table 5.2. Experiment 3 - Summary of the analysis of all measures: vs. chance; and free recall vs. spatial recall.

	Cat. cluster	Spat. cluster	Average total error	Percentage SS	Percentage 0
CFR v. chance	CFR > Chance Z=3.587 $p < 0.001$	NS	CFR < Chance Z=3.589 $p < 0.001$	CFR > Chance Z=1.993 $p < 0.05$	NS
CSR v. chance	NS	CSR > Chance Z=2.79 $p < 0.005$	CSR < Chance Z=3.585 $p < 0.001$	CSR > Chance Z=3.597 $p < 0.001$	CSR > Chance Z=3.585 $p < 0.001$

	Cat. cluster	Spat. cluster	Average total error	Percentage SS	Percentage 0
CFR v. CSR	CFR > CSR Z=3.584 $p < 0.001$	CFR < CSR Z=2.614 $p < 0.005$	CFR > CSR Z=3.578 $p < 0.001$	CFR < CSR Z=3.576 $p < 0.001$	CFR < CSR Z=3.578 $p < 0.001$

	No. recalled	Tr 1	Tr 2	Exp. time
CFR v. CSR	NS	NS	NS	NS

	Tr1 > Tr2
CFR	$p < 0.05$
CSR	$p < 0.05$

Table 5.3. Experiment 4 - Summary of the analysis of all measures: vs. chance; and free recall vs. spatial recall

	Cat. cluster	Spat. cluster	Average total error	Percentage SS	Percentage 0
CFR v. chance	CFR > Chance $Z=3.578$ $p < 0.001$	CFR > Chance $Z=3.578$ $p < 0.001$	CFR < Chance $Z=3.58$ $p < 0.001$	CFR > Chance $Z=2.792$ $p < 0.005$	NS
CSR v. chance	CSR > Chance $Z=3.602$ $p < 0.001$	CSR > Chance $Z=3.58$ $p < 0.001$	CSR < Chance $Z=3.58$ $p < 0.001$	CSR > Chance $Z=3.602$ $p < 0.001$	CSR > Chance $Z=3.582$ $p < 0.001$

	Cat. cluster	Spat. cluster	Average total error	Percentage SS	Percentage 0
CFR v. CSR	CFR < CSR $Z=2.618$ $p < 0.005$	CFR < CSR $Z=3.046$ $p < 0.005$	CFR > CSR $Z=3.311$ $p < 0.001$	CFR < CSR $Z=3.24$ $p < 0.001$	CFR < CSR $Z=3.401$ $p < 0.001$

	No. recalled	Tr 1	Tr 2	Exp. time
CFR v. CSR	NS	NS	NS	NS

	Tr1 > Tr2
CFR	$p < 0.05$
CSR	$p < 0.005$

The chance figure is obtained by comparing randomised lists of categories. The %O score shows that this is just an artefact of the experimental design. If there was a very strong spatial influence in free recall we would expect a %O score significantly greater than chance, which we have not got. Similarly, the analysis shows very significant categorical clustering in spatial recall compared to chance, and greater categorical clustering in spatial recall when compared to free recall, again for the reasons discussed.

5.4.5 <u>Results from experiment 5</u>

The raw data for experiment 5, using the labelled and alphabetically arranged categorical groupings, can be seen in appendix 5.3, tables 40 - 52. The analysis is summarised in table 5.4.

The characteristics of free and spatial recall are the same as those for experiments 2 - 4. The artefactual results arising from the categorical structuring of the lists used in the experiment are the same as for experiment 4.

There is one inconsistency which must be explained, however: the percentage SS measure in table 5.4, for CFR vs. chance, shows no significant difference, whereas it is significant in tables 5.2 to 5.3. A comparison of %SS, CFR, between tables 47 and 48 of appendix 5.3 reveals the reason for this. There are two inconsistently low values (11.11 and 10.71) in table 47, CFR, which if removed, along with their chance counterparts, results in the %SS, CFR vs. chance comparison becoming significant (CFR chance, $p > 0.05$). This result is then in line with those of tables 5.1 to 5.3.

5.4.6 <u>Summary</u>

The individual assessment of each of experiments 2 - 5 can tell us something of the characteristics of free and spatial recall. It cannot, however, tell us anything of the degree of these characteristics or anything about the effect of list structure on free and spatial recall. This can only be reflected by progressively comparing experiments 2 - 5 with each other.

Table 5.4. Experiment 5 - Summary of the analysis of all measures: vs. chance; and free recall vs. spatial recall.

	Cat. cluster	Spat. cluster	Average total error	Percentage SS	Percentage O
CFR v. chance	CFR > Chance Z=3.58 $p < 0.001$	CFR > Chance Z=3.58 $p < 0.001$	CFR < Chance Z=3.599 $p < 0.001$	NS	NS
CSR v. chance	CSR > Chance Z=3.58 $p < 0.001$	CSR > Chance Z=3.58 $p < 0.001$	CSR < Chance Z=3.597 $p < 0.001$	CSR > Chance Z=3.58 $p < 0.001$	CSR > Chance Z=3.597 $p < 0.001$

	Cat. cluster	Spat. cluster	Average total error	Percentage SS	Percentage O
CFR v. CSR	CFR < CSR Z=3.403 $p < 0.001$	CFR < CSR Z=3.576 $p < 0.001$	CFR > CSR Z=3.488 $p < 0.001$	CFR < CSR Z=3.578 $p < 0.001$	CFR < CSR Z=3.58 $p < 0.001$

	No. recalled	Tr 1	Tr 2	Exp. time
CFR v. CSR	NS	NS	NS	NS

	Tr1 > Tr2
CFR	$p < 0.05$
CSR	$p < 0.05$

5.4.7 Comparison of experiments 2 - 5

The combined results for experiments 2 - 5, both CFR and CSR, are listed in tables 5.5 - 5.18 following. The subsequent analysis of the important parameters, via the 'Omnibus' program, can be seen in table 5.19.

Table 5.5.

Numbers recalled - CSR and CFR combined due to no significant difference between conditions in each experiment

	Exp. 2		Exp. 3		Exp. 4		Exp. 5	
S1	27	23	26	28	25	27	23	27
S2	28	29	27	23	26	26	23	26
S3	24	29	28	28	22	27	27	27
S4	28	26	26	26	30	28	28	29
S5	28	26	25	25	27	25	27	27
S6	21	28	27	20	28	29	28	28
S7	26	29	25	24	28	25	28	30
S8	24	29	23	28	27	24	28	26
S9	27	25	27	25	24	26	29	25
$\bar{x}$	25.89	27.11	26.00	25.22	26.33	26.33	26.78	27.22

5.4.7.1 Number of categories recalled

Table 5.19 shows that no significant difference was found, between the number of job categories recalled, when comparing successive experiments for both CFR and CSR. In addition, earlier analysis of individual experiments demonstrated no significant difference between the number of categories recalled when comparing CFR and CSR. Initial consideration of these results would tend to suggest that free recall and spatial recall are equally efficient, and that the amount of categorical and spatial list structure has no effect on the efficiency of recall of job categories. However, this measure only reflects the number of job category identities retrieved from memory. It does not reflect the cues and

Tables 5.6 and 5.7.

Categorical Clustering - CFR and CSR

CFR

	Exp. 2	Exp.3	Exp.4	Exp.5
S1	36.36	50.00	47.10	40.00
S2	43.75	41.18	60.00	44.44
S3	40.00	38.90	50.00	68.75
S4	54.55	50.00	74.10	50.00
S5	32.00	33.33	75.00	61.90
S6	29.41	34.80	52.00	66.67
S7	52.17	42.11	47.83	50.00
S8	57.14	50.00	40.00	69.23
S9	34.78	43.48	68.18	77.27
$\bar{x}$	42.27	42.63	57.13	58.70

CSR

	Exp.2	Exp.3	Exp.4	Exp.5
S1	25.00	22.7	100.00	76.19
S2	25.93	18.75	88.90	88.89
S3	18.52	4.55	95.00	100.00
S4	14.29	15.00	100.00	82.61
S5	31.82	23.50	100.00	95.00
S6	12.00	16.66	86.96	69.57
S7	7.41	6.25	100.00	100.00
S8	25.93	18.20	37.5	78.95
S9	15.79	11.80	68.42	83.33
$\bar{x}$	19.63	15.27	86.31	86.06

Tables 5.8 and 5.9.
Spatial Clustering - CFR and CSR

CFR

	Exp.2	Exp.3	Exp.4	Exp.5
S1	4.55	12.50	78.95	76.19
S2	6.25	11.76	30.00	22.22
S3	13.33	16.67	27.78	31.25
S4	4.55	5.56	40.74	15.00
S5	16.00	0	33.33	28.57
S6	11.76	8.7	32.00	25.00
S7	8.60	10.53	21.74	22.73
S8	7.14	10.00	15.00	38.46
S9	13.04	0	40.91	22.72
$\bar{x}$	9.47	8.41	28.93	25.85

CSR

	Exp.2	Exp.3	Exp.4	Exp.5
S1	25.00	27.30	78.95	76.19
S2	22.22	25.00	72.22	88.89
S3	37.04	22.73	65.00	95.24
S4	42.86	60.00	90.91	82.61
S5	36.36	17.60	88.24	85.00
S6	24.00	33.33	73.91	43.48
S7	14.81	37.50	66.67	56.00
S8	11.11	50.00	25.00	57.89
S9	10.53	5.9	52.63	66.67
$\bar{x}$	24.88	31.04	68.17	72.44

Tables 5.10 and 5.11.

ATE - CFR and CSR

CFR

	Exp.2	Exp.3	Exp.4	Exp.5
S1	7.85	7.46	9.36	9.09
S2	8.93	8.70	5.04	8.26
S3	4.58	9.21	4.45	10
S4	11.21	7.46	2.47	9.61
S5	8.0	9.28	5.48	4.89
S6	5.81	6.0	8.00	8.61
S7	8.1	9.68	10.64	9.07
S8	9.0	9.39	6.52	4.21
S9	6.74	10.56	1.08	6.14
$\bar{x}$	7.80	8.64	4.83	7.76

CSR

	Exp.2	Exp.3	Exp.4	Exp.5
S1	2.52	2.11	0.19	0.70
S2	3.21	3.61	1.04	0.31
S3	1.34	2.82	0.47	0.15
S4	1.42	1.38	0.07	4.83
S5	2.31	1.6	0.12	0.11
S6	1.71	3.15	0.48	1.86
S7	2.28	2.00	0.56	0.43
S8	3.97	1.43	3.63	1.08
S9	3.72	2.92	2.42	2.40
$\bar{x}$	2.50	2.34	1.0	1.32

Tables 5.12 and 5.13.

%SS - CFR and CSR

CFR

	Exp.2	Exp.3	Exp.4	Exp.5
S1	29.63	23.08	28.00	17.39
S2	25.00	22.22	30.77	30.43
S3	20.83	25.00	54.55	11.11
S4	7.14	34.62	73.33	10.71
S5	32.14	8.33	37.04	40.74
S6	42.86	29.60	32.14	21.43
S7	34.62	16.00	10.71	42.86
S8	8.33	21.74	37.04	64.29
S9	37.04	28.52	75.00	44.83
$\bar{x}$	26.40	22.12	42.06	31.53

CSR

	Exp.2	Exp.3	Exp.4	Exp.5
S1	65.22	75.00	100.00	85.19
S2	51.72	69.57	92.31	96.15
S3	72.41	67.86	96.30	100.00
S4	69.23	92.31	100.00	93.10
S5	65.38	80.00	100.00	96.30
S6	67.86	60.00	93.10	82.14
S7	65.51	83.33	100.00	100.00
S8	48.28	78.57	62.50	88.46
S9	60.00	52.00	65.38	68.00
$\bar{x}$	62.85	73.18	89.95	89.93

Tables 5.14 and 5.15.

%O - CFR and CSR

CFR

	Exp.2	Exp.3	Exp.4	Exp.5
S1	0	3.85	0	0.00
S2	10.71	11.11	7.69	4.35
S3	0	7.14	4.55	3.70
S4	3.57	3.85	26.67	0.00
S5	3.57	12.00	3.70	7.41
S6	9.52	7.4	7.14	7.14
S7	11.54	4.0	0	21.43
S8	0	4.35	7.41	3.57
S9	3.70	0	45.83	3.45
$\bar{x}$	4.73	5.97	11.44	5.67

CSR

	Exp.2	Exp.3	Exp.4	Exp.5
S1	30.43	32.14	81.48	81.48
S2	17.24	43.48	69.23	84.62
S3	27.59	42.86	70.37	88.89
S4	42.31	57.70	92.86	93.10
S5	30.77	40.00	92.00	88.89
S6	21.43	20.00	68.97	57.14
S7	24.14	37.50	64.00	66.67
S8	20.69	57.14	25.00	73.08
S9	28.00	28.00	57.69	60.00
$\bar{x}$	26.96	39.90	69.07	77.10

Tables 5.16 and 5.17.

Training times for CFR and CSR - due to no significant difference between conditions in each experiment

Tr1

	Exp.2		Exp.3		Exp.4		Exp.5	
S1	1.98	2.03	2.13	2.7	2.42	1.92	1.75	1.72
S2	3.02	2.28	1.78	2.67	1.82	3.07	2.67	2.33
S3	3.35	1.55	2.88	2.75	2.58	2.18	1.91	2.42
S4	2.07	2.42	3.68	2.50	1.97	1.68	1.20	1.53
S5	2.35	2.12	2.10	1.75	1.93	2.12	1.53	2.63
S6	2.37	1.50	2.97	3.16	2.37	2.12	1.88	2.17
S7	2.62	2.47	2.70	2.92	3.92	2.65	1.55	1.60
S8	3.15	2.27	1.25	2.75	2.90	2.15	2.00	1.57
S9	1.97	2.83	1.95	2.77	2.05	1.85	1.55	2.25
$\bar{x}$	2.54	2.16	2.38	2.66	2.19	2.19	1.78	2.03

Tr2

	Exp.2		Exp.3		Exp.4		Exp.5	
S1	1.97	1.73	2.00	1.98	1.85	1.53	1.27	1.33
S2	2.42	1.80	1.50	2.00	1.37	1.83	2.28	1.83
S3	2.68	1.42	1.93	2.67	1.90	1.50	1.40	1.70
S4	1.87	1.33	2.25	1.97	1.53	1.58	1.12	1.25
S5	2.35	1.57	2.18	1.62	1.25	1.62	1.17	1.87
S6	1.97	1.40	2.03	2.25	1.55	1.45	1.50	1.33
S7	1.93	2.22	1.83	1.98	2.75	1.98	1.23	1.40
S8	2.52	2.22	2.47	1.97	2.67	2.17	1.70	1.42
S9	1.92	2.62	1.88	3.08	1.65	1.40	1.25	1.35
$\bar{x}$	2.18	1.81	2.01	2.17	1.67	1.67	1.44	1.50

Table 5.18.

Experimental time for CFR and CSR - due to no significant difference between conditions in each experiment

	Exp. 2		Exp. 3		Exp. 4		Exp. 5	
S1	46.27	35.50	45.53	43.37	47.00	26.50	26.72	28.25
S2	33.72	37.28	38.40	55.53	31.32	54.63	60.72	42.38
S3	49.95	31.12	35.43	44.12	45.25	29.50	32.38	55.45
S4	28.13	26.75	37.60	26.33	27.83	24.43	19.00	32.46
S5	29.50	36.10	51.31	34.45	20.67	25.50	25.75	32.12
S6	60.28	17.13	30.75	42.62	24.48	27.73	22.65	18.20
S7	27.70	33.97	42.38	41.95	50.58	40.18	35.25	25.57
S8	38.88	32.32	40.42	33.40	53.38	46.42	22.80	24.03
S9	31.75	49.34	40.00	35.40	31.90	36.50	18.56	22.25
$\bar{x}$	38.46	33.28	40.20	39.69	36.93	34.60	29.31	21.19

strategies used in recall, or the accuracy of localisation of the categories with respect to the experimental lists. For instance, the amount of categorical and spatial structure varies independently contingent upon the experiment being undertaken. The fact that the same number of categories were being remembered would indicate that an efficient memory model was being developed, in relation to cues available in the 'task context', in each experiment. Furthermore, this would suggest that other cues were being utilised in addition to those manipulated by the experimenter. It is evident, however, that as list structure increases the usage of these other cues must decrease, or there would be a resultant increase in the number of categories recalled.

Also, if categorical and spatial memory were not independent systems, we would expect an additive effective across the experiments as a result of an increase in both types of cues. This situation does not occur and so it seems likely that categorical and spatial memories are separate and independent systems. To obtain more detail concerning the interaction between categorical and spatial cues we must consider the other experimental variables.

	Exp.2 vs. Exp.3 CFR	Exp.3 vs. Exp.4 CFR	Exp.4 vs. Exp.5 CFR	Exp.2 vs. Exp.3 CSR	Exp.3 vs. Exp.4 CSR	Exp.4 vs. Exp.5 CSR
No. rec.	NS	NS	NS	NS	NS	NS
%CC	NS	$3 < 4$ $p < 0.01$	NS	NS	$3 < 4$ $p < 0.001$	NS
%SC	NS	$3 < 4$ $p < 0.001$	NS	NS	$3 < 4$ $p < 0.01$	NS
ATE	NS	$3 > 4$ $p < 0.05$	NS	NS	$3 > 4$ $p < 0.01$	NS
%SS	NS	$3 < 4$ $p < 0.01$	NS	$2 < 3$ $p < 0.05$	$3 < 4$ $p < 0.05$	NS
%O	NS	NS	NS	$2 < 3$ $p < 0.05$	$3 < 4$ $p < 0.01$	NS

Table 5.19. The progressive comparison and analysis of experiments 2 - 5 in terms of the experimental variable

5.4.7.2 Categorical clustering

A comparison of experiments 2 and 3 demonstrates no significant change in the amount of categorical clustering exhibited in free recall. This is not surprising, as experiment 3 uses lists of random categorical order, as in 2, even though organised into spatial groups of six. However, a comparison between experiments 3 and 4 shows a significant increase in the amount of categorical clustering in the latter's free recall. The major difference between these lists is that in experiment 4 the categorical relations between job categories are more explicit, due to being arranged according to their major categories, whereas in 3 they are implicit. Thus, it seems that if categorical relations can be explicitly perceived, they will be used in the construction of a categorical model. The addition of alphabetic order, and meaningful labels for the groupings in experiment 5, did not further significantly enhance the amount of categorical clustering in free recall. The alphabetical order was not always noted (see section 5.6), and the labels were perhaps redundant as the logical groupings were self evident. However, the labels might make the categorical relations evident at an earlier stage.

The addition of the coefficients 1, 2, 3 and 4 into the 'Omnibus' program, in comparing all the experiments together, showed a significant increase in categorical clustering in the direction of experiments 2 to 5. Thus the earlier findings are confirmed.

The previous results are also reflected in spatial recall, but this is an artefact of the experimental design and not a significant psychological effect.

5.4.7.3 Spatial clustering

The increase in spatial clustering between experiments 3 and 4, in free recall, was again an artefact of the experimental design. With the increase in categorical clustering in experiment 4, it is logical that comparing the free recall list with an already categorically structured list should cause a significant increase in spatial clustering (see table 5.19).

Considering spatial recall, there is no significant difference between experiments 2 and 3. Therefore, spatial grouping does not increase the amount of association between juxtaposed categories on the experimental list. There is a significant increase between experiments 3 and 4, however (see table 5.19). This could mean that either the juxtaposition of meaningfully related categories on the experimental list results in greater inter-item association, or that greater spatial accuracy in placing the items in spatial recall creates the impression of increased spatial clustering. This problem will be resolved by consideration of the other measures of spatial recall which relate to accuracy of positioning items relative to the whole list, rather than relative to each other. No significant difference was evident for a comparison of spatial clustering between experiments 4 and 5, again suggesting no increased accuracy of placement. Otherwise we would expect the amount of spatial clustering to increase.

The input of coefficients in the analysis showed a trend of increasing spatial clustering from experiment 2 through to 5, confirming the earlier analysis.

5.4.7.4 Average total error

Free recall shows a significant decrease in average total error for subjects using the categorically structured lists of experiments 4 and 5. On the surface, this indicates that the compatibility of the implicit categorical relations with their spatial grouping results in an increased influence of spatial cues in free recall. However, this is due to chance fluctuations in opposite directions in experiments 3 and 4 and the comparing of the experiments two at a time. If all four experiments are compared at once the test for trends, using coefficients, shows that there is no significant consistent variation between experiments.

Spatial recall does show a significant trend, running from experiment 2 to 5, with respect to average total error. The categorically grouped lists show a significantly smaller average total error compared to the random and spatially grouped lists. This indicates that meaningful spatial grouping of categorically related items results in items being located, in comparison with the experimental list, nearer to their actual positions. If categorical organisation merely increased the associations of items next to each other, then %SC would increase but not necessarily accompanied by a decrease in ATE. The reason for this is that inter-item associations would not necessarily reflect the order of major groupings on the list. Therefore, it seems reasonable that positions are encoded relative to the whole list 'image' rather than to each other, because %SC and ATE do not co-vary.

5.4.7.5 Percentage sector score (%SS)

A consideration of the comparisons of percentage sector score for free recall pairs of experiments, as in the last section, yields a significant difference between experiments 3 and 4 (see table 5.19). This suggests that the spatial grouping of lists into meaningful categories increases the amount of spatial influence on free recall. Again, however, a trends test of all the experiments together results in no significant trend being apparent. Therefore, there is no specific change in spatial influence on free recall, but it is not strictly true to say there is no spatial influence at all. A general influence of spatial cues has been shown in free recall by comparing ATE and %SS measures with those expected by chance. The nature of these measures shows this influence to be only in terms of general awareness of cluster groups in comparison to the whole experimental list; that is, there is a slight tendency to recall the categories in, for instance, the first half of the list prior to those in the second half. This is an addition to any categorical clustering, because if average categorical clustering was 100%, which it is not, there would be not spatial influence at all.

The comparison of %SS, for spatial recall, in experiments 2 and 3 shows that grouping random lists spatially increases accuracy of sector placement (see table 5.19). This seems fairly logical, because in experiment 3 the spatial groups are clearly defined. Table 5.19 shows, however, that there is no corresponding decrease in average total error. It is therefore evident that there is still some inaccuracy of position placement inside and outside sector groupings, even though there is a higher incidence of recall in the correct sector. It is also evident that the spatial grouping of related categories in experiment 4 (see table 5.19) further increases the incidence of spatial location in the correct sector. This must be as a result of being able to identify groupings meaningfully and thus enable logical deduction as to which categories were in which grouping. As with % categorical clustering, however, the addition of labels and alphabetical order had little effect.

The analysis of general trend showed an increase in %SS from experiment 2 to 5.

5.4.7.6 <u>Percentage nought score (%O)</u>

%O scores reflect exact localisation of recalled categories with respect to each experimental list. Not surprisingly free recall showed no significant differences between experiments 2, 3, 4 and 5. This is not surprising in the sense that, in the free recall lists of all the experiments, %O scores could be accounted for by chance (see tables 5.1 to 5.4).

Spatial recall, on the other hand, did show an effect of list structure on %O scores. The comparison of experiments 2 and 3 (see table 5.19) showed that spatial groupings significantly increased the amount of exact localisation of items. This can be accounted for in that the grouped lists had more points of reference (the top and bottom of each group) compared to the random list (just the top and bottom of the list). The introduction of categorical-spatial grouping in experiment 4 further increased the amount of exact localisation. This raises two questions as to the nature of this localisation.

Firstly, does the categorical grouping cause more categories to be apportioned to their correct sector, and hence the correct relative position within the sector? Secondly, does the association between adjacent, meaningfully related categories result in the correct order within the group? From the evidence, it seems that both possibilities occur. The reasons for this will now be discussed.

In considering experiments 2 and 3 it is noticeable that spatial grouping increased both sector localisation (%SS) and exact localisation (%O), but did not increase the amount of spatial clustering (%SC), or decrease the amount of average total error (ATE). This means that there was no higher incidence of adjacent categories on the experimental list being correctly localised together. It also means that those not correctly localised (approximately 60%), either in sector or exact position, must demonstrate at least as much ATE as in spatial recall of the random list. This does not conform with the idea of localisation predominantly with inter-associations. We would expect an increase in %SC if localisation was dependent on interassociation, which we do not get.

The categorical grouping of lists, in experiments 4 and 5, results in more categories being remembered in the correct sector, in their correct position. This suggests that once the correct grouping is identified, the relative position within that grouping can be decided upon. The increased localisation means that the internal interpretation mechanism must use a categorical strategy in spatial recall, at least as far as identifying the correct group of six. It also seems likely that a certain amount of meaningful inter-item association must now occur, and contributes to an increase in exact localisation within major category groupings. The previous comparison of experiments 2 and 3 suggested that items are also located relative to their position in the whole list. Therefore, we must conclude that both types of coding are used to locate items in lists, but that inter-item associations are not predominant until explicit meaningful relations are perceived between the items. Furthermore, an identity check, via the categorical model, must take place prior to location of each item in order for meaningful juxtapositions to be noted.

The preceding findings indicate that there must be some internal high level executive system which can direct retrieval from either the categorical and/or the spatial memory model. This executive system would operate according to strategies based upon categorical and spatial relations perceived in the information. It would seem logical that the categorical memory model is interpreted due to some categorical strategy, and that the spatial model is scanned according to some spatial strategy, that is, by scanning a spatial 'image'. However, if the available spatial cues and resultant 'image' were not very strong, it is conceivable that some other strategy based, for instance, upon perceived categorical relations could compensate. The introduction of spatial grouping to the random lists significantly increased the accuracy of spatial localisation, but only to approximately an average of 40%. The introduction of categorical organisation further increased this to an average of 69% and 77% respectively. Therefore in the absence of strong spatial cues it seems that categorical organisation can be used to compensate.

Finally, a comparison of %SS and %O shows that localisation of a category to the correct sector of a list is consistently easier than to an individual position within the list.

5.4.7.7 <u>Training times</u>

An 'Omnibus' analysis of the results from the first training period (table 5.16) shows that task times are significantly faster in experiments 4 and 5, as compared with experiments 2 and 3 ($p < 0.001$). This result is again evident in an analysis of the results from the second training period. Therefore, it seems that a faster search time is possible with categorically structured lists.

5.4.7.8 <u>Experimental times</u>

An 'Omnibus' analysis of the experimental times (table 5.18) shows the following results:

2 $>$ 4 and 2 $>$ 5 ($p < 0.05$)

3 vs. 4 NS

4 vs. 5 NS

2 vs. 3 NS

Although these results do not exhibit the clear difference between 2 and 3, and 4 and 5, as do the training times, it does seem likely that there is a non-significant trend towards faster times in experiment 5. Any significant effects on search times could be masked by the time taken to interpret each item of information; this was not necessary during the training periods.

5.5 The nature of the categorical and spatial memory models

5.5.1 The nature of the categorical model

5.5.1.1 Introduction

The characteristics of categorical recall have been discussed previously, and it was evident that a certain amount of internal structuring had occurred in terms of experimenter-defined relations. The measure used was categorical clustering which, although giving an indication of the effect of the different experimental lists on the categorical model of the job categories, does not provide much information concerning the models specific characteristics. Therefore, we need to investigate categorical recall in greater detail, and examine whether increased internal categorical structuring results in an increased number of job categories being recalled; to do this various correlation measures are used. Additionally, the number of job categories recalled, and the relative incidence of experimenter defined clustering are examined for each of the five major categories, in order to demonstrate the effect of variation in explicitness of categorical relations upon the internal model. The technique used is a modification of the inter-trial repetition score (Tulving, 1962).

Earlier measurement of categorical clustering in free recall never accounted for, on average, more than approximately 60% of the pairs of categories recalled, or any of those recalled singly. Therefore, in terms of the number of job categories recalled, it is a somewhat inadequate measure; neither does it successfully reflect the strength of coding of the various major categories of job categories in categorical memory.

Amongst the non-clustered items that were recalled there were probably some non-experimenter defined, but none-the-less meaningful, associations which could account for the successful retrieval of a pair of items from memory. Here again, the modification of the inter-trial repetition measure is used in the investigation.

The strength of coding of the items from each major category can be reflected by an analysis of the number of times each job category was recalled, assessed over all the experiments. Specific combinations of these values reflect the strength of coding not only of individual items, but also of each major category of items relative to the others.

It is pertinent, at this stage, to examine the characteristics of the categorical model in terms of experimenter defined categorical structure, and then to look at possible structure not covered by this definition. But first we must consider the method which will provide the relevant data, the modification of the inter-trial repetition score.

5.5.1.2 <u>The inter-trial repetition score</u>

The inter-trial repetition score was developed by Tulving (1962). Initially, this technique was used to note the incidence of specific associations of items being repeated on successive trials by the same subject. In this case, it will be used to note the incidence of specific experimenter defined associations repeated during free recall by different subjects. This will, however, only show strong and frequent associations. Other deviations from 100% categorical clustering are due to the weaknesses inherent in free recall (see chapter 4, section

4.4.2.9), non-experimenter defined associations, and possibly a certain degree of episodic and spatial cueing.

The method of analysis involved recording the number of times a particular pair of job categories occurred together, and then comparing this with the number of times we could expect this to occur by chance. To do this a 30 x 30 matrix was constructed, the thirty columns representing the thirty job categories, as did the thirty rows. To record the incidence of each pair combination in free recall the appropriate row was located for the first member of the pair, followed by the appropriate column for the second member; a tick was recorded in the matrix square where the row and column intersected. When this had been done for the free recalls of all four experiments the number of ticks in each matrix square were counted and the appropriate total recorded in that square. An added complication was that each pair of job categories could be either item A followed by item B, or vice versa. Therefore, a diagonal drawn from the top left hand corner of the matrix to the bottom right effectively divided the A - B pairs from the B - A pairs. Both forms of a particular pairing are relevant in assessing its incidence, therefore each square from one diagonal half of the matrix was added to its counterpart in the other. The result of this procedure can be seen in table 5.20, and the key to the row and column coding can be seen in table 5.20a.

The corresponding values that could be expected due to chance were calculated in the same manner as for the free recall lists. It was necessary, however, to arrive at a figure, using random lists of categories, for thirty-six lists, corresponding to the thirty-six lists used in experiments 2 to 5. Therefore, a computer program was written to log the number of times particular number pairings from random lists of the numbers 1 to 30 occurred. One hundred and eight lists were logged and the numbers consequently arrived at in the matrix were divided by three to arrive at the figures expected for thirty-six lists; they were expressed to one decimal place. The chance values can be seen in table 5.21. They are probably somewhat on the large side because each list compared contained twenty-nine pairs. In

	A1	A2	A3	A4	A5	A6	C1	C2	C3	C4	C5	C6	I1	I2	I3	I4	I5	I6	M1	M2	M3	M4	M5	M6	P1	P2	P3	P4	P5	P6
A1		9	8	7	6	5	0	0	2	1	0	0	1	0	0	2	0	0	0	1	0	0	1	0	0	1	1	1	1	0
A2			36	3	6	3	0	0	0	0	0	0	0	1	2	1	0	1	1	0	0	0	1	0	1	0	1	0	0	0
A3				4	10	2	0	0	1	0	1	1	3	3	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1
A4					6	17	1	0	1	0	2	0	1	2	1	1	2	2	0	0	0	1	2	1	2	0	0	0	1	3
A5						10	0	0	0	0	0	2	0	3	0	2	0	0	0	1	0	0	1	1	1	2	0	0	0	0
A6							0	0	0	0	0	1	1	1	1	0	3	1	2	0	2	0	1	1	1	0	0	2	1	2
C1								6	12	4	3	4	0	0	0	1	0	0	2	1	1	1	1	2	1	0	1	1	1	0
C2									6	3	2	0	4	1	2	0	0	1	1	1	0	6	1	3	0	1	0	0	1	0
C3										6	7	6	3	1	1	0	0	1	1	0	1	2	1	0	1	0	0	3	0	0
C4											0	6	3	2	1	0	2	0	1	0	0	2	2	0	1	1	3	5	0	0
C5												4	12	1	1	1	3	1	1	2	2	2	0	0	1	0	0	0	1	1
C6													2	2	1	1	1	1	0	1	0	0	1	1	1	0	1	2	0	0
I1														3	3	3	3	0	3	1	2	3	0	1	1	0	0	0	1	0
I2															2	2	0	6	1	2	3	0	2	3	1	1	0	0	1	0
I3																0	0	0	1	1	1	0	1	1	0	3	0	0	1	1
I4																	19	3	1	3	1	1	0	1	1	1	2	1	0	3
I5																		1	2	4	3	4	1	0	1	0	2	0	0	1
I6																			1	6	1	0	1	0	1	3	1	0	1	1
M1																				0	4	2	1	7	2	0	0	1	1	3
M2																					2	1	0	1	4	1	0	3	0	1
M3																						2	2	6	1	1	0	1	4	0
M4																							3	4	0	0	0	1	0	0
M5																								4	4	1	3	5	1	4
M6																									1	1	0	0	11	1
P1																										8	6	4	5	4
P2																											12	1	7	5
P3																												4	5	10
P4																													5	5
P5																														3
P6																														

Table 5.20. Frequencies of specific job category pair associations

Table 5.20a. Key to tables 5.20 and 5.21.

A = Academic
C = Commerce
I = Industry
M = Miscellaneous
P = Public Services

MA courses - Arts	A1
MSc courses - Physical sciences	A2
MSc courses - Social sciences	A3
Part-time education	A4
PhD research	A5
Teacher training	A6
Accountancy	C1
Advertising	C2
Banking	C3
Insurance	C4
Retailing	C5
Stockbroking and investment analysis	C6
Buying	I1
Engineering	I2
Industrial administration	I3
Management Services	I4
Management training	I5
Quality control	I6
Entertainment	M1
Environmental control and design	M2
Hotel management and catering	M3
Journalism	M4
Legal work	M5
Tourism	M6
Armed forces	P1
Civil service	P2
Local authority	P3
Medical	P4
Public transport	P5
Social work	P6

	A1	A2	A3	A4	A5	A6	C1	C2	C3	C4	C5	C6	I1	I2	I3	I4	I5	I6	M1	M2	M3	M4	M5	M6	P1	P2	P3	P4	P5	P6
A1		2.0	3.0	2.3	2.0	1.7	3.7	3.7	5.0	2.7	2.7	1.7	2.3	2.7	2.0	1.7	3.0	2.7	1.0	1.0	2.7	2.3	1.7	2.3	2.0	3.7	2.3	2.0	2.7	1.7
A2			1.3	2.0	1.3	2.3	2.7	2.7	2.3	1.3	3.3	2.7	2.0	3.7	2.3	2.0	1.7	3.3	3.0	4.0	3.3	3.3	1.3	1.7	3.3	2.7	2.0	2.3	3.0	1.7
A3				1.0	2.7	2.7	3.3	1.3	4.0	0.7	1.3	3.0	2.0	2.7	4.3	1.7	1.0	3.3	3.3	2.7	2.0	2.7	2.0	1.3	2.3	2.7	3.0	2.7	1.3	2.7
A4					2.7	2.3	3.3	2.0	1.7	3.0	2.7	2.0	2.0	2.7	1.7	1.7	2.7	1.7	2.3	4.0	3.7	2.3	1.7	5.7	2.0	2.3	1.3	2.7	3.0	2.3
A5						2.0	1.0	2.3	0.7	2.0	2.0	2.0	1.7	2.3	1.7	2.7	3.3	2.7	2.3	2.7	3.3	1.3	3.3	2.0	2.0	3.7	3.3	3.3	3.7	2.3
A6							1.0	2.7	1.0	2.0	1.7	3.0	5.3	1.3	4.0	3.3	3.0	3.0	2.0	2.0	1.0	5.0	2.3	1.3	2.0	2.7	2.7	1.0	2.0	3.7
C1								2.7	3.3	3.0	2.0	1.7	1.7	1.3	1.0	1.3	2.3	0.0	4.3	2.7	1.7	3.0	1.7	3.3	2.3	3.0	2.7	4.0	3.0	2.0
C2									2.3	3.7	2.0	2.3	2.0	3.3	2.0	2.3	3.0	1.7	1.7	3.0	2.3	2.3	3.0	3.7	2.3	1.7	2.0	1.7	3.0	2.3
C3										2.0	2.3	1.7	3.3	4.0	2.3	3.0	1.7	1.0	2.3	1.0	4.7	3.0	4.0	2.3	3.0	3.0	2.0	1.3	1.7	0.3
C4											2.3	2.0	3.3	1.7	2.7	1.3	2.0	2.0	2.3	3.7	0.0	3.0	2.7	2.0	2.3	4.0	2.0	3.0	2.3	4.0
C5												2.7	3.3	2.7	2.7	2.3	4.7	2.3	3.3	4.0	3.0	1.3	3.3	2.0	2.3	0.7	1.3	2.3	0.7	2.0
C6													2.0	2.7	3.7	2.0	1.3	1.7	3.7	2.0	3.7	2.3	3.7	3.3	1.7	3.0	1.0	2.0	2.7	2.0
I1														3.0	2.7	2.3	2.3	4.0	1.7	2.0	2.0	1.7	1.3	2.3	2.3	1.7	2.3	3.0	2.7	2.0
I2															1.3	2.3	3.3	2.0	2.0	2.3	1.7	1.7	4.7	1.7	2.7	2.0	1.3	3.7	2.0	1.0
I3																1.7	3.0	1.7	2.3	1.7	1.7	3.3	1.3	2.3	2.7	2.0	4.7	1.7	3.0	2.3
I4																	3.7	2.7	3.7	3.0	1.0	2.3	1.3	2.7	3.0	2.0	3.7	3.0	3.7	1.7
I5																		3.3	2.7	2.0	2.0	1.3	1.3	1.0	4.0	1.7	2.7	1.3	1.3	3.0
I6																			1.7	2.0	2.3	1.7	2.7	2.7	3.0	3.7	3.0	3.0	3.3	2.7
M1																				0.7	2.3	2.7	3.3	2.7	1.3	1.3	3.3	1.0	2.3	2.7
M2																					1.3	3.3	1.7	3.7	1.3	1.7	3.3	2.7	1.7	2.7
M3																						2.7	1.7	2.7	4.7	2.0	3.0	3.0	1.7	3.0
M4																							2.3	3.3	1.0	1.3	1.7	1.0	2.7	3.7
M5																								2.0	2.3	2.7	1.0	3.3	2.7	3.7
M6																									2.3	3.3	2.3	1.0	1.0	1.7
P1																										2.7	3.0	2.0	3.3	2.0
P2																											1.0	2.7	1.3	2.3
P3																												2.3	2.7	2.0
P4																													2.3	3.7
P5																														2.7
P6																														

Table 5.21. Frequencies of specific job category-pair associations expected by chance.

practice there were usually far less than twenty-nine pairings in each free recall list. A general assessment of the chance values reveals that the probability of a specific pair combination occurring on either four or more occasions in thirty-six recall lists is 0.529. Taking this, and the fact that the chance values are slightly large, into consideration, it is valid to expect that any specific pairing which occurs on four or more occasions must be significant at the 5% level. This would mean that the particular pairing was a significant and meaningful association available to, although not always used by, the subjects undertaking the experiments.

5.5.1.3 Experimenter defined associations

It is first necessary to establish whether the amount of experimenter defined structure is correlated with the number of items recalled. The correlation between percentage categorical clustering and the number of job categories recalled during free recall, across all the experiments, was found to be 0.33. This was calculated using a Commodore S-61 calculator and was found not to be significant at the 1% or 5% level. The lack of correlation suggests that the amount of organisation is not directly related to the number of items recalled. However, it is dangerous to conclude this in light of the knowledge that categorical clustering is never 100%. To answer this question specifically it is necessary to look a little closer at the relationship between the five major categories and the number of items recalled from each. The incidence of recalled cluster pairs per major category in conjunction with the number of items recalled per major category will give an indication of the dependence of recall upon specific organisation.

An anlysis of the amount of categorical clustering per major category can be taken as an indication of the strength of association, in memory, in terms of experimenter defined categorical relations. If each major category was perfectly recalled the six member items would provide five cluster pairs. The thirty-six free recall lists, from the four experiments, would therefore provide a maximum of one hundred and eighty cluster pairs per major category. Using table 5.20 we can express the actual occurrence of major category cluster pairs as a percentage of the maximum possible. This provides a measure of the relative strengths of coding of the various major categories in the subjects' categorical memory. The figures obtained are as follows:

ACADEMIC	=	73.33%
COMMERCE	=	38.33%
INDUSTRIAL	=	25.00%
MISCELLANEOUS	=	21.67%
PUBLIC SERVICES	=	47.78%

The academic major category is probably the best defined, in terms of perceptible relations between constituent items. It is no surprise, therefore that this major category is most strongly coded in memory judging by the high percentage of cluster pairs recalled compared to the maximum possible. As the amount of perceivable relations progressively decrease over the other major categories, so does the corresponding strength of coding. The miscellaneous category, where the relationship between items is the most loosely defined, exhibits the least amount of experimenter defined cluster pairs.

Table 5.22 gives the number of items recalled per major category, as a percentage of the maximum possible. The totals are as follows:

ACADEMIC	=	96.29%
COMMERCE	=	83.80%
INDUSTRIAL	=	82.41%
MISCELLANEOUS	=	81.94%
PUBLIC SERVICES	=	92.59%

A measure of correlation between the percentage pair clusters and the percentage of items recalled, per major category for free recall, gives a coefficient of 0.94, significant at the 5% level. This pattern of categorical clustering is also reflected in the major categories of each individual experiment to varying degrees. We must conclude, therefore, that the

	time forgotten	RECALLED Exp 2	Exp 3	Exp 4	Exp 5	Total
MA courses - Arts	4	9	9	5	9	32
MSc courses - Physical sciences	0	9	9	9	9	36
MSc courses - Social sciences	0	9	9	9	9	36
Part-time education	1	9	8	9	9	35
PhD research	2	8	8	9	9	34
Teacher training	1	8	9	9	9	35
% TOTAL		96.30	96.30	92.59	100.0	96.29
Accountancy	6	8	7	7	8	30
Advertising	10	6	6	8	6	26
Banking	2	8	8	9	9	34
Insurance	4	9	7	7	9	32
Retailing	5	7	8	8	8	31
Stockbroking & Investment Analysis	8	8	7	5	8	28
% TOTAL		85.19	79.63	81.48	88.89	83.80
Buying	4	8	8	8	8	32
Engineering	3	9	9	7	8	33
Industrial administration	16	6	4	8	2	20
Management services	2	8	8	9	9	34
Management training	3	8	7	9	9	33
Quality control	10	7	7	4	8	26
% TOTAL		85.19	79.63	83.33	81.48	82.41
Entertainment	8	6	8	7	7	28
Environmental control & design	9	6	7	6	8	27
Hotel management and catering	4	7	8	8	8	31
Journalism	11	5	7	8	5	25
Legal work	5	8	8	6	9	31
Tourism	1	8	9	9	9	35
% TOTAL		74.07	87.04	81.48	85.19	81.94
Armed forces	2	8	9	9	8	34
Civil service	1	9	8	9	9	35
Local authority	4	8	8	9	7	32
Medical	3	8	8	8	9	33
Public transport	4	9	7	9	7	32
Social work	2	7	9	9	9	34
% TOTAL		90.74	90.74	98.15	90.74	92.59

Table 5.22. The number of categories recalled per experiment per major category during free recall.

number of items recalled in free recall is contingent upon the amount of organisation in categorical memory.

We can place much more faith in the previous conclusion compared to the correlation between total categorical clustering and total number of job categories recalled. The reason for this is that total categorical clustering is expressed as a percentage of the total number of job categories recalled in each free recall list. Each list usually contained a significant and varied number of job categories either not in pairs or, if they were, not in pairs defined as categorical clusters by the experimenter. The consideration of number of categorical clusters per major category, however, eradicated the influence of the non-clustered categories. Also, splitting the number of job categories recalled into their respective major categories enabled a proportional representation, compatible with the relative organisational strengths of the major categories.

To summarise, organisational strength is dependent upon explicit, perceivable categorical relations, and the greater the amount of resultant internal organisation the greater the number of items recalled.

A further breakdown of the major categories into their constituent pairs reveals that certain associations have a stronger potential storage strength. Table 5.20 shows the frequency of specific associations from across the thirty-six subjects undertaking free recall. Each major category will be considered in turn.

a) Academic - Perhaps the strongest association of all possible pairs, recalled by all thirty-six subjects, are the M.Sc. courses; physical and social science. Not only have they a strong semantic relation within the academic context, but they also have very strong physical similarities. Part-time education and teacher training have more in common with each other than with the other four academic categories, this is reflected in a high incidence of occurrence. Other associations with frequencies of ten, or less, are probably associated by virtue of the academic context; when the frequency of association between Ph.D. research and teacher training is considered, the academic context is all they have in common.

b) Commerce - The strongest pair in this major category are banking and accountancy; they have probably the strongest financial link. Most of the other pairs seem most obviously linked by the financial context. The two pairs with ostensibly the weakest logical financial links, advertising and stockbroking and investment analysis and retailing and insurance, were not present in the free recall tests.

c) Industrial - As in academic the two strongest semantically and perceptually similar job categories, management services and training, were by far the most frequently recalled pair. This major category is, with miscellaneous, one of the two weakest major categories in terms of frequency cluster pairs. Apart from the engineering/quality control pair there are no other significantly frequent associations.

d) Miscellaneous - Entertainment/tourism and hotel management and catering or tourism are the two strongest associations from the weakest major category. The linkage between them seems to be by virtue of a common 'holiday' concept. Similarly with entertainment and hotel management and catering and legal work and tourism. The other interesting association is journalism/tourism. It seems likely that the fact that both end in -ism could have cued the association.

e) Public services - The strong associations in this major category are civil service/local authority, and local authority/ social work. In practice the link between these areas is very close and part of most people's experience. The major category as a whole exhibits the second highest potential organisation strength for categorical memory. Although it is not as tightly defined as the academic one the relationships between the constituent job categories are fairly well defined.

It seems, from the previous evidence, that job categories are more likely to cue each other from memory the stronger their association is. This reinforces the finding that organisation in memory results in increased recall. Further evidence is available if we correlate the number of times each job category is recalled as a member of a cluster pair with the number of times each is not recalled. The coefficient is 0.70 and the slope of the regression line is negative. The correlation is therefore negative and significant at the 1% level. This means that the stronger an item is associated with other items, the more likely it is to be recalled. Again, we are led to the conclusion that greater organisation in memory results in better recall; associations occurring by virtue of some super-ordinate contextual link.

The nature of the coding of items in memory follows two traditions, reductive and elaborative (see section 5.2.4). Certainly we have considered much evidence for the reductive coding of items in relation to super-ordinate, experimenter defined major categories. We have also seen, however, some evidence for elaborative coding, in terms of common perceptual features, in addition to the reductive aspects.

5.5.1.4 Non-experimenter defined associations

Table 5.20, in addition to experimenter defined associations, also contains a record of non-experimenter defined associations. The frequencies of these particular associations are found by cross-referencing particular job category rows with columns whose job categories are from another experimenter defined major category. In the previous section the cross-reference was with columns whose job categories were from the same major category; frequencies of four and above being considered significant at the 5% when compared with chance.

The two strongest non-experimenter defined associations are retailing/buying, with a frequency of 12, and tourism/public transport, with a frequency of 11. The former association has a very strong link in terms of concept definition within the context of commercial and consumer practices. In the experiment they were defined in different contexts; retailing in commerce, and buying in industry. It seems, however, that the association outside the experimental context is stronger. Again, the latter of the two pairs have a stronger association, in terms of travel, outside their contextual separation in the experiment.

Insurance/medical and legal work/medical are both significant associations. They are contextually linked by the fact that there are important insurance and legal aspects of the medical profession, and vice versa. Advertising and journalism are related, in that much advertising is prevalent in todays press. Quality control and environmental control and design both have the concept of control in common.

There are a number of remaining associations which are just significantly frequent. In some cases it is possible to ascertain the conceptual links involved, whereas in others there is not an obvious conceptual link. They are as follows:

Advertising/buying
Management training/environmental control and design
Management training/journalism
Environmental control and design/armed forces
Legal work/armed forces
Legal work/social work
Hotel management and catering/public transport

We can see from the non-experimenter defined associations that the perceived context in which information is handled is very important in determining the way information is organised in memory. Problems will be caused if certain information is classified in one context when there is a strong tendency amongst users to associate the information in a different context.

5.5.2 The nature of the spatial model

5.5.2.1 Introduction

The spatial models of recall, generally reflected by the subjects, can be studied by examining spatial recall parameters for the various positions of the lists. However, spatial recall can also be linked to the recall of particular categories; a job category cannot be located in a spatial recall template until it has been given an identity. It is interesting, therefore, to assess whether certain job categories are better located than others, in addition to particular list positions, and what relationship this bears to subjects' free recall. It is perhaps most appropriate to deal with spatial recall related to the specific job categories first, followed by its relation to actual spatial positions.

5.5.2.2 Spatial recall characteristics of major job categories

Table 5.23 summarises the important spatial recall parameters for each experiment. An average value, over nine subjects, is given for each major category in each experiment. An average value representing all four experiments is also given for each major category. We can see that, in terms of numbers of categories recalled in each major category, a similar pattern is apparent in both free and spatial recall. A measure of correlation between free and spatial recall, for the average % number of categories recalled per major category representing experiments 2 to 5, results in a coefficient of 0.93. This is significant ($p < 0.05$) indicating a close correspondence of the two recalls. It seems reasonable, therefore, to suppose that job category identities are elicited from categorical memory prior to their location via spatial memory.

The correlation between the average % number of categories recalled per major category and ATE, %SS, and %O (averaged for spatial recall in experiments 2 to 5) are - 0.82, + 0.87 and + 0.66. None of these are significant at the 5% level. Again this supports a separate categorical and spatial memory because the results show that recall of a category does not necessarily lead to correct location in terms of the spatial recall parameters used.

5.5.2.3 Spatial recall with respect to list positions

As already mentioned, to reflect the nature of the spatial image of the various lists, it is necessary to examine the spatial recall parameters in conjunction with each position on the list. We will first compare the individual spatial measures separately, comparing their profiles for each of

		% No Rec.	ATE	%SS	%O
MA courses - Arts MSc Courses - Physical sciences MSc courses - Social sciences Part-time education PhD research Teacher training	Ex 2	92.59	1.62	78.00	34.00
	Ex 3	94.44	2.67	72.55	35.29
	Ex 4	98.15	0.64	96.23	79.25
	Ex 5	100.00	0.07	100.00	92.59
	ALL	96.30	1.25	86.70	60.28
Accountancy Advertising Banking Insurance Retailing Stockbroking and investment analysis	Ex 2	85.19	3.07	60.87	17.39
	Ex 3	85.19	3.43	58.70	30.43
	Ex 4	81.48	0.82	93.18	61.36
	Ex 5	90.74	1.33	83.67	67.35
	ALL	85.65	2.16	74.11	44.13
Buying Engineering Industrial administration Management services Management training Quality control	Ex 2	92.59	2.66	64.00	24.00
	Ex 3	81.48	2.14	70.45	31.82
	Ex 4	87.04	1.74	78.72	57.45
	Ex 5	83.33	1.47	82.22	60.00
	ALL	86.11	1.75	73.85	43.32
Entertainment Environmental control and design Hotel management and catering Journalism Legal work Tourism	Ex 2	85.19	2.37	56.52	32.61
	Ex 3	70.37	2.16	76.32	47.37
	Ex 4	77.78	1.48	85.71	64.29
	Ex 5	81.48	1.50	84.09	68.18
	ALL	78.71	1.88	75.66	53.11
Armed forces Civil service Local authority Medical Public transport Social work	Ex 2	96.30	2.02	59.62	26.92
	Ex 3	92.59	1.32	84.00	56.00
	Ex 4	94.44	0.39	96.08	82.35
	Ex 5	98.15	0.11	100.00	92.45
	ALL	95.37	0.96	84.93	64.43

Table 5.23. Spatial recall measures per experiment per major category for spatial recall.

lists 2 to 5. Then we will average these profiles across the lists and compare the average profiles for each of the measures.

Figures 5.3 to 5.5 show comparisons of the spatial profiles for the four lists, for each of ATE, %SS and %O respectively. For each list position, the values of the respective measures were averaged for the nine subjects who undertook the spatial recall of each list. These values can be seen in tables 5.24 and 5.25. The graphs of these values against list position were then plotted on a graph plotter. The reason for not including a graph for the numbers recalled per position was because there was no significant difference between different lists. Therefore, this will be dealt with on the graph of the recall measures averaged across the lists. We will deal with each graph in turn:

i) ATE (figure 5.3)
To make the graph of average total errors more discernible, the values were multiplied by ten. The graph shows, in agreement with earlier results, that ATE for lists 2 and 3 (+ and o) is higher than for lists 4 and 5 (◊ and x). The most interesting feature, however, is that ATE is lowest, and therefore spatial accuracy is highest, at the top and bottom of each of the lists; spatial accuracy is lowest in the middle portions. The effect of progressive structuring was to extend the spatial accuracy of the beginning and end of the list to more positions, and also decrease the error in the middle portions.

ii) %SS (figure 5.4)
The above characteristics are repeated for the %SS values.

iii) %O (figure 5.5)
Most interesting of the three spatial recall measure graphs is that of %O per position. %O reflects absolute accuracy of placement, and shows the effects of progressive structure better than the other two. All the characteristics previously mentioned are present, but the most striking feature is the very significant general increase in absolute spatial accuracy when categorical structure is added to the spatial groupings. Lists 2 and 3

Table 5.24. ATE and %SS for experiments 2 to 5

ATE x 10				%SS			
E2	E3	E4	E5	E2	E3	E4	E5
0	0	0	0	100	100	100	100
5.6	2.5	1.1	0	100	100	100	100
41.1	22.0	3.8	0	66.7	60	100	100
10.0	34.4	2.5	2.2	88.9	77.8	100	100
24.3	27.5	1.1	2.2	71.4	77.8	100	100
13.3	21.3	0	0	55.6	62.5	100	100
21.3	3.3	32.5	7.8	37.5	100	75.0	88.9
27.5	38.8	11.1	17.1	50.0	50.0	87.5	85.7
41.3	11.4	6.7	8.9	62.5	100	100	88.9
35.0	18.3	6.7	10.0	62.5	66.7	100	88.9
28.8	17.1	16.7	32.9	37.5	85.7	77.8	57.1
23.8	18.8	7.5	7.5	75.0	75.0	87.5	87.5
23.8	18.9	8.9	8.9	50.0	66.7	88.9	88.9
24.4	25.0	16.3	24.4	55.6	75.0	87.5	66.7
23.3	31.4	11.1	0	66.7	57.1	87.5	100
21.4	24.3	38.8	12.2	100	57.1	37.5	88.9
27.5	30.0	20.0	16.7	50.0	50.0	75.0	88.9
27.8	36.7	23.8	16.7	22.2	44.4	62.5	66.7
34.4	13.8	1.3	0	33.3	62.5	100	100
37.8	37.1	17.5	26.3	44.4	42.9	87.5	62.5
17.5	33.8	14.3	7.1	75.0	87.5	85.7	100
45.0	20.0	7.8	30.0	33.3	66.7	100	71.4
20.0	53.8	11.4	23.8	75.0	75.0	100	75.0
21.1	23.3	23.8	0	33.3	62.5	62.5	100
23.8	35.0	15.0	1.1	37.5	50.0	87.5	88.9
41.4	42.2	2.2	0	28.6	66.7	100	100
31.1	8.8	2.0	3.3	88.9	87.5	100	100
5.5	8.8	2.9	0	100	87.5	100	100
5.5	13.8	2.5	2.2	100	87.5	100	100
0	5.6	0	0	100	100	100	100

Table 5.25. %O for experiments 2 to 5

%O			
E2	E3	E4	E5
100	100	100	100
44.4	87.5	88.9	100
11.1	40.0	62.5	100
33.3	11.1	75.0	77.8
14.3	25.0	88.9	77.8
33.3	37.5	100	100
12.5	50.0	75.0	77.8
12.5	12.5	62.5	71.4
12.5	28.6	66.7	75.0
25.0	20.0	66.7	55.6
25.0	42.9	55.6	42.9
12.5	62.5	87.5	77.8
0	55.6	77.8	66.7
22.2	12.5	50.0	44.4
50.0	14.3	50.0	100
0	28.6	37.5	66.7
37.5	33.3	50.0	44.4
11.1	22.2	50.0	66.7
0	37.5	87.5	100
11.1	14.3	62.5	50.0
50.0	12.5	57.1	57.1
0	33.3	33.3	28.6
0	37.5	28.6	62.5
0	44.4	62.5	100
25.0	25.0	87.5	88.9
0	22.2	77.8	100
55.6	37.5	80.0	77.8
55.6	75.0	71.4	100
77.8	62.5	75.0	77.8
100	88.9	100	88.9

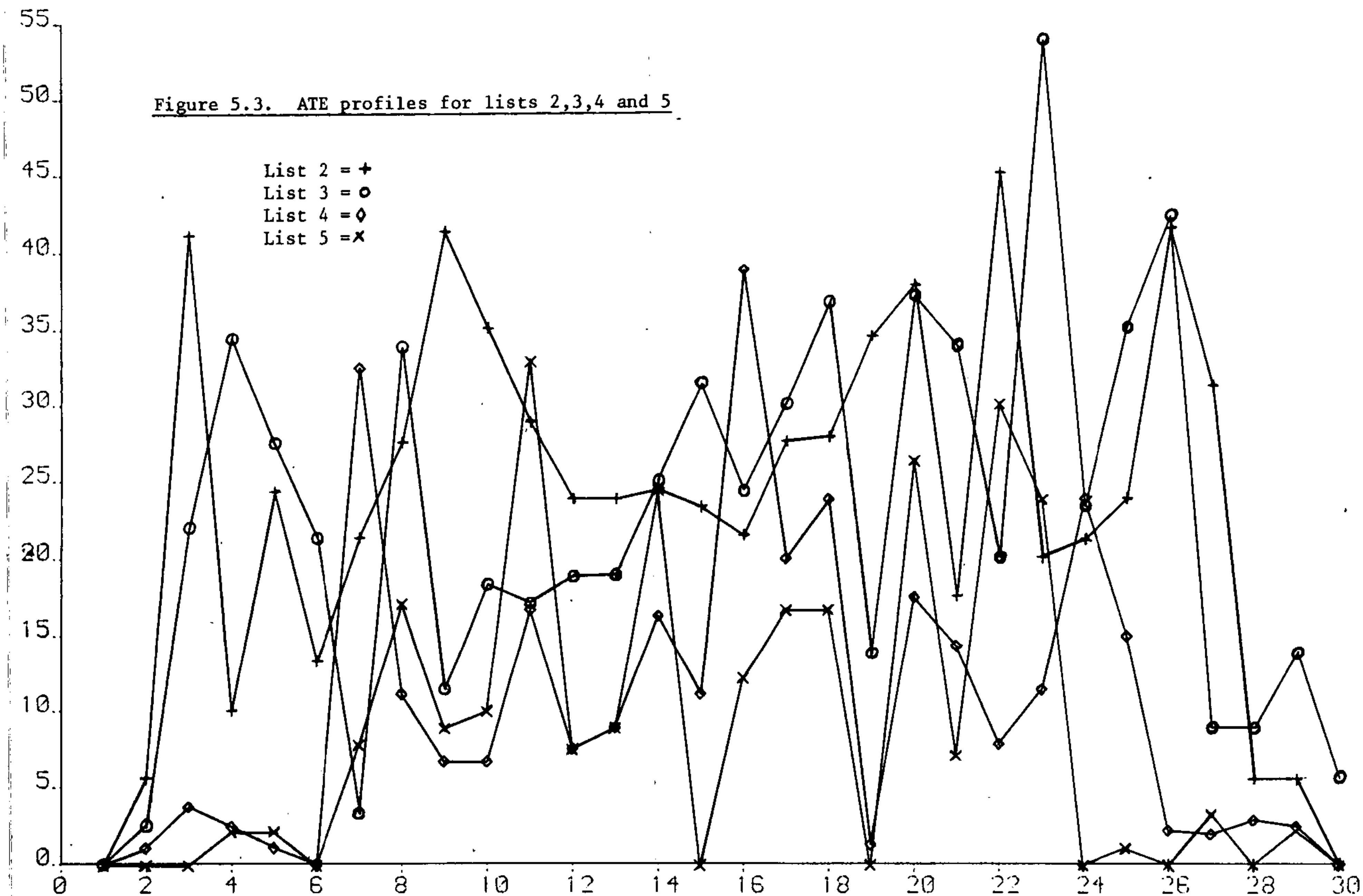


Figure 5.3. ATE profiles for lists 2,3,4 and 5

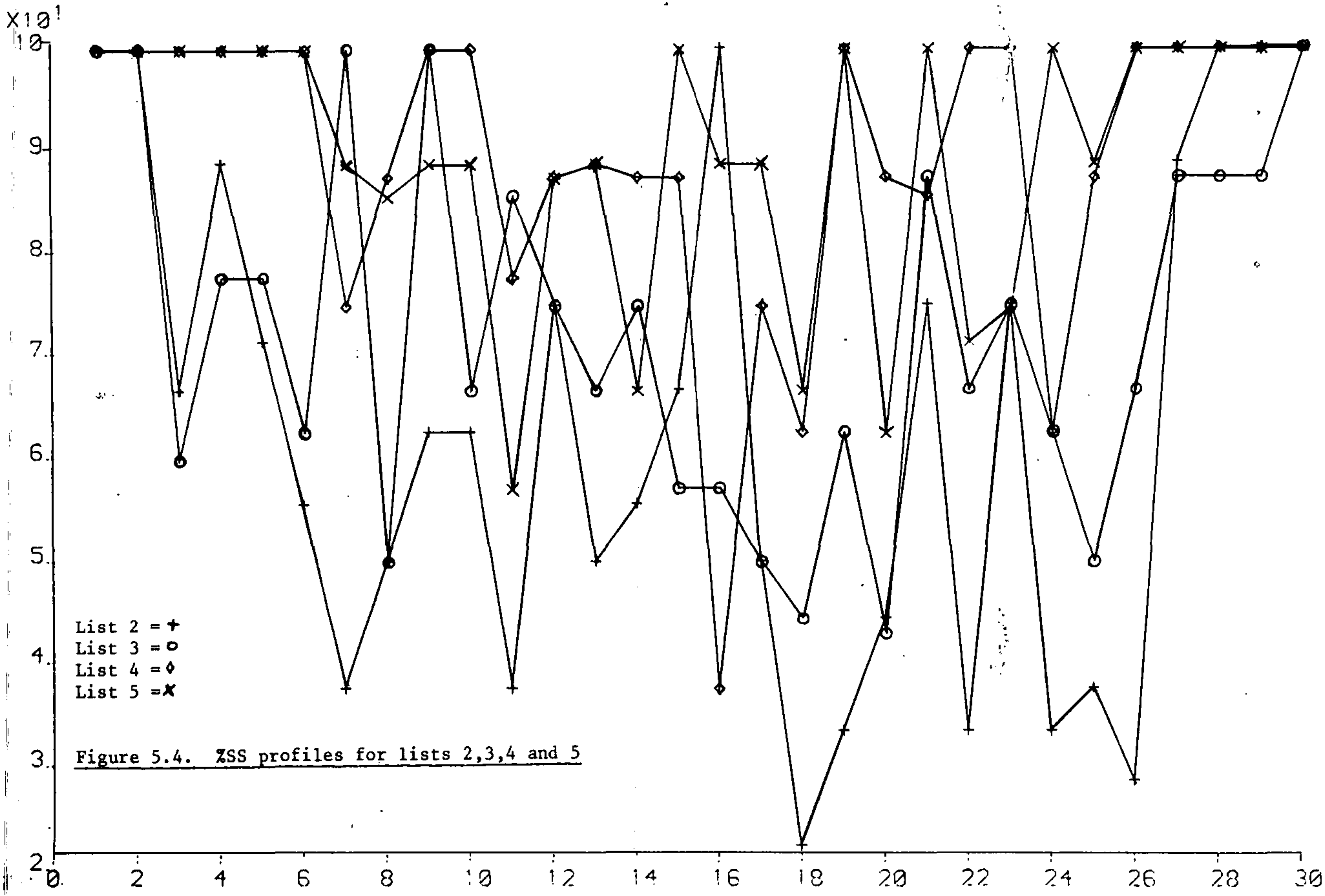


Figure 5.4. %SS profiles for lists 2,3,4 and 5

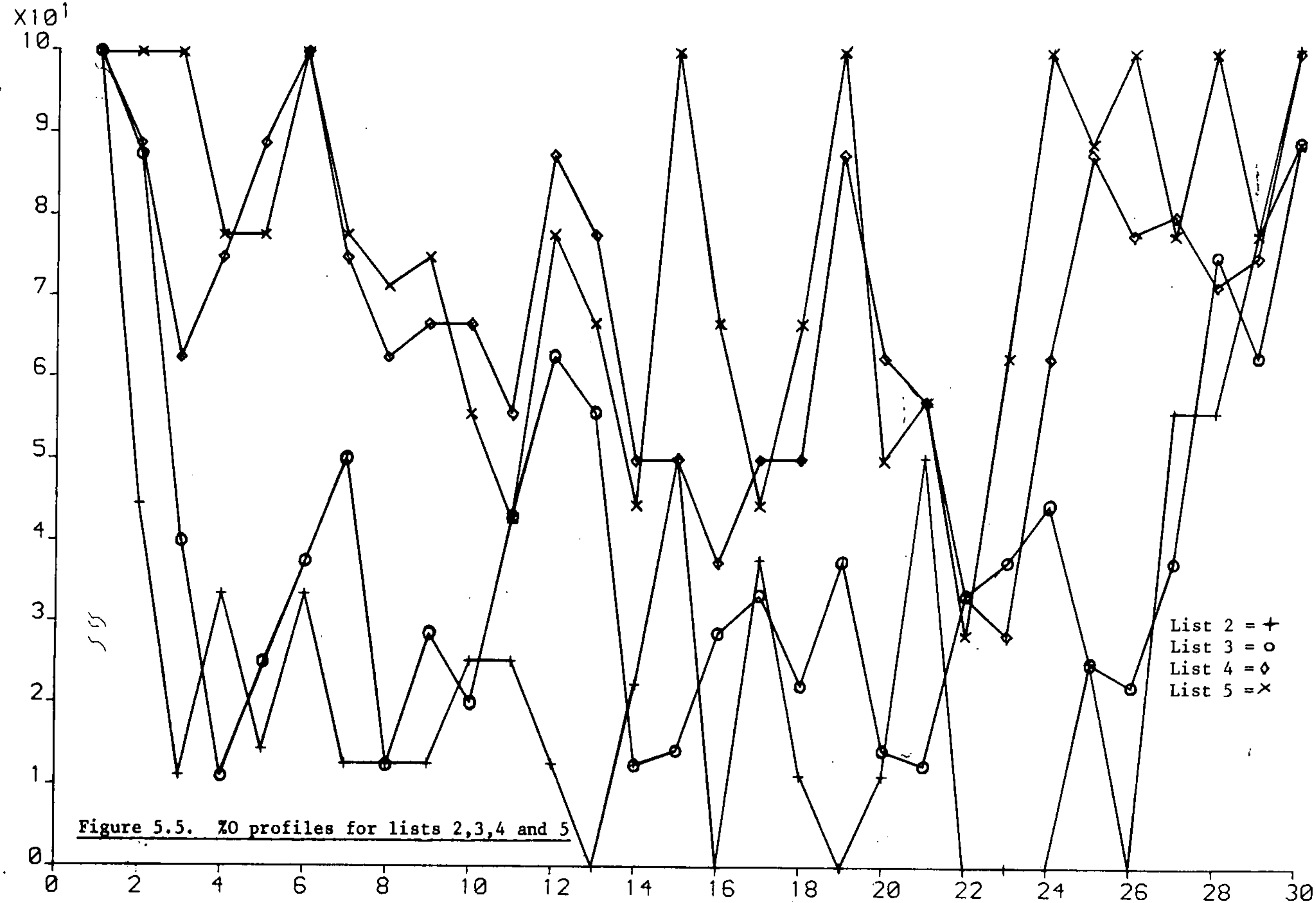


Figure 5.5. %O profiles for lists 2,3,4 and 5

(+ and o) show low SD measures except for the top and bottom. Lists 4 and 5 (◊ and x) however, show a much increased absolute accuracy in the middle portions of the lists in addition to the top and bottom effect.

In general, even though statistical significance was only present between lists 3 and 4, this visual representation of the spatial recall of the lists, shows a progressive increase in spatial accuracy from list 2 to 5 for each measure. It also seems that there is some periodicity to the graphs, but this would be better examined by representing all the measures of spatial recall on one graph averaged across experiments 2 to 5.

In order to examine the combined characteristics of spatial recall for the positions of the list, the spatial recall variables were averaged across experiments 2 to 5 for each of the 30 possible positions on each list (see table 5.26). These values were then plotted on a graph; the x-axis representing the thirty list positions and the y-axis the magnitude of the respective variables on a scale of one to one hundred (see figure 5.6).

The first feature to notice about the graph is that ATE, %SS and %O all reflect that the most accurate spatial localisation occurs at the beginning and end of the list. This indicates that the spatial 'image' is best in these areas. However, the number of categories recalled per position during spatial recall does not reflect the same distribution. The line of regression for the numbers recalled per list position has a slope of - 0.016 indicating that the probability of recalling a particular job category is virtually equal for each position. Therefore, we must conclude that the recall of job category identities employs a different mechanism to that of establishing their spatial positions in each list used by subjects in the filing task.

Table 5.26 Average measures for experiments 2 to 5 per list position

Position	No. Rec.	ATE x 10	%SS	%O
1	36	0	100.00	100.00
2	35	2.3	100.00	80.21
3	31	16.7	81.67	53.40
4	35	12.3	91.67	49.30
5	33	13.8	87.30	51.49
6	34	8.7	79.51	69.71
7	27	16.2	75.35	53.82
8	32	22.4	68.30	39.73
9	30	17.1	87.85	45.69
10	32	17.5	79.52	41.81
11	31	23.9	64.53	41.57
12	32	14.4	81.25	60.07
13	35	15.1	73.61	50.00
14	34	22.5	71.18	32.29
15	24	16.5	77.83	53.57
16	31	24.2	70.88	33.32
17	31	23.6	69.97	41.32
18	32	26.3	48.96	37.50
19	31	12.4	73.96	56.25
20	34	29.7	59.33	34.48
21	30	18.2	87.05	44.20
22	25	25.7	67.86	23.81
23	31	27.3	81.25	32.14
24	34	17.1	64.58	51.74
25	33	18.7	65.97	56.60
26	34	21.5	73.81	50.00
27	31	11.3	94.10	62.71
28	32	4.3	96.88	75.50
29	34	6.1	96.88	73.26
30	36	1.4	100.00	94.44

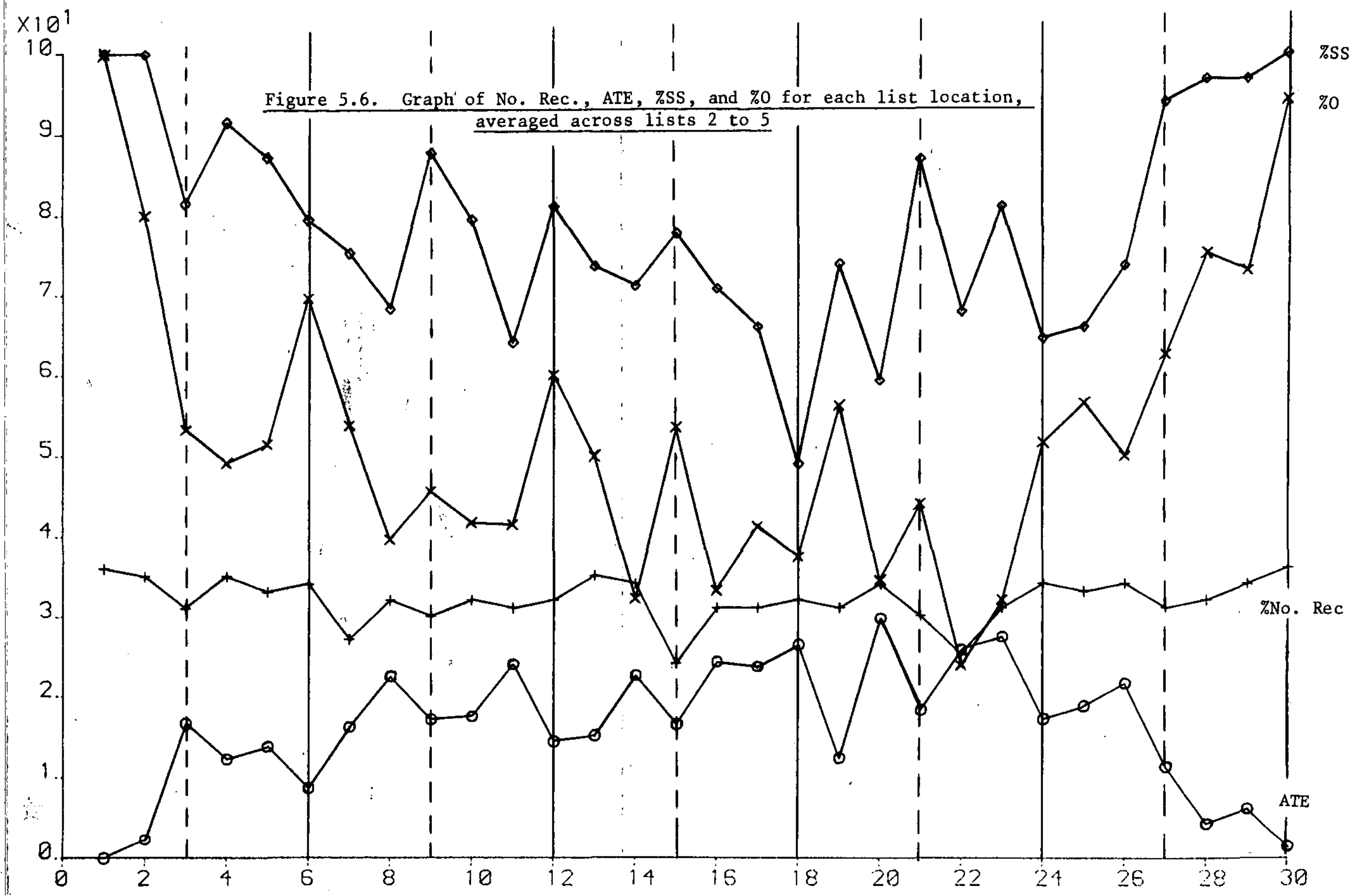


Figure 5.6. Graph of No. Rec., ATE, %SS, and %O for each list location, averaged across lists 2 to 5

A closer study of the graph (figure 5.6) reveals some indication that localisation of categories is perhaps more accurate at the top and bottom of the sectors into which the lists in experiments 3, 4 and 5 are divided. The lines drawn vertically up from the x-axis on each multiple of six often coincide with peaks of %SS and particularly %O, and also dips in ATE. There is also some evidence of this periodic effect occurring on multiples of 3. Perhaps this provides some indication of perceptual spatial organisation according to some natural cognitive 'chunking' facility.

5.6 Subjective comments and other measures

After their experimental task, each subject was asked a selection of the same five questions as in experiment 1, dependent upon whether they undertook free or spatial recall.

5.6.1 Awareness of the major categories of information

Table 5.27 shows the frequencies of subjects who reported various levels of awareness of experimenter defined major categories for free and spatial recall respectively.

Free recall:

Experiment	All experimenter major groups	Whole and sub-groups of experiment major groups	Sub-groups of experimenter major groups + others	Others
2	0	7	2	2
3	1	7	1	0
4	3	5	1	0
5	7	1	1	0
Spatial recall:				
2	0	7	2	0
3	0	8	1	0
4	8	1	0	0
5	7	2	0	0

Table 5.27: Results for question 1

Both free and spatial recall showed that all the experimenter defined major groupings were only frequently noted when the lists explicitly exhibited the particular major groupings. This corresponds with the data of section 5.4.7.2 which shows an increase in categorical clustering with the imposition of explicit categorical grouping. Experiments 2 and 3 were characterised by subjects perceiving some of the experimenters major categories, especially 'Academic', alongside sub-groups of the major categories (e.g. civil service - local authority - social work); corresponding with a lower level of categorical clustering.

Experiments 4 and 5, on the other hand, were characterised by a greater subjective awareness of the experimenter defined categories by virtue of being grouped accordingly. This corresponds to the earlier findings that explicit grouping resulted in higher categorical clustering in free recall; thus, it seems that categorical relations must be perceived in order to be used to organise information internally in memory.

A few groupings other than those within experimenter definitions were perceived by subjects, but they were usually peculiar to the particular person and of no general significance. Therefore, considering that the highest percentage categorical clustering in free recall was approximately 58%, there must have been other cues involved in addition to categorical assocations: for instance, subjects reported that they 'ran through all the jobs they could think of', 'thought of specific mistakes that they had made and information that they had handled', 'had tried to remember the long words'.

5.6.2 Stragegy of reading information items

Table 5.28 gives the frequencies of the different reading strategies employed to interpret the individual information items that were filed; heading read first followed by text scan, text followed by heading, and a mixture of the two.

Experiment		Heading/Text	Text/Heading	Mixture
Free recall:	4	4	3	2
	3	0	8	1
	4	2	6	1
	5	2	7	0
Spatial recall:	2	2	4	3
	3	3	3	3
	4	4	5	0
	5	1	7	1
		10	19	7

Table 5.28: Results for question 2

The results show that the majority of subjects adopted a specific strategy of reading information items, that is, they formed expectations of where the relevant cue words were. Most frequent was a strategy of scanning the text for keywords which matched the filing category descriptions, followed by the title if not enough information was found. The other, although less frequent, alternative was to read the heading first, then the text if not enough information was present. Approximately 15% of the subjects used a mixture of the two strategies. Thus, if documents of similar form and content are received we can expect people to form expectations as to where the relevant information is. This could conceivably lead to misinterpretations.

5.6.3 Strategy of recall

The different aspects of the strategies of recall fell into four basic categories; image, categorical, episodic and physical. Image included attempts to 'visualise' the list in order to cue categories. Categorical consisted of a recalled item cueing the recall of other related items. Episodic cues were, for example, mistakes made in classifying, or where that person had been in employment in one of the job categories used. Physical cues included remembering that some job category descriptions were long, and some were short. In addition, in free recall, subjects were asked their strategy of recall after a pause in writing down descriptions whilst trying to recall others. Table 5.29 shows the results for free recall, whilst table 5.30 shows the results for spatial recall; subjects could use more than one strategy.

Free recall:

Experiment	Image	Categorical	Episodic	Physical
2	6	8	2	2
3	6	6	1	0
4	8	8	0	0
5	8	8	0	0
	28	30	3	2

	Scanned previous descriptions recalled	Pictured list	Thought of actual information items	Thought of possible jobs
2	2	4	3	0
3	5	3	1	2
4	5	3	0	0
5	7	3	0	1
	19	13	4	3

Table 5.29: Results for strategy of free recall

Spatial recall:

Experiment	Image	Categorical	Episodic	Physical
2	9	6	0	3
3	9	7	1	4
4	9	8	0	0
5	8	5	0	0
	35	26	1	7

Table 5.30: Results for strategy of spatial recall.

In both free and spatial recall subjects used both imagery and categorical relations to cue recall. These strategies were used in approximately equal proportions in free recall, but imagery took precedence in spatial recall, as would be expected. It is interesting to note that imagery played such a prominent part in free recall. People seem to like to try to 'visualise' the lists even though the categorical relations predominate. Typical comments were: "I remembered that they were in groups and tried to remember the actual job categories, then I tried to remember where they were"; "I could remember the groups, but then had to remember the order within"; "I tried to visualise the list, though I was not very successful".

The results also show that people use episodic and physical cues to promote recall on occasion. This is especially noticeable in free recall where subjects were asked how they cued job categories after they had become stuck. Often they scanned those already written in order that they might cue related ones. Slightly less frequently they tried to 'picture' the list and run through the positions, hoping to remember particular job categories. Occasionally, subjects thought of the actual sheets of information that they had read and classified. They also occasionally ran through all the jobs that they could think of hoping that one would cue a job that was on the list. Subjects correspondingly exhibited some of the previous characteristics in spatial recall.

It was very significant that every subject undertaking spatial recall said that they could easily remember the top and bottom of the list; this is in agreement with previous quantitative analysis of spatial recall. Therefore, it seems that the spatial image system places a priority on establishing points of reference at the extremes of displayed information, as in experiment 1.

Finally, the introduction of alphabetic order was noticed by 3 and 5 subjects out of 9 for free and spatial recall respectively. However, this did not significantly contribute to an increase in the accuracy of spatial location (see section

5.5) and so could not have made a significant contribution to the interpretation of the spatial image.

It is apparent that subjects use many different strategies and cues in order to recall particular information. However, particular types of strategies and cues do predominate in particular types of recall.

5.6.4 Other measures

In addition to the main parameters, there were several interesting side issues which will be dealt with in turn.

5.6.4.1 Misnaming of job categories in recall

Out of 1875 recalled job categories, 259 (13.8%) were different in some way to the original stimulus, although it was always obvious which job category they were referring to. Typical examples of misnaming were: environmental design; hotel management; stockbroking; MSc physics; environmental health; stocks and investment; forces; legal; social services. It was evident that the specific contexts of the jobs were being remembered, but that the specific descriptors, especially multi-word ones, often were not. There were two basic types of misnames, rewording and deletions. Rewording involved either a change in word order or the replacement of words with others appropriate to the specific context. Deletion involved the shortening of words or leaving them out altogether.

5.6.4.2 Secretaries vs. computer professionals vs. non-computer professionals

A comparison between secretaries, computer and non-computer professionals, showed no significant difference in selected performance measures. The measures used were the number of job categories recalled, percentage categorical clustering and percentage noughts. This suggests that categorisation and spatial awareness are basic skills which are available irrespective of a professional person's background.

5.6.4.3 Number recalled vs. experimental time

A measure of correlation between the number of job categories recalled and the time taken to complete the experimental task produced a significant negative correlation. The implication of this is that people who were having difficulty with the task developed less adequate cognitive models in terms of the efficiency of recall; those who easily completed the tasks had developed better models.

In order to put the conceptual characteristics of list filing into perspective, it is necessary to compare it with the simulated 'real world' filing used in pigeon-holes.

5.7 A comparison of simulated 'real world' filing with simulated computer filing

It is evident from the literature survey (chapter 2) that naive users who can conceptualise information interaction in the 'real world' have difficulties conceptualising interaction with computer-based information. It is therefore pertinent that we should compare experiment 1, which investigated the conceptual model associated with a simulated 'real world' filing task (pigeon-holes), with experiments 2 to 5, which characterised computer filing (lists).

5.7.1 Comparison of the categorical memory characteristics of simulated office and computer filing

In experiment 1, explicit categorical relations in condition 1 do not significantly increase %CC in comparison to their implicit presence in condition 2. However, in experiments 2 to 5 explicit categorical relations did increase %CC, thus reflecting internal organisation in terms of these relations. A possible explanation for this is that in experiment 1 other cues could be mediating free recall, rather than purely categorical ones. The obvious difference between pigeon holes and lists are in their spatial characteristics. If the pigeon holes promote a strong spatial image and the job categories are either associated with, or embedded in, the locations within it, then the categorical model would be less dominant. In this case a general categorical model of the job categories would be developed during the pigeon hole task. The strong spatial cues making it less important for the subject to specifically note the categorical relations in comparison with experiments 2 to 5.

5.7.2 Comparison of the spatial memory characteristics between simulated office and computer filing

There was one striking difference in spatial memory characteristics between experiment 1 and experiments 2 to 5. In experiment 1 the strength of the spatial image, as measured by %O, was not dependent upon a meaningful categorical organisation of labelled pigeon holes. In experiments 2 to 5 however, equivalent 'image' strength was dependent upon a meaningful categorical-spatial arrangement of the list of job categories. The statistical comparisons using 'Omnibus' are as follows:

N.B. The %O results of each of experiments 2 to 5 were compared with the %O results of experiment 1, condition 3 (random arrangement).

The hypotheses are as follows:-

i) Exp. 1, cond. 3, %O > Exp. 2, %O: significant ($p < 0.001$)
ii) Exp. 1, cond. 3, %O > Exp. 3, %O: significant ($p < 0.01$)
iii) Exp. 1, cond. 3, %O > Exp. 4, %O: not significant ($p > 0.05$)
iv) Exp. 1, cond. 3, %O > Exp. 5, %O: not significant ($p > 0.05$)

Similar comparisons using the number of job categories recalled showed no significant difference between experiment 1, condition 3 and experiments 2 to 5. These results suggest that the recall of category identities is independent of our ability to locate them based upon our 'spatial image'. This, in turn, suggests that identities are recalled via a categorical model before locating them.

5.7.3 Discussion

The previous results show yet again that spatial and categorical memory are independent. Furthermore, we must conclude that the spatial cues available in lists are weak and that internal interpretation of spatial locations needs a categorical strategy in order to compensate. Pigeon holes, on the other hand, seem to provide much stronger spatial cues, therefore the development of a strong categorical model is not as important.

5.8 Summary and discussion

5.8.1 General characteristics of categorical and spatial memory

As in experiment 1 (chapter 4) it is apparent that the categorical memory model is dominant in free recall and that the spatial model is dominant in spatial recall. There was a very general level of spatial influence in categorical recall, however, which suggests that subjects use their general awareness of spatial positioning to organise their categorical recall of job categories. But, on the whole, categorical and spatial memory seem to be independent in terms of interpretation: this is not to say that other cues are not involved.

There was more internal categorical organisation apparent when explicit categorical structure was present in the lists. This demonstrates that a persons' categorical model can be structured on the basis of externally perceived categorical relations.

Concerning the spatial memory model, the lack of increase in %SC in experiments 2 and 3 suggests that it is not specifically based upon the inter-associations of juxtaposed items. Rather, it seems more predominantly based upon the relative positions of the items with respect to the whole list; location of items to appropriate sectors being easier than to specific locations. The %O results particularly would suggest that spatial grouping increases locatability of items by virtue of the provision of more points of reference for the memory 'image' (i.e. the top and bottom of individual groups). However, the additional increase in %O with the presence of categorical structure suggests that perceived categorical relations may promote inter-item associations within the groups which can be translated into spatial positions if necessary.

To account for these results it is logical to postulate the presence of a common executive mechanism which interprets both categorical and spatial memory. The functioning of this is best illustrated by considering the location of a descriptor on a spatially and categorically structured list (as in experiment 4). The present experiments have shown that in randomly arranged lists there is an absence of the strong spatial cues which provide an accurate location strategy, via points of reference in the spatial image, by which items can be located. In this case, additional categorical organisation could compensate for the weak spatial cues, because the executive mechanism could revert to the interpretation of categorical structure to provide a strategy for the location of items in the list; the strong spatial cues present in pigeon hole filing decrease the necessity to use a categorical strategy.

The proposed differential interpretation of both categorical and spatial memory would lead us to expect an increase in the number of job categories recalled, with the availability of extra cues, progressively from experiment 2 to 5. This in fact does not happen, which meant that other cues must be available in experiments 2 and 3, in addition to categorical and spatial, to cue recall of job category descriptors; separate from the location mechanism. For example, non-experimenter defined associations could be used. To resolve this uncertainty the categorical and spatial memory models were examined more closely.

5.8.2 Specific characteristics of categorical and spatial memory

A close examination of the categorical characteristics of free recall exhibited a number of characteristics. First, the amount of memory organisation according to experimenter defined relations was significantly correlated with an increase in the recall of those categories. This compares favourably with previous work (Mandler, 1967) which also showed an increase in the number of items recalled with increased memory organisation. Therefore, considering previous evidence, explicit external categorical organisation increases the amount of concomitant internal organisation, which in turn increases the probability of recall. The more explicit and contextually close pairs of job categories were more likely to be recalled together and less likely to be forgotten. However, care should be taken in structuring information, because what may seem like a strong association in a certain context to one person, might not to another; they may perceive a completely different associative pair in a different context.

Other cues, for instance, physical similarity, also served to elicit associations. This and the previous findings suggest that both reductive and elaborative coding takes place.

Much of the specific spatial recall data supported the hypothesis that categorical and spatial memory systems are independent. In addition, it seems likely that job category identities are retrieved predominantly from categorical memory, and via other cues, prior to location; this is suggested by the fact that the number of items recalled was independent of subjects ability to locate them.

In terms of location the main points of reference were the top and bottom of each list; here the accuracy of location was far superior to other list positions. There was also evidence that the top and bottom of spatial groupings may be used similarly, and that even this may be reduced to groups of three, in agreement with Wicklegren (1967).

With respect to the spatial memory model of list filing, it is interesting to note that there was significant evidence that the lists in experiments 4 and 5 decreased the search time for locating category descriptors during the initial training periods. There was also an indication that this might also have been so during the experimental period, although the results were non-significant. These results suggest that the enhanced spatial memory model, resulting from categorical organisation in addition to spatial structure, promotes a faster and easier location of category descriptors.

5.8.3 Subjective comments and other measures

Subjects perceived all the experimenter major groups only when they were explicitly organised by category. Without explicit grouping they noticed some of the more obvious major categories, such as academic, but were not aware of the total organisation. This corresponds to the subjects' displaying greater categorical organisation when using lists explicitly structured by category; it demonstrates that categorical relations must be perceived to be used as part of the categorical memory model. However, subjects did perceive sub-groups of major categories and some other non-experimenter designed categorical relations, so an organisational strategy tends to be adopted.

When reading information items, subjects tended to develop a particular strategy based on an expectation of where the relevant information could be found. This could conceivably lead to misinterpretation in cases where relevant information is not where subjects expect it to be.

The main strategies that subjects reported they employed, in free and spatial recall, were based on imagery and categorical relations. The categorical strategy was slightly more prevalent in free recall, and the imagery in spatial recall. It was interesting, however, that most subjects said they used both. It seems that most people naturally try to 'visualise' an information display, even if they do not tend to use the 'image' as the basis of their recall strategy.

However, other strategies were used based either on categorical memory (e.g. running through all possible jobs known), episodic memory (e.g. specific mistakes made and information used in the task), and imagery (e.g. trying to remember the long words). Again, the flexibility of memory and the recall strategies it employs was demonstrated.

Amongst other measures, the implication of 13.8% misnaming is quite important. To use the correct descriptor for accessing computer files it would seem to be an advantage to locate the appropriate descriptor from the information display, rather than try to recall it from memory. Therefore, assuming that a strong spatial model produces more effective descriptor location than a weaker one, it would seem most efficacious to promote the appropriate organisation of displayed information. Moreover, this would remove the need for extra software to recognise synonyms.

5.8.4 Comparison of pigeon holes and lists

A comparison of the memory models developed during simulated 'real world' and computer filing tasks highlighted a major difference. The pigeon holes were informationally rich with respect to the development of a spatial image, whereas the lists were not. To attain comparable location recall it was necessary to categorically structure lists in spatial groups. Therefore, some aspect(s) of the pigeon holes, missing in the unstructured list, made a significant contribution to the formation of a strong spatial memory model. Assuming that a strong spatial memory model is important in order to locate information descriptors, then the discovery of this factor, or factors, would enable us to understand how to compensate for the poor spatial characteristics of randomly organised lists.

5.8.5 Conclusions

The conclusions that can be drawn from chapter 5 are as follows:

1) The categorical organisation of information in memory, as reflected by free recall, can be enhanced by the explicit categorical organisation of the list. Therefore, the recall strategy from categorical memory utilises perceived categorical relations in the information.

2) The more meaningfully related two descriptors are the more likely they are to be associated in categorical memory, and hence the more likely they are to be recalled. Therefore, the more organised the categorical memory model is the higher the probability of descriptor recall.

3) A random list of descriptors promotes a very 'weak' spatial memory model.

4) The introduction of spatial grouping in a random list enhances the spatial memory model of that list to a limited extent. Hence, spatial reference points are [illegible] important factors in the development of an effective spatial memory model. These points of reference are the top and bottom of the list and possibly also the top and bottom of any groupings present.

5) It is easier to remember the approximate sector of a list which contains a specific descriptor than it is to remember the descriptor's exact location.

6) In the absence of 'strong' spatial cues in lists of descriptors, categorical relations can be utilised to form the basis of a spatial recall strategy. Explicit categorical grouping is required before the accuracy of spatial recall of the list reaches the same level as that evident after using the random array of pigeon holes.

7) Categorical and spatial memory are independent and separately interpreted.

8) The separate and differential interpretation of categorical and spatial memory, and the evidence for the use of other types of cues, both suggest the likely presence of an executive interpreting mechanism; this mechanism would seem to employ the appropriate retrieval strategy based upon the strongest available cues.

9) Because of the lack of 'strong' spatial cues in lists of descriptors, categorical aspects of the information become increasingly dominant in the formation and interpretation of the cognitive models arising from interaction with the lists.

10) A stronger spatial memory model promotes faster and more efficient location of descriptors.

11) The exact recall of descriptor title is not always achieved. Therefore, it would be better to display appropriate descriptors rather than relying on recall. Consequently, it is important to promote a strong spatial model by judicious structuring of the displayed information.