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**THE ROLE OF INCIDENTAL RECALL
IN THE DESIGN OF
PERSONAL FILING SYSTEMS**

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ABSTRACT

The thesis aims to investigate the implications of incidental recall for the design of personal information systems. Incidental recall is defined here as memory, without prior intent to recall, for information that is not meaningfully related to the information handling situation. When an information worker fails to recall how information is filed, is uncertain of its whereabouts, retrieval of that information becomes problematic and can result in the system not being used. One possible approach to solving this problem is to increase technological power, but even though electronic filing systems may offer varied and complex functions to assist information management, these functions lose their value if the systems are not actually used. An alternative approach to solving this problem is tailoring the system to make use of information that human memory can remember with little or no effort, in particular using attributes that human memory can recall incidentally, as labels for files.

An experimental paradigm was developed to explore the nature of incidental recall for aspects of office information. The scarcity of investigative work using realistic, information handling, tasks to investigate incidental recall prompted the experimental design using a realistic task for an office worker. A business simulation game was employed involving the subjects sorting information, in the form of documents, based on decisions about their information content. Situated on the documents' were "Icons", logo-like designs, each with unique attributes of colour, location, and shape. Following the sorting task, the subjects participated in an unexpected test for each attribute of the icon. Four experiments were run within this paradigm which involved subjects experiencing varying levels of exposure to different combinations of attributes.

The analysis provided substantial evidence for incidental recall of the attributes. Incidental recall of the attributes varied as a function of the task orientation. Evidence suggested a predisposition to integrate colour and shape in memory, while in contrast, location had a tendency to be recalled independently of the other attributes. The findings suggest that incidental recall as a filing aid will be most useful when attributes incidental to the information content are actively used in the course of handling the information.

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CHAPTER 1

PSYCHOLOGICAL ISSUES RELATING TO THE DESIGN OF FILING SYSTEMS

Chapter Contents

This chapter aims to define the topic area of the thesis. The chapter focuses on identifying information handling activities and associated psychological processes which contribute to inadequate information retrieval systems. Effective retrieval of information is viewed as a by-product of the initial filing procedures. The psychological barriers to filing information originate from various sources including difficulties associated with the appropriate categorisation of information, poor recall of how the information was filed, and the time, effort and motivation involved in filing. The chapter introduces the potential of a mnemonic approach to solving the issues relating to inefficient information retrieval. The argument is that memorable information identification tags can reduce the time and effort required at the filing stage whilst not adversely affecting recall.

1. PSYCHOLOGICAL ISSUES RELATING TO THE DESIGN OF FILING SYSTEMS

1.0 INTRODUCTION: THE AIM AND STRUCTURE OF THE THESIS

The thesis is concerned with supporting information retrieval from personal information systems. Information as a commodity is both economically and socially valuable. Commercial and social success can hinge on the availability and effective use of knowledge. Developing effective means of manipulating knowledge will therefore lead to both economic and social benefits. Electronic systems possess that potential to provide efficient manipulation and storage of information. The thesis considers how electronic systems can be used to support and extend personal filing practices.

The abundance of social scientific research on the development of an information-driven society is exemplified in writings such as Toffler's (1980) "Third Wave". The "Third Wave" is a term used to describe the information revolution. The information society is introduced as following the first wave (the agricultural revolution) and the second wave (the industrial revolution). Toffler states that

"For Third Wave civilization, the most basic raw material of all - and one that can never be exhausted - is information". p 368

The dominant industries of the third wave are service industries whose activities centre around the handling of information. The economic importance of these industries is reflected in the fact that during 1986, in the U.S., service industries accounted for 71% of the total employment and 68% of the Gross National Product (Quinn, 1987). This growth in the use of information is well documented. For example the U.S. Congress Office of Technology Assessment (OTA) reported that in 1985 U.S. offices processed about 500 billion documents, and the volume of paperwork is increasing by 72 billion additional documents every year. The transition from an economy based on industrial production to one based on the transfer of information and is not problem free (e.g, Hillman, 1982). Office systems represent a major growth area within the information technology market. Christie (1985) cites the Commission of the European Communities as estimating that

"Office systems will represent the largest single market for information technology" p.5

In this information society, to work efficiently, an office worker needs effective access to relevant information. Christie (1985, p.45) describes seeking information as one of the five activities an information worker engages in, the other activities include waiting (for information), acting (upon information), generating information, or opting out of the situation (e.g, having a coffee break). The thesis starts with the intention of focusing on a particular facet of the information society: the ease of access to information by retrieval from personal filing systems.

One approach aimed at improving access to extended quantities of information is to employ electronic systems. Unfortunately, simply employing automated systems is not a guarantee of efficient information retrieval (Eoseys, 1986). This thesis is centred in an alternative approach which aims to assess the potential benefits of the mnemonic aspects of information retrieval and apply these to the design of electronic systems. The first chapter reviews previous work that relates to the psychological aspects of information flow and structure in an office environment. The review is used to identify where information workers encounter problems while handling and, more specifically, retrieving information. These problems associated with the retrieval of information are viewed as a by-product of the initial filing stage. For example, finding information may be hindered by the fact that it was filed in a manner inappropriate for future retrieval (e.g, Heeks, 1986,p.31), or perhaps was not afforded enough attention at the filing stage. There appears to be a positive correlation between time and effort spent filing and the likelihood that information will be easily retrieved as has been suggested by Lansdale et al (1987). Consequently, an obstacle to effective retrieval occurs in the form of an apparent natural reluctance amongst information workers to spend time and effort filing. Therefore, when considering the efficient retrieval of information there appears to be a trade-off between requiring information workers to undertake a number of filing procedures or automating those procedures. When filing procedures are automated the information worker is less likely to recall how the information was filed (Slamenka and Graf, 1978). One plausible solution to this problem lies in the usage of memorable tags or enrichers associated with the information which may be incidentally recalled or easily remembered. The concept of remembering information with minimal

effort is implicit in psychological theories of automatic processing (e.g. Hasher and Zacks 1979; Posner and Snyder, 1975; Shiffrin and Schneider, 1977).

Consequently, the existence of automatic processing of information in human memory could present a productive way to approach the design of information retrieval systems. This contrasts with other existing methods that use computational power (e.g. Jones, 1986).

There is a plethora of work investigating the possibility of automatic processing in human memory, this work is discussed in the second chapter. The research suggests that information about various dimensions such as event frequency (e.g. Hasher and Chromaik, 1977; Zacks, Hasher and Sanft, 1982), temporal coding (Brown, 1973; Tzeng and Cotton, 1980), and location (e.g Rothkopf, 1971; Mandler et al, 1977; Von Wright et al, 1975) are automatically processed in human memory. Automatic processing of information in human memory is generally typified by its apparent immunity to change with either age, practice, or intent to recall. If automatic processing of information in human memory does occur the use of dimensions that are processed in this manner has potential for the design of information retrieval systems. The dimensions could be employed as identification tags for information items thereby improving the likelihood that the information could be accessed from the system at a later date. The potential benefits of using dimensions (information item attributes) that are automatically processed by human memory as tags for information items in a personal retrieval system include a reduction in the cognitive load on the user's memory, a reduction in the activities performed by the user at the filing stage, increased motivation to file, and an increased likelihood of accurately retrieving the information.

Another way of looking at this matter is that system-selected attributes need not be intentionally memorised by users if successful retrieval depends upon the strength of association (between the attributes automatically processed in human memory and the information item) rather than the mental effort expended during the filing process (Schönpflug, 1988). The questions addressed in this thesis are designed to clarify this problem area. The thesis raises questions such as "what features are most easily recalled and how can they best be exploited?", and "How can the necessary filing tasks

be elicited in a manner that does not deter the users of the system?". These questions have distinct practical implications for the design of filing systems. The thesis tackles these questions using an approach which aims to produce realistic, practical findings that can be related to existing theoretical issues.

The first chapter serves two purposes. The first purpose is to determine some of the general problems associated with filing and retrieving information from electronic systems. The second purpose of the chapter is to introduce the potential of solutions to these problems arising from the adoption of a memory based approach. A mnemonic approach is not the only plausible approach. However, this chapter introduces the advantages this approach supplies for solving the problems associated with efficient information retrieval. The second chapter further explores the potential of a mnemonic approach for reducing the problems associated with information retrieval. The chapter specifically focuses on the possibilities of automatic processing in human memory. Once the aim of the thesis is established through an understanding of the relevant issues the third chapter describes the experimental paradigm which is used as a practical means of investigating them. Chapter 3 provides an overview of the environment within which the experiments are run. The type of data collected within the paradigm is described. The planned approach to the analysis of this data is then outlined. The following four chapters (chapters 4, 5, 6, and 7) explain the specifics of each method and procedure used in the individual experiments. These chapters also include the results and preliminary analysis of the data they produce. The introduction to chapter 8 provides an overview of the conclusions from the previous four chapters. The overview is then considered in the light of existing work and theoretical issues. The discussion goes on to consider the implications of the analysis as regards the literature on memory and learning. This final chapter discusses the conclusions and practical implications of the work.

1.1 ELECTRONIC SYSTEM DESIGN.

As vehicles for information management, electronic systems have great potential for making an information worker's job more efficient. This potential lies in the fact that

electronic systems can enable almost unlimited organization, multiple indexing with cross referencing, and are capable of rapid and complex search operations. When applied to automating existing office practices these capabilities can deliver benefits such as increased storage capacity and the ability to manipulate and transmit enormous quantities of information. However, a major problem in designing electronic office systems based on existing office practices is that automating existing practices not only accentuates the advantages of these practices but also the disadvantages associated with them. The general inadequacy of such an approach to automating office systems is well recognised (e.g, Christie, 1985; Doswell, 1983; Lansdale, 1988; Reisner, 1981). For example, as part of the Department of Trade and Industries "Information Technology Awareness Program" an independent consultancy firm surveyed the views of 19 top executives by in depth interviews (Eosys, 1986). The report highlights a general feeling of dissatisfaction with the technology and exemplifies this with quotes from office workers such as:

*"It is easier to ask someone for information than to use the system" and
"finding items of information is a continuing management headache, but a
haphazard paper system is good compared to the task of remembering
codes and using menu's." pp 20-24*

These comments reflect the difficulties associated with retrieving information from technological systems. Reducing the problems associated with information retrieval will be a step toward technology reaching its full potential as an information handling tool. Recognition of the failure of IT to support information handling can be seen in the creation of various national and international initiatives. These initiatives include the Japanese Fifth Generation Computer Program, the European Strategic Research Program into Information Technology (ESPRIT), and the Alvey committee. Research initiatives such as these acknowledge the need to improve the use of information technology.

The Eosey's report (1986) concludes that the chief obstacles to the effective use of information systems are human and organisational, rather than technical. It is not only feasible but desirable that systems are designed to suit the specific requirements of the users. Identifying the requirements of a particular user population is essential to ensure that an electronic system constitutes an improvement and not just an alternative to a

paper-based system. Landauer et al (1982) appropriately sum the situation in relation to database usage:

"No matter how powerful a system, if the functions it performs are not comprehensible or useful to its users, no amount of tinkering with its screens and command languages will make it acceptable" p.2488

Automating existing systems may provide both appropriate and inappropriate functions that can effect how useful the users perceive the system as being.

The customary approach of computing experts to office automation has been to formalize the existing office functions. This approach is exemplified by the "desk-top" computers such as the Apple Macintosh and the Xerox Star (e.g, Smith et al, 1982). As mentioned previously, this can lead to an amplification of the difficulties associated with a paper-based system as well as the advantages. By studying the structure and flow of information in paper-based offices some of the advantages and disadvantages associated with them can be highlighted (e.g, Falzon, 1990a; Lansdale, 1990). Falzon studies the nature of human-human communication with a view to applying this information to the design of human-computer software. The transfer of information gathered in a study of human behaviour (in the absence of a computer) to a human computer situation is not straightforward. Lansdale (1990) points out that the observed "natural" behaviour may not be optimal. The transfer of a non-optimal behaviour to a computer environment is obviously counter-productive. A second cautionary note stems from the fact that the environment being studied is a complete system, and aspects of that system will be physically changed by the introduction of technology into the system. The value of this approach is that it enables a level of description of the psychological processes which is detailed enough to facilitate an evaluation of their contribution to the task in hand. Once the non-optimal, or disadvantageous, aspects of a task are identified they can be removed from the design of systems involving computer interaction. This approach to gaining an insight into the psychological components of information handling techniques appears productive. Consequently, this thesis uses the findings and philosophy behind these "natural" studies of information handling (e.g, Cole, 1981; Coles, 1990; Malone, 1982) as a means of identifying and justifying specialisation upon a specific facet of information handling.

1.2 PUBLIC AND PERSONAL DATABASES

The distinction between public and personal databases proves useful as a means of describing the variety of obstacles associated with information handling. This thesis uses the distinction as a practical means to define the topic area and therefore examine the appropriate information retrieval activities. There are two main types of database: those developed for use by a several people or a wider selection of the public (e.g, a library system), and personal databases (e.g, a filofax). In general, personal databases are created and maintained by a single user (Somberg, 1982), whereas public databases are used by a larger number of people who are not necessarily involved in their creation.

The originator and user population of a database are not the only features that can be used to distinguish between personal or public databases. Additional features in the definition of personal databases include their relatively small size (Cooney, 1980), and the probability that they are annotated by personal comments (Stibic, 1980; Lundeen, 1981). The distinction between personal and public databases becomes unclear in situations where a personal database can be used in a manner similar to that of a public database. For example, when the user of a personal database is not the person who created it, the problems associated with its use will be similar to those associated with a public database. One such problem could be the user being uncertain whether or not a particular piece of information is within the database. Alternatively, some public databases can be adapted and used in a fashion similar to that of personal databases. For example, some systems allow the user to include information that they have contributed and/or tailor the classification of information within the system for their own access routes (Lancaster, 1978). Consequently the dividing line between these two types of database is somewhat fuzzy. The division is used in this thesis to specify the topic area and explain the associated information handling activities.

The user's prior knowledge of the contents and structure of public databases is generally minimal (Meadow, 1970). Humans are very good at identifying whether they have a specific piece of information stored in their memory (Glucksberg and

M^cCloskey, 1981). Consequently, retrieval of information from human memory is generally a quick, competent process. This competency is probably due to the fact that through frequent usage an individual is very familiar with the information structure in their memory. For analogous reasons people are usually fairly accurate and fast in determining that specific information is not stored in their memory. Unfortunately, comparable levels of certainty about specific content cannot be expected with users of public databases (Meadow, 1970; Somberg, 1982). Lansdale (1986) noted some of the problems associated with the use of public databases. These problems mainly arise from the fact that the function of the database is to provide information that users do not have. Consequently, the search procedures employed are likely to be based upon unsuitable or vague information. This can lead to time consuming search procedures in order to locate information or conclude that the information required is just not available. It is also probable that the user may be unable to find information even when it is available. Lansdale (1986) concludes that the system will not get used if the users construe the task of finding information too time consuming and tedious. The perceived usefulness of a public database is therefore limited by these factors.

In a personal database the problems are different. The main source of these differences originates from the fact that a user (where the user created the database) is familiar with the contents and history of a personal database. According to Lansdale (1986) information retrieval from familiar databases can be viewed as a procedure involving the balancing of two memory processes: recognition of information items presented to the user, and recall of where the wanted information is stored. Recognition in this situation is where a user scans information provided by the system and recognizes some of it as fitting the initial requirements. Recall in this situation is where the user is searching for a specific piece of information they recall, but is uncertain of where exactly it has been filed. Lansdale suggests that the practical utility of information and storage systems can be evaluated in terms of the amount of support they offer for both recall and recognition. Though it is not clear how this support can be supplied or evaluated.

Another way of assessing the practical utility of a database is by looking at the balance between "*precision and recall*". Precision is defined as *the proportion of retrieved*

items that are relevant while recall is defined as *the proportion of relevant items that have been retrieved* (Christie, 1985, p.157). In an ideal situation a search of the system would supply all the items in the database that are relevant (ie 100% recall) and no others (ie 100% precision). In practice, procedures which increase the number of relevant items a system recalls tend to also have a similar effect on the recall of irrelevant items. That is, increasing recall leads to a reduction in *precision*. Whereas, increasing precision so that fewer irrelevant items are retrieved leads to a reduction in *recall*. In most systems *precision* and *recall* are not exact enough to satisfy the users (Sparck-Jones, 1981), and are usually inversely related so that as precision improves recall deteriorates (Cleverdon, 1972). There appears to be little research into what balance of this trade-off users prefer. With no information on what level of this trade-off users prefer, and the possibility that both can be improved, providing support for these functions seems the most productive solution at present.

There is a similar trade-off apparent in the processes of recognition and recall described by Lansdale (1986). Systems in which the user places reliance on recognition become increasingly haphazard and arduous to use as their information quantity grows (e.g, what Malone (1982) described as a "messy" office). Alternatively, systems which place all the emphasis upon strict categorization and recalling exactly information identifiers (such as filenames) can put too strenuous a demand on the individual's memory. It follows that if the user can not recall where a document was filed they will have difficulty finding it again. That is, a messy office exploits the ease of recognition but at the expense of precision, whereas a tidy office tends to result in reduced likelihood of being able to recall where information is filed. There is evidence suggesting that systems which place a high reliance on recall tend to produce a reluctance in their users to file documents at all (Cole, 1981; Malone, 1982).

With all these potential difficulties in the use of personal databases why do people continue to use them? Work regarding why people maintain personal databases is scarce and suggests that there are three basic functions performed by a personal database. The database mainly serves as a personal reference. The personal reference function can include features such as a record of past and future activities. The second function of a personal database involves making information available to others, upon

request or when the owner of the database is absent (Cole, 1981). The third identified function is that personal information systems serve to "remind" the user of activities that should be done (Malone, 1982). It is possible that personal databases serve more than these three main functions for instance factors relating to the specific use of the contents (Pritchard, 1983; Jones, 1986). Another reason why people maintain personal databases could emanate from an apparent preference for their use (Vickers, 1983) as opposed to using public databases. Vickers suggests that this preference is due to the users lacking confidence in the effectiveness of systems that they have not created themselves. The handling of personal information is a major task for most information workers who manage an estimated 20,000 pages of information in a paper office increasing at a rate of 10% annually (Jarrett, 1982). This growth of information that the information worker has to handle could lead to an amplification of the problems associated with present information retrieval systems. The apparent preference for using personal information systems and the growth in information handled by them suggests that adapting existing personal information handling techniques to cope with the growing information provides an appropriate area for research. Consequently, this thesis concentrates on investigating the problems associated with retrieval of information from personal information systems.

In summary, there is a fuzzy distinction between personal and public databases. This thesis recognises and uses the distinction as a practical means of defining the topic area, personal databases. In general, personal databases tend to be created and used by a single person who is familiar with the structure and content. The perceived usefulness of the database can be assessed by how much support it offers for the retrieval of information by the processes of recognition and recall (Lansdale, 1986) or precision and recall (Christie, 1985). The personal/public database distinction puts into perspective an area where there are opportunities for studying automatic processes in human memory (automatic processes in human memory are discussed in the following chapter). A user's memory for information stored in public databases is limited to the information they have previously accessed. The value of improving retrieval procedures from personal information systems follows from two points. The first point is the apparent preference of people to use personal rather than public databases (Vickers, 1983). The second point is that the amount of information that personal

databases have to deal with is increasing (e.g Jarrett, 1982) and will conceivably amplify the problems associated with their usage. For these reasons the thesis focuses on issues related information retrieval from personal databases. The problems associated with information retrieval from personal information systems are more fully detailed in the following section.

1.3 PSYCHOLOGICAL STUDY OF "NATURAL" INFORMATION SYSTEMS

"Natural" studies are so called because they are studies of office practices prior to the implementation of computerised systems. For example, Kelly and Chapanis (1982) interviewed twenty three professional persons about how they kept and used their appointment calendars. From the interviews information and suggestions about what functions the calendars fulfilled, and how best these functions could be computerised, was obtained. Studies such as Kelley and Chapanis' are "Natural" studies in the sense that they are studies of the information systems that were commonly employed before electronic systems were introduced. The rationale behind "natural" studies of office information is that they can supply an extensive insight into the structure and flow of the information. This insight can serve to focus where major obstacles to effective automation may occur.

One argument advocating natural studies of office information systems stems from the notion of conceptual congruency. The argument is that by developing an understanding of external information organization, and its representation in human memory, conceptual mismatches between office workers' and computers' information handling techniques can be identified. This conceptual mismatch is reduced by adapting the computers to the way office workers work. To some extent this is an effective argument in that increased congruency between the concepts of a new system and the previous system increases the likelihood that the initial use of the new system will be easy for users to learn. However, at one extreme, to have complete conceptual congruency between two systems would lead to two almost identical systems. This essentially limits the potential advantages offered by "new" technology. Improving

compatibility between computer systems and previously attained users-concepts will result in users learning to the new system quickly. If users cannot conceptualize the information stored in computer systems and the operations that systems are capable of they will not be able to use them optimally. However, humans are very flexible and if they perceive some benefit and are highly motivated to learn the new conceptualisation of the information storage they will attempt to learn how to use a new system. Thus, conceptual congruency between systems has advantages for systems being easily learnt but may not necessarily result in the most effective system being employed. Conceptual congruency can overlook the advantages that may be gained from employing new concepts to the manipulation of information. Consequently, using the findings of natural studies to promote conceptual congruency between a paper-based and computerised systems appears limited.

The pertinence of "natural" studies to the design of electronic systems lies in their capacity to identify and evaluate the psychological processes involved in the maintenance of the studied system. If any of the psychological processes involved in information handling appear inefficient, then potential alternatives can be evaluated through more rigorous study. This thesis uses these natural studies to identify where the psychological processes used for information handling do not produce efficient handling techniques. Due to the scarcity of studies of "natural" personal databases this section will concentrate on the findings of three "natural" studies of information handling, Cole (1981), Coles (1990), and Malone (1982). The study by Cole (1981) involved 30 people answering a series of structured questions about various aspects of their information storage and retrieval. Coles' (1990) work involves three main studies, the first is investigative and involved informal interviews where participants were encouraged to talk freely about any aspect of their filing and retrieval at work. The second study looked at individual differences and information handling techniques, while the third investigated job characteristics and information handling techniques. The study by Malone (1982) looked at how ten individuals organized their information by asking them to describe their filing systems and how successful they were.

The study by Cole (1981) concludes that paper-based filing systems are not rigidly maintained, organization is idiosyncratic, and dependent upon the demands of the

users and their motivations. This finding contrasts with the usual computer centred approach to information storage and retrieval which is inclined to impose rigid operations and procedures on users. These rigid operations and procedures can result in restricting the user to behaviours which they are unaccustomed to. Cole's study suggested that the design of user compatible, computer based, information management systems must allow for the various characteristics of the information with which users interact and the way that users prefer to organize their information. The conclusions of the study place the responsibility for increased flexibility solely on the system.

Malone found that the most prominent difference among the subjects was the variation in how "precisely" organized their offices were. The two extremes he identified were "neat" offices that relied heavily on information stored in files and in precisely organized piles, and "messy" offices that were filled with diverse piles in ill defined groups. Malone proposes that these two styles of office organization frequently reflect the job content, as well as the personality differences between the subjects. Jobs with a rigid structure involving routine paperwork and/or subjects who could not tolerate "mess" had very meticulously organized offices. As with Cole's study these findings focus on the affects of individual preferences, information characteristics, and on the structure and flow of information in paper-based offices.

Malone went on to note that much of the organization on peoples desk tops consisted of "untitled piles", whilst almost all computer systems require any new documents to be titled. Malone proposes that these piles serve two main functions; to "remind" the worker of their existence (and any work associated with them) and to avoid the difficulties involved in classifying (and hence retrieving) them. The function of piles to remind users of an articles existence and work related to it has been noted by other researchers (e.g, Heeks, 1986; Faisbisoff and Ely, 1976). Ideally, an electronic filing system should support these functions.

The difficulty of deciding how to classify information can be an important barrier to filing, and as such is a re-occurring theme in the literature. It is possible that an information article can be classified into more than one of the existing categories in a

filing system. Does the user file the article in only one category and risk not being able to find it later or having to search through all the relevant categories? Alternatively the user could duplicate the file and place a copy in each of the relevant categories. Thereby increasing the size of the database and the number of articles to be scanned in any one category when retrieving an article retrieval (hampering the process of recognition). With both these options exists the possibility that the classification of the file will change with time. The classification of information changing with time involve features such as the context and the purpose of the information being filed. The purpose for which information was filed may not be the same purpose that initiates an attempt to retrieve it and this can hinder retrieval (e.g, Heeks, 1986, p.31). Another problem is that a file might not fit into any of the existing categories. Does the user create a new category every time this happens and end up with a large number of categories with few items in many of them? These problems associated with the categorisation of articles in information systems are well documented and include the design and use of menu systems (e.g, Dumais and Landauer, 1983), keyword systems (e.g, Mantie and Cattell, 1982; Whalen and Mayson, 1981), and natural language systems (e.g, Grace, 1987). This dilemma of how to classify an article for the filing system can cause the user to postpone or even refrain from filing that article (Malone, 1982). Coles (1990, p62) identified five conditions apparently associated with ease or difficulty of retrieval. One of the conditions was the users ability to remember the document-category associations used at the filing stage. Coles (1990) second study concentrates on individual differences and job related aspects of aspects of information retrieval. From interviewing 30 researchers Coles observes that

"No-one claimed to have totally problem-free retrieval, and when problems occurred they were all similar in type. Namely, the familiar looking for information which is no longer there, in the 'wrong' category, or in a large undifferentiated category"

Reinforcing the findings of Malone's study, classification problems are evident in the existence of a large undifferentiated category, and looking for information in the wrong category. While no support for the problems associated with classifying information exists miscellaneous piles will exist. In fact "piles" due to classification problems do exist in electronic offices though not necessarily in a physical paper form, they are often manifest as large directories with labels such as "miscellaneous". There has not

yet been a viable proposal for the resolution of these problems associated with categorisation (e.g, Gomez and Lochbaum, 1984). Automatic processing in human memory (see chapter 2) could provide a means to bypass some of the problems associated with categorisation by utilising classifications which are automatically remembered. It is possible that aspects of information that are automatically remembered do not change with time or individual differences (e.g, Hasher and Zacks, 1979) and are therefore not subject to these familiar problems of categorisation that can hinder the retrieval of filed information.

In summary, these "natural" studies have centred attention on the substantial effects that job/information characteristics and user characteristics have on the structuring and flow of information in the office. They also serve to highlight the effects of the perceived difficulties in classifying information such as piles of information on desks. Categorising and classifying information is essential to the effective use of existing electronic systems. The natural studies reflect literature surveying the design of electronic systems in suggesting that problems associated with the categorisation of information can have substantial effects on the efficiency of the system (e.g, Dumais and Landauer, 1983). There is room for the improvement of electronic information management systems by the provision of information handling techniques that serve to alleviate some of the problems concerned with filing information, which will also lead to a reduction in the number or size of miscellaneous piles. Automatic processing in human memory (discussed in chapter 2) could provide a means to alleviate some of the problems associated with categorisation.

1.4 A NATURAL RELUCTANCE TO FILE ?

There appears to be a natural reluctance amongst information workers to spend time and effort filing. There are many possible contributing factors to this apparent reluctance. Complicated filing activities, or more immediate time priorities, may deter an information worker from filing. If the act of filing information reduces the ease with which it can be accessed, there will be an associated reluctance to file important information (e.g, Malone, 1982). When the user cannot recall how information was

initially filed then subsequent access to that information will be adversely affected. Alternatively, more effort will be put into recalling how important information has been filed. Putting effort into filing information improves the memory for how it was filed (e.g, Lansdale et al, 1987) and therefore how to retrieve it. But, as has already been noted, users are reluctant to spend time and effort filing. Cole (1981, p.124) describes the reasons that people give for not structuring their filing systems as lack of motivation and time. So there appear to be three major component factors that contribute to the decision of whether or not to file a piece of information. The motivation to memorise how the item was filed, the time and effort expended in the filing procedures, and how these factors affect the likelihood of retrieval affect the users decision to file. The implications of these contributing factors to the apparent reluctance to spend time and effort filing are discussed in the following section.

The act of retrieving information is contingent upon the initial filing procedures. Although difficulties may be manifest at the retrieval stage they can be seen as problems of storage as well as retrieval. Coles (1990) found that people who allowed limited time for initial filing activities to keep their information systems "up to date" gave a variety of reasons for their limited filing activities. The reasons given included other activities being regarded as more important, the information was inherently disorganised so time spent attempting to organise it would be counter productive, and that the job could tolerate slow retrieval. From these observations it appears that reluctance to file results from a subjective cost-benefit analysis by the users primarily based on the factors illustrated in Figure 1.1. For example, judgement are made about whether there are more important activities are pending, or whether filed information may difficult to retrieve. According to Coles (1990, p.160) when it was essential for the job, or the user had a strong preference for an efficient filing system, then an efficient filing system was maintained. The implications are that an ideal retrieval system should be able to cope with unclassified/disorganised material, because users are reluctant to maintain systems which are not.

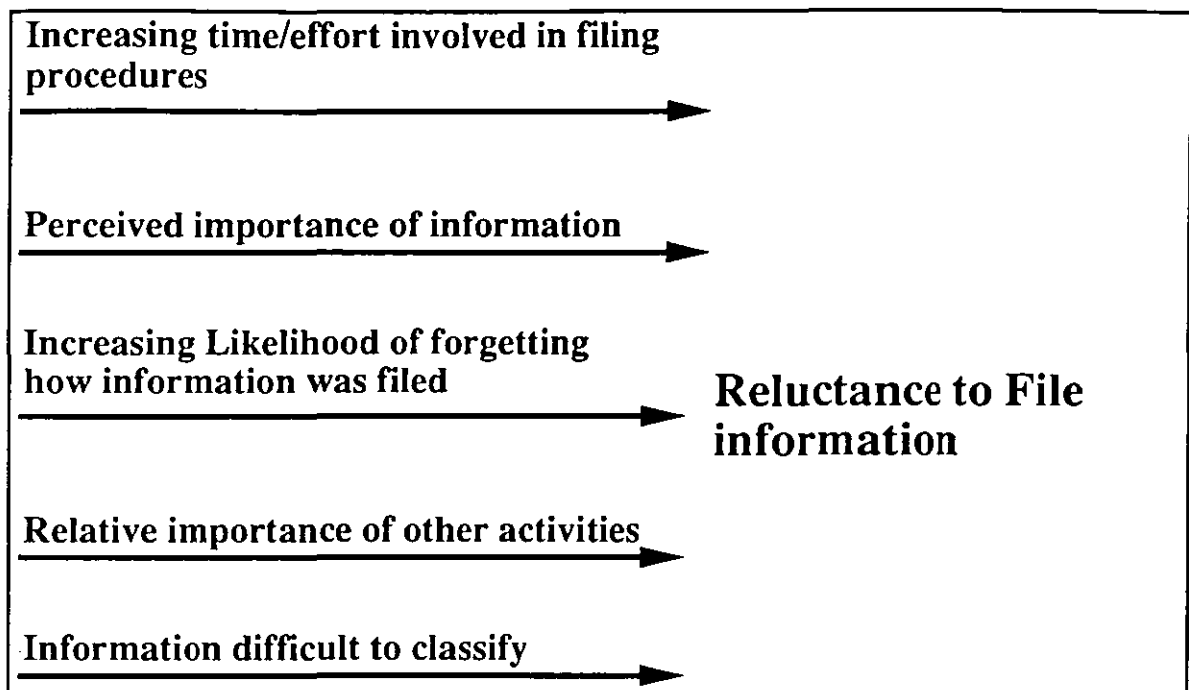


Figure 1.1 Factors contributing to a reluctance to file.

Another aspect of the initial filing procedures that can adversely affect information retrieval is related to context. The filed information may have been originally used, and filed, in relation to an aspect of its content not relevant to the purpose for which it is being retrieved. For example, filing a document entitled "Urban redevelopment project" under "urban", recalling the file as "redevelopment" related and not being able to find it due to looking in the wrong category. The user may not recall how the information was initially filed because the context within which the information is required has changed. This can be viewed as a category related problem, for example the file could have been filed under "urban", "redevelopment", and "Projects" to reduce the likelihood of looking in the wrong category for retrieval. This solution reintroduces the problem of increasing the number of files to be scanned through at the retrieval stage due to the creation of large categories. The amount of attention paid to the filing procedure can also affect the efficiency with which it is retrieved. If the user does not pay much attention to how an article was filed, then this may later be forgotten. One extreme example of lack of attention paid to filing procedures is evident in a situation where an information worker employs a secretary do all the filing. The information worker's knowledge of the filing system is consequently limited due to infrequent use. If that information worker needs a file they either have to rely on the

secretary recalling how it was filed, or their own understanding of the filing system. The context in which the file was used when it was filed, the amount of attention paid to the filing procedures, and the category system employed all have consequences for how the information is filed, and therefore how it is retrieved. Retrieval difficulties can thus be viewed as resulting from the initial filing procedures.

To summarize, reluctance to file information appears involve a trade off between three factors. One factor is the amount of time and effort that the user must expend in order to ensure that retrieval will be of a required standard. The amount of effort expended appears to be contingent upon the second factor, the user's motivation to file. The final factor is the perceived likelihood of being able to retrieve the information once it has been filed. An approach taken to relieving the problems due to these factors would have to consider increasing the motivation to file, reducing the time and effort spent filing and increasing the likelihood of efficient retrieval. A mnemonic approach, investigating the processes of human memory (see chapter 2), could have consequences for all these factors. A mnemonic approach could identify filing procedures which do not involve much time or effort on the part of the user and are easily recalled. A system incorporating such features could conceivably increase the user's motivation to file.

1.5 IDENTIFYING FILES FOR FUTURE ACCESS.

To search for a particular information item within a set, the information items must be identifiable according to an organisation of "tags" or labels. This is an indexing system, and can vary from the alphabetical ordering of the items to the use of keywords or other tags (e.g. colour coding). When information is filed it is filed under some form of identification system. Accurate retrieval of information is dependent upon the user's understanding and memory of the identification system used. The use of computers makes it easier to base the indexing of an item on multiple aspects of its content, enriching the description the system uses to identify the information item.

Human memory is very flexible and can incorporate many dimensions, using these different dimensions as types of cue (e.g. olfactory, auditory, spatial, physical, temporal) for prompting the recall of information. From this, it seems reasonable to assume that increasing the number of dimensions used to label an information item will reduce the number of items to be scanned through when retrieving the item from a filing system. This is the notion of "cue enrichment" (Cole, 1982) and presents one possible means of aiding the retrieval of an information item from a computer system.

Surprisingly, the use of numerous cues to identify information items does not appear to give substantial benefits to the retrieval of that information from an electronic system. Christie (1985) cites Keen (1981) as demonstrating that for any given level of required (electronic system) recall there is an optimum level of indexing exhaustivity. In other words using a limited number of cues to identify information items reduces the likelihood of them being recalled from an electronic system, while conversely, using an abundance of cues reduces the precision needed for accurately identifying an information item (i.e. indexing specificity improves precision). The ideal solution to this problem would be using a limited number of cues to identify information items, where the cues are all likely to be remembered in association with that information item by the user. However, it is possible that the type of cues used may affect how easily they are remembered. Increasing the number of verbal cues may lead to a level of indexing exhaustivity, whereas combining different coding dimensions (e.g. colour, temporal, locational) may not have such a limiting effect.

In existing electronic filing systems it seems that only some of the many identifying features a user may be able to recall regarding a desired file are likely to be used by the computer as part of its indexing system. Incorporation of features that a user is likely to recall about a file in the computer's indexing system has potential for increasing the precision of the computer's search for that file. Subjective reports suggest that people remember features such as the colour of a book, the relative thickness of a document, or when a piece of information was used in relation to other events (e.g. Kaiser, 1983). Coles (1990) first study involved informal interviews with 12 staff members at Loughborough University of technology about how they used their filing systems. The results of the study showed that subjects recalled information such as the location of information,

"the colour of book-spines, the presence of pictures and text layout" p.66

The subjects employed this information to support their search strategies. Features such as those just described are rarely used by electronic filing systems as parameters in the computers search for a file. Including the features a user recalls as parameters in the filing systems classification of a file could favourably influence the ease of retrieval. When the computer's representation of a file is confined to dimensions that the user cannot easily recall the file may not be easily accessed by the user. One approach to improving access to information stored in electronic filing systems would be to use file identification tags that are likely to be remembered by the user. Identifying dimensions that a user is likely to remember will therefore be of practical use in the design of filing systems. The aim of this thesis is to identify dimensions that are easily remembered and can be utilised to support effective information retrieval.

We can remember far more information about documents to be filed than is presently used in retrieval procedures. As regards filenames, the recall process is the deficient because the user's ability to categorize documents with appropriate file names and their ability to remember those file names is restricted. A limited amount of research has been carried out upon the relative reliability of memory for different methods of coding i.e. The *Spatial Data Management System* (S.D.M.S.) at M.I.T. (Bolt, 1979), the *automated office* by Robert Spence, Panorama (Spence and Apperley, 1982), and the various *desk top* simulators (i.e. Xerox Star, Apple Macintosh and Lisa) are all based on the notion that the delivery of information to the user should rely heavily on visual and spatial coding. The argument for this emphasis on visual and spatial coding is based on the assumptions that:-

- i) human beings are intrinsically spatially orientated.
- ii) spatial information can present a great deal of information instantly which would other wise have to be given to the users sequentially, thereby avoiding a considerable load on their memory.

The popularity of systems based on these assumptions, such as the Apple Macintosh suggest that the use of location as a means of coding appears promising.

Unfortunately, none of the above mentioned systems have been formally evaluated.

This lack of evaluation, together with facts such as the argument that humans are also

intrinsically verbally oriented suggests that though these systems may be popular they may not be based on wholly appropriate metaphors. Nevertheless, there is a strong body of evidence suggesting that at least some spatial information is remembered when attention is not initially directed at the recall of that location (Christie, and Just, 1976; Mandler, Seegmiller, and Day, 1977; Rothkopf, 1971; Von Wright, Gebhard, and Karttunen, 1975; Zechmeister and McKillip, 1972). Not all the research investigating the potential of location as a coding method for information is positive. For example, there is evidence suggesting that locating information in a two dimensional space has value only when its location within that space has some organization or meaning (Dumais and Jones, 1985). There is also evidence suggesting that location is not recalled without prior knowledge that location is a to-be-remembered item (Kail, and Seigel, 1977; Shulman, 1973; Zechmeister, McKillip, Pasko, and Bessalec, 1975). There is, however, a subtle difference between the evidence in favour of automatic recall of location and that against. Pezdek, Sobolic, and Roman (1986) pointed out that most of the research suggesting that location is easily recalled used objects for stimuli rather than words. They backed up their theory by an experiment comparing recall for the locations of words and objects and concluded that

"Different processes are involved in encoding item and location information for words but not for objects" p530

Thus the location of an object seems a potentially memorable feature and could therefore prove a very useful means of coding information items for retrieval.

Research relating to the quality of memory for different coding methods recommending which forms of coding should be employed is scarce. Wright and Lickorish (1988) looked at the possibility of using colour cues to aid readers knowledge of the location of information in lengthy texts on screen and paper. Long texts were divided into thematic sections, each of which was colour coded. The experiments compared the subjects' knowledge of the location of information within the text either with or without the use of colour coding and using two presentation media, paper-based and CRT. An advantage was found for the colour coding in the paper-based medium but not with the texts presented on the CRT. The main conclusions of the study are based around the notion that extreme caution should be used when transferring findings between media. The study is interesting because the improved recall of the location of information

within the paper-based media using colour coding does not transfer to the CRT mode. This suggests that it was not the action of the colour coding in isolation that improved the recall of location, but that other factors are involved. More effective use of locational cues in an electronic system could result from an understanding of the facets which affect locational recall in an electronic media. There is evidence that location is effective as a cue for remembering. The "method of loci", as described for example by Yates (1966) and Bower (1970) is a well recognised mnemonic technique for remembering information that has been deliberately associated with spatial locations. It is possible that information is stored in memory with reference to location and utilising this connection in a filing environment could be productive. Furthermore, the combinational effect of various dimensions, including location, upon recall would prove useful.

A set of experiments concerning the recall of several coding dimensions was carried out by Lansdale et al (1988). The first experiment involved the subjects in a role playing exercise where they were simulating one facet of working in an employment agency by filing job advertisements. The filing task required the subjects to select a shape, then a colour, then placing this coloured shape on a job advertisement. In an ensuing memory test the subjects were presented with the job advertisement as a cue. Their task was to recreate the shape, colour, and location combination that they had initially placed on the advertisement. This experimental group was compared with another group that used verbal labels to file the advertisements. There were no distinct advantages noted due to either set of filing labels since users performance was approximately the same for both systems. When analysing the structure of recall for the attributes it was noted that recall was statistically independent where recalling one attribute was not conditional upon the recall of another attribute. Therefore, in a richly indexed system it seems unlikely that users will remember nothing of an information items identification, it also seems unlikely that the users will recall all of the combinations. This suggests that an information management tool which permits users to employ their partial knowledge will be of considerable utility. However, the design of the experiments facilitates independent recall of the attributes. The subjects select a shape, then a colour, and then a location. Each of these attributes could be selected to relate to a different characteristic of the advertisement. If the subjects employed the

strategy of using each attribute to identify a separate aspect of the information being filed it is likely that they will be recalled independently because they are selected independently. If the selection of a colour was contingent upon the selection of a particular shape will the recall of that colour be contingent upon the recall of its associated shape? Recalling file identification attributes in combination could improve the precision with which those files are accessed from an electronic system. For example, if each information item is labelled with a unique combination of attributes and recalling one of those attributes is contingent upon the recall of the others then the user will either be able to access the information item directly or not at all. This "all or none" form of recall would therefore be a useful means of reducing search strategies in electronic filing systems if the identifying attributes are likely to be recalled.

The fact that time and effort spent on creating material can improve recall of that material is known as the generation effect. The generation effect, first reported by Slamenka and Graf (1978) states that memory is greater for self generated material than material which is generated externally. The generation effect is not limited to the use words/filenames (e.g. Nairne and Widener, 1987; Lansdale et al 1987). The generation effect implies that if users actively assign retrieval tags to information items they will have improved their chance of accurately remembering the tags and therefore retrieving the associated item. Unfortunately, the solution to the problem of encouraging users to recall how information items were filed is not as simple as merely increasing the active role played by the user at the filing stage. The problem with this approach is the apparent reluctance to spend time and effort filing information (as outlined in the previous section). Consequently using an approach that employs "cue enrichment" to reduce the amount of time and effort expended by the user at the filing stage does not necessarily mean that the user will remember how a file was identified. The use of meaningful connections between the information and the file identification has potential (Schönpflug, 1988). Meaning is an important issue but it is not the focus of the approach within this thesis because meaning can change with both time and context. Providing a means of filing information that uses cues which are likely to be recalled irrespective of the meaning associated with them is one possible approach to alleviating this problem. The use of file identification tags that are easily remembered,

such as the location of an object appears to be a promising means to approaching this problem.

It seems that increasing the the filing procedures carried out by the system has an adverse effect upon the user's recall of how the file was labelled (Slamenka. and Graf, 1978). The adverse recall associated with file identification that is supplied automatically by the system leads to a reduction in the likelihood that the user can retrieve the item (e.g, increases the recognition scanning process necessary at the retrieval stage). Future research should be attentive to the balance between the positive aspects of easy filing facilities (less effort on the part of the user), and the negative effects they have upon the user's memory (the user is less likely to be able to remember how an article was filed). A relevant question to this problem is :- how can the filing tasks be facilitated in a manner that is not so burdensome that users will not carry them out? In other words, which tasks can safely be left to the user to perform and which can be left to the system without adversely affecting the user's recall? The overall aim of the thesis is to optimize what an individual can remember about the classification of information items thereby reducing the number of items searched through at the retrieval stage.

1.6 SUMMARY

This chapter has identified information as an increasing commodity. Improving access to this expanding commodity can result in both social and economic benefits. The availability and capabilities of technology make it an ideal tool for information management. However, ineffective retrieval procedures are evident in both paper and electronic based offices. The ineffective retrieval of information can be traced to problems associated with the psychological processes involved at the initial filing stage. These problems include aspects related to categorisation, a reluctance amongst users to spend time and effort filing, motivation to file, and the likelihood of recalling how information was filed. An approach that looks at the mnemonic aspects of information retrieval could to produce viable solutions to some of these problems. An information identification system which utilises tags that are easily remembered could keep extra

filing activities to a minimum while not adversely affecting the likelihood of the user remembering where information is filed. Consequently, the cost of filing in terms of future retrieval could be reduced by such a system and this has potentially positive effects on the user's motivation to file. For example, the positive feedback gained from using such a system could increase the user's confidence in that system thereby reducing the reluctance to file. There is a scarcity of literature relating to the effect that different file coding methods have upon the user's ability to remember them. This thesis intends to investigate the possibility that easily remembered coding methods could be useful when incorporated in an automated retrieval support system. In particular, the following chapter evaluates research relating to automatic processing of information in human memory as a source for identifying features which could be used in such a system.

CHAPTER 2

MNEMONIC ASPECTS

Chapter Contents

Chapter 1 identified obstacles to the effective retrieval of information from personal information systems. The chapter specifically noted the adverse effects arising from an information worker's poor recall of how information was initially filed. Chapter 2 takes a more focused look at the literature regarding human memory. This literature is used as a means of assessing whether certain dimensions of information items are easily remembered. Specifically, the chapter focuses on the existence and potential of automatic processing and incidental recall in human memory to identify easily remembered dimensions. In an electronically automated filing situation automatically processed (in human memory) and incidentally recalled (in human memory) dimensions used as information tags would serve to reduce the load on memory while not reducing the likelihood of retrieving the information. From this perspective the location of a (logo-like) shape and colour is identified as having potential for being memorable and consequently of use in an automated filing support system.

2. MNEMONIC ASPECTS

2.0 INTRODUCTION

The first chapter examined certain psychological processes which contribute to effective information handling techniques. One of these processes involves memory for how information was initially filed. If an individual cannot remember how an information article was filed, accessing that information from an electronic filing system can prove expensive in terms of time, effort and success (e.g, Eoseys, 1986; Coles, 1990). Consequently, the study of human memory could provide a constructive source for solving information access problems in electronic systems, more specifically those problems arising from poor memory of file identifications. Knowledge of the workings of human memory could be applied to reduce the likelihood of a user forgetting how information was initially filed, thereby improving the likelihood of accessing that information. An understanding of the performance of human memory is therefore pertinent to the design of information retrieval systems (e.g, Jones, 1986; Lansdale, 1990). There is an abundance of literature relating to the workings of human memory. This chapter focuses on aspects relevant to the design of a retrieval support system that would reduce time consuming and effortful filing procedures. The aim of the chapter is to identify dimensions that may prove useful in the design of an information retrieval support system. These dimensions can then be evaluated in a realistic information handling situation (see chapter 3).

A reduction in the time and effort required to file information could be achieved through increasing the filing activities performed by an electronic system. However, memory for file identifications not generated by the user may be less effective than file identifications generated by the user (e.g, Lansdale et al, 1987; Slamenka and Graf, 1978). An automated filing support system would therefore need to utilise file identification tags that are easily remembered. The memory literature provides a potential source for identifying memorable dimensions. The literature suggests that some dimensions may be automatically processed in human memory (e.g, Hasher and Zacks, 1979). Automatically processed dimensions can be conceived of as those

dimensions which are processed into human memory with minimal attention and effort. However, definitions of automatic processing vary, the central issues are addressed in section 2.1. If automatic processing in human memory does exist an automated electronic filing support system could use information dimensions that are processed (in human memory) in this way as file identifiers. Consequently, the concept of automatic processing in human memory is central to this thesis.

This chapter outlines some of the definitions of automatic processes. These definitions are essential to an understanding of how dimensions which are automatically processed in human memory can be utilised by a filing support system. For information labels to be of practical use to the design of an information retrieval support system they must be easily memorised. The focus on utilising automatic processing (in human memory) as a means of identifying dimensions which may prove useful necessitates that other areas of memory literature are only considered in brief for instance Craik and Lockhart's (1972) theory of 'levels of processing' (see page 44) has limited use in identifying features which are memorable with minimal effort, and has been criticised (e.g, Nelson, Walling. and McEvoy, 1979). Automatic processing is investigated as one source of identifying easily memorable features (Section 2.1). Incidental recall is examined as another source for identifying features that could be utilised in an automated file support system (Section 2.2). Where incidental recall is recall of information that has not been encoded into memory specifically for the purpose of being recalled. Attention is relevant to the design of an automated filing system because automated procedures will be in receipt of less attention than manual filing procedures. This chapter covers the issue of attention as a central theme in the definitions of automatic processing. Finally, the chapter focuses on work relating to incidental recall and automatic processing that is directly related to office information handling techniques. The aim of the chapter is to identify features which are easily memorised and consequently have potential for being utilised in the design of a retrieval support system.

2.1 AUTOMATIC PROCESSES IN HUMAN MEMORY

The idea that there are two basic processes of human behaviour, one voluntary, and one involuntary can be traced back to Descartes. Descartes' view of this dichotomy was that whole behaviours could be considered as automatic. The notion of this duality has persisted, however, automatic processing is now conceptualised as being a integral part of other behaviours. Some components of a behaviour may be automatic while others are not (e.g. Jonides, et al, 1985; Logan, 1985; Newmann, 1984; Strayer and Kramer, 1990). Schneider et al (1984) suggest that

"Even brief consideration of an complex task, such as tennis playing, makes it clear that such tasks are carried out with a mixture of automatic and control processes" p.2

It is possible that some behaviours are totally automatic. In the following discussion the processes referred to are components of behaviour that co-exist with non-automatic processes. The automatic behaviour may result from a conscious activity or produce a conscious activity, but for clarity the automatic processes will be discussed as individual processes.

The reason for focusing this section of the literature review on research relating to the existence of automatic processing in human memory, is because incorporating attributes which are automatically processed and remembered as a means of classifying information could serve to enhance retrieval procedures. That is, retrieval of information from a filing system will be facilitated if the user can remember (automatically) the identification of a file. To serve as an aid to retrieval procedures the information that is automatically encoded in memory will also need to be available for recall. This is the notion of *incidental recall* where incidental recall is the recall of information that has not been encoded specifically for the purpose of being recalled. As such the notions of automatic encoding and incidental recall in human memory are central to this thesis and the design of the experimental paradigm as described in the following chapter. The following section opens with an overview of the the definitions of these automatic processes.

2.1.1 DEFINITIONS OF AUTOMATIC PROCESSES.

There are a variety of definitions of automatic processing in human memory (Hasher and Zacks, 1979; Logan, 1980; Posner 1978; Posner and Snyder, 1975; Regan, 1981; Shiffrin and Schneider, 1977). These definitions include features describing automatic processing as the processing of information which is involuntary, does not draw on general resources and is not affected by and does not affect attention. Automatic processes are generally defined as being the complement of some form of effortful processes. These theories of information processing have received extensive interest in recent years (e.g, Fisk and Schneider 1984; Kahneman and Treisman, 1984; Logan, 1990; Naveh-Benjamin and Jonides, 1984; Schneider et al, 1984). Definitions for automatic encoding in human memory vary, the most predominantly used definitions are provided by Posner and Snyder (1975), Shiffrin and Schneider (1977), and Hasher and Zacks (1979). Posner and Snyder (1975) refer to automatic processes as "unconscious strategies". These unconscious strategies are the counterpart of "conscious strategies" and are defined as occurring:

- i) without attention.
- ii) without necessarily giving rise to awareness.
- iii) without interfering with other processes.

The processes are automatic in the sense that they can occur without attention. The implication is that no effort is expended on them. The automatic encoding processes require no attention, consequently, their occurrence does not necessarily have an effect on attention (e.g, drawing on a limited attentional capacity). The fact that the automatic processes do not put any load on attentional capacity leads to the third point; that they do not interfere with other processes which do require the use of attention. The implication for the design of an automated filing support system is that the user need not pay attention to the actual filing procedures. This lack of attention will not affect how easily the dimensions are remembered and will not interfere with any other activities that the user may be engaged in while filing. These Automatic processes contrast with Effortful processes. According to Posner and Snyder (1975) the

identifying features of effortful processes are that

- i) their efficiency increases with practice.
- ii) they are used voluntarily.
- iii) individual differences can be observed.

Examples of such effortful processes are imagery (e.g, Finke, 1980), elaborative devices (e.g, Eysenck, 1979), organization and clustering (e.g, Tulving, 1962), and rehearsal (e.g, Rundus, 1971). The third proposition, that individual differences can be observed in effortful processes, implies that they are not present in automatic processes. The possibility that automatically processed dimensions are immune to individual differences is potentially very useful to the design of an automated file retrieval system. For example, the system could be designed without including a flexible element for tailoring it to individual users.

The definitions of automatic processing provided by Shiffrin and Schneider (1977), and Hasher and Zacks (1979) take Posner and Snyder's (1975) definition as their starting point. Shiffrin and Schneider (1977) refer to the processes involved in encoding information as "control" processes. These control processes are either *veiled* (automatic) or *accessible* (controlled via effort). Shiffrin and Schneider's understanding of automatic processes is based on a further five propositions:

- i) once activated, they run to completion.
- ii) they are difficult to suppress, once aroused.
- iii) they do not, on their own, result in the storage of new information.
- iv) they develop (under certain circumstances) if given large amounts of practice.
- v) they are invulnerable to differences in motivation, education, early experience, culture and intelligence.

Veiled processes are exemplified in search tasks by the way target appears to "pop out" of a field of distractors regardless of their number (e.g, Egeth, Jonides and Wall, 1972). The third proposition, that automatic processes do not, on their own, lead to the storage of information implies that dimensions subject to automatic processing are

not necessarily easily remembered. The focus of this chapter is to identify those automatic processes which do have a positive effect on memory. Consequently, it will be necessary to consider the literature which refers to automatic processing with that which refers to incidental recall (see sections 2.1.3 and 2.2). Hasher and Zacks (1979) paper looks specifically at "Automatic and Effortful processes in memory" and will consequently be centred on as a means to identifying easily remembered dimensions.

Hasher and Zacks included a set of criteria to judge whether or not an event was automatically encoded. They made two basic assumptions:

- 1) Encoding operations vary in their attentional requirements.
- 2) Attentional capacity varies both within and among individuals.

From their first assumption they go on to define automatic encoding as that which uses minimal attentional capacity. The use of minimal attention has several consequences for the occurrence of automatic encoding including their occurrence without intention or interfering with other cognitive activities. This lack of interference and intention contributes to the processes functioning at a constant level under all circumstances. Encoding occurs without attention as efficiently as it would with attention therefore the operations do not benefit from practice. The existence of this form of automatic processing would prove useful as a means of identifying memorable dimensions. From this definition of automatic encoding Hasher and Zacks developed criteria for testing the existence of automatic processes. In brief their criteria state:

- 1) Learning conditions will not affect the occurrence of automatic processes.
Effortful processes are improved under intentional learning conditions.
- 2) Instructions and practice will not effect the occurrence of automatic processes.
Instructions and practice usually help effortful processes.
- 3) Automatic processes allow other, non-automatic, processes to occur with minimal disruption.
Effortful processes share the limited attentional capacity potentially disrupting other effortful processes.
- 4) Stress, depression, and high arousal are assumed to reduce attentional

capacity, and therefore may disrupt the automatic processes.

There should be no effect on the effortful processes by these variables.

5) Automatic operations are fully developed early in life.

Effortful processes are learnt at a slower rate, and the attentional capacity may decline for elderly people.

Hasher and Zacks (1979) postulate that humans are genetically "prepared" for certain automatic processes and that these processes encode the fundamental aspects of the flow of information, aspects such as spatial, temporal, frequency of occurrence, and word meaning information. The implementation of any test to investigate the existence of these presumed differences between effortful and automatic encoding involves a task requiring cognitive effort and attention, to compare performance with different cognitive loadings. If a process is automated it requires no attention. To ensure that a process under test is not in receipt of attention an attention demanding task is employed on the assumption that the subject's attentional resources are fully committed. In this way, attention demanding (and therefore non-automatic) activities are evident through a decrement in the primary task performance. Hasher, Zacks and others went on to use these criteria as a means of investigating whether frequency of occurrence (Hasher and Zacks, 1984; Zacks et al, 1982), category size information (Alba et al, 1980), and temporal order (Zacks et al, 1984) are subject to automatic encoding.

The results of these studies do not necessarily identify the existence of automatic encoding in human memory. Greene (1984) pointed out an important oversight in the criteria that Hasher and Zacks had produced. They had not taken into account the retrieval strategies that the subjects may employ. If a subjects performance on a retention task does not improve with practice it may be due to the subjects inefficiency at retrieving the extra information from memory instead of a constant level of information being encoded. Hasher and Zacks' criteria do not take into account that some attributes might be easier to retrieve than others. Currently there are no reliable metrics for measuring the amount of effort for either encoding or retrieval. Greene pointed out that what was needed was a criterion that could separate encoding from retrieval strategies. To accurately identify whether encoding processes are responsible for any variations in performance the retrieval and decision processes need to be

controlled. Only under these circumstances would it be possible to ascertain whether automatic encoding actually exists. This theoretical issue does not hinder the fact that the research may be useful in pointing towards dimensions that might be useful in the design of an automated file support system. For the purposes of this thesis, though potentially useful, it is not necessary to distinguish between information being encoded or recalled automatically. What is of importance is identifying features which can be remembered with minimal effort in an information handling environment. For instance, if an attribute is automatically encoded but requires effort for recall then it will have limited use as an aid in the design of a filing retrieval support system. Research which has not distinguished between automatic processing and incidental recall is valuable in identifying attributes which will be remembered and therefore useful as file identifiers.

The varying definitions for automatic processes lead to varying criteria for judging whether or not a process is automatic. For example, Regan (1981) noted a distinction between automatic processes that are effortless, and those that are effortless and involuntary. These need not necessarily coincide. For example, an effortful activity can be initiated without voluntary control (Paap and Ogden, 1981). Most investigators cite other investigators as reference sources for the criteria that they have employed to evaluate whether the processes they are investigating are automatic. The differing definitions of automatic processing lead to these differing criteria. Since definitions are not subject to empirical analysis the only way to choose between them appears to be personal preference. Jonides et al.(1985) suggest that the best approach to selecting the criteria for judging the occurrence of automatic processes should depend on a model of the task in question. Central to this notion is that the characteristics of an automatic process are dependent upon the particular context. This implies that there is no unified concept of automaticity. However, recurring themes within the definitions and criteria suggest that this may not be the case.

The most popular view of Automatic encoding in human memory is that based around the notion of an continuum of attentional requirements (Hasher and Zacks, 1979; LaBerge and Samuels, 1974; Shiffrin and Schneider, 1977), where at one extreme activities are automatic, in the middle some activities can be learned by practice to become more automatic (e.g, driving a car), and at the other extreme are unlearned

activities that require effort. The gradual achievement of automaticity is coupled with the gradual withdrawal of attention. This modal view of automatic processing is based in the assumption of a single, limited, capacity theory of attention.

The importance of these theories are that they indicate the possible existence of automatic processing in human memory and can suggest which dimensions may be memorised with minimal effort. Dimensions that are likely to be automatically processed in human memory can then be used in a simulated information handling situation to investigate their potential for the design of automated filing support systems. Aligning with an exact definition and criteria to identify the existence of automatic processing in human memory is not an essential pre-requisite. Having identified that there is a body of research within the memory literature which can be used to suggest attributes which may have practical relevance to the design on a filing support system, the following section attempts to identify which attributes the literature suggests are memorable.

2.1.2 ATTENTION AND AUTOMATIC PROCESSING.

An understanding of the concept of attention is central to the definitions of automatic processing. Reducing the attention necessary to file information would lead to a decrease in the amount of effort required to file. Therefore, an automated filing support system would benefit from utilising filing dimensions that are memorised with minimal attentional requirements. The question of whether attention is necessary, and to what degree, could affect the design of such a system. Increasing demands on attention will reduce the effectiveness of such a system to provide a quick easy means to file information. This section looks at the role of attention in the theories of automatic processing in human memory, then goes on to cover theories of pre-attentive processing in perception. In studying the role of attention within the theories of human automatic information processing the chapter aims to focus on identifying features which will prove likely candidates for use in a retrieval support system. The identification of features which are remembered with minimal attentional effort have potential for reducing the effort generally required to file and retrieve information from

filing systems. The practical applicability of these features can then be evaluated in a realistic information handling situation (see chapter 3).

According to Posner and Snyder's (1975) definition for an activity to be automatic it requires little or no attention. A large number of theories of attention have been developed in cognitive psychology (for reviews see Broadbent, 1982; Kahneman, 1973; Kahneman and Treisman, 1984; Keele and Neill, 1979). The properties of attention most frequently treated by investigators are selectivity and capacity limitation. One of the theories that is quite successful in accounting for a wide range of attentional phenomena was originally proposed by Kahneman in 1973. Kahneman's theory is essentially a capacity model of attention. In this model there is a limited capacity on the amount of energy available for performing mental operations. This capacity can be allocated flexibly to different types of processing, acts, or objects. Mental operations vary in the amount of attentional capacity they require. Attention is defined as a non-specific resource for cognitive processing, necessary in varying amounts to carry out mental operations, but of limited supply. It is Kahneman's point that mental operations differ in the amount of mental capacity they require that Hasher and Zacks (1979) extrapolated to define their conception of "automatic encoding".

Hasher and Zacks (1979) propose that there is a continuum of attentional requirements among encoding processes. This continuum varies from automatic (minimal attentional capacity required) to effortful. Hasher and Zacks also postulate that there is a variable capacity limit to attention, and this limit interacts with the encoding demands. Where automatic encoding of information only minimally diminishes the capacity to process other components of the flow of information. Learning without effort occurs when certain relevant attributes must be attended, but once attended these attributes are learned independent of any additional processing. This approach becomes problematic upon attempting to specify how much attention specific stimuli require before they can be learned without effort.

A practical problem arising from the assumption that there is a continuum of encoding from automatic to effortful is that without an actual metric for the continuum it is only possible to determine relative positions. Hampson (1989) includes a review of the

literature on automatic encoding and suggests a subdivision of automatic processes into a small class of fully automatic processes and a larger class of partially automatic processes. An example of fully automatic processes would be feature detection (Treisman and Souther, 1985). Partially automatic processes are described as being fast and efficient, comprising of many non-conscious components though do not appear to be completely automatic in the sense that their occurrence leads to some interference with co-occurring activities. The criterion that automatic processes demand no attention, i.e. they do not affect concurrent attention demanding tasks, is in practice rarely the case when rigorously applied (Kahneman, Treisman and Burkell, 1983). It appears that some small but nevertheless significant amount of attention is needed to initiate automatic processes. The existence of fully automatically processed dimensions appears to be limited. As an example of fully automatic processes 'Feature detection' theory (Treisman and Souther 1985) provides a potential source for identifying attributes which may be fully automatically encoded in memory.

It is possible that partially automatic processes can be of practical value to the design of retrieval information systems. Partially automatic processes could serve to reduce filing procedures by being incorporated in an automated filing support system. With such a system recall of the file identification would prove to be better than with tags that required effortful processing. The small but significant amount of attention apparently required by partially automated processes could be supplied in a filing situation which employs an automated support facility. In this system where some filing activities are not automated the information workers attention is directed towards the task of filing. The important factor is the increased likelihood that the user can retrieve a file without expending extra effort.

Treisman and Gelade's (1980) "Feature Integration" theory of attention, is an account of attention proposing that features are perceived first in attention. This contrasts with the Gestalt approach where the "whole" is perceived first and the features analyzed in a "top-down" fashion, or the Associationist approach where the object parts are perceived and "bottom-up" processing is used. Treisman posits that features are registered early, automatically, and in parallel across the visual field. While objects are identified separately and only at a later stage which requires focused attention.

There is some physiological evidence to suggest that the visual scene is analyzed at an early stage by specialized aggregates of receptors which respond selectively to properties such as orientation, colour, movement, or spatial frequency, and map these properties in different areas of the brain (e.g., Cowey, 1979; Hubel and Weisel, 1968; Zeki, 1976). The analysis of features automatically, and pre-attentively could apply to the perception of information items in a filing situation. Features which are analysed in this fashion (e.g., colour) provide prime candidates as identification tags in an automatic retrieval support system.

Treisman and Gelade (1980) assume that the visual scene is initially coded along a number of separable dimensions. This theory is compatible with the findings of Lansdale et al. (1987) where recall of the three attributes used for filing information was statistically independent. Treisman and Gelade suggest that location is processed serially with the use of focal attention in order to combine these separate representations. Features present at the same central *fixation* are combined to form a single object. The focal attention is the activity that provides the *glue* which integrates the initially separate features. This theory suggests that attention needs to be drawn towards a locational attribute for memory of the features existing at that location to be processed automatically. For example, if an information worker's attention is directed towards a particular location during the filing stage it will facilitate the automatic processing of features at that location. There is some physiological evidence to support the notion that dimensions such as colour and shape are physiologically processed separately (e.g., Garner and Felfoldy, 1970). The methodology will be concerned with investigating whether certain dimensions are easily remembered and whether memory for the attributes is improved by interactional effects, rather than the physiological basis of the memories.

Research into the effects of inattention on form perception suggests that features such as colour and shape exist in separate maps in pre-attentive vision and can only be integrated through the use of spatial location (e.g., Houck and Hoffman, 1986). The existence of colour and shape in pre-attentive vision suggests that they are good candidates for inclusion in an automated file support system. Rock and Gutman (1981) designed an experiment that implies shape is not recognized without attention whereas

other figural properties are. The subjects were lead to believe that they were participating in an experiment concerned with aesthetic judgments of a set 10 slides. The subjects were asked to fixate their vision on a black dot that was displayed consistently in the centre of the screen where the slides were displayed. Each slide consisted of two outlines of novel forms, one outline in red and one in green. The subjects were asked to rate either the red or green shapes for how "pleasing" they were while the slides were displayed in quick succession. The coloured figures that the subjects were not rating are the unattended figures. When the subjects had rated all the slides a recognition test using only black shapes was given. The set of shapes displayed for recognition involved 5 new shapes, 5 attended shapes, and 5 unattended shapes. Under no time restrictions the subjects were required to circle any of the figures they recognised regardless of their original colour. They found no evidence of beyond chance recognition of the unattended shape. However, with only a slight change in their procedure so that the figures were viewed with attention but no intention to recall, recognition was good. Memory for the shape in this experiment was incidental e.g, the subjects were not expecting to have to remember the shape. The implication is that shape has potential as a tag for information retrieval if attention is directed towards it. In another variation on their design (Rock and Gutman, 1981) the subjects were questioned about the figural properties of the unattended shape, e.g, were the lines straight or curved. Though there was a failure to recognise the actual shape, these figural properties were recognised. If the user of a filing system can recognise the figural properties of a shape it is possible that shapes which have distinctive figural properties may prove useful in the design of an automatic retrieval support system.

Varying attentional requirements are proposed for automatic processing (e.g, Hasher and Zacks, 1979). Ideally the dimensions used by an automated filing support system would be have minimal attentional requirements. Feature integration theory suggests that colour and shape are pre-attentively processed in perception (e.g, Beck, 1967; Treisman, 1985). This makes colour and shape prime candidates for incorporation in an automated filing support system. Similarly, attention to location is suggested as providing the "glue" to combine pre-attentive features such as colour and shape. This implies that attention to location will involve the pre-attentive processing of colour and

shape while also combining these attributes in memory. The combination of the attributes is important because in a filing situation the more file tags that can be recalled (in combination) the more precise the search for that file. The literature relating to attention and automatic processing in human memory indicates that there may be value in using the dimensions of colour, shape, and location as file identifiers in an automated file retrieval support system.

If dimensions are automatically processed in human memory but cannot be remembered then they will not prove useful in the design of an automated file support system because they will not improve the likelihood that files can be retrieved. To reduce the effort expended by an information worker, while filing, an automated support system should not require the users intending to recall, and therefore putting effort into memorising the file identification. An automated support system should provide tags that are easily recalled despite the lack of intent to recall. It is not intended to suggest that information workers will not be intending to recall the information, merely that minimising the cognitive load associated with attending to memorising file identifiers without adversely affecting the likelihood of retrieving files would be beneficial. Consequently, the following section looks at work relating to the effects of intent to recall on automatic processes.

2.1.3 THE EFFECTS OF INTENT TO RECALL

One finding that has been demonstrated frequently in the research on intentional versus incidental learning is that whether a subject intends to learn or not is not as critical as how the material is processed during its presentation (see Postman, 1964, for a review). If the subject performs identical mental activities when not intending as when intending to learn the subject will produce identical memory performance in both conditions (e.g., Greene, 1984). The reason memory performance improves with intention to memorise information is because they are likely to engage in strategies more conducive to good memory such as rehearsal (e.g., Rundus, 1971) and elaborative processing (e.g., Eysenck, 1979). The strategies a subject employs affect where attention is directed and what information is actively encoded and subsequently

retrievable. Consequently, recall of information that was not initially to-be-remembered does not imply that the encoding and recall of that information was automatic. Recall in this instance is a by-product of the particular effortful strategy employed on a task. This form of incidental recall as a bi-product of the task is viable as a means to improve the recall of information from a personal filing system. Features of information to be filed that are recalled as a result of being used or filed will prove useful as a means of identifying that information for retrieval.

Craik and Lockhart (1972) similarly suggest that it is not necessarily the intent to remember that is important but rather how the information is processed in the first place. Memory is conceived of as a by-product of the type of processing employed on the information. Support for their theory comes from incidental learning studies in which subjects were asked to make judgments about the material, unaware that their memory would be tested for the material (e.g., Craik and Tulving, 1975). Judgments involving deeper processing of the material produced better performance on unexpected memory tests than judgments that required minimal processing. The implication is that incidental recall of filing tags would require those filing tags to be subject to deep processing. Incidental learning for colour and shape was studied by Light, Berger, and Bardales (1975). They demonstrated that both the colour and case in which words are presented to subjects (as to-be-remembered material) are better remembered in an intentional learning condition than in an incidental learning condition. However, there appears to be a trade-off between the two memory tasks since more words are remembered in the incidental than the intentional condition. This suggests that recall of the colour of a word as well as its identity is a dual processing task with a cost associated with the processing of both kinds of information.

Results have been mixed in the studies of incidental memory for location (see Mandler et al, 1977), though there is a suggestion that a great deal of spatial information is available for retrieval without attention having been directed to it (e.g., Christie and Just, 1976; Rothkopf, 1971; Von Wright, Gebhard and Karttunen, 1975; Zechmeister and McKillip, 1972). This memory for location seems to be facilitated when it involves the location of an object as opposed to the location of words (Pezdek, Sobolic and Roman,

1986). As a potentially highly memorable combination the location of a coloured object appears to be a good candidate for incorporation in an automated filing support system.

There is a substantial body of research that supports the notion that certain types of information are automatically processed or incidentally recalled in human memory. Most of this research has been too specific to be of any direct practical use in a filing situation, but there is a limited amount of evidence already existing to suggest that some dimensions are more likely to be recalled than others. The methodology will practically evaluate whether these potential automatic processing and incidental recall of the dimensions of colour, location, and shape are directly applicable to the design of an automated file retrieval support system. The literature pertaining to automatic processing in human memory and incidental recall tends to use materials that are not directly relevant to the tasks on an information worker. The following section reviews previous work that looks at the possibilities of incidental recall when handling office information.

2.2 INCIDENTAL RECALL AND OFFICE INFORMATION

There have been relatively few studies investigating the use of automatic processes or incidental recall within an office information handling situation. Rothkopf (1971) pointed out that people often remembered a number of "superficial" or "irrelevant" features of something that they had read, such as the colour of a book's binding or the location on a page of a particular item. Kirsner (1973) showed that printed words were more likely to be recognized if they recurred in the same type-face than in alternative type-face. Studies such as these imply that some attributes of information items are more memorable than others and may even be recalled incidentally. This section looks at studies which involve handling documented information as a means of identifying attributes which may be incidentally recalled.

Kaiser (1983) carried out a naturalistic, controlled, study of information handling. The aims were to determine what, if any, physical attributes of a document could be recalled and recognized, and which may aid scanning. It was suggested that the

findings of the study might prove to be the starting point for identifying attributes or cues that could prove useful when incorporated into an automatic filing system as an aid to the scanning processes involved in retrieval. The main aim was to find out what people actually remember about documents they receive and may use in the course of their work. The study tested subjects' incidental recall for the documents, in the sense that the participants could not have known that their memory of the document would be tested. Kaiser identified a document that had been circulated to subjects in the normal progress of their work and asked them to answer a "general recall" questionnaire, and a "general usage and familiarity" questionnaire. Memory for physical attributes of the document were tested by a series of forced choice recognition tests, where each test concentrated on a particular physical attribute. The overall aim being to build up a profile of attributes that may, or may not, be recognized. Kaiser looked at the attributes of cover-size, type-face, position of text, thickness, colour, and formats. One interesting finding that emerged from this work was that not only can the subjects most familiar with an article (i.e. its author) recognize physical attributes such as type-face, thickness and colour, but those least familiar with it (i.e. it was not actually used by them) appear to recognize some physical attributes also. Kaiser concluded that though recall and recognition vary according to familiarity, the gross physical features of the document, such as colour, and thickness, are recognized equally well, irrespective of familiarity. The implication is that the subjects process this information so that it is available for incidental recall. This indicates that incorporating some physical attributes as document identification into an electronic system might be useful where the user's familiarity with the information is potentially low. The three attributes Kaiser found to be most memorable in her study were thickness, colour, and "logo-like" type-face.

Penn (1988) studied incidental memory for the format of documents. Twenty subjects were asked to read 30 documents while expecting to be questioned about the content of the documents. After a delay of approximately 7 minutes the subjects were given a forced choice recognition test for 20 of the documents. The subjects were shown two documents one which they had originally read and one which they had not. The forced choice recognition test was delivered in two conditions. In the first condition the document and distractor were displayed in the form that the stimulus was originally

presented to the subjects for reading. In the second condition the documents presented for the memory test were visually degraded until the text was unreadable. The visual degradation was achieved by photo-reducing the stimuli and then photo expanding the reduced stimuli. Recognition of the undegraded stimuli was high with only one subject making an error. The degraded images produced a recognition rate of approximately 78%. From subjective comments Penn noted that the subjects used distinctive visual features such as letter headings with distinctive shapes, tables, lists etc. to recognise the documents. The study suggests that there is incidental memory for the physical features of documents and that this memory is linked to the document's information content.

Some of the studies of incidental recall in office information handling settings suggest that there are poor levels of recall. Lloyd (1990) gave subjects written descriptions of 12 European cities, the subjects' task was to name the cities. The descriptions were handed out in pairs over a period of 12 weeks. Subjects who accurately identified all 12 cities (thereby ensuring that they had read the documents) were asked to participate in a memory test for various attributes of the documents. The attributes tested included text, shape, format, and type-face. A repeated cueing design was used to investigate the subjects memory for the documents. The repeated cueing design involves a subject being presented with one cue (e.g, the shape of the document) and asked to reconstruct the other associated attributes. In the course of the test the subject is cued for each document by each attribute. The analysis showed consistently low recall levels. Findings such as this appear to suggest that there is no incidental recall of these attributes in information handling situations. The poor recall could be attributable to a number of possible sources. One explanation could originate from the amount of attention that the subjects paid to the attributes. All the attributes were incidental to the task the subjects were performing and as such probably received minimal attention. If the subjects were using the attributes as as part of the task it is feasible that they may display improved incidental recall. Another possible explanation is the lack of meaning associated between the attributes under test and the information content of the documents. It appears that the ease of memorising an attribute depends on both what the attribute is, and how the attribute is used.

In summary, there is evidence that document attributes which are incidental to the task are recalled. If recall of these incidental attributes does exist then they can be used as a means of identifying files for retrieval from an automated file-retrieval support system. The fact that incidental recall may be dependent upon the task that the subjects perform suggests that a realistic task should be employed to investigate the nature of incidental recall. The studies suggest that there incidental recall may exist for physical attributes of information such as location on a page (Rothkopf, 1971) and logo-like type-face (Kaiser, 1983).

2.3 CONCLUSIONS

The first chapter noted that at present there is inadequate user support for retrieving information from electronic filing systems. Retrieval of information is ineffective when the user is unable to recall exactly how an item was initially classified. What the user can actually remember about an information item ought to be used in its original classification, but what is the user most likely to remember? In designing an automated filing system optimizing the overlap between how a system has classified an item and what the user can remember of the item will greatly increase the systems practical and perceived utility.

Providing a large pool of dimensions to classify an information item (cue enrichment) does not ensure that these dimensions will be accurately remembered by the users whose attention may be directed elsewhere. Some kind of balance is needed between the increased likelihood that an item will be filed if the user does not have to put a great deal of time and effort into the filing task and the reduced likelihood of the user being able to recall how to access the item if little attention was paid to the filing procedures. This problem could be alleviated by using tags which are known to be recalled relatively well despite any problems such as low attention at the initial filing stage. Easily memorised tags would reduce the filing activities performed by the user whilst not reducing the likelihood that the item will be retrieved efficiently. The existence of dimensions which are automatically processed, or incidentally recalled, in human memory provides a potentially productive road to the solution of this problem.

The objective of this thesis is to identify and assess the relative efficiency of tags which could be used in an electronic filing system as an automatic retrieval support function. The starting point is to investigate the relative quality of recall for attributes of information items (e.g, documents, letters, memos) that are incidental to their information content. The fact that it may be difficult to transfer the findings between media (see chapter 1, p.22, Wright and Lickorish, 1988) has lead the approach to use electronic media.

The attributes selected for this project are those of colour, shape, and location, specifically the colour shape and location of an icon design on an information item. The attributes are displayed in the form of an icon due to claims that there is a strong likelihood that icons are well recalled (e.g, Kaiser, 1983; Lodding, 1983) and the presence of a logo-like icon on information items is not unusual. The fact that the subjects should accept the presence of an icon on the information items is necessary to avoid them paying the icons an excessive amount of attention. The attributes were selected for investigation for two main reasons; first the literature suggests that they may be easily recalled, and secondly they can be produced and applied by an electronic system. The following chapter explains the design of a paradigm within which the incidental recall for these attributes is investigated.

CHAPTER 3

EXPERIMENTAL PARADIGM

Chapter Contents

Chapter 3 describes the experimental paradigm that is developed to investigate incidental recall for the dimensions of colour, location, and shape in a realistic information handling situation. The paradigm consists of a business simulation task involving subjects making decisions about how to prioritise information items. Each information item is endowed with an icon. Every icon is an unique shape and colour, displayed at a unique location. The experiments described in the following chapters provide information about how each dimension is used by the subjects during the sorting task in a variety of combinations. After sorting the information items an unexpected test of memory for the icons performed. The subjects' use of the icon attributes in the sorting task is varied to investigate whether the amount of exposure to the attributes affects recall. Two levels of procedurally defined exposure are used : circumstantial (displayed when a document is available for reading) and functional (displayed when sorting/ranking documents). The following four experiments are run within this paradigm and consequently this chapter provides an overall background to the generic experimental design they use.

3. EXPERIMENTAL PARADIGM

3.0 INTRODUCTION

In general, empirical work can be described as falling into three broad categories: comparison research, data collection based research, and evaluative research. In comparative research experiments are aimed at determining whether one principle is more appropriate than another principle (e.g, Ross & Bower, 1981). In the data collection based research work is based on the examination of a mass of data (collected by observation, questionnaires, error counting etc). From these data collections and post analysis of this data, conclusions can be drawn about the structures, weaknesses and strengths of the processes involved (e.g, Malone 1982). The final category of general observation of systems covers observations, measurements, tests, comparisons and adjustments of particular systems. These observations result in systems, models, or theories being redesigned to complement the behaviour of typical users. The aim of the general observation category is to understand the user's needs and optimise the systems behaviour by tailoring it to the users (e.g, Furnas, Landauer, Gomez, and Dumais, 1983). This paradigm is designed to fall within the second category described, collecting data then attempting to describe the structures that emerge from it. The reasoning behind this choice stems from its advantages for enabling a collection of large quantities of varied data. The approach does not restrict the data collection to specific variables which are assumed a priori to be the important variables. Consequently, patterns of behaviour can be identified which may otherwise have been overlooked.

The choice of a research setting involves making complicated trade-offs in the availability of time, money, and equipment. Research carried out in the field has the advantage of realism in terms of relevant task variables, environmental constraints, and subject characteristics including motivation. There is a better chance that the results obtained from such a study can be generalised to the real world environment. The disadvantages involve costs in terms of both time and money (to the experimenter and/or the subjects), lack of experimental control, limitations on the opportunities to

replicate studies a sufficient number of times, and often certain types of data cannot be collected because the process would be too disruptive.

The laboratory setting has the principle advantage of experimental control. Laboratory settings enable extraneous variables to be more readily controlled, the experiment can be replicated with more ease, and data collection can be made more precise. For these advantages the experimenter may have to forfeit some realism and the potential to generalize extensively. A compromise between these two approaches can be achieved through simulation. Simulation is an attempt to combine the capacity of field work to generalize with the control of laboratory research. With a simulation study the findings are less likely to be experiment-specific than with a laboratory study, because they can be generalised to the actual situation being simulated.

The use of a field study in the case of this project had to be ruled out on the grounds of impracticality in terms of time, subject availability, expense, and data collection complications. The subsequent choice is that of simulation. The rationale is to design an experimental paradigm that simulates a realistic task for an information worker. Another consideration in the design of this paradigm is that of versatility. The paradigm is designed to be versatile to facilitate investigation of data trends that seem potentially useful in building an overall picture of what is actually happening during an experiment. Consequently, any interesting factors that are brought to light in the early experiments can be followed through with only minor adjustments to the original set up.

There are several methodological obstacles associated with the study of automatic processing in human memory and incidental recall. For processing information into memory to be automatic the subjects must pay little or no attention to the attributes under consideration. This situation is generally achieved by attempting to direct the subjects attention to a task which requires extensive cognitive effort. Assuming a limited capacity model of attention (e.g, Kahneman, 1973) if the subject's attention is directed to the main task then little or no attention will be directed towards the attributes. In practice it is difficult to assess where the subject is actually attending. Furthermore, it is known to be difficult for subjects to attend fully to any task for even quite modest

periods of time (e.g. 5 minutes) without attentional drift (Fisk and Schneider, 1981). The task chosen must therefore be one which is interesting and varied enough to hold the subjects attention for the length of the experiment. For recall to be incidental the subjects must not be expecting any form of memory test. If the subjects are expecting a memory test then an attribute being assessed for how well it is recalled incidentally might be used in their strategies to memorise information and therefore confound the data as regards the incidental recall and automatic processing of information. The consequences for the experimental design are that the main task must be plausible as an experiment in its own right to avoid subjects supposing that there is more to the experiment than they are initially lead to expect, and each subject may only perform the memory test once.

The task decided upon is a business simulation task known as the "In-Tray" exercise. This particular task was designed by the Careers Research and Advisory Centre (CRAC) in association with ICI. CRAC use the exercise as part of their "Insight" program to help students understand more about the diverse content of management jobs. The In-tray exercise is designed to introduce students to a range of Personnel Management dilemmas and encourage them to decide what actions they should take. The exercise involves the subjects reading a number of letters and memos which simulate the incoming mail of the personnel manager of a fictitious company: "Plastic Products". The subjects are given background information about the company, and are asked to indulge in a role playing exercise where they assume they are the personnel manager sorting through the morning's mail. Subjects are asked to make evaluative judgments about the information in the in-tray.

The "In-Tray" exercise was selected as a task for the subjects for several reasons. Firstly, the task is based on and simulates genuine incidents and correspondence. The exercise consists of written information items that are notably file-able (letters and memos). The letters and memos portray a complex, thought-provoking, situation which engages the subjects attention in a plausible task. The subjects are initially lead to believe that the sorting task is the only part of the experiment and that the purpose of the task is to evaluate the design of the interface as a means for handling information in decision making tasks. The information content of the letters and memos is varied and

portrays a complex picture of the plastic products company. Even though the information in the task is complex the task has no "right" or "wrong" answers so the subjects are not under the stress of believing they are being personally evaluated by their performance. It is not possible to be absolutely certain where the subjects' attention is actually directed during their inspection of the letters and memos (hereafter referred to as the information items). Due to the fact that the exercise is a simulation exercise it is assumed that the subjects attention is directed in a manner comparable to that of an information worker when handling and evaluating office information.

The exercise was originally developed so that after reading the letters a group of participants discuss the contents of the letters in the presence of a personnel manager and discuss the possible courses of action they could employ. The limited availability of space and equipment prevented the subjects participating in the In-Tray exercise simultaneously. Consequently, the subjects were encouraged to discuss their ideas with the experimenter.

The attributes targeted for this project are location, shape, and colour. These attributes were chosen because the literature regarding their salience in memory, though mixed, is promising (see chapter 2, Houck and Hoffman, 1986; Mandler et al, 1977; Park and Mason, 1982; Treisman and Gelade, 1980; Rothkopf, 1971; Rock and Gutman, 1981). The attributes are combined in presentation form as an "icon" - a colour and shape in a particular location. Kaiser (1983) noted that

"the three attributes found most memorable in this study were thickness, colour, and logo-like typeface".

The usage of an icon seemed appropriate for several reasons. Information items usually have an associated logo as a means of identifying their source, e.g, a company logo/name, the name of a subsidiary group. From a practical point of view the icons are easily controlled variables. In the context of the In-Tray exercise the icon on the information items is consistent with the notion that the icon represents a form of logo. It is therefore reasonable to assume that the subjects will accept the existence of an icon on the information items without excess curiosity and attention.

The decision to present the information items to the subjects electronically was based on several factors. Electronic presentation of the information items does not represent a deviation from the simulation of a realistic task. Presentation in another medium would involve problems in generalising the findings to an electronic medium (Wright and Lickorish, 1988). The information items are in the form of letters and memos, electronic presentation is consistent with the notion that the letters and memos are received by an electronic mailing system. The personnel manager's In-Tray is conceived as his electronic mailbox.

The paradigm is used to investigate two main aspects of incidental recall. The first aspect is whether incidental recall of the attributes under consideration exists in a form that will be of practical use to the design of personal filing systems. The second aspect involves the nature of incidental recall. In all the experiments carried out the attributes can be described as incidental in the sense that there is no intention on the part of the subjects to recall them. However two different forms of incidental recall are investigated. One form will be referred to as "functional" and is incidental in the sense that the subjects are not expecting to have to recall the information at a later date and is functional in the sense that the attributes can be used as a consistent means of identifying the information items. To manipulate the information items the subjects can use the functional attributes as a means of identifying which item they wish to read or move. All 12 variations of each of the functional attributes are therefore displayed when the subjects are making a decision about which item to read or move. When reading an information item the functional attributes associated with that particular item are displayed, in combination with the appropriate circumstantial attribute. In each of the experiments described later the one attribute is described as circumstantial in the sense that its existence is not relevant to the subject's task. The circumstantial attribute is only available for the subject to view when actually reading an information item. Consequently, viewing the circumstantial attribute is contingent upon viewing the information within a particular information item. The nature of these two forms of incidental recall will be explained in more detail during the description of the first experiment.

3.1 OVERVIEW OF THE PROCEDURE

3.1.1 THE STIMULI USED

(i) In-Tray exercise.

The In-Tray exercise consists of 12 information items in either letter or memo form (copies of these can be found in Appendix 1). The information items vary in length but are all written in the same font and with the same basic structure. Figure 3.1 (p58) provides an example of one of the information items. Due to Screen size limitations the information items can only be read one at a time. Each information item is embellished with an icon. Accompanying the 12 information items is a diagram of the structure of the organisation - "Plastic Products" (Appendix 1), and a sheet of information with background information about the company (Appendix 1).

(ii) Icons

The icons are figures with a distinct shape, colour and location, the selection of these attributes is described in the following paragraphs. The main aim in selecting each of the Icon attributes is that they have minimal confusability and maximum discriminability. Within these parameters the selection of attributes was limited by the available technology. For example, the size of the screen limited the distance possible between locations.

- Shape.

There are 12 shapes, one associated with each of the information items. The two alternative groups of icon shapes used in the set of experiments described within this thesis are illustrated on pages 80 (Figure 4.1) and page 147 (Figure 7.1). Both sets of shapes were designed to be abstract. The premise behind the abstract design is to avoid the subjects consistently imposing a similar meaning or verbal label to the shapes. The imposition of a consistent meaning on a particular shape by the subjects could produce data that would include a systematic bias. This bias would be due to the finding that meaningful material is known to be more readily recalled than abstract, and that humans tend to attempt to impose meaning or structure on stimuli (Tulving 1962).

From : N. Williams

Electrical Maintenance Supervisor

To : P. Greeves

Copy to : J. Goodman

Maintenance Manager

Personnel

Last night, I received a telephone call at 3.00 am concerning a technical difficulty on site. While I was investigating the problem I found that the shift electrician was absent from the place he was supposed to be working. I could not find him, although I did not conduct an exhaustive search. He says he was not absent from the site, although several people had not seen him. It is only three months since we found this character drinking in the local during the evening shift, and we told him then that he would be dismissed if ever again he left the premises during working hours. As he is the Shop Steward, and bearing in mind the generally sensitive climate, (in which the chairman will be touring the site next week) I thought you would wish to consider this one.

N.Williams

Figure 3.1: An example of an information item
used by the In-Tray exercise.

In this set of experiments the aim is to look at abstract shapes. Abstract shapes were targeted because if they prove to be memorable they could help alleviate the problems associated with categorisation. A computer system automatically allocating shapes to information items as a means of tagging them for future retrieval does not have to possess a categorisation system for both the shapes and the information items. The user would first have to understand the same categorisation systems as the computer, and then the user would have to recall the same categorisation in order to recall how the item was filed. Using abstract shapes side-steps this issue of categorisation so that the user only has to recall the association between the information item and the shape. The shapes were drawn as pixel-pictures on a 50x50 pixel map. They are stored in the Pluto memory buffer (for details of the Pluto see Section 3.2) as black and white pixel maps, from where they can be copied quickly to the screen and coloured appropriately. Alternative sets of icons can be used within the paradigm should aspects of the design of the icons be another variable worth exploring. Experiment IV (Chapter 7) uses the same design as Experiment I (Chapter 4) with a different set of icons enabling the effects of icon design on incidental recall to be evaluated.

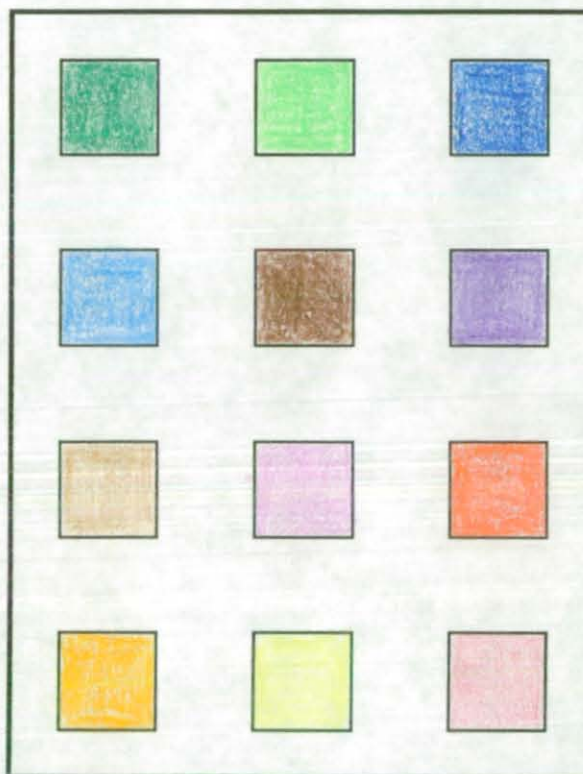
- colour.

12 colours are used, one for each icon/information item. The selection of these colours is limited by two conditions. The first condition is that the icon has to be a light shade to avoid rendering any text it appeared under illegible. The second condition affecting the selection of the colours is that of distinction, minimum confusability. The colours finally chosen were represented in Figure 3.2 (p60) by their red, blue, and green components used by the Pluto "look up table". Figure 3.3 (p60) illustrates the colours displayed on a Pluto graphics terminal.

Figure 3.2: The colour components used in the following experiments described by their red, blue and green components.

Stimulus Number	Colour	Green	Blue	Red
1	Green	189	63	21
2	Lime green	231	63	21
3	Royal blue	63	231	21
4	Turquoise	189	231	21
5	Brown	21	21	189
6	Purple	105	189	189
7	Beige	147	105	189
8	Lilac	147	231	189
9	Red	21	21	231
10	Orange	147	21	231
11	Yellow	189	21	231
12	Pink	21	231	231

Figure 3.3: Illustration of the colour set used in Experiments I, II, III, and IV



- location.

12 locations were used, so that each shape, colour, and information item could have a distinct location associated with it. The locations are sections within the information items and are arranged equi-distantly in the form (where the number is the stimulus number used for identification):

Figure 3.4: The locations identified by numbered boxes

1	2	3
4	5	6
7	8	9
10	11	12

These locations are also illustrated in Figure 3.3 (p60) when illustrating the colours, Figure 4.1 (p80) when illustrating the icon shapes used in Experiments I, II, and III Figure 5.1 (p111) when illustrating the screen layout used by the subjects when sorting their information items and Figure 7.1 (p147) when illustrating the icon shapes used in Experiment IV.

The icons are produced as a combination of these three attributes. For each subject 12 distinct combinations of shape, colour, location and information item are used. These combinations are produced by a programme procedure that acts as a random generator. The random generator assigns one of each attributes to each information items, thereby creating a distinctly located, coloured, shape.

The rationale behind randomising the attributes is to reduce any interference in the data due to subjects imposing consistent meaning onto particular attribute combinations i.e. if a red icon consistently appeared on an information item that referred to the death of an employee, subjects may find it easy to make a meaningful association between death and red which would give results that misleadingly indicate red is easily recalled. The randomisation enables any situation where, if a particular attribute value is recalled

well, the quality of recall can be accredited to the attribute and not any specific meaningful associations with other attributes and the information items.

When developing a file identification system the issues of discriminability and confusability have consequences for the effectiveness of the system. Discriminability is a measure of the range of the overall set of values, while confusability is the ease with which individual values within a set can be differentiated. For example, a set of grey colours will be less discriminable than a set consisting of a different colours, however, some individual values within a set of different colours may be more confusable than others. Consequently, when attempting to design a file identification system the range of the identification system and the distance between individual identification tags are both relevant. It makes intuitive sense that the design of a file identification system should incorporate limited confusability and extensive discriminability. That is, the values should be as different from each other, and cover as wide a range, as is feasible. In selecting the attribute levels (e.g. where green is an attribute level of the dimension colour) the objective was to maximise their discriminability, and limit their confusability. The rationale behind this decision is to facilitate identifying whether incidental recall exists, prior to identifying at what point the confusability and discriminability of the attribute levels significantly adversely affects memory for that set of levels. Thus the locations were selected to be spread across the whole area of information item, maximising the distance between them. Similarly the colours were selected to reduce confusion rather than being shades of one colour scale (e.g. shades of grey) they were distinctly different colours.

The attributes of colour and shape were not orthogonal in the sense that the display of the shape of the colour display was not independent of the icon shape. When colour and shape were displayed simultaneously the shape was portrayed in the colour. The shapes all covered similar pixel area's ranging from 10,000 to 14,000 pixels (in both sets of icons used). Assuming that the design of the icon will affect memory for the icon, it is suggested that the random combination of colours and shapes coupled with the small variations in the area of the shapes size will minimise the effects of the shapes not being orthogonal. The alternative of superimposing a shape upon a consistent size/shape coloured area has several associated problems. For instance, the icon shape

has to be delimited in some fashion and this will introduce a further colour or shade. Similarly, where the shape of the colour is consistent this effectively means that two shapes are displayed: the shape of the colour and the shape of the icon. The display used simply employs one colour and one shape level in association with each information item.

3.1.2 THE SUBJECTS:

For each experiment 20 subjects are used. None of the subjects participate in more than one experiment. Each subject can only participate once because of the nature of the incidental recall. If a subject is expecting a memory test the subject is likely to employ mnemonic strategies. The mnemonic strategies may involve the use of the attributes which the project requires to be recalled incidentally. The subjects would consequently have higher levels of recall for the attributes than might be expected from incidental recall due to the increased attention they received via the mnemonic strategies employed. All the subjects are students at the university, from a variety of courses. Subject age ranged from 18 to 29. In total, the set of four experiments using twenty subjects per experiment required access to 80 subjects.

3.1.3 THE SUBJECTS' TASK.

Stimulus presentation:

The subjects first read the instructions (Appendix 2). The instructions involve becoming familiar with some background information (Appendix 1) on the company within which the In-Tray exercise is set, "Plastic products". The subjects also have a set of written instructions describing how to use the mouse in this particular application (Appendix 2). The instructions on how to use the mouse and the background information on "Plastic products" are available throughout the experiment.

The subjects are asked to play the role of the personnel manager of the company. The subjects imagine that the information items they read are their own incoming mail as

personnel manager. They are required to read the 12 information items and sort them out into an order based on which item they would deal with first if they were the personnel manager of the company. The task is essentially a decision making task. The subjects have to decide what priorities they would have as a personnel manager. The subjects rank order the information items based on subjective judgements of the urgency of any action needed to be taken regarding the contents of a particular item. The subjects can practice using the mouse until they are happy with it as a tool for sorting before starting to sort the information items.

The subjects are aware that there is no standard "correct" order into which the information items should be sorted. The order depends on the values the subject assumes the personnel manager of such a company would have. Once the subjects have finished sorting the information items to their satisfaction they are asked to comment on what they thought of the task in terms of how interesting and easy they found it. They are then asked if they had noticed the icons, and if so, did they have any impressions of what the icons might be for?

No time constraints were imposed on the subjects. There were no limitations on how many times the subjects could access each information item, which order they chose to access the items, or which rank the subject chose to assign the respective items. The size of the Pluto graphics display screen limited the number of information items that could be displayed in a legible form at any one time to one item.

In summary, the subjects are required to rank the relative importance of 12 information items in an order that they believe reflects the priorities of the personnel manager of the fictitious company called Plastic Products. The task is accomplished by the subjects displaying and reading the letters via an electronic mouse and virtual buttons on the display screen. An example representation of the screen display used in Experiments I and IV is available in Figure 4.1 (p80), and the display used in Experiments II and III is available in Figure 5.1 p(111).

Response condition:

Once the sorting task is completed the subjects are asked if they are prepared to participate in a forced-choice recognition test for the icon attributes, of colour, location, and shape. The information items that the icons appeared on during the sorting task are presented sequentially as recognition cues.

Written instructions are supplied to the subjects explaining the forced-choice recognition test and use of the mouse (Appendix 2). After familiarising themselves with this particular adaptation to the use of the mouse the subjects are presented with one of the information items (cue) that was sorted in the stimulus condition. The information item, or cue, is selected randomly by the system and is not embellished with an icon. Adjacent to the cue are two displays. One display is of the 12 colours (that the icons were originally coloured). The second display is of the 12 shapes (the original 12 icon shapes) in black on a white background. Superimposed on each cue as it appears are boxes. These boxes are drawn in a pale-coloured broken-line and indicate the original locations of the 12 icons (for an example Figure 4.4, p83).

Supplied with an information item as a cue, the subjects have to make, and place, an icon on it. All 12 information items are presented to the subject, sequentially. The subjects are instructed that they should try to reproduce the icon that was on the information item initially in the sorting task, but failing that they should make a guess. The program enables the subjects to select a shape and colour then place it in one of the boxes on the cue. The next cue will not be displayed until one of the icons is coloured and placed on the present cue. When the subject is satisfied with the choice they have made for a particular cue, pressing a mouse button will record the selection and display the next information item. This task is repeated 12 times until all the information items have been allocated an icon constructed by the subject. The method of cueing the subjects with an information item is employed to enable recall for all three attributes to be assessed. Since the thesis is not investigating incidental recall for other aspects of the information item it seems appropriate to use the information item as a cue, thereby investigating the connection between the information item and incidental recall of its associated icon attributes.

3.1.4 THE PROCEDURE.

The appropriate version of the program for presenting the In-Tray exercise is loaded onto the system and run. The subject is introduced to the experimenter and the system.

For the sorting task the subjects are given two sets of written instructions, one explaining the In-Tray exercise (Appendix 1), and one explaining the use of the equipment (Appendix 2). After reading the instructions the subjects are asked if they have any questions and encouraged to familiarise themselves with the equipment before starting to sort the information items.

While the subject reads and sorts the information items the experimenter is available to answer any questions the subject may raise. When the subject finishes sorting the information items the task is discussed with the experimenter while the program writes the data file for that particular subject. Towards the end of the discussion the experimenter queries whether the subject has noticed the icons on the information items and if so, postulated any explanation for their presence? At this stage any subjects who indicate that they suspect the possibility of a following memory test are noted. If the subject is expecting a memory test and wishes to participate their data is collected, however it is not included with the data of subjects who are not expecting any form of memory test.

The subjects are asked if they are prepared to participate in a memory test for the icons that were initially present on the information items. If they agree they are presented with two further sets of written instructions, one describing the design of the memory test and their task (Appendix 2), and the other explaining the interface (Appendix 2). While the subject is reading these instructions the memory test program is loaded on the computer. Once the instructions are read the subject is encouraged to "play" with the equipment until confident of its use. In the following experiments the typical interval between the finishing the sorting task and starting the test was approximately twelve minutes, ranging from ten to fifteen minutes. The experimenter is available to answer any queries that the subjects may have about the procedure throughout the test.

3.2 THE HARDWARE.

There are three main sections to the hardware, a Pluto graphics display, which is run by a "host" computer and a Summa-mouse. The host computer was initially a Future FX30 that was later replaced with an Olivetti M24. The Summa-mouse is used by the subjects to control the displays presented to them by the Pluto.

Pluto Colour Graphics Display:

The subject sorts and reads the information items as they are displayed on a Pluto colour graphics display controller. The screen is set at a high resolution mode of 640h x 576v pixels. The Pluto has its own frame buffer memory. This enables the icons to be drawn and then stored in the frame buffer memory. When it is necessary to move, or redraw, the icons they are simply and quickly copied from the frame buffer memory. Another advantage of using the Pluto system is that the Pluto's firmware includes a number of graphic manipulation functions that can relieve the host computer of time consuming activities. This effectively reduces the time taken to redraw the screen display. The speed of presentation is important to the subjects who may become frustrated with time consuming procedures, becoming bored and distracted.

The Summa-Mouse:

The Summa-mouse is used to steer a cursor (pointer) around the Pluto display screen. The subjects use the cursor to select virtual switches the program has defined on the Pluto screen. There are three buttons on the back of the Summa-mouse. Pointing at the virtual switches on the screen and then pressing the mouse buttons enables the subjects to control the which screen display is available to them at any given time. The mouse is produced by the Summagraphics corporation and is designed to be compatible with IBM PCs via the use of an RS-232-C interface lead. The use of the Summa-mouse in conjunction with the Future FX30 and the Olivetti necessitated writing special mouse driver software. The mouse driving software¹ is written into the module "Modone" (Appendix 3) in the procedures: Initialmz, Mousein, MoveCursor, and DrawCursor. The module "Modone" is part of every program used in the paradigm.

¹ written by Dr. M.W.Lansdale.

3.3 THE SOFTWARE.

The software involved a presentation program for each of the four experiments carried out, each program involved some form of modification within the paradigm depending on the aims of the particular experiment. All four experiments contained the same testing program ("Memtest" in Appendix 3). These programs were written in MS-Pascal and incorporated procedures from the Pluto graphics package. They can be seen in Appendix 3. The programs contain information about the size and position of the information items, the virtual switches, the icon locations, thereby facilitating accurate replication of the screen displays where a Pluto system is not available. The specifics of each program will be explained with the method for each experiment in the following chapter.

3.4 DATA GATHERING

The first three experiments have several common features in their design. Each experiment involves the subjects sorting the information items of the In-tray exercise, while unaware that they will be asked to participate in a forced-choice recognition test for the icons on the information items. When a subject is reading an information item the associated icon, with all three of the attributes, is displayed. While the subject is sorting the items, or deciding which item to read next, only two attributes are displayed. The subject's task involves sorting the information items with respect to the information that they contain. The two (functional) attributes are a means by which the subjects can identify the information item, and are referred to as the functional attributes because they can be used as a means to identify and therefore access information item. In each of the experiments only one of the attributes is of no obvious use to the subject whilst performing the sorting task (it can only be seen when the information item it is associated with is being read), this attribute will be referred to as the circumstantial attribute.

The initial set of three experiments enables data to be gathered which will indicate the relative levels of recall in several conditions. One such condition is the relative levels of

recall for all three attributes as circumstantial attributes. The experiments also enable an evaluation of the relative levels of recall of the functional attributes. Also of interest is whether attributes that are not linked together as functional (i.e. one of the attributes is functional and one is circumstantial) are linked in memory. Memory for the icon could be recalled as a Gestalt, in an "all-or-none" fashion (e.g, Jones, 1976), or memory could be statistically independent (e.g, Lansdale, 1988).

The forth experiment is similar in design to the first, it has the same functional and circumstantial attributes. The variable in this experiment is in the design of the icons. The icons in the first three experiments are of an intricate design (see Figure 4.1, p80), in the final experiment the shapes are less intricate blocks (see Figure 7.1, p147). This variation in the design of the shape enables a comparison between how the interaction of the attributes is affected by the design of the icons.

3.5 INTRODUCTION TO THE ANALYTICAL APPROACH

3.5.1 POST HOC ANALYSIS

The thesis employs post hoc analysis to investigate the data collected. The experiments are designed to investigate the nature and existence of incidental recall for location, colour, and shape, and a general hypothesis is used to focus the research. The general hypothesis is that there is incidental recall for the dimensions of colour, shape, and location. Beyond this, there are no grounds for being more specific as this might hide interesting trends in the data. Consequently, this research is starting with a very general hypothesis, and once the data is collected more specific hypotheses will be formulated and used to analyse apparent trends. The research is concerned with the relations between the icon attributes of colour, shape and location, their relations to the information items, and how those relations change in various conditions. The purpose of the study being to find some unifying organisation among the events, not necessarily a very simple organisation but an order or a pattern that is at least more coherent than the total set of events. The general hypotheses leads to questions being

asked of the data with a view to discovering its organisation, or structure:

- 1) What is the structure of memory for the location, colour, and shape of an icon?
- 2) How is the level, and structure, of recall affected when location, colour, and shape of an icon are either circumstantial or functional?

As already stated, at this stage no predictions are made about these structures.

Hypotheses about particular structural details should emerge from the patterns that are encountered in the data. This approach focuses on the analysis of trends which are evident in the collected data. In doing so it has the advantage of not limiting the data collected to that which will either support or refute the existence of incidental recall.

The structure of recall for the attributes and the effect of other variables upon recall are all open to investigation once the data has been collected.

The electronic paradigm facilitates the collection of a bulk of varied and complex data. Recording data that initially may not appear to be of direct relevance to the aims of the project leaves scope for investigating unforeseen relationships which may arise, allowing for post hoc analysis. In contrast it is also possible that some of the data may not appear to be relevant to the trends that are becoming apparent. It could be argued that this is an approach where the researcher uses a variety of statistical tests until one demonstrates significance where the researcher believes there are significant trends. Here, the intention is to use the statistical test which is most appropriate to the form of data collected (predominantly Non-parametric tests) and accept the results of that test. This can lead to a more comprehensive understanding of the data and its structure.

3.5.2 ANALYTICAL STARTING POINT

The basic principle behind the use of statistical tests can be summed up as comparing obtained results with chance expectations. From this starting point, the structure of the attributes that would be expected by chance needs to be defined. There are 12 levels of each variable and 12 information items used as stimuli then cues, so the probability of

the subjects allocating an attribute correctly by chance would appear to be 1 in 12. If the subject correctly recalls this 1 in 12 then the probability of making a correct allocation by chance on the remaining 11 cues is increased to 1 in 11. Assuming this form of sophisticated guessing the chance probabilities are affected by what a subject actually recalls, and therefore change with each response that the subject makes. Subjects who recall more of the stimulus will also be more likely to guess the attributes that they do not know with greater accuracy than subjects who recall very little and therefore have a larger pool to guess from. This makes the data analysis rather complex because what the subject actually recalls and correct guesses need to be distinguished to make a realistic comparison.

Lansdale and Laming's (1990) set of papers summarized in "The anatomy of an experiment: An overview" give a plentiful insight into the problems that are encountered when dealing with the analysis of multi-attribute recall and repeated memory trials such as carried out in this thesis. Lansdale and Laming identify methods of analysis that can have substantial effects on the conclusions drawn from data. They demonstrate this on their own data and a re-analysis of Ross and Bower's (1981) data (Lansdale and Laming, Unpublished), where Ross and Bower are comparing three theories of memory structure by their capability to describe data obtained from a multi-attribute experiment.

The suggestion that Lansdale and Laming make is that researchers should employ a Sequential analysis of data. The analysis should gradually build up a picture of the structure of memory, by looking at all the possible sources of each response made by the subjects. The responses that subjects make are identified as originating from three alternative sources, recall of the actual stimulus, recall from another source, or sophisticated guesses. A preliminary analysis of the data collected from the experiments in this thesis is therefore necessary before the structure of recall for the attributes can be seen.

3.5.3 PRELIMINARY ANALYSIS

A preliminary analysis is necessary in order to identify the source of each response made by the subject. In a forced-choice recognition test the response has two possible sources, a guess, or a genuine recall. Similarly, a genuine recall of all three icon attributes may appear in two forms; associated with the cue or not associated with the cue. The latter case is when a correct combination of attributes is applied to the wrong information. There are three probable sources for guesses, the random or blind guess which is the traditional model for dealing with variation in data due to guessing. In random guessing it is assumed that the responses are made with no constraints upon choice at all. A further recognised form of guessing strategies is that of *sophisticated guessing*, where some alternatives are excluded from the pool of possible guesses because they are known to be inappropriate guesses (i.e, what is known to be a correct answer elsewhere is known to be an incorrect answer in another instance). An additional possible source of guessing identified by Lansdale (1979) is the notion of *Yoked guessing*. Yoked guessing occurs in situations where a memory test involves several trials for the recall of a combination of more than one attribute. Yoked guessing is when the answer to a trial involves a correct combinations of attributes applied to an inappropriate cue (see Section 4.3.4 for a more detailed discussion).

The first step in the analysis is to identify which type of response is used by the subject for each cue. Lansdale and Laming suggest that responses should first be presumed to be a recall of the previous item with which the response has most congruency. This procedure can lead to the identification of yoked guesses and correct recalls. It is possible that these correct recalls also include some, unique, correct guesses. Whereas some of the errors may be genuine recalls though incorrectly associated with the cue. Although this method omits identification of some genuine recall and includes some correct guesses it serves to clarify the data into a more concise form.

Use of a forced choice recognition test means that the subjects are obliged to make a response to each cue. In some instances the subject will not be able to recall some, or any, of the attributes. When the subject does not recall an attribute they are obliged to guess. Subjects who remember more of the stimuli are more likely to guess correctly

due to sophisticated guessing techniques. For instance, if a subject recalls the association of three colours with their cue, when forced to guess which colour is associated with a cue the guess is made from a pool of nine alternatives. In comparison, if a subject recalls the association of six colours with cues, the pool from which the subject guesses involves only six alternatives therefore increased recall increases the likelihood of a correct sophisticated guess.

3.6 CONCLUSIONS

The paradigm is designed to investigate the existence and nature of incidental recall. Where incidental recall is the recall of attributes that have not been subjected to any mnemonic techniques for the purpose of a memory test. The attributes under investigation are shape, colour, and location. They are displayed in the form of an icon on information items. The notion of incidental recall is investigated at two levels. The first level is described as "functional". Functional attributes are exposed to the subjects during the sorting task and can be used as a means of discriminating between the information items. The second level is described as circumstantial. Attributes which are only available for the subjects to view when they are reading the information item that the attribute is associated with are described as circumstantial.

For the recall of these attributes to be incidental the subjects attention is directed toward performing a complex task and they are not lead to expect a memory test. The memory test is a forced choice recognition test using the information items that the subjects sorted in the initial task as cues for their reconstruction of the icons.

The analysis will be lead by questions relating to the structure of memory for the attributes under consideration. Investigating the levels of recall for each attribute and how their inter-relationship is affected by the mode in which they are presented i.e, functional or circumstantial. The findings of such investigations have implication for the manner in which the attributes can be of optimum use in the design of a retrieval support system. The following four chapters involve the details of the running and

analysis of each experiment in turn. The eighth chapter opens with an overview of the analysis of these experiments by way of a cohesive introduction to the discussion.

CHAPTER 4

EXPERIMENT I

Chapter Contents

This Chapter describes the procedure used for the first experiment, the format of the collected data, and the analysis. The colour and shape are displayed as functional attributes while the *location* is the circumstantial attribute. The analytical techniques used are detailed in this chapter and then referred to in following chapters. The results indicate that

- a) there is evidence of incidental recall for the colour and shape attributes.
- b) the colour and shape attributes are integrated in memory.
- c) the location attribute was not recalled.
- d) there is evidence of yoked guessing.

4. EXPERIMENT I

4.0 INTRODUCTION.

This experiment is the first in a set of three experiments which complement each other. The experiments investigate incidental recall for the three attributes under consideration while systematically varying the subject's exposure to those attributes. Two levels of exposure are used, one level is procedurally defined as functional and the other as circumstantial (see Chapter 3, p.56). Attributes which are described as functional are exposed to the subjects more frequently than those described as circumstantial. All twelve alternatives of the functional attributes are displayed while the subject is either sorting the information items or choosing one to read. The subjects have the option to use the functional attributes as a means of identifying the information items. The circumstantial attributes are exposed only when the subjects are looking at the information item that is associated with the icon. Both levels of exposure are incidental in the sense that the subjects are not expecting to have their memory tested for the attributes, and the experiment is not designed to direct the subjects' attention towards the attributes. For Experiment I the paradigm is adjusted to enable the colour and the shape of the icon to become the functional attributes for accessing the information items while the location is the circumstantial attribute. For clarity throughout this thesis, the circumstantial attribute will be written in italics. For example in this experiment use of the notation: "shape, colour, and *location* " will be employed, where "*location* " is the circumstantial attribute. The subsequent two experiments compliment this one in that each has one attribute that is circumstantial (*shape*, then *colour*) and two functional attributes used to access the information items (location/colour, then location/shape). The colours used for all ensuing Experiments are those defined in Chapter 3 (see Figure 3.2 and Figure 3.3, p60). The locations used in this and the following Experiments are those described in Chapter 3 (see Figure 3.4, p61). The Icon shapes used in the first three Experiments are illustrated in Figure 4.1 p80.

4.1 METHOD.

Stimulus presentation:

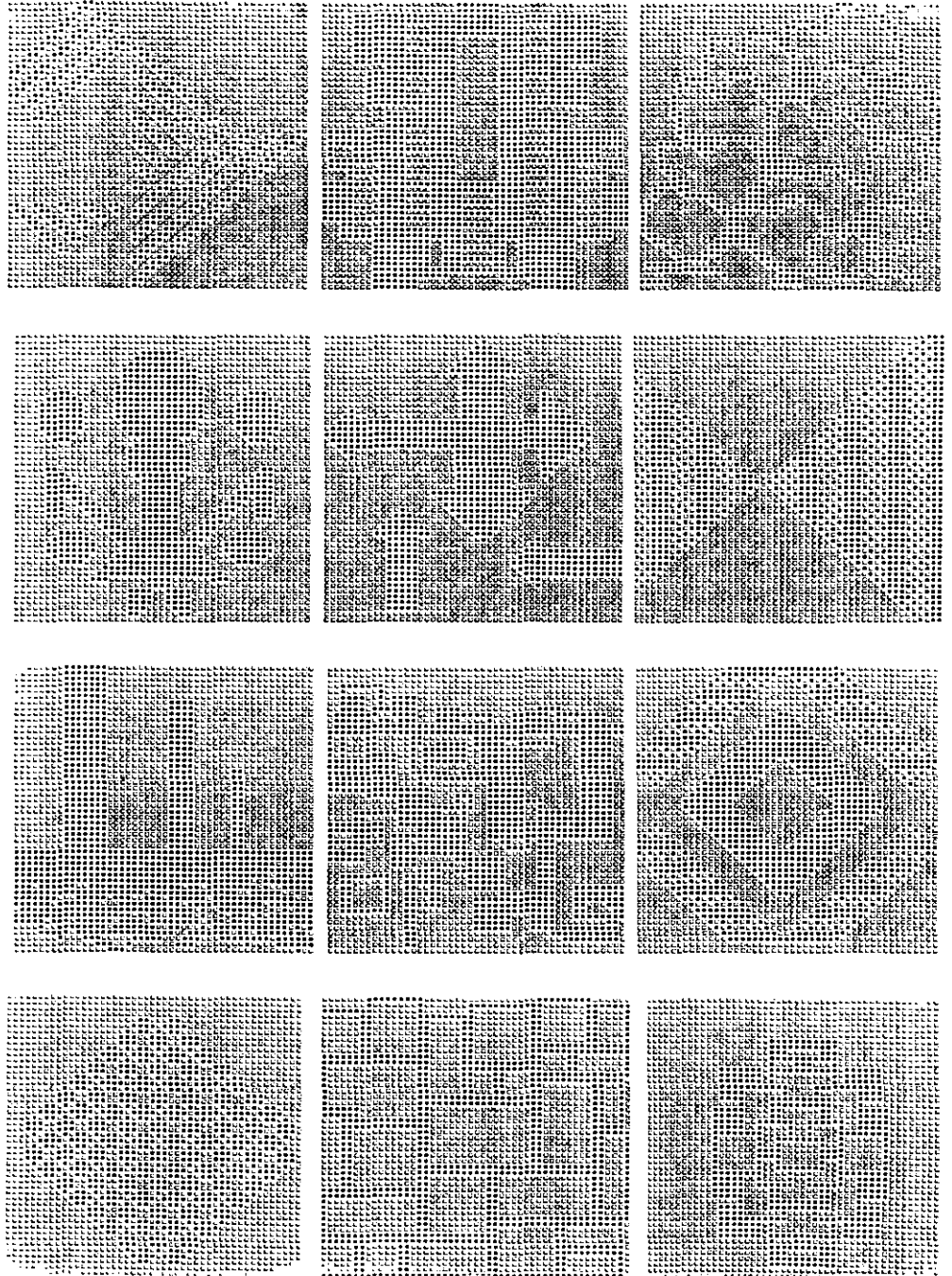
The stimulus presentation program (Appendix 3) has two display modes, one mode enables the subjects to view reduced-size representations of all the information items and will be referred to as the "sorting mode". The second mode enables the subject to read a specific information item, and will be referred to as the "reading mode". The subject controls which mode the program displays via use of an electronic mouse.

In the sorting mode the information items are represented as twelve, overlapping, white rectangles (Figure 4.2, p81) suggestive of a pile of letters/documents. Each rectangle has an icon (shape and colour) on the top left hand corner. For any one subject, the colour, shape, *location*, and information item combination is consistent throughout the sorting task. The combinations of colour, shape, *location*, and information item are initially randomly produced and distinct for each subject.

The subject can change the sorting mode to the reading mode by selecting an item to read. This selection is made by 'clicking' the mouse on one of the information item representations, the white rectangles. Thus, the information item representations act as virtual switches, and change the display to the reading mode. The reading mode alters the display to show the full size information item associated with the icon represented on the switch. Only when the fully-displayed information item is available for reading are the all three dimensions of the icon in displayed simultaneously (Figure 4.3, p81). To return the screen to the sorting mode the subject clicks the mouse on a virtual switch that is always present on the left hand side of the screen.

The program uses a "shuffle" procedure to sort the information items. When the screen is in sorting mode the subject can identify an information item to move by clicking one of the mouse buttons while pointing at its representation on the screen. Similarly, the subject can identify a place in the pile that they would like this information item moved to by clicking another button on the mouse while pointing at that position. Once the subject has identified a place to move the information item to, the information items are

Figure 4.1: The set of Icon shapes used in Experiments I, II, and III.



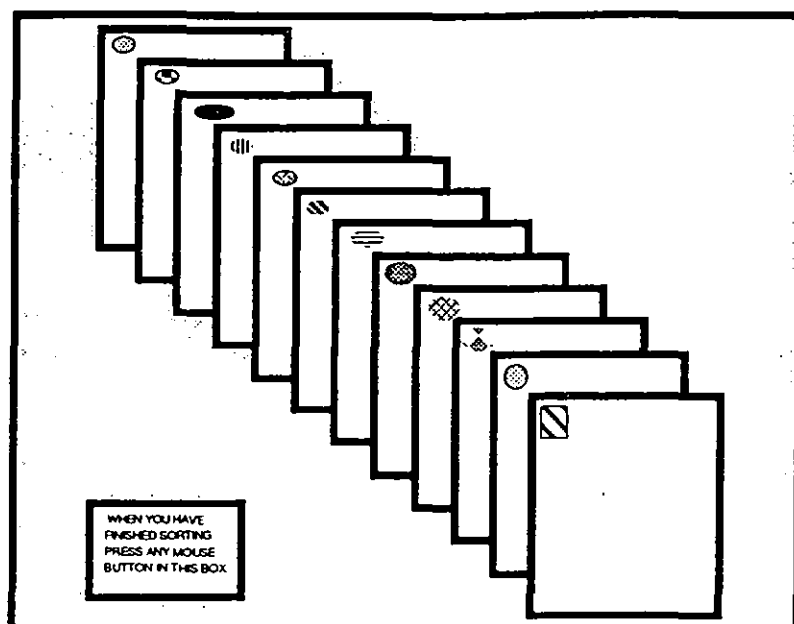


Figure 4.2: A representation of the screen layout used in Experiments I and IV during the sorting mode.

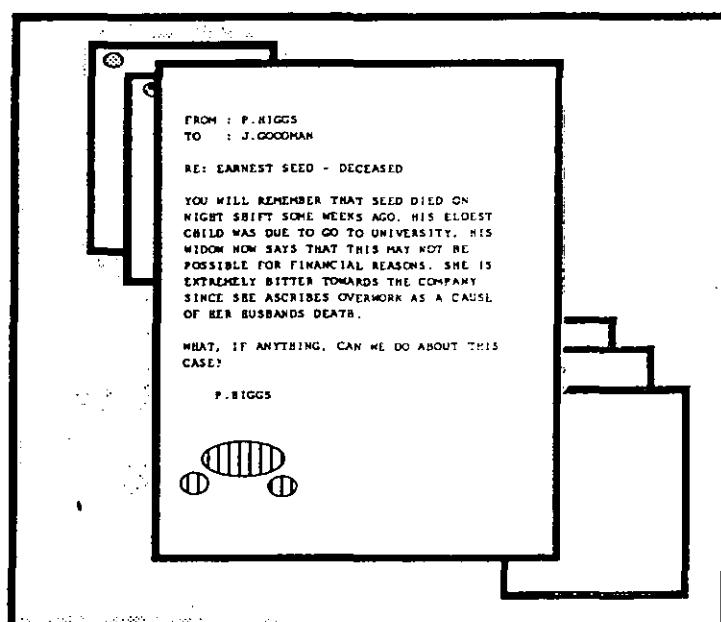


Figure 4.3: A representation of the screen layout used in Experiments I and IV during the reading mode.

N.B. the diagram is not to scale and the icon representations are not those actually used. The icon's used in Experiment I are displayed on page 80, and those used in Experiment IV are displayed on page 147. An illustration of the colours used is available on page 60.

shuffled accordingly as if they were in an overlapping pile with the bottom right hand side of the screen as the top of the pile. In the sorting mode the subjects can identify the information items by their colour and/or shape. The sort procedure involves moving the information item representations, consequently they cannot be consistently identified by their location in the pile. When the subject is satisfied with the order that they have sorted the items into, they express this by clicking the mouse on a virtual switch in the bottom left hand side of the screen which indicates that they have finished sorting. Once the subject has indicated that he/she is satisfied with the arrangement of the information items the program creates a data file. The subject then discusses the task with the experimenter for approximately five minutes. At the end of this discussion the experimenter ascertains whether the subject had any suspicions as to the purpose of the icons. The subject is asked if he/she is willing to undertake a forced choice recognition test for the icon attributes.

The Response:

There is only one mode of presentation during the memory test. The test involves the subjects attempting to reconstruct the icons by selecting a colour, and a shape and placing this combination in one of the twelve locations indicated on the information item which has been presented as a cue (Figure 4.4, p83). The twelve information items are presented as cues sequentially, in random order. For extra clarity through out the thesis when the information items are presented in the memory test they will be referred to as the cues. While the cue is available on screen the subjects are able to change their selection if they are dissatisfied with it. Once the subject has asked the system to supply the next cue via the mouse, provided there they have placed an icon on the present cue, the next cue will be provided. The subject can not change the selections made on cues that have been previously shown.

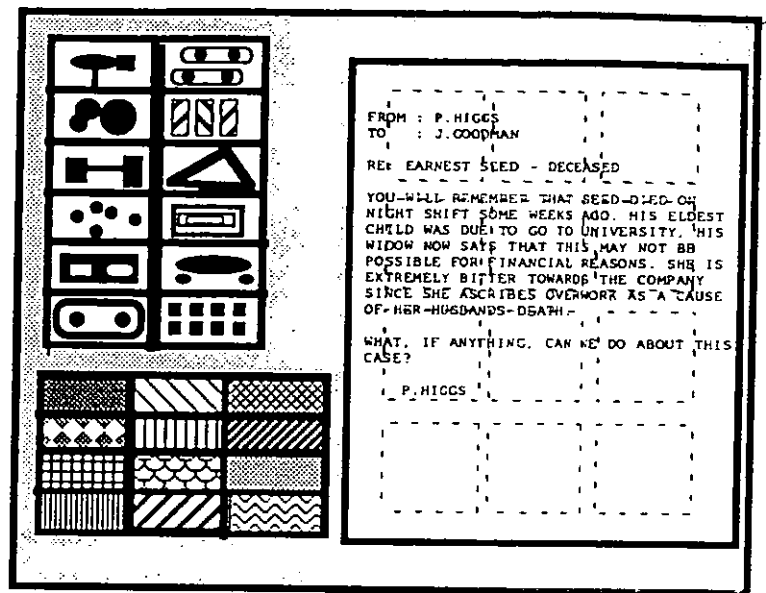


Figure 4.4: A representation of the screen layout used for recreating the icons.

N.B. the diagram is not to scale and the icon representations are not those actually used. The icons used in Experiment I are displayed on page 80, and those used in Experiment IV are displayed on page 147. An illustration of the colours used is available on page 60.

The Subjects:

Twenty subjects completed both the sorting task without expecting the following test, their ages ranged from 18 to 29. The subjects were all students at Loughborough University, Technical College, or Art College, having varying degrees of familiarity with computing systems.

4.2 RESULTS.

The data for the presentation program includes details of each mouse click by the subject (on which virtual switch the click was made). This gives information about:

- i) the initial set up - the configuration of the shape, colour, and location of the icon with which particular information item.
- ii) which information items were accessed and how frequently.
- iii) which information items were moved, their original position and their destination.
- iv) the final order of the information items, i.e, the ratings given to the information items by the subjects.

The test program collects data about:

- i) the presentation order of the information items as cues.
- ii) the icon shape, colour, and location that the subject allocates to an information item.

Not all the data have been subject to analysis, the analysis has concentrated upon the usage of the particular attributes.

4.3 ANALYSIS.

The data collected is of a complex nature, and thus requires complex analysis. In all four ensuing experiments the data has the same format and consequently similar methods of analysis are applied to each experiment. For clarity of presentation the analytical techniques are laid out in detail during the analysis of Experiment I and then referred to during the following experiments as required. The introduction to Chapter 8 includes a summary of the findings of the analyses from all 4 ensuing experiments.

The analysis takes a logical progression through the data. Initially, a coding system is developed to enable the classification of subject responses into mutually exclusive categories. This coding system serves to display the responses in a more readily accessible fashion making the data easier to comprehend. Starting the analysis with an inspection of the absolute levels of recall enables an assertion as to whether the subjects have recalled any of the attributes. If the subjects had no recall for an attribute, and employed a random guessing strategy, recall of the attributes will not be distinguishable from a chance level. Where the levels of recall are of a magnitude that would be expected by chance, the distribution of the attributes is compared to the binomial distribution in order to discover whether the distribution varies significantly from that expected by chance.

Once it has been established whether or not there is evidence that the subjects recall the attributes an analysis of the structure of this recall is approached. In experiments such as this where multi-attribute stimuli are used the recall levels of any one attribute could be dependent upon the recall levels of one, or more, of the other attributes.

Consequently, the possibility of each attribute's independence needs to be investigated. Probability theory is used to predict the combinations of attributes that would be expected to occur if they are independent of each other. The structure of the data is investigated further by taking into account the combinations of attributes which are correctly combined but associated with an inappropriate cue. These instances are known as "Yoked guesses" (Lansdale, 1979). The prospect that some of the combinations of attributes have occurred purely by the chance is considered. An attempt to identify these chance pairings is made and the data is adjusted to take their

existence into account. From this string of analyses an overall picture of the data is drawn.

4.3.1 CODING THE DATA

To facilitate the analysis a classification system is developed. When the subjects make a response to a cue the response is classified into one of the mutually exclusive 15 categories described below. The upper-case letters represent the allocation of an attribute to the cue it was initially displayed with. The lower-case letters represent the allocation of an attribute to a cue that is not the cue it was initially displayed with. The attributes identified by lower-case letters are not included in the null category because they are cases where the attributes are combined as they were during the sorting task and as such it is possible that the subject is displaying recall of this combination.

- CLS colour, location, and shape correctly applied to the cue.
- (cls) colour, location, and shape combined as they were during their presentation, but not applied to the correct cue.
- CL colour and location correctly applied to the cue.
- CS colour and shape correctly applied to the cue.
- LS location and shape correctly applied to the cue.
- (cl) colour and location correctly combined, not with the appropriate cue.
- (cs) colour and shape correctly combined, not with the appropriate cue.
- (ls) location and shape correctly combined, not with the appropriate cue.
- C(ls) colour correctly allocated to the cue. Location and shape appear together as they did in the sorting task, but on the wrong cue.
- L(cs) location correctly allocated to the cue. Colour and shape appear together as they did in the sorting task, but with the wrong cue.
- S(cl) Shape correctly allocated to the cue. colour and location appear together as they did in the sorting task, but with the wrong cue.

- C colour correctly applied to the cue.
- L location correctly applied to the cue.
- S shape correctly applied to the cue.
- Null None of the above combination appeared.

4.3.2 ANALYSIS A: Levels of Recall.

An appropriate starting point to the analysis is to look at the absolute levels of recall (Table 4.1, p88). There are twelve alternatives for each attribute. In a situation where a subject remembered nothing, employing a random guessing strategy would give a 1 in 12 chance of correctly allocating an attribute. Each of 20 subjects participated in 12 trials, a total of 240 trials. Therefore, assuming a random guessing strategy, the number of correctly allocated attributes expected by chance equals 20 (approximately 8%). By an initial inspection of Table 4.1 (p88) the data appears to suggest that this is might be the case where *location* is concerned.

To judge whether the occurrence of *location* varies significantly from a chance level the distribution of the correctly allocated locations is compared to the binomial distribution in Table 4.2 (p88). If the subjects allocate *locations* to the cues at a chance level the distribution of *locations* will resemble the binomial distribution. Alternatively, a significant difference between the distributions would indicate that some subjects displayed better recall of the *location* attributes than others. The evidence of a non-significant difference between the binomial distribution and the distribution of the location attributes does not confirm that the location attribute is recalled at a chance level but circumstantially supports the hypothesis. The binomial distribution is used for the comparison because the small quantity of relevant data suggests that other tests will not have the required sensitivity.

To compare the two distributions (Table 4.2, p88) a goodness of fit test was employed. The statistic used for the comparison was the "G-test" (Sokal and Rohlf, 1973, Chapter 13).

Table 4.1: The absolute levels of recall for each attribute in Experiment I

Colour	= 53 (22%)
Location	= 29 (12%)
Shape	= 81 (34%)

Table 4.2: A Binomial distribution of predicted frequencies, and the corresponding observed frequencies of the correct allocations of the *location* attribute.

Number correct	Relative Predicted Frequencies	Absolute Predicted Frequencies	Observed Frequencies (<i>location</i>)
0	0.3520	7.0400	6
1	0.3840	7.6800	3
2	0.1920	3.8400	8
3	0.0582	1.1640	2
4	0.0119	0.2380	1
5	0.0017	0.1420	0
6	0.0002	0.0040	0
7	0.0000	0.0000	0
...
12	0.0000	0.0000	0
Total	1.0000	12.0000	20

The G-test is based on the likelihood ratio statistic and in general is numerically similar to the chi-square distribution. Nominally the degrees of freedom for this calculation are 7, however they are calculated here as being 4. This approximation is employed because after 4 degrees of freedom the differences between the observed and predicted frequencies of occurrence are very near to zero. For example, with 5 degrees of freedom the difference between the observed and expected frequencies is in the order of 10^{-3} , and would therefore have a minimal effect on the size of the G-statistic obtained. Whilst the critical value of the G-statistic increases with the degrees of freedom. Using 7 degrees of freedom would therefore bias the test in favour of a non-significant result.

Comparing the distribution of correct location applications and the binomial distribution produces a non-significant result ($G = 4.43$, $p=0.01$, with 4 df). This result circumstantially supports the hypothesis that the location attribute is not recalled in combination with the cue. If the location attribute is recalled this recall is minimal. Consequently it seems reasonable to continue the analysis under the assumption that the *location* attribute either occurs at a chance level or recall of *location* is scarce enough to be negligible.

4.3.3 ANALYSIS B: Independence of Recall.

When examining data involving multidimensional stimuli, as in these experiments, it is important to identify whether the attributes are remembered independently (e.g, Lansdale, 1988) or non-independently (e.g, Jones, 1976). The question of interest here is whether the *location*, shape, and colour, attributes occur in pairs or triplets at a frequency that suggests the occurrence is not just the co-occurrence of independent attributes (combinations are at a chance level). Using the coding system described previously, the responses of all twenty subjects are summed in each category (illustrated in Table 4.3, p90).

The occurrence of combinations of attributes in the data appears to be quite high. Table 4.3 implies that colour and shape are recalled well in combination. The comparatively

Table 4.3: The occurrences of the attributes in the coded categorisations during Experiment I.

Attribute combination	Number of occurrences
CLS	10
(cls)	8
CL	1
CS	29
LS	4
(cl)	11
(cs)	38
(ls)	6
C(ls)	1
L(cs)	3
S(cl)	5
C	12
L	11
S	33
Null	68
Total	240

good recall of colour and shape can be seen in the 29 CS pairs and the 38 (cs) pairs. Adding together all of the instances where colour and shape are correctly applied to their associated cue (CLS + CS) gives 39 such observations. From Table 4.1 colour was recalled correctly 53 times in total. Of these, 39 involved colour being recalled in conjunction with the shape: nearly three quarters. This strongly suggests that the attributes do not vary independently of each other.

To test whether the attributes are co-occurring at a chance level the number of correctly allocated *location*, shape, and colour, attributes (Table 4.1, p88) are used as estimates to predict the distribution of attribute combinations based on the assumption that they are independent of each other. Considering only the results where the attributes were correctly applied to the documents, probability theory predicts the expected co-occurrence of attributes for each subject to comply with the equalities laid out in Table 4.4 (p92). These predictions are calculated for each subject separately and then summed for all twenty subjects in order to compare them with the observed group data in Table 4.5 (p92). The calculations are made for individual subjects because predictions from the group average could be misleading.

The observed frequencies of occurrence of attribute combinations vary significantly ($X^2 = 41.83$, $p < 0.01$, with 7df) from the frequencies expected by chance with the existing levels of recall. Looking at the data in Table 4.5 (p92), the main variation between the observed and expected frequencies can be seen in three areas: there are fewer attributes occurring on their own, more occurrences of colour-shape and colour-*location*-shape combinations, and more occurrences of nulls than would be expected if the attributes were independent of each other.

The occurrence of *location* on its own (observed 14 times) appears to be comparable to that expected if it were independent of the other attributes (expected 14 times). The occurrence of *location* in combination with either colour (occurring 1 time as opposed to the expected 4 times) or shape (occurring 4 times as opposed to the expected 8 times) is similarly low. Thus, there appears to be a strong implication that *location* varies independently, while memory for colour and shape conveys potential evidence of some mutual dependency. Considering the previous analysis this is not surprising, if *location*

Table 4.4: The formula used, for each subject's data, to predict the expected occurrences of combinations of attributes from the absolute levels of recall of those attributes:

$$\begin{aligned}
 P(l) &= l/12 \\
 P(c) &= c/12 \\
 P(s) &= s/12 \\
 P(cl) &= (l/12)*(c/12)*(1-s/12) \\
 P(ls) &= (l/12)*(s/12)*(1-c/12) \\
 P(cs) &= (c/12)*(s/12)*(1-l/12) \\
 P(c|s) &= (l/12)*(c/12)*(s/12) \\
 \text{null} &= (1-l/12)*(1-c/12)*(1-s/12)
 \end{aligned}$$

Table 4.5: The summation of each subject's observed and predicted occurrences of attribute combinations for Experiment I:

Arrangement	Observed	Expected
<i>col/loc/shp</i>	10	3
<i>col/loc</i>	1	4
<i>col/shp</i>	29	18
<i>loc/shp</i>	4	8
<i>colour</i>	13	28
<i>location</i>	14	14
<i>shape</i>	38	52
<i>nulls</i>	131	113
Totals	240	240

occurs at a chance level it will be independent of both colour and shape. This lends support to the hypothesis that *location* has not been recalled above chance.

To illustrate more clearly the interrelationship between colour and shape, the *location* attribute data is collapsed out of Table 4.5 (p92). The *location* data is collapsed out of the group data by subsuming the Ls in the nulls category, the CL data is subsumed in the C category, the LS data is subsumed in the S category, and the CLS data is subsumed in the CS category. A chi-square analysis is performed on the subsequent Table (Table 4.6). If *location* is occurring independently the significant variation in the data will remain in the variation of the occurrences of colour and shape. Consequently, collapsing out the *location* data would leave the variation in Table 4.6 significant. The data in Table 4.6 produces a significant ($X^2 = 34.19$, $p < 0.01$, with 3 df) result from the chi-square analysis, illustrating the finding that colour and shape do not vary independently of each other. In Table 4.6 it can be seen that there is an over occurrence of colour-shape pairs and nulls, and an under occurrence of these attributes on their own. The implication is that colour and shape are more likely to be recalled in combination, or not recalled at all, than recalled separately.

The suggestion that *location* is independent is supported by looking at the relationship between *location* and the two other attributes separately. The group data from Table 4.5 is adjusted in the same fashion as for Table 4.6 (p94). In this case shape is collapsed out (Table 4.7). The non-significant chi-square ($X^2 = 3.63$, $p = 0.01$, with 3 df) that is obtained from this comparison implies that the *location* and colour vary independently of each other. Using the same method, an inspection of the relationship between shape and *location* is carried out next. As in Table 4.7 (p94), Table 4.8 (p94) supplies a non-significant result ($X^2 = 1.34$, $p = 0.01$, with 3 df). The implication is that shape and *location* vary independently of each other. Together these tables give credence to the notion that *location* occurs independently of colour and shape. This finding is what would be expected if *location* was occurring at a chance level. This approach to the analysis does not constitute the most rigorous approach possible, however the analysis is sufficient to indicate the nature of the variations in the data.

Table 4.6: The summation of each subject's observed and predicted occurrences of colour and shape collapsing the *location* out:

Arrangement	Observed	Expected
col/shp	39	21
shape	42	60
colour	14	32
nulls	145	127
Totals	240	240

Table 4.7: The summation of each subject's observed and predicted occurrences of colour and *location* collapsing shape out.

Arrangement	Observed	Expected
col/loc	11	7
<i>location</i>	18	22
colour	42	46
nulls	169	165
Totals	240	240

Table 4.8: The summation of each subject's observed and predicted occurrences of shape and *location* collapsing colour out.

Arrangement	Observed	Expected
loc/shp	14	711
shape	15	18
<i>location</i>	67	70
nulls	144	141
Totals	240	240

The independence of *location*, coupled with the very low total correct score (Table 4.1, p88, location = 12%) is consistent with the notion that little, or no recall of *location* has taken place. The analysis continues under the assumption that *location* occurs at a magnitude expected from by chance. Consequently, the levels of recall for *location* are of a negligible level. It therefore seem reasonable, in the following analysis, to collapse *location* out of the data in the same fashion as for Table 4.6 (p94). This enables the analysis to concentrate primarily on the nature of the colour and shape data.

4.3.4 ANALYSIS C: Assessing yoked guessing.

Analyses based primarily on the levels of correct recall can be misleading because they do not take into account the full range of responses possible. For example, the (cs) pairs are attributes from the same icon that have not been associated with the correct cue during the memory test. Such pairs of attributes are suggestive of recall but are lost in analyses that look purely at correct allocations of the attributes to the cues.

"Yoked guessing" is a phenomenon identified by Lansdale (1979), which has relevance to the analysis of the data in this experiment. Yoked guessing occurs in situations where subjects are required to recall multi-attribute data i.e, where there is more than one attribute to be recalled in association with the stimulus cue. Lansdale and Laming (1990) define Yoked guessing as "the recall of an incorrect stimulus fragment". In this set of experiments the stimulus fragment consists of the Icon attributes and information item. Applying the notion of yoked guessing to the data collected here, incorrect stimulus fragments are the occasions such as (cs) combinations when part of an original icon is recalled in combination but not allocated to the correct cue.

These (cs) pairs are important because they reflect the nature of subjects' incidental recall, although they are not "correct" in the strict sense that they were not applied to the correct cue. It is important to consider the occurrence of the (cs) pairs because together with the correct results they give a more comprehensive reflection of the memory representation.

One problem worth consideration in the analysis is that subjects can use the information they know about the testing sequence to employ idiosyncratic guessing strategies in order to improve their response. An example of this would be a subject using the knowledge that each alternative of the attributes is only used once. In an extreme case, a subject could employ a strategy of repeating the usage of one alternative to ensure that at least one response was correct. The particular strategy just described would be inefficient in the sense that the subject would also ensure that eleven of the twelve responses were incorrect. However, the situation becomes more complicated when the subject is sure of some of the attribute combinations and therefore guessing from a smaller pool of alternatives. The purpose of these experiments is to assess incidental recall. Identifying the guessing strategies employed will facilitate this objective by enabling a clearer picture of the memory structure to be drawn. Looking at the usage of the various responses to each stimulus, can give an insight into the guessing strategies employed by the subjects.

The starting point of the analysis of yoked guessing involved writing a program¹ to supply the data in a format which displayed each subject's usage of the alternative attributes. The program provides data that identifies the cue (identified by a number between one and twelve) and how the attributes associated with this cue originally during the sorting task are used by the subject during the test. Examples of this data are given in Tables 4.9 (p98, with the *location* still in) and 4.10 (p98, with *location* collapsed out). Looking at Table 4.10, information item 11, the subject used the colour attribute initially associated with this information item 3 times, and the shape twice. First the subject used the colour with an incorrect cue and not with the shape it was initially associated with, represented by a lower case "c". Next the subject used the colour and shape that were originally associated with information item 11, but applied these attributes to an inappropriate cue, represented by a bracketed lower case "cs". Finally, the subject applied the correct colour-shape combination to information item 11, represented by capital letters "CS". An inspection of response patterns such as these will enable an analysis of whether or not the high usage of (cs) pairs is due to subjects employing strategies which involve the repeated usage of one particular (cs)

¹ The analysis program was written in SNOBOL by Dr. M.W.Lansdale.

pair, or frequent miss-placement of different pairs. In the case of repeated usage of a particular pairing there would be a high number of (cs) pairs shown to be used, but this would not reflect a high level of recall. For example, the data would include instances of the nature (cs),(cs),(cs),(CS), where a subject has used the same combination of colour and shape several times. This can be identified as several recalls of one (cs) pair rather than four recalls of different (cs) pairs.

Table 4.11 displays the response patterns (as described for one subject in Table 4.10, p98) compiled for all 20 subjects. There are five columns, the first column contains all the response patterns which included a CS pair (Correct Colour-Shape). Column 2 contains all the response patterns of (cs), yoked guesses that were never actually applied to the correct cue (Yoked only). Column 3 contains all the response patterns which include correctly applied colour attributes that were at no time used in conjunction with their associated shape (Single Colours). Similarly column 4 contains all the correctly applied shapes that were at no time used in conjunction with their associated colour (Single Shapes). The 5th column contains all the nulls, those occasions when neither the colour or the shape were actually applied to the correct cue or used in their original combination. The rows identify the number of different response patterns identified in each column. Within each column the number of times a particular pattern of responses was used during the experiment is listed beside the description of that pattern. For example in column one row number 2, there are 4 instances when the colour is applied to the wrong cue, then the colour-shape combination is applied to the correct cue (4 c,CS).

The first column in Table 4.11 shows the usage of attributes which were correctly applied to the cue (CS pairs). There are 39 occasions when a colour-shape pair is correctly applied to the cue. The first row in column one indicates that there are 26 occasions when a CS pair is used only once, that single usage being with the correct cue. These 26 occasions are presumably occasions when the subject is confident of the relationship between the colour, shape, and cue. Consequently they do not use any of these attributes in inappropriate combinations. Apart from this first item in column 1 the subjects apply various combinations of the attributes to different cues before they apply the right combination to the appropriate cue.

Tables 4.9 and 4.10 are examples of one subject's response patterns, where the cue document is identified in the first column. The pattern of usage of the icon attributes associated with the cue document during the sorting task is described in the second column. Table 4.9 includes the *location* data, while Table 4.10 is the same same subjects usage patterns with the *location* collapsed out.

Table 4.9:

Document (stimulus) number	Usage of associated attributes
1:	l,(cs),l
2:	(cl),(cs)
3:	CLS,l
4:	l
5:	s
6:	CS,l
7:	s,L,c
8:	S,c
9:	CS
10:	l,s
11:	c,(cs),l,CS
12:	l,(cs),l

Table 4.10:

Document (stimulus) number	Usage of associated attributes
1:	(cs)
2:	c,(cs)
3:	CS
4:	
5:	s
6:	CS,
7:	s,c
8:	S,c
9:	CS
10:	s
11:	c,(cs),CS
12:	(cs)

An interesting feature to note about the responses in column one is that the correct CS pair is frequently the last response in the usage sequence (with the exception of the third item in the column). There are 36 occasions of the 39 usage patterns end with a correct application of a colour-shape combination. The most likely explanation of this, is that the subjects are certain of the colour-shape combination but do not recall which cue this combination is associated with. When the cue is actually presented to the subjects they recognise the cue as being associated with the colour shape pair and therefore recognise when they have allocated the pair correctly. Consequently, prior to the subjects being prompted by the appropriate cue the colour and shape may be used for yoked guessing. Assuming that the 26 cases in column 1, row 1, represent occasions where the subject is certain of the colour-shape-cue combinations these cases can not be included in the explanation above where the subject only recognises the colour-shape-cue relationship upon presentation of the cue. Therefore there are 10 occasions when the response pattern ends in a CS pair, and 3 when the pattern does not. In circumstances where the subject appears certain of the combination of colour and shape but unsure if it is associated with the cue being presented, the colour and shape will occur only in combination. For example (cs),CS (row six in column 1). The fact that the combination is not repeated after being correctly applied to the right cue could indicate that the subject is aware that the combination has been correctly applied.

The second column in Table 4.11 shows response patterns where yoked guessing has occurred excluding those instances where the colour-shape combination is applied to the cue it was originally associated with in the sorting task (those CS instances are covered in column 1). In total 42 distinct (cs) pairs are used (yoked guesses) and never applied to the cue they were originally associated with. The 21 occasions (first item in column 2) where the (cs) pair is only used once could originate from several possible sources such as being combined purely by chance (this possibility will be discussed later), the subject could be employing a strategy of using each attribute alternative only once, or the subject believes that the application is correct and consequently does not use the combination again.

Table 4.11: The occurrence frequency of various response patterns in the group data.

	Correct Colour-Shape	Yoked only	Single Colours	Single Shape	Nulls
Row	Column 1	Column 2	Column 3	Column 4	Column 5
1	26 CS	21 (cs)	2 C	14 S	13 -
2	4 c,CS	8 c,(cs)	1 c,C	6 S,c	39 s
3	3 CS,c	6 (cs),c	1 C,c,c	7 c,S	8 c
4	1 c,(cs),CS	1 c,s,(cs)	1 s,C,s	1 s,S	16 s,s
5	1 s,CS	1 c,c,(cs)	1 c,c,s,C	3 S,s	14 s,c
6	1 (cs),CS	2 (cs),(cs)	1 s,C	4 c,s,S	2 c,c
7	1 s,c,CS	1 (cs),c,(cs)	2 C,s	1 c,S,c	10 c,s
8	1 c,c,CS	1 (cs),c,s	1 c,C,s	1 S,c,c	3 c,s,c
9	1 (cs),(cs),CS,c	1 C,(cs)	1 c,s,C	1 c,c,S	2 c,c,s
10			1 s,c,C	2 S,c,c,c	2 s,c,c
11			1 C,c,s	1 s,c,S,s	1 c,c,c
12				1 c,c,S,c,c	1 s,s,c
13					1 c,c,c,s
14					1 c,c,c,c
15					1 s,c,c,c
Total	39	42	13	42	104 = 240

From the 39 cases in column 1 yoked guessing can be identified as having occurred on three occasions (the patterns described in the forth, sixth, and ninth rows of column 1). With the 42 cases of yoked guessing identified in column 2, and the 3 in column 1, in total there are 45 colour-shape pairs that are used as yoked guesses. These 45 cases represent a substantially higher level of recall for the colour-shape pairs than is identifiable from looking at the CS pairs alone.

Another interesting point to notice about column 1 is that the colour is used separately from the colour-shape pair more frequently than the shape. The colour is used on its own, applied to the wrong cue, in 11 cases, while shape is only used in this fashion during 2 cases. On a purely speculative level this could imply that the subjects use different strategies for the applying the colour and shape attributes to the cues. When applying colour to the cues the subjects appear to be using a more repetitive strategy for than for shape, that is, they tend to apply a single colour more than once despite knowing that the colour was only used once originally.

The pattern noted in column 1, evidence that the colour appears separated from its associated shape more frequently than vice versa, occurs in column 2. The shape occurs on its own in 2 cases, whereas the colour occurs on its own in 19 cases. The effect of the of the separate styles of usage of the colour and shape attributes is accentuated in column 2. This tendency to use colour separately more frequently than shape is also reflected in the data of column 4 (shape is used incorrectly in 9 cases and colour is used in correctly in 24 cases). In each response made by the subjects a shape must be used. Therefore, the apparent under usage of shape must be accounted for somewhere in Table 4.11. The bulk of these shapes can be found in the second row of column 5. The final column containing all the remaining responses, that were never actually applied to the correct cue or in their original combinations. 39 of the 240 shapes were used only once, and that single usage was with an incorrect cue. By contrast only 8 colours were used in this fashion. One possible explanation for this apparent difference in the usage patterns of the shape and colour attributes could stem from their how easy to distinguish they are. It is possible that the twelve shapes are easy to distinguish. During the test the subjects can recall whether or not they have used a particular shape or not. Since the subjects are aware that each attribute is used

only once they may be employing a strategy of using each shape only once. This strategy is possible because they can distinguish between the shapes and hence recall whether or not a particular shape has already been used. In the case of colour, it is possible that the colours are difficult to distinguish and so the subjects favoured strategies which involved the repeated usage of colours they recall from the sorting task.

The response patterns in column 2 end with a (cs) pair 35 out of the 42 cases. Using a correct combination of colour-shape pairs as a final usage of attributes in a response pattern is evident in column 2 though less pronounced than in column 1. The reduction in this trend could be explained with reference to the subjects confidence in allocating the attributes. The subjects do not apply any of the colour-shape pairs in column 2 to the correct cue, implying that they do not recall the correct combination of colour-shape-cue attributes. If the subjects are aware that they do not recall the colour-shape-cue combination increased uncertainty of the combinations would increase their usage in alternative combinations. The fact that there is a trend to use (cs) pairs as the last application in the response pattern can be explained by the probability that the subjects were fairly sure of these combinations of attributes and once they thought that the attributes had been applied to the correct cue they stopped using it.

The third column displays the response patterns that include colour being allocated to the cue it was associated with in the sorting task. 2 colours were accurately placed on the appropriate cues without being used more than once. The fourth column displays the response patterns that include shape being allocated to the cue it was associated with in the sorting task. In contrast to the usage of colour displayed in column 4, there are 14 shapes identified alone with the correct cue. The contrast in the usage of the colour and shape attributes can be most noticeably observed in the totals of these columns, where 13 colours are applied to the correct cue without the associated shape. While 42 shapes are applied to the correct cue without the associated colour.

In summary, it seems feasible to speculate that the subjects use different strategies for allocating the colour and the shape attributes to the cues. The combined effect of these strategies is that more colours are recalled in conjunction with their associated shapes

than separately. The proportions of shapes recalled on their own or in conjunction with their associated shape are similar (approximately 50%). It is possible that the recalled shape acts as a cue for recalling the colour, and that colour is only recalled in conjunction with shape. The fact that only 13 colours are recalled separately from shape supports this hypothesis. These 13 allocations could be the result of chance (assuming random guessing chance levels of recall equal 20 allocations, 8%). Another feature of the data is evident in the fact that the response patterns in column 1 tend to end with the allocation of a correct colour-shape pair. Similarly the response patterns in column 2 tend to end with the application of a (cs) pair. One possible explanation of this occurrence is that the subjects are aware (column 1) or believe (column 2) that they have made the correct allocation of those attributes and so refrain from using them again.

Of the 81 colour-shape combinations identified, some may be the result of the colour and shape being placed together on the cue purely by coincidence, it would be useful to identify how many are coincidental, or chance, pairings and how many are due to the subjects actually recalling their combination. Identifying these chance pairings is the aim of the next analysis.

4.3.5 ANALYSIS D: Chance Pairings.

Despite the fact that memory for colour and shape appears to be linked in some fashion, there could be cases where memory for the colour and shape are independent of each other i.e., where colour-shape pairings have occurred merely as the result of a colour and shape being chosen arbitrarily by the subject. These occasions will be referred to as "chance pairings". There are two properties of a chance pairing which may help in their identification: The attributes in a chance pairing will not occur together very frequently, (because they are not linked in memory), and the attributes that occur together in a chance pairing, may also occur separately on other occasions.

Looking at the data from Table 4.11 (p100), the first property of chance pairings (the attributes will not occur together very frequently) appears to be the norm since colour-

shape pairs only occur together more than once on six occasions. However, it is unlikely that the occasions when colour-shape combinations are repeated are the result of chance pairings consequently they will be excluded from this analysis. Using the conditions that chance combinations of attributes will only occur once, and the combination will be within a sequence of usage of the attributes separate from each other, the chance pairings are identified. An example of the pattern of usage by a subject suggestive of a chance pairing would be: (cs),c,s. On one response the subject uses the (cs) pair, on a later response the subject just uses the c from the initial stimulus set, then later uses just the s from this stimulus set. This re-use of the attributes, not in conjunction, could indicate that the subject does not link them in a consistent fashion in memory, as would be the case for yoked guessing. The implication in this case is that the (cs) pair is a chance combination.

These chance pairings need to be estimated from the data before the subjects memory for the attributes can be accurately quantified. Removing the chance pairings will leave the pairs whose constituent attributes only occurred with each other. From Table 4.11 (p100) the total number of colour-shape pairs without either or both of the constituent parts used separately can be identified and is displayed in Figure 4.5 (p105). By this form of analysis 50 out of the 81 colour-shape pairs are identified as having been recalled in combination rather than being a result of chance pairings. An adjustment of the totals of the group data (from the totals of Table 4.11, p100) so that the CS and (cs) combinations do not include chance pairings, is displayed in Table 4.12 (p105). From this analysis approximately one quarter of the colour-shape pairs that were applied to the cue they were originally associated with can be understood as having been a result of the chance combination of a correct colour and correct shape. A larger proportion (nearly one half) of colour-shape pairs that the subjects did not apply to the cue that they were originally associated with, are due to chance pairings.

Figure 4.5: Identifying the chance pairings from the data in Table 4.11.

occurrences of CS without any c, s, C, or S = 27
(Rows 1 and 6 from column 1 in Table 4.11, p100)

occurrences of (cs) without any c, s, C, or S = 23
(Rows 1 and 6 from column 2 in Table 4.11, p100)

Table 4.12: Adjusting the data to account for the existence of chance pairings
(identified in Figure 4.5 above):

S	C	CS	(cs)	null	Total	
42	14	39	42	104	240	Data from Table 4.11
50	22	27	23	141	240	Adjusted data.

4.4 SUMMARY

The levels of recall for *location* are low and do not vary significantly from chance levels. When the distribution of the *location* attribute is compared with the binomial distribution there is no significant difference, as would be expected if there was no recall for the *location* attribute. Additionally the *location* is recalled independently of the other two attributes. From the low levels of recall, the apparent independence, and the results of the comparison with the binomial theory, it is concluded that there is little evidence for the recall of *location* as a circumstantial attribute in this experiment.

There is evidence for the recall of the functional attributes, colour and shape. The colour and shape appear to be integrated in memory, this conclusion is drawn from the fact that their co-occurrence does not vary as would be expected by chance. Colour and shape occur together at the expense of their recall independently. The levels of recall of the colour attribute separately from its associated shape are of a low level and not distinguishable from chance. This implies that the colour is only recalled in conjunction with the shape. In contrast, when the shape is recalled separately from the colour it is recalled more frequently than would be expected by chance.

On a more speculative level the strategies for applying the colour and shape attributes to the cue's appear to differ, this can be seen by the fact that a substantial number of colours are used repeatedly and applied to cues without the shape they were associated with in their original icon, whereas very few shapes are used repeatedly or applied to the cues without the shape they were associated with in their original icon.

The colour-shape pairings are not all due the fact that they are recalled as a pair, in some instances the attributes occurred together by chance, these instances have been identified and constitute approximately one quarter of the colour-shape pairs allocated to the correct document, and half of the colour shape combinations that were never associated with the correct cue.

The data suggests a structure of recall that essentially occurs in four forms:

- a :- CSD (colour, shape, and cue document remembered in combination)
- b :- CS (colour and shape remembered in combination but not with the cue document)
- c :- S (Shape remembered in association with the cue document)
- d :- Null (Nothing remembered)

CHAPTER 5

EXPERIMENT II

Chapter Contents

This chapter outlines an experiment similar to the one in chapter 4. The main difference is in how the attributes of colour, *shape*, and location are displayed to the subjects. In this experiment the colour and location are functional attributes while the *shape* is the circumstantial attribute. The experiment is described in detail and followed by an analysis of the data. The results show that

- a) there is incidental recall of the attributes.
- b) the functional attribute of location is recalled more frequently than the colour.
- c) levels of recall for colour and shape are comparable.
- d) there is some indication that colour and shape are integrated in memory

5. EXPERIMENT II

5.0 INTRODUCTION.

For Experiment II the presentation program is modified allowing the colour and location (instead of the colour and shape, as in Experiment I) to become the functional attributes, available to the subjects as a means of identifying the information items, whilst the *shape* is the circumstantial attribute. This adjustment necessitates various adjustments to the sorting program whilst the testing program remains unchanged. The sorting program had to be adjusted to enable the twelve locations to displayed as functional attributes, i.e, the locations are not moved by the sorting operation. The locations, shapes, and colours used are identical to those used in the previous experiment. The subject's task is the same as the previous experiment, to sort and prioritise a set of twelve letters as the personnel manager of the fictitious company "Plastic Products".

5.1 METHOD.

The two modes of presentation are the same as in the previous experiment, a reading mode, and a sorting mode. The displays associated with these two modes differ from the displays in Experiment I. The presentation program (Appendix 3) produces an initial display that presents the colour and location attributes of the icon in a functional manner. The colour and the location are available to the subjects in a similar fashion to the colour and shape in Experiment I. All twelve alternatives of each attribute are presented on the screen when it is in the sorting mode.

The sorting mode display in Experiment II (Figure 5.1, p111) consists of a large grey rectangle the same size, shape, and position as an expanded readable information item. On this large grey rectangle are twelve coloured squares, of a similar size to the icons (50 pixels²). These 12 coloured squares are positioned in the location that each icon is situated on its associated information item. Throughout the experiment the location of

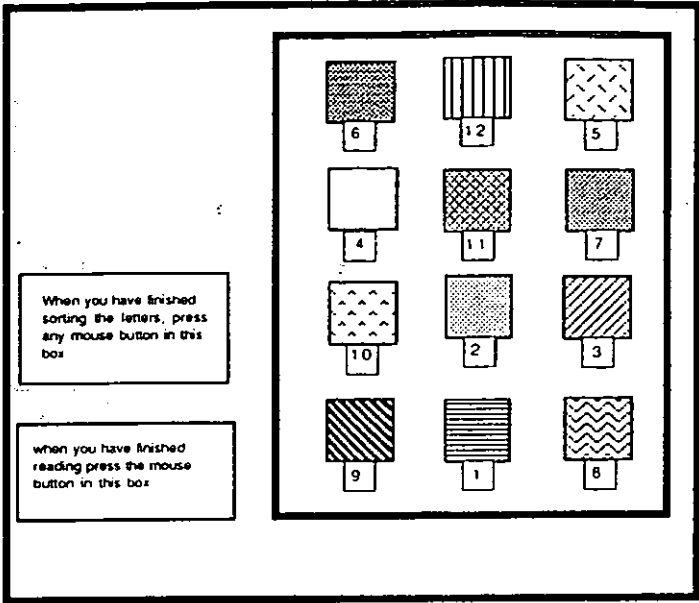


Figure 5.1: A representation of the screen layout used in Experiment II during the sorting mode. (NB the diagram is not to scale). Experiment III used a similar layout with shapes replacing the colour squares.

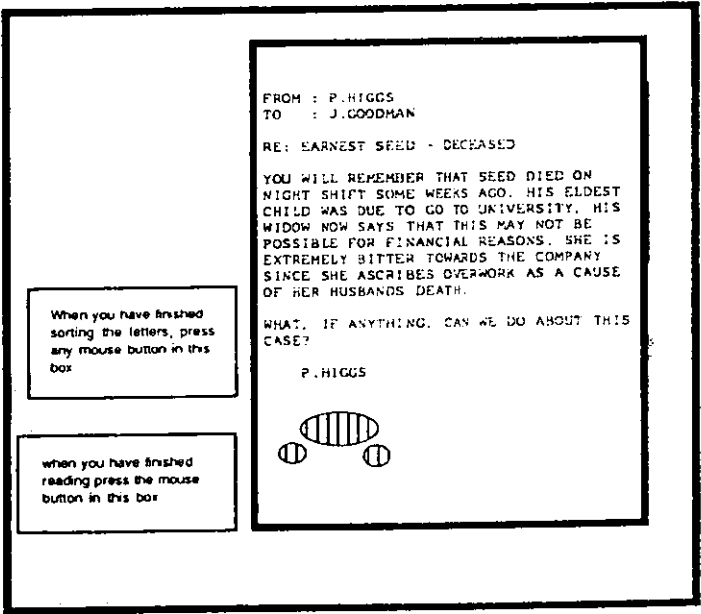


Figure 5.2: A representation of the screen layout used in Experiments II and III during the sorting mode. (NB the diagram is not to scale).

any one icon is unchanged. Similarly, throughout the experiment the colour at any one of these locations is consistent.

When the subject wishes to read an information item they move the mouse to one of the coloured squares (virtual switches) and 'click' the mouse in it. This action changes the screen to the reading mode and displays a full information item to be read (Figure 5.2, p111). The information item is displayed over the grey rectangular box. On the information item is a single coloured icon, in the same colour and location as its associated coloured square on the grey rectangular box. For each subject the combination of *shape*, location, colour, and information item is consistent. This combination is randomly produced for each subject prior to their being introduced to the software.

When the subjects wish to return to the sorting mode, with all twelve information items available, they click the mouse in a virtual switch on left hand side of the screen. The program uses a shuffle routine (as in Experiment I) to enable the subjects to sort the information items. During the sort the means of access (colour/location) to the information items remains consistent and what the subjects actually shuffle are the ratings they give the information items which are represented by numbers placed under the colour/locations. This method of sorting was employed in preference to actually moving the information items (as in Experiment I) because the location attribute had to be presented in a consistent manner throughout the experiment. Only one location is associated with each information item, otherwise the location would lose its functionality as a consistent mode of access.

The sort procedure requires the subjects to place a number one under the information item they believe most important, a number two under the next most important etc. These numbers are displayed in boxes under the colour/location squares and the sort procedure shuffles them in the same fashion as the information items representations were shuffled during Experiment I. When the subjects are satisfied with the arrangement of ratings applied to the information items they end the program by clicking the mouse on a virtual switch in the bottom left hand side of the screen. This first part of the experiment is then discussed with the experimenter. The subject is

asked if they are prepared to participate in a forced-choice memory test for the icon attributes. The subjects were asked if they were expecting a memory test, if they were the data collected was separated from those who were not. The fact that the subject is not expecting a memory test is important to ensure that the memory for all the attributes is incidental. Data collected for subjects who were expecting a memory test was retained, but excluded from further analysis.

The memory test and subject population are identical to those used in Experiment I. The memory test has to be unexpected, therefore, the actual subject sample of 20 was different to that of Experiment I

5.2 RESULTS.

The data collected from the presentation program and the memory test contains the same type of data as collected in Experiment I. This facilitated the analysis by enabling the usage of the same coding system used previously. Consequently, the data from the experiments can easily be compared.

5.3 ANALYSIS.

The approach to the analysis takes the same initial format as Experiment I. Starting with an inspection of the absolute levels of recall for each attribute. Where the levels of recall are minimal and possibly attributable to chance, the distributions of the correctly applied attributes are compared to the binomial distribution by a goodness of fit test using the G-Statistic (see Chapter 4, p89).

The independence of the attributes is investigated. For each subject probability theory is used to predict how the attributes would occur in combinations if they varied independently of each other. These predictions are summed for all twenty subjects and then compared to the observed occurrences of the combinations.

The data is inspected for the occurrence of yoked guesses, for both the functional attributes and the colour-*shape* combinations.

5.3.1 ANALYSIS A: Levels of Recall.

An initial look at the absolute levels of recall, in Table 5.1 (p115), shows that colour and *shape* have comparable, low, levels of recall: 13% and 15%. These levels of recall seem close to the recall level of location in Experiment I: 12%. In Experiment I recall of both the functional attributes was good in comparison to recall for the circumstantial attribute. In Experiment II it appears that recall for one of the functional attributes, location, is good while recall of the other, colour, is comparable to that of the circumstantial attribute.

The low recall levels of colour and *shape* could be due to the subjects employing random guessing strategies. To investigate whether the colour and *shape* attributes vary at a level not expected to occur by chance the distribution of the correctly allocated attributes is compared to the binomial distribution in Table 5.2 (p115). The G-Stat is calculated for both colour and *shape*. For colour, nominally the degrees of freedom are 7. However, the quantities of data beyond 5 degrees of freedom are too small to have a substantial effect on the value of G while the associated critical value of G will be affected by the increasing degrees of freedom, consequently 5 df was considered the most appropriate level view the data from. For colour the comparison with the binomial distribution produced a non-significant result ($G = 2.625$, $p=0.01$, with 5df). This provides circumstantial evidence for the notion that the colour attribute varies in a manner associated with chance. The calculation is somewhat more complicated for the *shape* attribute, since the calculation of the G statistic involves natural logs and therefore cannot be calculated for empty cells. In Table 5.2 the data for *shape* includes two empty cells where no subjects recalled either 4 or 5 shapes. The fact that two subjects recalled 6 and 7 shapes respectively suggests that these two subjects have recalled the shape. Working out the G statistic for the remaining 4 categories produces a non-significant result ($G = 1.863$, $p=0.01$, with 3df). For 18 out of the 20 subjects there is no significant recall of the *shape* attribute. These low levels of recall

Table 5.1: The absolute levels of recall for each attribute from Experiments I and II.

Experiment II	Experiment I
Location = 85 (35%)	<i>Location</i> = 29 (12%)
Colour = 32 (13%)	Colour = 53 (22%)
<i>Shape</i> = 35 (15%)	Shape = 81 (34%)

Table 5.2: A comparison of the observed colour, *shape*, and location distributions with the binomial distribution

Number of Corrects	Relative Predicted Frequencies	Absolute Predicted Frequencies	Observed	Frequencies		
			colour	location	<i>shape</i>	
0	0.3520	7.0400	5	2	3	
1	0.3840	7.6800	6	2	9	
2	0.1920	3.8400	4	3	5	
3	0.0582	1.1640	3	2	1	
4	0.0119	0.2380	1	3	-	
5	0.0017	0.1420	1	4	-	
6	0.0002	0.0040	-	-	1	
7	0.0000	0.0000	-	-	1	
8	0.0000	0.0000	-	-	-	
9	0.0000	0.0000	-	2	-	
10	0.0000	0.0000	-	1	-	
11	0.0000	0.0000	-	1	-	
12	0.0000	0.0000	-	-	-	
Totals:	1.0000	20.0000	20	20	20	

coupled with the lack of significant variation from the binomial distribution implies that there is little recall for the attributes.

The data in Table 5.2 (p115) includes the distribution of the location attribute, by inspection it is clear that the location distribution differs significantly from what would be expected by chance because of the four subjects who between them recall 39 of the correctly recalled locations. The distribution of location therefore suggests that the high levels of recall for location are mainly due to the high recall of these four subjects since they account for nearly half of the correctly applied locations.

Table 5.3 (p117) has similar origins and design to Tables 4.9 and 4.10 (p.98) in Chapter 4. The number in the left hand column is the identification number of the information item that the icon attributes were originally displayed with. The right hand column is an indication of how frequently, in what combination, and what order those attributes were used. In the right hand column (Table 5.3, p117) a capital letter representing either *shape* or location indicates that the attribute was correctly paired with the cue. A lower case letter in the right hand column indicates that the attribute was used but not with its original stimulus. For example, during the memory test subject Number 4 used the *shape* associated with information item 9 (9: s,L,s) twice, neither times with information item 9. Subject number 4 used the location associated with information item 9 once, with information item 9, after having used the *shape* once, and before using the *shape* again.

The fact that four subjects recall a large proportion of the correctly allocated locations could reflect a tendency to employ effective strategies for recalling the information required in the memory test. Looking at the data of the four individual subjects who recalled location well (Table 5.3, subjects 4, 14, 15, and 19) it can be seen that subject 4 who recalled 11 of the locations recalled none of the *shapes*. Subjects 14 and 15 both recalled 9 locations and 2 *shapes*. The chance level of correctly applying a *shape* using a random guessing strategy is 1 out of the twelve options available to each subject. These three subjects appear to have good recall for location while their recall for *shape* is near to chance levels. On the other hand, subject number 19 recalled 10 of the locations and also recalled 7 of the *shapes*. In the case of subject 19 it appears that

Table 5.3: Selected subject response patterns for location and *shape*.

The first column is the identification number of the stimulus that the attributes in the second column were originally associated with. The second column represents the pattern of usage of the icon attributes by the subject.

Subject No 4:		Subject No 12:	
1:	L, l, s,	1:	
2:	LS, s,	2:	LS,
3:	L, s,	3:	l, S,
4:	L,	4:	S,
5:	s, L,	5:	s, L,
6:	s, L,	6:	S, l,
7:		7:	l, s, l, l, L,
8:	LS,	8:	LS,
9:	s, L, s,	9:	s, L, l, s,
10:	s, L,	10:	l, S,
11:	LS,	11:	
12:	L, s,	12:	s, s,

Subject No 14:		Subject No 15:		Subject No 19:	
1:	s, L,	1:	L, s,	1:	S,
2:	L,	2:	(ls),	2:	LS,
3:	s, s, L,	3:	S,	3:	L,
4:	s,	4:	L,	4:	LS,
5:	l, l, L, s, s,	5:	(ls),	5:	L, s,
6:		6:	L, s	6:	s, L,
7:	L, s, l,	7:	L, s, l,	7:	LS,
8:	L, s, s	8:	LS,	8:	s, L,
9:	LS,	9:	L, s, s,	9:	l, LS,
10:	LS,	10:	s, L,	10:	(ls), LS,
11:		11:	L, s,	11:	s,
12:	L, s	12:	s, L,	12:	LS,

the subject has a good memory for all the attributes, whereas subjects 4, 14, and 15 appear to recall the location well but not the *shape*. Considering the performance of subject 19, 6 out of the seven *shapes* recalled are in conjunction with a correctly recalled location. The trend for all four subjects who recall location well is to recall *shape* in conjunction with a location. The issue of the independence of the attributes is investigated in more detail during the following section.

5.3.2 ANALYSIS B: Independence of Recall.

First, looking at the occurrences of the attributes in Table 5.4 (p119). The recall of location-*shape* combinations [LS=13 & (ls)= 13] in Experiment II is better than the recall of the functional attributes [CL=6 & (cl)=11]. It seems likely that the tendency in Experiment I to integrate colour and shape in memory was not due to the fact that both these attributes were functional since the same effect is not readily apparent in Experiment II. Following this line of reasoning and focussing attention on the functional attributes, the colour-location pairings in Experiment II seem to be of a low magnitude [CL=6 & (cl)=11] in comparison to the colour-shape pairings in Experiment I [CS=29 & (cs)=38].

Applying the method used in Experiment I, probability theory is used to predict the expected co-occurrences of the attributes from their absolute levels of recall. The comparison of the expected and observed co-occurrences of the attributes (Table 5.5, p119) is significant ($X^2 = 25.51$, $p < 0.01$, with 7 df). Consequently it can be concluded that the combinations of attributes do not vary in the manner that would be expected by chance. The observed occurrence of the location attribute (L=58, LS=13, CL= 6) is close to its expected occurrence (L=61, LS=15, CL= 6) which suggests that the variation in the data is not due to variations in the location. The variation in the data is most evident in the number of colours that are identified on their own (13 observed and 21 expected), the number of all three attributes combined (8 observed and 2 expected), and the occurrence of nulls (128 observed and 117 expected). To investigate the nature of this variation in more detail the *shape* data is collapsed out (as in Experiment I)

Table 5.4: The occurrences of the attributes in the coded categorisations during Experiments I and II

Attribute combination	Number of occurrences	
	Exp I	Exp II
CLS	10	8
(cls)	8	11
CL	1	6
CS	29	5
LS	4	13
(cl)	11	11
(cs)	38	11
(ls)	6	13
C(ls)	1	1
L(cs)	3	6
S(cl)	5	2
C	12	12
L	11	52
S	33	7
Null	68	82
Total	240	240

Table 5.5: The summation of each subject's observed and predicted occurrences of attribute combinations for Experiment II.

Arrangement	Observed	Expected
col/loc/shp	8	2
loc/shp	13	15
col/loc	6	6
col/shp	5	3
colour	13	21
location	58	61
shape	9	14
nulls	128	117
Totals	240	240

enabling a closer examination of the variation due to the functional attributes, location and colour.

The comparison of the observed and expected occurrences of the location and colour in Table 5.6 supplies a non-significant result ($X^2 = 5.34$, $p=0.01$, with 3 df). This suggests that despite the fact that colour is functionally linked to location they are recalled independently of each other. This implies that the mutual functionality of the attributes does not ensure they will be recalled well in combination. Consequently, the integrated recall of colour and shape in Experiment I may not be due to the fact that they were the functional attributes. One possible explanation for the lack of evidence suggesting the integration of the functional attributes in memory could be that the subjects employ a strategy where they select one functional attribute to use as a means to identify the information items. If this is the case then one of the functional attributes becomes redundant. Assuming this strategy, from Table 5.1 (p115), it would appear that the subjects have a preference for choosing shape (Experiment I), or location (Experiment II), over colour, when they are functional.

It is possible that the apparently low levels of recall for *shape* and colour have negligible effects on the data. It is also possible that the colour and *shape* have a natural tendency to become integrated in memory, as was the case in Experiment I. In Table 5.7 (p121) the location data is collapsed out to investigate this hypothesis. The significant result demonstrated by the comparison made in Table 5.7 ($X^2 = 17.10$ $p < 0.01$ with 3 df) points to the conclusion that colour and *shape* are integrated in memory, even though colour was a functional attribute and *shape* was circumstantial. Although colour and *shape* do not occur very frequently, this occurrence has a tendency to be together rather than independently. All the variation in the data might be due to this covariance. It is possible that there might be a covariance between location and *shape* as well, this is checked by collapsing out the colour data in Table 5.8 (p121). The non-significant result of this ($X^2 = 1.67$, $p=0.01$, with 3 df) comparison, coupled with the non-significant result from Table 5.6 (p121) implies that the location varies independently of the *shape*, and independently of the colour (as in Experiment I). This finding mirrors that of Experiment I and leads to the supposition that the level of recall, and the functionality

Table 5.6: The summation of each subject's observed and predicted occurrences of location and colour with *shape* collapsed out.

Arrangement	Observed	Expected
col/loc	14	8
colour	18	24
location	71	77
nulls	137	131
Totals	240	240

Table 5.7: The summation of each subject's observed and predicted occurrences of *shape* and colour with location collapsed out.

Arrangement	Observed	Expected
col/ <i>shp</i>	13	5
colour	19	27
<i>shape</i>	22	30
nulls	186	178
Totals	240	240

Table 5.8: The summation of each subject's observed and predicted occurrences of *shape* and location with colour collapsed out.

Arrangement	Observed	Expected
loc/ <i>shp</i>	21	18
location	64	67
<i>shape</i>	14	18
nulls	141	137
Totals	240	240

of the attribute, does not affect whether the attribute is recalled independently or in conjunction with another.

In summary, this analysis suggests that there is a tendency to integrate colour and shape even when the levels of recall are minimal and they are not both functional attributes as they were in Experiment I. Location is recalled well and appears to be recalled independently of the other attributes. The functionality of the attributes does not appear to affect whether they are recalled independently or in conjunction with each other.

5.3.3 ANALYSIS C: Yoked Guessing.

The analysis of yoked guessing in Experiment II will cover both the colour-*shape* pairs because they appear to be integrated in memory, and the location-colour pairs because they were the functional attributes. Useful comparisons can be drawn between these sets of data and the data in Experiment I (Table 4.11). The existence of (cs) and (cl) pairs indicates the existence of yoked guessing. The design of Tables 5.9 (p123) and 5.11 (p124) is based on that of Table 4.11, this design is explained in more detail in Chapter 4 (p98).

The first column in Table 5.9 (p123) shows a similar trend to column 1 of Table 4.11 (p100). The correct CS pair is the final allocation in the response patterns for a substantial majority of the responses (12 out of the 13 cases). For the colour-location combinations (Table 5.11, p124) a similar trend is identifiable in that the CL pairs are identified at the end of each case in 12 out of 14 occasions. In both Tables there are nearly twice as many yoked guesses as correct applications [CS=13, (cs)=26, CL=14, (cl)=22]. Whereas in Experiment I, Table 4.11 (p100), the levels are initially comparable [CS=39, (cs)=42]. Even though the co-occurrence of location and colour is not significant the usage patterns are very similar to the usage patterns of colour and *shape*.

Table 5.9: The occurrence frequency of various response patterns in the group data for colour and shape.

	Correct Colour-Shape	Yoked only	Single Colours	Single Shape	Misplaced: Nulls
row	Column 1	Column 2	Column 3	Column 4	Column 5
1	8 CS	8 (cs)	1 C,s	4 S	12 -
2	1 (cs),CS	5 (cs),c	2 C,c	7 c,S	18 c
3	2 c,c,CS	2 c,(cs)	4 s,C	3 S,c	37 s
4	1 c,CS	2 (cs),s	1 s,s,C	2 S,c,s	6 s,s
5	1 c,CS,s	1 s,(cs)	1 C,s,c	2 c,S,c	28 c,s
6		1 (cs),C	2 s,c,C	1 s,S,s	29 s,c
7		1 C,(cs)	1 s,C,s	1 c,c,S	5 c,c
8		1 (cs),(cs)	1 c,s,C	1 s,S,c	8 s,c,s
9		2 (cs),c,c	1 C,c,c	1 c,c,S,c	2 c,s,s
10		1 c,(cs),s			3 s,c,c
11		1 (cs),s,c			5 c,s,c
12					5 c,c,s
13					1 s,c,s,c
14					1 c,c,s,s
15					1 s,s,c,s
16					1 s,s,s,s
17					1 c,c,s,c
Tot.	13	26	16	22	163 :240

Table 5.10: Comparing the totals from Table 5.9 with those of the corresponding Table of data in Experiment I

	C	S	CS	(cs)	null	Total
E I	13	42	39	42	104	240
E II	16	22	13	26	163	240

Table 5.11: The occurrence frequency of various response patterns in the group data for the salient attributes; colour and location.

	Correct Colour- location	Yoked only	Single Colours	Single Location	Misplaced: Nulls
row	Column 1	Column 2	Column 3	Column 4	Column 5
1	5 CL	7 (cl)	5 C	19 L	13 -
2	1 (cl),CL	2 (cl),c	2 C,l	9 c,L	29 c
3	2 c,CL	2 (cl),l	1 C,c	2 l,L	21 l
4	1 Cl,(cl)	2 C,l,(cl)	1 l,C	14 L,c	18 l,c
5	2 l,CL	1 c,l,(cl)	1 c,C	1 L,l	9 c,c
6	2 c,c,CL	1 L,c,(cl)	1 c,C,l	4 c,L,c	11 c,l
7	1 l,c,CL,l	1 (cl),c,c	3 c,l,C	2 l,L,c	4 l,l
8		1 c,c,(cl)	1 C,c,c	1 L,c,l	2 l,c,l
9		1 c,(cl),l	1 l,c,C	3 L,c,c	2 l,c,c
10		1 l,(cl),l		1 l,l,L	4 c,l,l
11		1 L,(cl),l		1 L,l,c	1 c,l,c
12		1 l,l,(cl),l		2 c,c,L	1 c,c,l
13		1 c,l,(cl),c		1 c,l,L	2 c,l,c,l
14				2 L,c,c	1 l,l,c,c
15				1 l,l,c,L	1 l,l,c,l,l
16				2 c,c,L,l	
17				1 c,l,L,l	
18				1 c,L,c,c	
19				1 c,L,l,c	
20				1 l,l,c,l,L	
totals	14	22	16	69	119 :240

5.3.4 ANALYSIS D: Natural Integration of Colour and Shape?

In both Experiments I and II there is evidence to suggest that colour and shape are not recalled independently of each other. Comparing the usage of L & C in Experiment II (Table 5.11) because they are both functional attributes with that of S and C (Table 5.9) highlights the tendency to integrate shape and colour. In Experiment II, though location and colour are the functional attributes, the strength of this association is comparable to that of colour and *shape* (CS=12, LC=12, cs=24, lc=22) even though the *shape* is circumstantial. It is obvious that the main differences between these pairings is in the region's of L (when there is a high occurrence of L on its own: 69), C (a low enough occurrence to be considered negligible: 16), and nulls (less with the location-colour pairs). There appears to be a tendency amongst subjects to have memories linking colour and shape, even when this link is not stressed, as in Experiment II.

5.3.5 ANALYSIS E: Chance Pairings

Within the data there will be cases where pairs of attributes occur together in the correct combination purely by chance. Using the same method of identifying these as in Experiment I for colour and *shape* Figure 5.3 (p126) identifies 9 CS pairs and 9 (cs) pairs that have most likely not occurred by chance. The same process applied to the location colour (Figure 5.4, p126) pairs identifies 7 CL pairs and 7 (cl) pairs. The data is adjusted to account for these chance pairings in Table 5.12 and Table 5.13 (p126) respectively.

Figure 5.3: Identifying the colour-shape chance pairings from the data in Table 5.9

occurrences of CS without any c, s, C, or S = 9

occurrences of (cs) without any c, s, C, or S = 9

Table 5.12: Adjusting the data from Table 5.9 to account for chance pairings

	C	S	CS	(cs)	null	Total	
E II	16	22	13	26	163	240	
E II	20	26	9	9	176	240	Adjusted for chance pairings

Figure 5.4: Identifying the colour-location chance pairings from the data in Table 5.11.

occurrences of CL without any l, c, C, or L = 7

occurrences of (cl) without any l, c, C, or L = 7

Table 5.13: Adjusting the data from Table 5.11 to account for chance pairings

	C	L	CL	(cl)	null	Total	
E II	16	69	14	22	119	240	
E II	23	76	7	7	127	240	Adjusted for chance pairings

5.4 SUMMARY

One of the functional attributes, location, is recalled well. Recall of the other functional attribute, colour, does not significantly vary from a chance level. Though location and colour are linked as functional attributes they are recalled independently of each other. This contrasts with the trend in Experiment I where the functional attributes of colour and shape appear to be integrated in memory. The implication is that the mutual functionality of attributes does not ensure that they will be recalled well in combination. Perhaps the subjects are only using one of the functional attributes as a means to access the information items, preferring to use location, therefore making the functionality of the other attribute redundant.

The recall levels of both colour and *shape* are near chance, if they are recalled, recall is at a minimal level. However, there is evidence that suggests that *Shape* and colour are integrated in memory in this experiment as well as in Experiment I.

Modelling the structure of recall in this experiment suggests that there are only two forms of recall occurring:

- a: Location-Cue (the "L" code)
- b: colour-*shape* (the "(cs)" code)

The following experiment will serve to substantiate whether the integration of colour and shape occurs when the location and shape are displayed together as the functional attributes. The consistency of the occurrence of the location attribute independently in memory will also be investigated in this situation.

CHAPTER 6

EXPERIMENT III

Chapter Contents

This chapter describes an Experiment in which the procedural combination of the attributes as functional and circumstantial compliments the previous Experiments. In this Experiment the location and shape are displayed as functional attributes while the *colour* is displayed as the circumstantial attribute. The chapter involves a description of the procedure used and analysis of the data collected. The results show that

- a) there is evidence for incidental recall of the attributes.
- b) the functional attribute of location is recalled more frequently than the shape
- c) recall of shape appears to occur only in conjunction with location
- d) there is no evidence for the integration of *colour* and shape

6. EXPERIMENT III

6.0 INTRODUCTION.

The third Experiment compliments the previous two. It completes a set in which each of the three attributes is used as a circumstantial attribute in one Experiment and as a functional attribute in the other two Experiments. The location, colour, and shape attributes are identical to those used in the previous two Experiments. The presentation program is adapted for Experiment III. The sorting task is identical in both Experiments II and III. The display is altered slightly for Experiment III. The program (Appendix 3) uses the icon attributes location and shape as the functional, item-identifying attributes, whilst the icons are only presented to the subjects with their associated *colour* when a full information item is displayed to be read.

6.1 METHOD.

There is only one main difference between the methods used in Experiment II and III. This difference is in the attributes that are used on the display when it is in the sorting mode. The virtual switches for accessing the information items are black shapes instead of coloured squares. The program employs the same method of sorting the information items as in Experiment II.

The program and procedure used to collect the data relating to what the subjects recalled of the icon attributes is the same as in both previous Experiments. The subject sample of 20 is drawn from the same population as the previous Experiments, though none of them had participated in any of the previous Experiments. This helped to ensure that the subjects were not expecting any form of memory test succeeding the initial sorting task.

6.2 RESULTS.

The data collected from the presentation program and the memory test in this Experiment was of the same kind that collected in the previous two Experiments.

6.3 ANALYSIS.

The analysis of previous Experiments has indicated that location varies independently of shape and colour, while shape and colour have been integrated in memory. The analysis will follow a similar path to previous analyses first looking at the absolute levels of recall for the attributes and ascertaining whether their occurrence is likely to be due to recall or random guessing strategies. The independence of recall for the attributes will be investigated to ascertain whether the location continues to vary independently and whether there is further evidence for an integration of recall for shape and *colour*. The response patterns are looked at to note the existence of yoked guessing and enable an identification of any combinations of attributes that may have occurred together as a result of chance. This results in a picture of the structure of the recall for the attributes in this Experiment.

6.3.1 ANALYSIS A: Levels of Recall.

Looking at the absolute levels of recall for the attributes in Experiment III (Table 6.1, p132) indicates that the circumstantial attribute, *colour*, is recalled 24 (10%) times. Assuming that the subjects had no recall of the colour attribute, and were employing a random guess strategy, the chance levels of correctly allocating an attribute would be 1 in 12, summing for all twenty subjects would give an expected occurrence of an unrecalled attributes as 20 times (8%). The 24 (10%) correct identifications of *colour* are very near this chance level and of similar proportions to the correct identifications of *location* in Experiment I. The implication is that the *colour* attribute in this Experiment has not been recalled.

Table 6.1: The absolute levels of recall for the first three Experiments.

Experiment III	Experiment II	Experiment I
<i>Colour</i> = 24 (10%)	<i>Colour</i> = 32 (13%)	<i>Colour</i> = 53 (22%)
<i>Location</i> = 101 (42%)	<i>Location</i> = 85 (35%)	<i>Location</i> = 29 (12%)
<i>Shape</i> = 46 (19%)	<i>Shape</i> = 35 (15%)	<i>Shape</i> = 81 (34%)

Table 6.2: A comparison of the observed *colour* and *shape* distributions with the binomial distribution

Number of Corrects	Relative Predicted Frequencies	Absolute Predicted Frequencies	Observed Frequencies	
			<i>colour</i>	<i>shape</i>
0	0.3520	7.0400	3	5
1	0.3840	7.6800	10	3
2	0.1920	3.8400	7	3
3	0.0582	1.1640	-	3
4	0.0119	0.2380	-	2
5	0.0017	0.1420	-	4
6	0.0002	0.0040	-	-
7	0.0000	0.0000	-	-
...
12	0.0000	0.0000	-	-
Totals:	1.0000	20.0000	20	20

To investigate this hypothesis further the distribution of the correctly identified *colour* attributes is compared to the binomial distribution in Table 6.2 (p132). It is obvious from Table 6.2 that the shape attribute does not vary in a manner expected by chance since the distribution of the data involves 4 subjects recalling five shapes when the binomial distribution suggests that they would only recall approximately one tenth of an attribute. The G-statistic is used to test the goodness of fit between the binomial distribution and the *colour* attribute and produces a non-significant result ($G=2.86$, $p=0.01$, with 2df). This result gives no reason to suppose that the *colour* attribute is applied to the correct cue above chance levels.

The recall level of the circumstantial attribute in this Experiment (10%) is the lower than the recall levels for the circumstantial attributes in previous Experiments (12% and 15%). Conversely, location is recalled 101 (42%) times, more frequently than any other functional attribute in previous Experiments. In Experiment II *colour* and *shape* were associated in such a way that one attribute was displayed for the subjects functionally and the other displayed circumstantially. However, in Experiment II the levels of recall for *colour* and *shape* were comparable despite the difference in the functionality of the attributes. In Experiment III there is a similar, reversed, difference in the functionality of the attributes. When shape is displayed as the functional attribute instead of *colour*, recall for each of these attributes is of dissimilar levels, with the functional attribute being recalled more frequently (19%). Though recall levels of shape in this Experiment are almost twice those expected by a random guessing, no recall, model they are low. Comparing the recall distributions of shape to the binomial distribution in Table 6.2 ($\chi^2 = 14.76$, $p=0.01$, with 11 df) indicates a non-significant variation. This suggests that though there may be some recall of shape this recall is of a minimal level and distributed in a fashion similar to that expected by chance.

Table 6.3: The occurrences of the attributes in the coded categorisations during Experiments I, II, and III.

Attribute combination	Number of occurrences		
	Exp I	Exp II	Exp III
CLS	10	8	6
(cls)	8	11	1
CL	1	6	8
CS	29	5	2
LS	4	13	30
(cl)	11	11	11
(cs)	38	11	7
(ls)	6	13	18
C(ls)	1	1	2
L(cs)	3	6	4
S(cl)	5	2	2
C	12	12	6
L	11	52	53
S	33	7	6
Null	68	82	84
Total	240	240	240

Table 6.4: The summation of each subject's observed and predicted occurrences of attribute combinations for Experiment III.

Arrangement	Observed	Expected
<i>col/loc/shp</i>	6	2
<i>col/loc</i>	8	7
<i>loc/shp</i>	30	23
<i>col/shp</i>	2	2
<i>location</i>	57	69
<i>shape</i>	8	19
<i>colour</i>	8	12
<i>nulls</i>	121	106
<i>totals</i>	240	240

6.3.2 ANALYSIS B: Independence of Recall.

The previous Experiments imply that colour and shape vary in a linked fashion, while location varies independently. The data from this Experiment could support and therefore strengthen the notion that the independence of location, and the integration of colour and shape, are consistent features of the analysis. However, the independence of location and integration of colour and shape may be affected by the manner in which they are displayed. From Experiment II it was concluded that displaying colour and location together as functional attributes did not significantly encourage their integration in memory. Whereas splitting colour and shape so that one attribute is functional and one is circumstantial did not remove the evidence of their being linked in memory, albeit minimal. The questions of interest here are whether the tendency to integrate colour and shape is still evident, and whether location varies independently or when displayed functionally with shape has a tendency to be integrated with shape in memory.

Table 6.3 (p134) shows the occurrences of each coded response made by the subjects for Experiments III, II, and I. The data concerning the allocation of functional attributes to the correct cue for Experiments I (29) and III (30) implies that there is a similar tendency for combinational recall of the functional attributes with the appropriate cue. However, there is a substantial difference between the functional pairs that are combined in their original form but applied to an inappropriate cue. In Experiment I 38 (cs) pairs are identified, while in Experiment III only 18 (ls) pairs are identified. This suggests that in Experiment III when the subjects recalled a combination of the functional attributes they also recalled its associated cue, though they actually remembered fewer combinations of functional pairs than in Experiment I. This trend in the data suggests that recall for location is linked to the recall of shape. If location were linked to shape in memory during Experiment III this would explain why there are more locations correctly recalled in Experiment III than in Experiment II. i.e., recalling shape acts as a cue to recall a location which might otherwise not have been recalled. Considering the second two Experiments where location was a functional attribute in each, comparable levels of recall are apparent for the location attribute on its own (Experiment II L=52 Experiment III L=53). The main difference in the spread of the

Table 6.5: The summation of each subject's observed and predicted occurrences of location and shape with the *colour* collapsed out..

Arrangement	Observed	Expected
loc/shp	36	25
location	65	76
shape	10	21
nulls	129	118
totals	240	240

Table 6.6: The summation of each subject's observed and predicted occurrences of *colour* and shape with the location collapsed out..

Arrangement	Observed	Expected
co/shp	8	4
<i>colour</i>	16	19
shape	38	42
nulls	178	175
totals	240	240

location attributes recalled is in the higher number of LS pairs (30) identified in Experiment III. The CL pairs have comparable occurrence levels in both Experiments despite the functionality of the combination in Experiment II.

From the data in Tables 6.1, 6.2, and 6.3 it would appear that there is little or no recall for *colour*, and location does not vary independently of the shape. To further investigate these hypotheses the absolute levels of recall for each attribute were used to predict the the combinational occurrences of the attributes on the assumption that the attributes are independent (Table 6.4, p134)

The comparison of observed and expected combinations of attributes in Table 6.4 when subjected to a chi-square analysis gives a significant ($X^2 = 20.50$, $p < 0.01$, with 7 df) result. This result confirms the hypothesis that the attributes do not vary independently.

The consistently low occurrence of *colour* and the similarity of its distribution to the binomial distribution suggests that it is reasonable to look at the data with the *colour* collapsed out. The *colour* is collapsed out in the fashion employed during the previous Experiments (see Chapter 4, p93). The resulting variation is still significant (Table 6.5: $X^2 = 13.80$, $p < 0.01$, with 3 df) implying an interdependency between location and shape. Unlike Experiments I and II the location variable in Experiment III does not appear to vary independently of the other attributes.

The interdependency of location and shape could account for all significant variation in Table 6.4 (p134) in which case the *colour* and shape attributes would not vary significantly. Since the level of recall for *colour* is low and its distribution similar to that of the binomial distribution it is hypothesized that collapsing the location from the data will enable the lack of interdependency between *colour* and shape to be highlighted (Table 6.6, p136). Unlike the previous Experiments this comparison is non-significant ($X^2 = 3.72$, $p=0.01$, with 3 df). In Experiment III the evidence so far does not point toward the existence of a link between *colour*, shape and cue.

6.3.3 ANALYSIS C: Yoked Guessing.

There is evidence for Yoked guessing with both *colour*-shape pairs (Table 6.7, designed in the same manner as Table 4.11, for an explanation see p.98) and location-shape pairs (Table 6.8, p139). In Table 6.7 (p139), column 1 there are fewer *colour*-shape pairs than in the previous Experiments, and half of these cases do not have the last application of the sequence as the correctly applied *colour*-shape pair. This is hardly surprising if the subjects have no recall for the *colour*. However, if there is an interdependency between colour and shape the positioning of the CS pairs in column one implies that the subjects do not actually recognise the *colour*-shape-cue combination when they are presented with the cue. From Table 6.8 (p140) it can be seen that fewer combinations of *colour* and shape are recalled, while more of the *colours* and shapes are correctly applied separately, than in previous Experiments. This is suggestive of the possibility that in Experiment III the *colour* and shape are recalled independently of each other.

The existence of a large number of (31) location-shape attributes in the first column of Table 6.9 (p140) is a strong indication that the subjects were very sure of the connection between the location-shape and cue. These instances are instances where the subjects used the location shape pair only once, correctly, and they never used the constituent parts again. This strong occurrence of LS pairs is accompanied by fewer incidences of yoked guessing with the location-shape combination. In previous Experiments the yoked guesses occurred substantially more frequently than occurrences of either accurately applied functional or CS pairs. One possible explanation for the unusual trend in this Experiment is that the subjects either knew the location-shape-cue combination, or they recalled none of the attributes, memory tending to be "all-or-none" (e.g, Jones, 1976).

Table 6.7: The occurrence frequency of various response patterns in the group data for colour and shape.

	Correct Colour-Shape	Yoked only	Single Colours	Single Shape	Misplaced: Nulls
row	Column 1	Column 2	Column 3	Column 4	Column 5
1	1 CS	1 (cs)	1 C	11 S	5 -
2	2 c,CS	1 (cs),c	2 C,c	4 s,S	22 c
3	1 CS,c	1 s,(cs)	3 C,s	4 c,S	51 s
4	1 c,c,CS	3 (cs),s	2 s,C	9 S,c	12 s,c
5	1 c,CS,c,c	1 (cs)c,c,	1 C,c,c	2 S,c,c,	8 s,s
6	1 CS,c,c,c	1 (cs),(cs)	1 s,C,s	1 s,c,S	11 c,c
7	1 c,CS,c,s	1 c,(cs),C	1 s,C,c	1 c,s,S	25 c,s
8		1 c,c,(cs)	2 C,c,s	1 s,S,c	12 s,c
9		1 c,s,(cs)	1 c,c,C,s,c	1 s,s,S	6 s,c,c
10			1 c,C,s,c,c,c	1 S,c,c,c	2 c,c,c
11				1 S,c,s,c	3 s,s,c
12				1 c,S,c,c	10 s,c,s
13				1 S,c,c,s,c,c	1 c,c,s
14					1 c,s,s
15					7 c,s,c
16					1 c,c,s,c
17					1 c,s,s,s
18					1 s,c,c,c
Totals	8	11	15	38	168 : 240

Table 6.8: Comparing the totals from Table 5.7 with those of the corresponding Tables of data in Experiments I (Table 4.11) and II (Table 5.8).

	C	S	CS	(cs)	null	Total
E I	13	42	39	42	104	240
E II	16	22	13	26	163	240
E III	15	38	8	11	168	240

Table 6.9 The occurrence frequency of various response patterns in the group data for the salient attributes.

	Correct Location- Shape only	Yoked Location	Single Shape	Single Nulls	Misplaced:
row	Column 1	Column 2	Column 3	Column 4	Column 5
1	31 LS	11 (ls)	6 L	2 S	10 -
2	2 LS,s	3 s,(ls)	13 s,L	2 s,S	16 l
3	2 s,LS	1 (ls)L	19 L,s	2 l,S	23 s
4	1 s,LS,l	1 (ls),s	3 l,L	1 l,S,s	19 s,l
5		1 l,(ls)	2 l,L	1 s,l,S	14 l,s
6		1 s,(ls),l	4 s,L,s	1 s,s,S	7 l,l
7		1 s,L,(ls)	4 s,l,L	1 s,l,l,S	3 s,s
8		1 s,l,(ls)	2 s,L,l		3 l,s,s
9		1 (ls),l	2 L,s,l		2 s,s,l
10			3 s,s,L		2 s,l,s
11			3 L,s,s		3 l,s,l
12			3 l,L		3 s,l,l
13			1 l,L,s		1 l,l,s
14			1 s,L,l,s		1 l,s,l,l
15					1 l,s,s,s
16					1 l,s,l,s
17					1 s,l,l,s
Totals	36	21	63	10	110 : 240

Figure 6.1: Identifying the location-shape chance pairings.

occurrences of LS without any l, s, L, or S' = 31

occurrences of (ls) without any l, s, L, or S's = 11

Table 6.10: Adjusting the data from Table 6.10 to account for chance pairings

	L	S	LS	(ls)	null	Total	
	63	10	36	21	110	240	
	68	15	31	11	125	240	Adjusted for chance pairings

Figure 6.2 : Identifying colour-shape chance pairings.

occurrences of CS without any c, s, C, or S = 1

occurrences of (cs) without any c, s, C, or S = 2

Table 6.11 Adjusting the data from Table 6.7 to take into account the chance pairings

	C	S	CS	(cs)	null	Total
E III	15	38	8	11	168	240
E III	22	45	1	2	172	240

6.3.4 ANALYSIS D: Chance Pairings.

The identification of the chance pairings is carried out using the same parameters as applied in previous as Experiments, using the data from Tables 6.7 (p139) and 6.9 (p140). In Table 6.10 (p141) the location-shape data is adjusted to take into account the chance location-shape pairings (Figure 6.1, p140). The result of this adjustment is most dramatic in the region of the incidences of yoked guesses, nearly halving their occurrence (From 21 incidences to 11). While the occurrences of location-shape, shape, and location are barely changed by the adjustment. The fact that more of the (ls) pairs occurred due to chance than the LS pairs supports the implication that when the subjects used a location-shape combination they were fairly certain of its association with the cue.

Looking at the *colour*-shape data after the chance pairings have been identified (Figure 6.2, p141) and the data has been adjusted (Table 6.11, p141) suggests that the majority of CS and (cs) pairs were due to chance combinations, and that these attributes are not linked in this Experiment

6.4 SUMMARY

Recall of the circumstantial attribute, *colour*, is minimal and not significantly different from chance levels. The distribution of the correctly allocated *colours* does not vary significantly from the binomial distribution or suggest that any individual subjects recalled the *colour*. It therefore seems reasonable to assume that there is no recall of the *colour* attribute in this Experiment.

The location attribute is recalled well, and not independently of recall for the shape attribute. Unlike the previous Experiments there little no evidence to suggest that the *colour* and shape have been integrated in memory, as there is no evidence that *colour* is recalled. As noted in Experiment II there is an imbalance between the levels of recall for the functional attributes. Though in Experiment II there was minimal evidence for the recall of one of the functional attributes (*colour*). In this Experiment the recall of

shape is statistically significant. The occurrence of shape not in conjunction with location is low, possibly at chance level, implying that it is only remembered in conjunction with the location. The resulting model of recall for the attributes in this Experiment takes three forms:

- a: Location-Shape-cue (The "LS" code)
- b: Location-cue (The "L" code)
- c: Null

CHAPTER 7

EXPERIMENT IV

Chapter Contents

This chapter describes the procedure of an Experiment similar to Experiment I. Experiments I and IV differ in the design of the icons. In this Experiment IV the icons are less intricate designs. The procedure is the same as Experiment I, with colour and shape as the functional attributes and *location* as the circumstantial attribute. The results show that

- a) there is recall for the colour and shape attributes.
- b) the colour and shape attributes appear to be integrated in memory.
- c) the integration of colour and shape is more pronounced
in Experiment IV.
- d) the location attribute was not recalled.
- e) there is evidence of yoked guessing.

7.0 EXPERIMENT IV

7.0 INTRODUCTION.

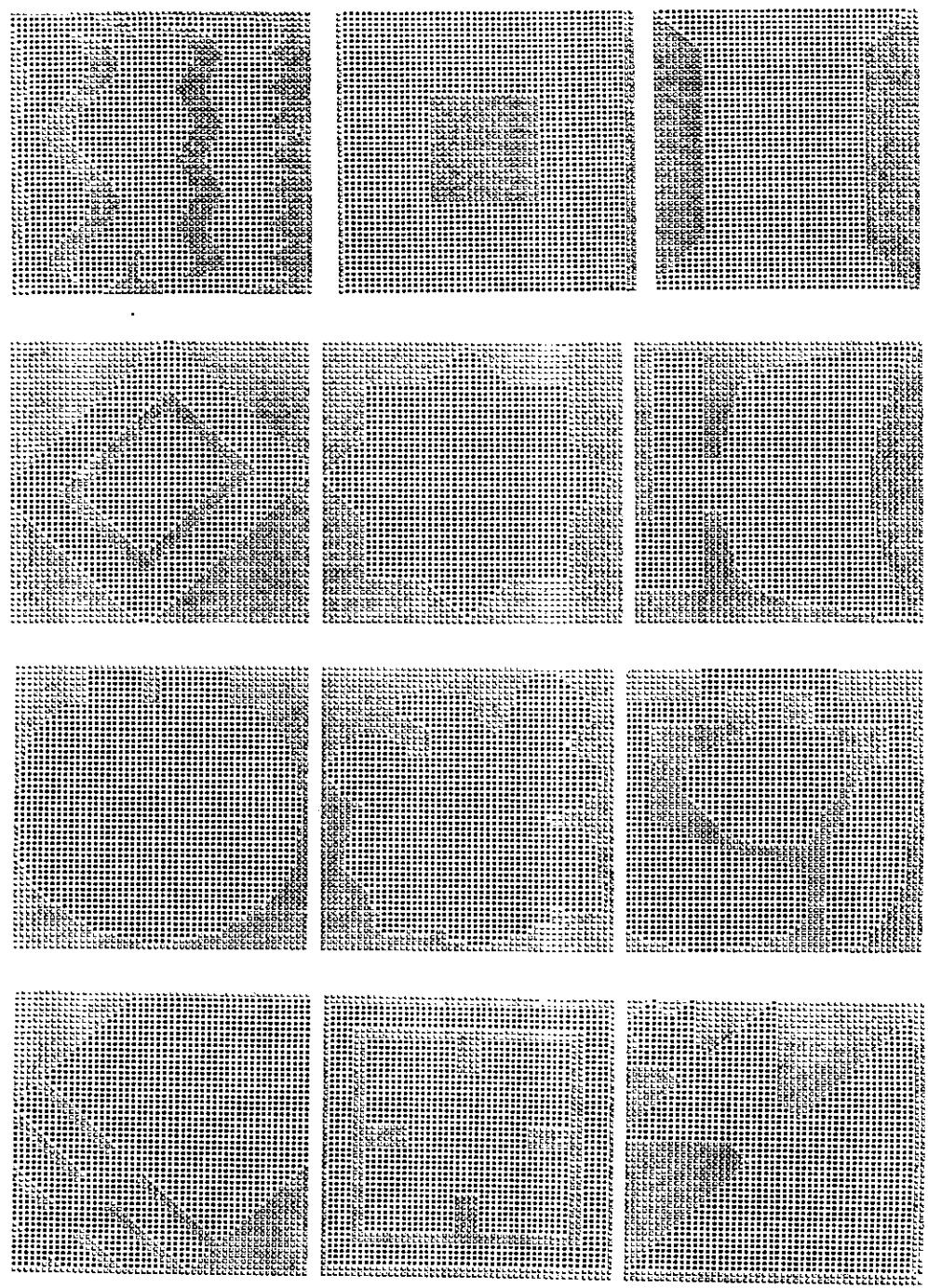
This final Experiment is aimed at investigating whether the design of the icons affects the structure of the memory. The initial set of icons used in Experiments I, II, and III, are an intricate design. In contrast, the icons used in Experiment IV are less intricate. The intricacy is reduced by the icons in Experiment IV (see Figure 7.1, p147) having fewer edges, but similar area to those used in the previous Experiments (see Figure 4.1, p80). The result of the changes in design is a set of icons that are less intricate, more solid "blocks" of colour, than those previously used.

The method is identical to that of Experiment I (see page 79). The same presentation program is used, the only change being the file of pre-drawn icons used by the program. Consequently, the data collected is of an identical format to that collected for Experiment I.

7.1 ANALYSIS.

The data is collected and coded in the same manner as the previous Experiments. The analysis of Experiment IV starts from the assumption that the data collected in Experiments I and IV is drawn from the same population, and therefore, there will be no significant differences between the two Experiments.

Figure 7.1: The set of Icon shapes used in Experiment IV.



7.1.1 ANALYSIS A: Levels of Recall.

The absolute levels of recall (Table 7.1, p149) for Experiment IV appear to have a similar format to that of Experiment I. The largest variation, a level of 5%, is in the level of recall for the shape. The change in the shape of the icons is the major adjustment in Experiment IV, and it appears that there is some variation due to this change. The attributes of *location* (12% and 13%) and colour (22% and 24%) are recalled at very similar levels in both Experiments. If there are no significant differences between the data from Experiment I and Experiment IV then not only will it be feasible to claim that the data comes from the same population, but that the Experimental paradigm is reliable.

As in Experiment I if the *location* is recalled this recall is minimal. This low occurrence level of *locations* could be due solely to correct allocations of the attributes occurring by chance. To check this, the distribution of the correctly applied *locations* is compared with the binomial distribution (Table 7.2, p149). This comparison produces a non-significant ($G = 3.99$, $p = 0.01$, with 4 df) result suggesting that there is no reason to assume that subjects do recall *location*. Though this non-significant result could reflect the small numbers involved. Due to this result the assumption that there is no recall of the location attribute will be adopted.

7.1.2 ANALYSIS B: Independence of Recall.

As with previous Experiments, the data is coded and then the distribution of these codes is looked into in Table 7.3 (p151). From Table 7.3 it can be seen that, as with Experiment I, the recall of *location* is markedly lower than that of colour or shape. There also appears to be a high number of colour-shape pairs.

Table 7.1: Absolute levels of recall for all four Experiments.

EXP I	EXP IV
Colour = 53 (22%)	Colour = 57 (23%)
Location = 29 (12%)	Location = 32 (13%)
Shape = 81 (34%)	Shape = 69 (29%)
EXP II	EXP III
Colour = 32 (13%)	Colour = 24 (10%)
Location = 85 (35%)	Location = 101 (42%)
Shape = 35 (15%)	Shape = 46 (19%)

Table 7.2: A Binomial distribution of predicted frequencies, and the corresponding observed frequencies of the correct allocations of the *location* attribute.

Number correct	Relative Predicted Frequencies	Absolute Predicted Frequencies	Observed Frequencies: <i>Location</i>
0	0.3520	7.0400	5
1	0.3840	7.6800	5
2	0.1920	3.8400	4
3	0.0582	1.1640	5
4	0.0119	0.2380	1
5	0.0017	0.1420	0
6	0.0002	0.0040	0
7	0.0000	0.0000	0
...
12	0.0000	0.0000	0
Total	1.0000	20.0000	20

An interesting point to note is that the emphasize of the variation in the first two columns is reversed. There are more yoked guesses of all three attributes combined correctly, though fewer of these combinations allocated to their associated cue in Experiment IV than in Experiment I. In Experiment VI there are more CS and (cs) pairs, and fewer occurrences of C or S singly, than in Experiment I. The general trend in Experiment IV appears to be a stronger integration of colour and shape at the expense of their occurrence individually.

To investigate whether this general trend is a significant variation in the data, probability theory was applied to the absolute levels of recall enabling a prediction of the expected combinations of attributes to be made, and a chi-square analysis applied to this data in Table 7.4 (p151). This comparison is significant ($X^2 = 45.42$, $p < 0.01$, with 7 df) and indicates that the attributes do not vary independently of each other. *Location* occurs at a low level not statistically distinguishable from chance, so it seems feasible to collapse the *location* data from Table 7.4, to see whether the colour and shape vary independently of each other (Table 7.5, p152). Collapsing the *location* from the data produces a significant ($X^2 = 38.12$, $p < 0.01$, with 3 df) result which suggests that the recall of colour and the shape is integrated. Collapsing out the shape, to check whether there is any inter-dependency between colour and *location* (Table 7.6, p152) does not give a significant result ($X^2 = 00.10$, $p < 0.01$, with 3 df), supporting the notion that *location* varies independently of colour. For similar reasons the colour was collapsed from the group data (Table 7.7, p152). Here also the variation was non-significant ($X^2 = 03.94$, $p = 0.01$, with 3 df). Similarly, this non-significant finding supports the notion that the *location* varies independently of shape. With the occurrence of *location* being independent of colour and shape, and at a low level, it is reasonable to suspend it in further analysis in order to study the structure of recall for colour and shape more directly.

Table 7.3: The occurrences of the attributes in the coded categorisations for Experiments I and IV.

Attribute combination	Number of occurrences	
	Exp I	Exp IV
CLS	10	8
(cls)	8	12
CL	1	3
CS	29	37
LS	4	9
(cl)	11	6
(cs)	38	51
(ls)	6	7
C(ls)	1	1
L(cs)	3	6
S(cl)	5	0
C	12	8
L	11	6
S	33	15
Null	68	71
Total	240	240

Table 7.4: The summation of each subject's observed and predicted occurrences of attribute combinations Experiment IV:

Arrangement	Observed	Expected
<i>col/loc/shp</i>	8	5
<i>col/loc</i>	3	5
<i>loc/shp</i>	9	7
<i>col/shp</i>	37	20
<i>colour</i>	9	26
<i>location</i>	12	15
<i>shape</i>	15	37
<i>nulls</i>	147	125
Totals	240	240

Table 7.5: The summation of each subject's observed and predicted occurrences of shape and colour with *location* collapsed out:

Arrangement	Observed	Expected
col/shp	45	26
shape	24	43
colour	12	31
nulls	159	140
Totals	240	240

Table 7.6: The summation of each subject's observed and predicted occurrences of *location* and colour with shape collapsed out:

Arrangement	Observed	Expected
col/loc	11	10
<i>location</i>	21	22
colour	46	47
nulls	162	162
Totals	240	240

Table 7.7: The summation of each subject's observed and predicted occurrences of *location* and shape with colour collapsed out:

Arrangement	Observed	Expected
loc/shp	17	12
<i>location</i>	15	20
shape	52	57
nulls	156	151
Totals	240	240

7.1.3 ANALYSIS C: Comparing Experiments I and IV

The above analysis has already served to highlight some of the similarities and apparent differences between Experiments I and IV. In both Experiments there is minimal recall, if any, for *location* which varies independently of colour and shape. Recall for colour and shape is integrated. The effects of this integration seem to be more pronounced in Experiment IV. There appear to be more instances of yoked guessing and correctly applied colour-shape pairs in Experiment IV. The only difference in the presentation of the experiments was the design of the icons, consequently, any differences between the two experiments can be attributable to the effects of that change.

A direct comparison of the data gathered from Experiments I and IV will serve to indicate whether there are any significant variations in the distribution of the data. A goodness of fit analysis was employed to investigate whether the data gathered from Experiments I and IV could conceivably have been drawn from the same population (Table 7.8, p154).

There is a significant difference ($\chi^2 = 152.7$ $p < 0.01$ with 7 df) between the two samples. By inspection, these differences appear to be apparent in the spread of the data in Experiments I and IV falling mainly in the higher number of single shapes accurately identified in Experiment I, the higher number of colour-shape pairs, and the nulls, identified in Experiment IV. In Experiment IV the subjects have identified fewer attributes independently, more attributes in pairs, and made more incorrect allocations, than in Experiment I. The tendency being towards an "all-or-none" memory structure for the attributes. That is, the subjects tend to recall the complete fragment, in this case of colour and shape, or they recall nothing. The design of the object appears to affect the degree to which the colour and shape are integrated in the subjects memory. One possible source for this difference in the data could be differences in the strategies employed by the subjects, such as the degree of yoked guessing.

Table 7.8: The data from Experiment I compared with that from Experiment IV for a Goodness of fit test

Arrangement	Exp I	Exp IV
<i>col/loc/shp</i>	10	8
<i>colour</i>	13	9
<i>location</i>	14	12
<i>shape</i>	38	15
<i>col/loc</i>	1	3
<i>loc/shp</i>	4	9
<i>col/shp</i>	29	37
<i>nulls</i>	131	147
Totals	240	240

7.1.4 ANALYSIS D: Yoked Guessing.

Using the analysis technique laid out in Experiment I the sequences of responses used by the subjects are considered in Table 7.9 (p156, the design of this Table is explained in more detail p98, with Table 4.11, on p100). The most noticeable difference between this Table and those of previous Experiments (Tables 4.11 p100, 5.9 p123, 5.11 p124, 6.7 p139, and 6.9 p140) lies in the lack of data in the third and forth columns. On the few occasions when subjects apply a colour or shape to the correct cue, the colour or shape have been used previously in a yoked guess, i.e, column 2 rows 5, 6, 9, and 10. This could be due to the yoked guesses being chance pairings of the attributes.

As in Experiment I there is a tendency amongst the subjects to use repeat the use of colour. An extreme example of this strategy is exemplified in column 2 item 13, where the subject uses the same colour attribute on six occasions. On only one of these occasions does the subject combines the colour with its associated shape implying that the colour shape combination is not recalled but occurs by chance.

In column 1 there is the tendency not to use the correct combination of the attributes once they have been applied to their associated cue. This tendency is not as pronounced as in Experiment I, but is still evident. On five occasions in Experiment IV a subject repeated a (cs) pair and on one occasion applied its associated cue (rows 4-7 inclusive), suggesting that on these five occasions the subject was confident of the link between the colour-shape pair, but unsure of the link between the colour-shape pair and the cue.

Comparing the data from Table 7.9 directly with the corresponding data from Table 4.11 of Experiment I, in Table 7.10 (p156), confirms the emphasis in Experiment IV to recall the colour and shape attributes in combination with each other. There appears to be a pattern emerging of very few colours being recalled singly, but more recalled in pairs for Experiment IV. The redesign of the icons does seems to have a positive affect on the levels of recalling pairs of colour-shape at the expense of their occurrence independently.

Table 7.9: The occurrence frequency of various response patterns in the group data.

	Correct Colour-Shape	Yoked only	Single Colours	Single Shape	Misplaced only
Row	Column 1	Column 2	Column 3	Column 4	Nulls
1	29 CS	31 (cs)	1 C	16 S	17 -
2	4 c,CS	6 c,(cs)	4 C,s	4 c,S	9 c
3	6 CS,c	3 s,(cs)	2 s,C	1 S,s	29 s
4	1 (cs),s,CS	7 (cs),c	1 C,s,c,s	1 s,S	14 s,c
5	1 (cs),(cs),CS	1 (cs),C	1 c,s,c,C	1 c,S,c,s,c	19 c,s
6	1 CS,(cs)	1 C,(cs)			2 s,s
7	2 (cs),CS	2 (cs),(cs)			1 c,c
8	1 c,c,CS	1 (cs),c,c			4 s,c,s
9		1 (cs),C,s			3 c,s,c
10		1 (cs),S			2 s,c,c
11		1 c,(cs),c			1 c,s,s
12		2 (cs),c,(cs)			1 c,c,s
13		1 c,c,c,(cs),c,c			1 c,c,c,s
14		1 c,c,(cs)			1 s,c,s,c
Total	45	59	9	23	104: 240

Table 7.10: Comparing the occurrences of the colour shape combinations in Experiment I with those in Experiment IV.

C	S	CS	(cs)	null	Total	
13	42	39	42	133	240	Exp I
3	14	13	26	184	240	Exp II
21	29	8	11	171	240	Exp III
9	23	45	59	104	240	Exp IV

Figure 7.2: Identifying chance pairings:

occurrences of CS without any c, s, C, or S = 33

(Rows 1, 5, and 6 from column 1)

occurrences of (cs) without any c, s, C, or S = 33

(Rows 1, and 6 from column 2)

Table 7.11: Adjusting the data from Table 7.9 to account for chance pairings

C	S	CS	(cs)	null	Total	
9	23	45	59	104	240	Data from Table 7.9
21	35	33	33	118	240	Adjusted for chance pairings.

Table 7.12: Comparing the data from Experiments I and IV adjusted to account for chance pairings

C	S	CS	(cs)	null	Total	
22	50	27	23	141	240	Experiment I
21	35	33	33	118	240	Experiment IV.

7.1.5 ANALYSIS E: Chance Pairings.

The increased recall of colour-shape pairs in Experiment IV mainly occur as yoked guesses. These could yoked guesses could be cases where (cs) pairings have occurred as the result of a colour and shape being chosen arbitrarily by the subject. Using the method employed in the previous Experiments to identify these occasions of chance pairings from Table 7.9 in Figure 7.2 (p157), identifies 33 occasions where the CS pairs are not chance pairings and 33 occasions when the (cs) pairs are not chance pairings. Once the chance pairings have been removed the data from Experiment I resembles the data from Experiment IV more closely (Table 7.12, p157). A goodness of fit test applied to this data gives a significant result ($X^2 = 14.95$, $p < 0.01$, with 4 df). Even after the variation in the data due to chance pairings has been removed there are still significant differences.

7.2 SUMMARY

Recall of the *location* attribute is minimal and not significantly different from the occurrence levels expected by chance. The distribution of the correctly allocated *locations* is not significantly different from the binomial distribution, again giving no reason to suppose that the occurrence of *location* is due to any source other than random guessing. The occurrence of *location* is independent of the occurrence of either shape or colour, this finding is consistent with the notion that there is no recall of the *location* attribute. It can be concluded from these findings that if there is any recall of the *location* attribute, this recall is minimal and therefore can be excluded from further analysis. The findings regarding the *location* attribute are congruent with the findings regarding the *location* attribute in Experiment I.

There is evidence for the recall of both colour and shape. There is a tendency to recall colour and shape together rather than independently. More shapes are recalled singly than colours. It is possible that there is no recall for the colour when it is not associated with the shape. However, for the present it is enough to note that very few colours are

recalled except in combination with the shape. These trends are all evident in Experiment I.

There is a significant difference between the data supplied by Experiment's I and IV. This difference is evident in the extent of the integration of the colour and shape attributes, with more pairings occurring in Experiment IV. The less intricate design of the icons leads to the recall of the colour and shape becoming more integrated. The structure of the recall appears to be in the same form as Experiment I:

- a: Colour-Shape-Cue.
- b: Colour-Shape.
- c: Shape-Cue.
- d: Null.

CHAPTER 8

DISCUSSION

Chapter Contents

The chapter opens with an integrated overview of the findings. These findings suggest various models of recall in each experiment. Clearly it is desirable to integrate the results as far as possible. Promising theoretical explanations for the various models of recall are discussed which include the distinctiveness of the attribute variations, the subject's orientation during the task, and the notion of redundancy. The practical implications and the related theoretical issues are discussed with further potentially rewarding avenues of research. In conclusion, incidental recall does exist though it is highly sensitive to context.

8. DISCUSSION

8.0 INTRODUCTION

This chapter opens by developing the analyses performed in the previous four chapters to present an overall picture of the findings. The aim of the chapter is to relate the experimental findings to existing work and evaluate the practical implications. For this purpose it becomes necessary to take a second look at the literature in the light of the experimental findings. When examining the findings of this thesis in the light of theoretical work it is necessary to understand how the two approaches relate to each other.

Theory is by definition context free:

"the part of a science or art that deals with general principles and methods as opposed to practice" (Longman Dictionary of Contemporary English, p1149)

Whereas applied work is constricted to the context of application. The ideas produced by theory can be brought to practical situations by applied specialists, for example, the development of the atom bomb. Conversely, applied work can occur in advance of theoretical understanding. For example photography was developed without a grasp of the underlying chemical processes. Bakan (1980) provides an historical review of approaches to psychological research, commenting on how early research can be viewed as being a two step process. The first step is the knowledge acquired by experiment and theory. The second step is the application of the knowledge to concrete problems. This approach is often characterised by its isolation from human problems. An alternative to this two step view is taken by Broadbent (1980) who suggests that research should start with by enquiring into practical real world problems. This thesis has adopted the approach espoused by Broadbent (1980) and taken the practical problems associated with information retrieval as its starting point. As neither a purely theoretical nor purely applied piece of work this thesis aims to cover the middle ground

and produce a working hypothesis of the memory structure evident from the experimental data. A working hypothesis can serve to support discussion relating to the applied value of the research.

The following sections serve to summarize the findings of chapters 4, 5, 6, and 7 then develop some working hypotheses aimed at clarifying the mode of their potential application in filing retrieval systems.

8.1 ANALYTICAL OUTLINE

An outline of the analysis summarizes the structure of recall for the attributes in each of the experimental situations. Whether incidental recall exists and how this recall is affected by the nature of the activities the subjects undertook is evaluated. Working hypotheses are developed to clarify the structure of recall in each experiment.

8.1.2 EVIDENCE FOR THE EXISTENCE OF INCIDENTAL RECALL.

In each experiment there is evidence that the subjects remembered some attributes of the icons at levels above chance. Consequently, all the experiments provide evidence for incidental recall of the icon attributes. There is a notable difference between the two types of procedurally-defined incidental recall ("circumstantial", and "functional"). Recall is generally higher for those incidental attributes which are used by the subjects (functional attributes). In each of the experiments one of the functional attributes is recalled well while recall for the other functional attribute is equivalent or greater than that of the circumstantial attribute. The case regarding recall of the circumstantial attributes is complex. Looking at the distribution of recall for the circumstantial attributes in comparison with the binomial distribution provides evidence that some of the subjects recall the circumstantial attributes. For example, in Experiment II one subject accurately recalled 58% of the *shapes*. Though some subjects obviously recall the circumstantial attributes the group levels of recall for the circumstantial attributes are

not statistically distinguishable from chance i.e. the overall levels of recall are very low. This result is consistent with the results reported by Lansdale (1990).

8.1.3 MODELLING THE STRUCTURE OF RECALL.

In Experiments I and IV there is evidence to suggest an integration of colour and shape attributes in memory. This integration is indicated by the distribution of the colour, shape, and colour-shape occurrences. For example, in Experiment I (from Table 4.6, p94) the subjects recalled approximately 16% of the correct colour-shape pairs, 18% of the correct shapes separately, and 6% of the correct colours separately. The integration is evident in the fact that most of the colours are recalled in combination with a shape, 22% of the colours were recalled correctly with only 6% recalled without the associated shape. The reverse is not true. A larger proportion (18%) of shapes are recalled without the associated colour. This suggests that the subjects can recall the shape without the colour but not the colour without the shape. There are fewer colours recalled separately than shapes. If the 6% occurrence of colour is compatible with the probability that colour attributes are occurring at a chance level this would indicate that there is little, if any, recall for the colour attribute when the shape attribute has not been recalled. It may be possible to confirm whether or not the 6% of colours recalled are compatible with chance occurrences. However for the purposes of this thesis it is sufficient to note that the difference between the recall of colour and shape separately is substantial, and that if colour is recalled separately recall is minimal.

Experiment IV displays a similar trend suggestive of the integration of colour and shape in memory. Table 7.5 (p152) shows that approximately 10% of the shapes, 5% of the colours, and 19% of the colour-shape pairs are recalled. In this experiment the trend to integrate colour and shape appears more pronounced. A larger proportion of shapes are recalled in the colour-shape combination at the expense of their recall independently.

One plausible explanation for the difference in the extent of this trend lies in the fact that the shapes in Experiment IV were less intricate in design. The reduction in intricacy could affect the ease with which the subjects distinguish between the shapes and

therefore affect the number that they can accurately select when asked to recreate the icons during the test. This possibility will be discussed in section 8.2.

The recall levels for *location* in Experiments I and IV are statistically indistinguishable from chance. Comparing the distribution of recall for the location attribute with the binomial distribution produced no statistical evidence to suggest that there was recall of the location attribute. Consequently, the hypothesis used to model the subjects recall in Experiments I and IV suggests that recall only occurs in three forms (also see Figure 8.1, p166):

-
- | | | |
|----|-----------------------|------------------|
| 1: | Colour-Shape-Document | (the CS code). |
| 2: | Colour-Shape | (the (cs) code). |
| 3: | Shape-Document | (the S code). |
-

The second experiment contrasted with Experiments I and IV in that the imbalance between the recall of the functional attributes is accentuated. For example, (from the data in Table 5.6, p121) approximately 8% of the colour attributes are recalled separately, 30% of the location attributes are recalled separately, and 6% of the correct location-colour combinations are recalled. There is no substantial evidence to suggest that colour and location, the functional attributes, are integrated in memory (See Section 8.2 for further discussion). In Experiments I and IV the functional attributes were integrated in memory. If the functional status of the attributes is not responsible for their being integrated in memory it is possible that colour and shape are naturally integrated.

In Experiment II recall for both colour and *shape* is low, possibly negligible. Despite the fact that recall for colour and *shape* is minimal there is some suggestion that it might be integrated since significantly more colours and *shapes* occur together than would be expected by chance. It is possible that though the subjects recalled colour-*shape* combinations they could not recognise which cue the combinations were originally displayed with. For example, in Table 5.10 (p123) the subjects recall approximately

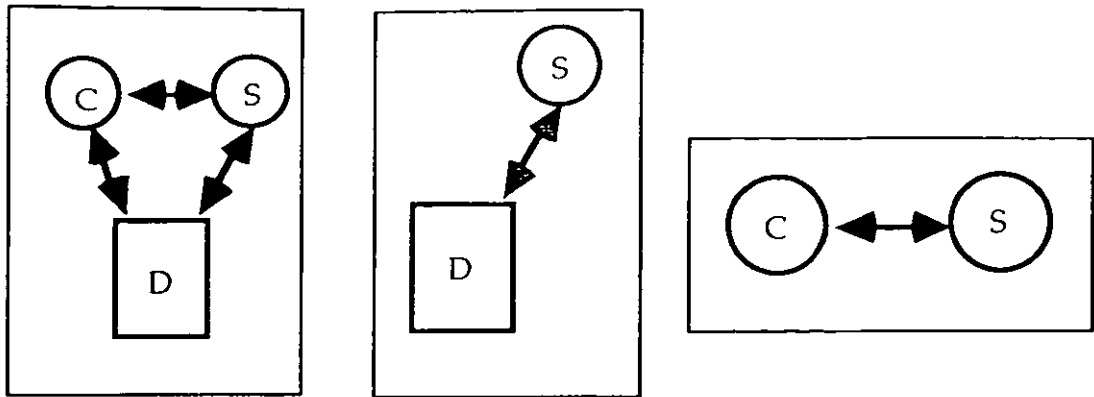


Figure 8.1 Model of recall states for Experiments 1 and 4

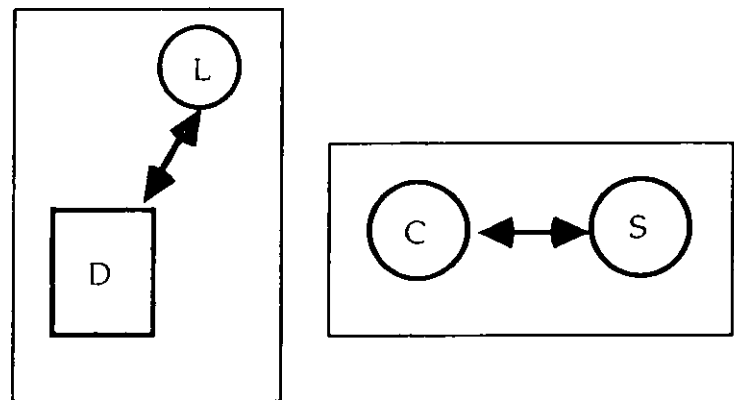


Figure 8.2 Model of recall states for Experiment 2

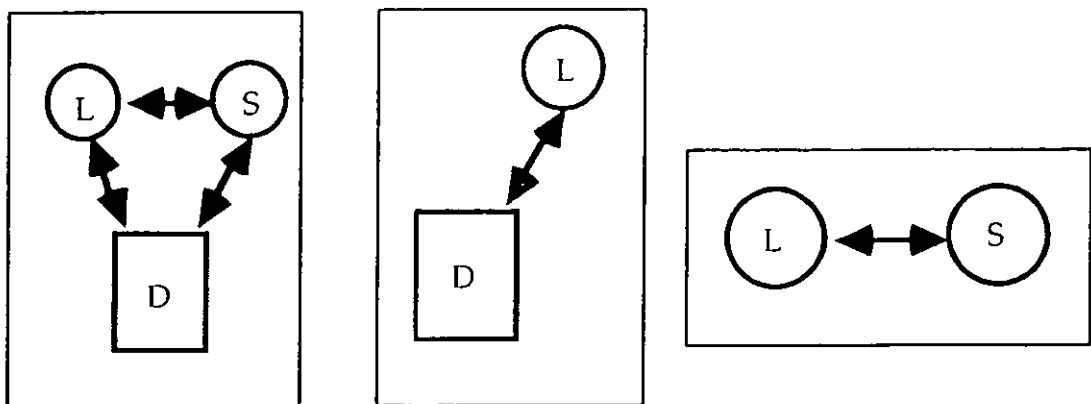


Figure 8.3 Model of recall states for Experiment 3

5% of the correct colour-*shape* pairs with the correct cue, but they also recall a further 11% of the colour-*shape* pairs that are not associated with the correct cue. Using the method laid out in Section 4.3.5 (p103) to identify chance pairings the data is adjusted to take their occurrence into account. Adjusting the data for chance pairings reduces the number of colour-*shape* combinations that are identifiable as having been recalled to 4% of CS pairs and 4% (cs) pairs (Table 5.12, p126)). This recall of approximately 8% of the colour shape pairs is still substantially higher than the 1% (Table 5.5, p119) predicted by probability theory (see Section 8.6, p185, for further discussion).

Recall of the location attribute in this experiment is not low but it does appear to be independent of the other attributes. The hypothesis used to model the subjects' recall in Experiment II suggests that recall only occurs in the following forms (also see Figure 8.2, p166):

-
- 1: Location-Document (the L code).
 - 2: Colour-*Shape* (the (cs) code).
-

The third experiment produces no evidence for the integration of *colour* and shape in memory. The recall level for *colour* is statistically indistinguishable from chance levels. The distribution of the *colour* attribute is not significantly different from the binomial distribution. These results are compatible with the hypothesis that there is absolutely no recall of the colour attribute during Experiment III.

There is again an imbalance between the recall levels of the functional attributes, the location is recalled well (42%), and the shape is recalled above chance (19%). Unlike previous experiments the location is not recalled independently but in conjunction with the other functional attribute: shape. When looking at the distribution of the combinational recall of the functional attributes, most of the recalled shapes (approximately 78%) are in combination with the location. If the 4% of shapes not recalled with location occurred by chance this would imply that recall of the shape is dependent upon recall of the location. It appears that in this experiment the functional

attributes are integrated in memory. The model of recall suggested for this experiment is (also see Figure 8.3, p166):

1:	Location-Shape-Document	(the LS code)
2:	Location-Shape	(the ls code)
3:	Location	(the L code)

In summarizing the findings of all four experiments an overall pattern emerges. There is no evidence in Experiment III for recall of the circumstantial attribute (*colour*). There is little evidence for the recall of the circumstantial attributes in the other experiments (*Shape, location*) What there is can be seen when the distribution of the circumstantial attributes is compared with the binomial distribution. This comparison indicates that several individuals have some recall for the circumstantial attributes. Recall of the functional attributes tends to favour one of the attributes, particularly location, when it is functional (e.g, Experiments II and III). Recall for the colour attribute was generally minimal and not statistically distinguishable from chance levels. There is some evidence that the recall of colour is dependent upon the recall of shape. Possible explanations for the emerging data patterns and their implications for designing an automated file support system are discussed in the following sections.

8.2 THE EFFECTS OF ICON DESIGN ON INCIDENTAL RECALL.

Comparing the data collected from Experiments I and IV using a goodness of fit test (See Section 7.1.3, p153) gives a significant result ($\chi^2=152.7$ $p<0.01$ with 7df) enabling a rejection of the null hypothesis that the data are samples from the same population. The only change in the experimental design between Experiments I and IV was in the design of the icons. It seems reasonable to conclude that minor changes in the design of the icon shape have significant effects on the structure of the subjects recall. This effect may not be limited to changes in the design of the icon shape.

Evidence that recall of the locational attribute is affected by minor procedural experimental changes is apparent by comparison of the findings of this thesis with those of a project carried out by Crolla (1990). Crolla compared subjects recall for location in intentional and incidental conditions. Crolla's findings suggested that there was minimal recall for location in both conditions. The project required subjects to perform an In-Tray exercise consisting of 16 information items. The In-tray exercise was similar to the one used in this experimental paradigm. The items were represented on an electronic screen by 16 locations (squares) in a 4x4 layout. The design of Crolla's experiment was comparable to the design of Experiments II and III. For example, the subjects could only read one information item at any time and accessed the information item by an associated location. Crolla did not find evidence to endorse the existence of incidental recall. He also found that subjects intending to recall location were severely limited in their success.

The differences in the subjects task provide one feasible explanation for the poor recall of the locations in Crolla's experiment compared to those reported in this thesis. The design of the experiments in this thesis enabled subjects to access and re-access documents whenever they wished to do so. In Crolla's experimental design access to the documents was restricted to one viewing consequently each document was accessed by the location once. The poor recall of the location attribute in Crolla's experiment could be due to the subjects not being able to use the locations, and therefore not learning the association between location and document.

Another possible explanation for the apparent contradiction between Crolla's findings and those of this thesis lies in the design of the locational attribute. In Crolla's project the locations occupied a small area of and already small (Macintosh) screen and were consequently close together. In Experiments II and III of this thesis there are fewer locations and these are displayed with a greater intervening distance on a larger, 19" screen. Eriksen and Eriksen (1974) found that when asked to make a response to letters of the alphabet in pre-cued locations, subjects could not prevent letter information being taken in from sites 1 degree from the target. As distance of a distractor from the target increases beyond 1 degree the automatic processing of information appears to diminish (Dyer, 1973, Kahneman et al, 1983). It is conceivable

that the subjects found it easier to differentiate between the locations in Experiments II and III of this thesis because they were further apart than the locations in Crolla's work. The ease with which the subjects could differentiate between the locations facilitated their accurate recall of the locations.

The hypothesis that distinctiveness affected recall can also be applied to the data from Experiments I and IV. The intricate shape designs used in Experiment I enabled the subjects to differentiate between the shapes more easily than with the blocked shapes of Experiment II. Consequently, recall of the shape in Experiment IV (29%) was less than recall of the shape in Experiment I (34%). Small changes in the icon design could be responsible for producing substantial effects on incidental recall. There is evidence to suggest that distinctiveness is employed as a strategy to judge whether or not information is recognised (e.g., Penn, 1988, see Section 2.2). In the levels of processing paradigm studies of elaboration produce support for the notion that distinctiveness can improve recognition (e.g., Jacoby and Craik, 1978). It is possible that the consistently poor recall of colour throughout the thesis could be attributable to how distinctive the subjects found the alternative colours. There is room for further work to investigate the affects of features such as distinction that may influence the quality of incidental recall.

From the statistically significant differences in the data structures of Experiment I and IV it can be concluded that design of the icon shape affects the structure of the subjects recall for the attributes of colour and shape. The differences between Crolla's Experiment and Experiments II and III here suggest that minor changes in the layout of the locations, or how they are used, have substantial effects upon the incidental recall of location. The possibility that use of the icon attribute affects how well it is recalled incidentally is discussed in the following section.

8.3 INCIDENTAL RECALL FOR THE FUNCTIONAL ATTRIBUTES.

In each of the experiments at least one of the two functional attributes shows substantial evidence of being recalled, especially in the case of location as can be seen from the data in Figure 8.4.

Figure 8.4: The proportions of correct recall for the functional attributes in all four experiments.

Experiment	Functional attributes (percentage correctly recalled)			
I	Colour	(22%)	Shape	(34%)
II	Colour	(13%)	Location	(35%)
III	Shape	(19%)	Location	(42%)
IV	Colour	(23%)	Shape	(29%)

These levels of recall are manifest by statistically significant variations in the occurrence of the attributes compared to the occurrences predicted by a random guessing model and significant variations in the distribution of the attributes compared to the binomial distribution. In contrast, using the same measures there is minimal evidence of recall for the circumstantial attribute. For example, using a random guessing model the expected occurrence of an attribute would be 8% while the overall levels of recall for each circumstantial attribute are displayed in Figure 8.5 (p172)

Figure 8.5: The proportions of correct recall for the circumstantial attributes in all four experiments.

Experiment	<i>Circumstantial</i> attribute	Percentage Correct
I	<i>location</i>	12%;
II	<i>shape</i>	15%;
III	<i>colour</i>	10%;
IV	<i>location</i>	13%

Recall of the circumstantial attribute is evident by comparing the distribution of the recall of the attribute with the binomial distribution where some subjects display evidence of recall while most do not. The consistently low levels of recall for the circumstantial attribute suggest that there is a difference between the structure of recall for the functional and circumstantial attributes. There is also some suggestion of a difference in the structure of recall between the two functional attributes.

The functional attributes are combined at presentation and can only be viewed the simultaneously. It therefore seems unlikely that the imbalance of recall levels for the two functional attributes can be resolved by reference to their degree of exposure. One conceivable explanation for the imbalance in recall of the functional attributes could be related to the notion of "redundancy". The twelve values of each attribute are associated with one of the twelve information items. Therefore, the ability to discriminate the values of one set of functional attributes will enable the subject to accurately discriminate between the information items. Consequently one of the functional attributes is redundant as a means of identifying the information items. The subjects may be employing a strategy aimed at reducing the amount of effort necessary to identify the information items. The suggested strategy involves the subjects using only one of the functional attributes as a means of identifying the information items they are manipulating. This hypothesis would explain why one of the functional attributes is recalled in preference to the other. However, this hypothesis does not explain why one

particular dimension appears to be preferred (location in Experiments II and III, shape in Experiments I and IV)

Though redundancy of one of the functional attributes can explain why the other functional attribute was recalled well, it does not explain why there is recall of the redundant attribute in Experiments' I (colour), III (shape), and IV (colour). Referring to the notion of incidental learning can put the situation into context. The functional attribute which is used as a means to distinguish between the information items is recalled well because it is instrumental to the subjects goal. The subjects attention is directed towards the functional attributes which are displayed concurrently. The connection between the functional attributes is learned incidentally as a result of the attention directed towards them. The hypothesis is that the subjects learn the association between the functional attributes while using them. For example, In Experiment I the subject may be using the shape as a means of differentiating between the information items and identifying which item is accessed. Each time the subject looks at the shape the colour is viewed simultaneously this association is reinforced with repeated viewing and results in the combination of shape and colour being learnt incidentally. In the context of automatic processing theory (e.g, Shiffrin and Schneider, 1977) this situation can be explained by the hypothesis that the learning process does not require the use of extra attentional resources yet serves to improve recall for the redundant attribute. Implicit in theories of automatic encoding is the notion that once attended certain attributes are learned independent of additional processing. For example, Schneider et al (1984) describe "consistent Mapping" as being a necessary pre-requisite for learning to process information automatically. Where consistent mapping is defined as

"when the subject makes the same overt or covert response each time the stimulus occurs" p2.

Within the paradigm employed a subject could be responding to one of the functional attributes as a means of identifying the information items and this response is consistently mapped to the other functional attribute consequently the link between them is learned incidentally. The problem with this notion lies in actually specifying the

amount of attention given to either attribute. What can be concluded from the experiments is that actually using the attributes during the task affects the level of incidental recall. Following this line of reasoning it would be useful to find out how the increasing the number of redundant attributes used in the sorting task affects which attributes are learned incidentally and how well they are learned.

The existence of one or more redundant attributes could have a number of effects on the recall of the remaining functional attribute. If learning the redundant attribute requires additional processing its presence could represent a drain on attentional resources. Therefore loading additional redundant attributes could serve to adversely affect the recall of the initial non-redundant functional attribute. If this is the case increasing the number of redundant attributes used to label an information item in an automated filing support system would have *adverse* effects on the later identification of that item. Alternatively, the subject may learn the redundant attributes incidentally and be able to use them as a means of supplementary confirmation of the information item when it is difficult to distinguish between several alternatives of the functional attribute. In this case using redundant attributes to label information will *increase* the likelihood of recalling something of how the information was initially filed. Whether or not the addition of redundant attributes as a means of labelling an information item detracts from the unique identification of that item (reduces precision) or serves to support the identification of the information item (increases precision) is a line for further research.

One way of investigating this issue would be to run experiments where the number of redundant dimensions used to identify the information items is increased for different subject groups. For example, one group only has the use of dimension A to distinguish between the information items, a second group has dimensions A and B as distinguishing dimensions while a third group has A, B, and C, and a fourth could have A, B, C, and D as distinguishing dimensions etc. The experimental design for 4 dimensions (A, B, C, and D) with 3 alternative levels (e.g, a1, a2, and a3) as a means of identifying four information items, numbered 1, 2, and 3, is represented in Figure 8.6 (p175). For example, distinguishing between a red square and a blue triangle only requires knowledge of either the colour or the shape.

Figure 8.6: Hypothetical use of coding using two redundant dimensions to identify information items for filing and retrieval.

Information Item	Dimensions			
	A	B	C	D
1	a1	b1	c1	d1
2	a2	b2	c2	d2
3	a3	b3	c3	d3

It is conceivable that the particular combination of attributes could affect the findings and this would also have to be investigated. This experimental design could be set up within the existing paradigm and would serve to indicate whether the loading of redundant attributes detracts from recall, supplements recall, or has a maximum level beyond which it has no positive advantages for recall. The literature on divided attention (See Kahneman, 1973, for a review) provides studies which show that a subjects performance deteriorates when trying to accomplish an increasing number of tasks simultaneously, or attend to an increasing number of stimuli. The difference between these studies and the suggested study is that the subject would not be consciously attempting to attend to the stimuli simultaneously but may be doing so incidentally. The findings would have implications for the complexity of the design of iconic labels for personal filing systems.

Figure 8.7: Hypothetical use of dimensions to identify information items for filing and retrieval.

Information Item	Dimensions		
	A	B	C
1	a1	b1	c2
2	a1	b2	c1
3	a2	b1	c1
4	a2	b2	c2

An alternative structure for using dimensions to label information items would be to have unique combinations of dimensions while particular alternatives of the dimensions are repeated. To identify an information item it would therefore be necessary to recall the exact combination of attributes as oppose to recalling one attribute. This design would enable fewer attributes of any dimension to be used therefore enabling more information items to be uniquely identified and is exemplified in Figure 8.7. In Figure 8.7, there are 3 dimensions used (A, B, and C), two alternatives of the dimensions (e.g, a1 and a2), and four information items labelled (1, 2, 3, and 4). The experiments in this thesis all used unique alternative attributes to identify the information items as suggested for the previous experiment. How incidental recall is affected by necessitating the subjects to use more then one dimension for uniquely identifying an information item has implications for the design of an automated filing support system. For example, Using the system described in Figure 8.7 when a user wishes to access information item 1 and recalls that it is identified by the attribute a1 the user would access information items 1 and 2. In this design there may be an information item represented by a red triangle and one represented by a red square consequently knowledge of colour alone would not lead to an immediate identification of the information item. In a larger system this could lead to the user performing

lengthy search procedures to identify the required information item. If memory for the attributes is integrated the search procedures would be reduced. The system described in Figure 8.6 does not depend on the users recalling more than one of the attributes. If the user recalled attribute a_1 the information item would be immediately accessible.

Redundancy is one plausible explanation of the imbalance of recall for the functional attributes. A further possible account of this apparent imbalance can be supplied by hypothesizing that the locational attribute is recalled better than the shape attribute, which is recalled better than the colour attribute. This hypothesis would depend upon the 12 alternatives of each attribute being matched for discriminability. For instance, if the 12 colours were all subtly differing shades of red while the 12 shapes were very distinct accurately discriminating between the information items would be best supported by using the shapes. If the subjects find difficulty in discriminating between the colours they are unlikely to recall which colour is associated with which information item. Duncan (1980) pointed out that differences between types of cue (e.g. between colours and shapes) may reflect quantitative rather than qualitative differences in cue discriminability. In isolation, these experiments may not, therefore, suggest that recall for location was superior to recall of colour and shape. It could transpire that recall of various attributes depends on the relative ease of discriminating their values. However, the possibility that location is a special case is promising. As regards feature identification in some situations location is more easily identifiable than colour or shape despite cue discriminability (e.g. Nissen, 1984). The use of colour, shape, and location in a filing support system depends on the aspects of the design of each particular cue, and their interrelations. Further research is necessary to identify the conditions which affect the quality of incidental recall for these attributes.

8.4 ORIENTATION

Automatic versus effortful processing of information provides the theoretical domain for this research. There is general agreement on the criteria used for identifying the occurrence of automatic processing (e.g. Hasher and Zacks, 1979; Logan, 1980; Posner, 1978; Schneider et al, 1984). Automatic processes must be unintentional and

not draw on general resources (interfere with attended activities). Hence, the processing of the information occurs without using any attentional resources. The problem in using attention as a criterion for differentiating between automatic and effortful processes lies in the possibility that attention itself can be automatised via an orienting response. The results of the experiments in this thesis cannot be satisfactorily be explained purely by reference to the attention that the subjects are directing at the attributes they were required to recall. This is partly due to the difficulties involved in assessing the amount of attention given to any particular attribute. Recall of the two functional attributes was not equivalent in Experiments II and III despite the fact that the subjects are exposed to them in a similar manner. Recall of the locational attribute was approximately double that of the other functional attribute in both cases. Defining orientation as the direction of a goal directed activity it can be used to explain the imbalance in the levels of recall for the functional attributes.

Smirnov (1973) defines memorization as being the product of psychological processes that are an integral part of activities. These mnemonic processes are not independent of the characteristics of the activity but are determined by the activity. Consequently the nature of an activity, how the activity is performed, its content, what is used to perform the activity, are prime determinants of memorization. Smirnov defines *involuntary memorization* as memories which occur

"when there is no intended mnemonic task and the activity leading to memorization is directed towards some other goal" p26

The experiments in this thesis are therefore investigating the nature of what Smirnov referred to as involuntary memorization what has been referred to in this thesis as incidental recall. The definition does not involve the convolutions of considering how much attention was paid to a particular feature but rather considers the *orientation* of the activity.

"Any human activity is characterized primarily by its orientation. It produces not only a particular result but is always aiming at something which can be different from the actual results or the activity" p25

Involuntary memorization is dependent upon the orientation of particular activities that are performed though these activities are not aimed at producing memorization. In the experimental paradigm used here the main orienting activity is to sort the information items. To accomplish the sorting task the subjects are oriented towards the functional attributes during the activity of sorting the information items whereas there is no orienting towards the circumstantial attributes. The subjects are oriented towards the functional attributes because they are a means of discriminating between the information items.

A set of experiments devised by Leont'ev and Rosanova (1951) demonstrate the effects of orientation. Subjects sat in front of a screen which had a 4x4 matrix of disks placed on it. A four letter word was written on each disk. The discs were lit in turn by a spotlight. There were three groups of subjects, each performing a different task within this set up. Group 1 were instructed to remove disks from the board that were indicated by the experimenter pointing to them. The second group were instructed to remove disks with words beginning with a certain letter. The third group were instructed to establish with which letter the largest number of words began. The results indicated that the subjects remembered the features associated with the objective of their activity. Group 1, who were passive in their attention to the disks remembered nothing. Group 2 remembered the starting letter of the discs that they had removed. Group 3 remembered all the first letters that were used, and they could also point to the location of the words that began with the letter that was the most common first letter. From this experiment it was concluded that memorisation of material does not result from it being passively perceived but from the material being part of the goal directed activity. The results can be explained by a difference in the degree of attention. However, in an earlier experiment Zinchenko (1939) designed a procedure where the attention directed at the stimuli was similar for two tasks, while the tasks varied in their orientation. The stimulus material consisted of a two sets of pictures. One set of pictures was placed in front of the subject and the experimenter handed the subject the other set. The task in both cases involved the subjects pairing the pictures handed to them with those on the table. One group matched the pictures using the first letter of the name of the object in the pictures. The second group formed pairs of objects that looked alike. Both

experiments required attention to the object depicted in the picture its name. The subjects were not expecting a memory test. In both experiments the subjects' memory for the names of the pictures was tested. The subjects in the second group performed better than those in the first group. This imbalance cannot be attributed to attentional requirements but can be accounted for by the orientation of the subjects' task since the subjects in the second group were matching similar pictures as oppose to matching the first letters of the objects in the picture. However, the subjects' orientation is not the only plausible explanation of Zinchenko's results. The findings can be explained with reference to a "Levels of processing" theory (Craik and Lockhart, 1972). The subjects in the first group discriminate between the objects by using the first letter of the objects name, the subjects in the second group have to evaluate the visual similarity of the pictures. It could be reasoned that the second group are performing a task that involves deeper, semantic, processing and therefore produces a more durable memory trace.

In the context of this thesis recall of the functional attributes being higher than recall of the circumstantial attributes can be interpreted as being due to the subjects' orientation. The subjects are oriented towards the functional attributes, and thus recall of the functional attributes is better than recall of the circumstantial attributes. This interpretation does not account for the imbalance in the levels of recall for the two functional attributes. However, the notion of redundancy can explain the imbalance between the recall of the functional attributes. While incidental learning through orientation can resolve why there is recall of the redundant attribute. The subjects is oriented toward one of the functional attributes as a means of manipulating the information items. Memory for this attribute is therefore improved. Since the functional attributes are displayed concurrently the second attribute is learned incidentally.

An alternative hypothesis for explaining the structure of recall for the functional and circumstantial attributes can be found in the levels of processing theory. It is possible that as a means of manipulating the information items the functional attributes were subject to deeper processing then the circumstantial attributes. Again redundancy and incidental learning can be used to explain the imbalance between recall for the functional

attributes. Poor recall of the circumstantial attribute can be ascribed to it being in receipt of minimal processing.

Theories of automatic processing in human memory suggest that a minimal amount of attention is required for the processes to occur. As discussed earlier (Chapter 2, Section 2.1.2, p38) the common conception of automatic processes arises from the assumption that processing activities vary in the amount of attention they require. For example, Hasher and Zacks (1979)

"Operations that drain minimal energy from our limited-capacity attentional mechanism are called automatic" p356 (my emphasis)

Working with the assumption that minimal attention is required for automatic processing provides another source of explanation for why the functional attributes produce superior recall levels to the circumstantial attributes. The paradigm employed for this research provided the functional attributes with minimal attention as a by-product of the orientation of the subject's task. Whereas, the circumstantial attributes received less attention due to the lack of task orientation towards them. It appears that recall of at least one of the functional attributes is probably a product of task orientation. Consequently, an automated filing support system may benefit from requiring the users to perform a task that orients them towards the act of filing. This orientation could lead to the file identification being incidentally recalled. Orientation alone does not explain why the redundant functional attribute was recalled. If recall of the redundant attribute is due to incidental learning then the effectiveness and extent of this incidental learning could serve as a useful avenue of investigation. A filing system that requires the users to be oriented towards one file identification attribute but results in their learning a number of auxiliary attributes will increase the likelihood of the users accurately retrieving that file.

8.5 PHYSICAL ORIENTATION.

There is a body of research that suggests motor enactment can produce higher levels of recall than verbal or visual encoding techniques (e.g., Saltz and Donnenworth-Nolan, 1981; Saltz and Dixon, 1982; Zimmer and Englekamp, 1985). The research typically involves subjects enacting a verb (e.g., a motor action - "to hop") or a noun (e.g., an object, person, or animal - "table", "waiter", or "dog") recalling them later (with or without enactment at the retrieval stage). These enactments are compared with verbal and visual encoding techniques. What is of interest to this thesis is whether motor activity has an effect on recall, and the nature of this effect. The subjects task within the experimental paradigm used in this thesis requires them to move an electronic mouse. This movement is the means of identifying and manipulating the information items during the sorting task. The subjects also use the mouse to recreate the icons in the following test. It is conceivable that the subjects acquired some motoric memory for the movement associated with identifying the information items. It is also possible that this action served to enhance the attention paid to the spatial information.

In Experiments II and III the subjects accessed information items by physically moving the cursor (by moving the electronic mouse) to the icon location. This motor activity can be seen as a physical orienting towards the icon. One interpretation of the relatively high recall for location could stem from the physical orientation of the task. There is some experimental evidence to support the notion that physical orientation in subject-performed tasks, produces consistent recall despite manipulations involving levels of processing (Cohen, 1981), slowing down the presentation rate (Cohen, 1985), and the generation effect (Nilsson and Cohen, 1988). These manipulations have all been shown to affect the recall of tasks involving verbal material. The work regarding the generation effect is particularly relevant because the recall of the non-generated subject performed tasks appears to be superior to the recall of non-generated verbally performed tasks. Nilsson and Cohen (1988) designed an experiment that compared verbally performed tasks (VPTs) and subject performed tasks (SPTs) under conditions where the task was either generated by the subject or performed under instructions from the experimenter. Subjects were presented with an object (e.g., a battery), in the SPT-generation group the subject generated and performed an operation

on the object (e.g, lifted it) while vocalising this activity. In the SPT-non-generation group the subject's activity was yoked to that of a subject in the SPT-generation group (e.g, the subject was asked to lift the battery and vocalise the activity). In the VPT-generation task the subject was asked to generate and verbalise an operation upon the object (e.g, the subject could say "I lift the battery"). In the VPT-non-generation group a subject was yoked with a subject in the VPT-generation group and asked to read aloud a phrase given to them by the experimenter. The phrase was a transcribed description of the operation on the object generated by a subject in the third group. There was no significant difference between the mean correct recalls for SPT's in the generated and non-generated conditions. There was a generation effect for the VPT, with the VPT-generation group recalling similar proportions as both SPT groups. Nilsson and Cohen conclude that the cognitive enactments of generated VPT have a mnemonic effect similar to that produced by physical enactments. The implication is that actively processing the verbal information increases the likelihood that it will be recalled, while passively encoding physically enacted information does not effect the likelihood that it will be recalled. Cohen and Heath (1988) conducted a study that suggests the probability of recall is not dependent upon the motor aspects of the action but on the goals of these actions, the physical orientation.

In the context of Experiments II and III the subjects are physically oriented to a particular location for accessing an information item. The implication is that the physical orientation involved in identifying the location of the icon during the sorting task leads to improved recall of the locational as a functional attribute. In Experiments I and IV there is physical orienting toward the information item, but this response is not consistent for each information item (and icon) since the sorting task involves changing the locational point of reference for each item. The subjects were not consistently mapping a specific motor activity with specific icon attributes. Consequently, it is hypothesized that the goal directed motor activity did not serve to enhance recall of the attributes in these experiments. In contrast the physical orienting in Experiments II and III was consistent for each icon since access to the information items was by one of 12 established locations. It is hypothesized that memory for the physical orientation towards each icon served to enhance the recall of its locational attribute. Whilst Experiments I and IV do not benefit from the consistent mapping of physical orientation

because the the subjects move the information item representations during the sorting task and therefore access them from different locations.

8.6 THE RELATIONSHIP BETWEEN COLOUR AND SHAPE.

Experiments I and IV are the only experiments that produced statistically significant evidence for recall of the colour attribute. In these experiments the colour attribute was functionally displayed with the shape attribute. There is an indication in Experiment II that colour and shape are integrated in memory, though the recall levels of both attributes are so low as to be statistically indistinguishable from chance levels. If colour and shape do have a tendency to be combined in memory facilitating this tendency could prove useful as a means of enriching the design of visual labelling systems. Assuming that colour and shape are integrated in memory, when retrieval of information is required, memory for the colour would be accompanied by memory for the shape (and vice versa). Consequently, (assuming that the particular combination of the attributes did not render one redundant as a means of identification, as in Figure 8.6) retrieval of the information would be more precise than if only one attribute were recalled. If the integration of colour and shape in memory is dependent upon the colour and the shape being unique, and therefore one of them is effectively redundant as a means of identifying the information article, this integration in memory will have less practical utility as a means of improving the precision of recall. Consequently, the issue of whether colour and shape are integrated in memory is an important practical issue for their use in the design of a file retrieval system. The factors affecting the nature of this integration similarly delimit how a file retrieval system should be designed. If colour and shape are integrated in memory an investigation of the possible designs of file labelling systems could prove beneficial for retrieval purposes.

Studies relating to the physiological bases of colour coding have demonstrated that some genetic disorders can result in partial, or occasionally complete, absence of colour vision where there are pigment deficiencies in the retinal cones. These disorders do not lead to disorders in the perception of shape, suggesting that it is processed separately. Lesions of the brain can also lead to defects in colour vision without any

defects in other areas of vision (Pearlman et al, 1979). Garner and Felfoldy (1970) used an experimental paradigm designed to distinguish between different types of dimensional interaction in information processing tasks. Within this paradigm Garner and Felfoldy concluded that at a behavioural level it is easy to separate colour and shape. In brief, it appears that there is physiological evidence suggesting that colour and shape are processed separately. The fact that the two codes of colour and shape show such low physiological interdependence suggests that an observer is not restricted to processing them simultaneously. This difference in the physiological basis of the coding of colour and shape does not necessarily mean that the observer has not learnt to encode these features in an integrated fashion automatically. Whether an individual can choose to process colour and shape separately is not an issue of concern to incidental recall. The important issue is whether individuals tend to integrate colour and shape in memory without necessarily intending to do so. In some situations this appears to be the case. For example, in the case of words and colours an integration can be demonstrated by the Stroop (1935) test where subjects are presented with a colour word (e.g, green) and required to vocalise the colour of the ink it is printed in which is not the colour of the word (e.g, red). When the ink is the same colour as the word the subjects have a faster correct response time. This effect can be explained by the fact that subjects verbal response to a colour word is to vocalise that word, this automatic response interferes with the oral expression of identifying the different coloured ink. Poor readers do not exhibit this interference effect as dramatically as good readers (Gibson, 1971). Language and colour processing may not have the same physical basis but the colour names are learned to be associated automatically with the colour. This compliments the hypothesis previously made in this thesis that subjects automatically learn the association between the functional attributes.

It is possible that subjects have learnt to integrate colour and shape. The hypothesis is that when oriented towards the colour of a shape the shape is encoded automatically or vice versa. There appears to be mixed evidence on this point. Park and Mason (1982) found that the arbitrary colour (red or green) in which a line drawing is displayed was remembered no better than chance. Colour was only recalled if express instructions to remember colour were given. They conclude that memory for the colour in which an object or symbol is displayed appears not to be automatic. While Houck and Hoffman

(1986) suggest that colour and shape appear to be conjoined pre-attentively when perceptual after-effects are used as a measure. Using the same stimuli and a search task Houck and Hoffman found that colour and shape were separable, they explain this apparent inconsistency in their findings by hypothesizing

"that different experimental procedures may be tapping into different stages of pre-attentive vision" p186.

Even though the processing of colour and shape information appears to be physiologically distinct the experiments described above and the results from Experiments I, II, and IV of this thesis suggest that under some circumstances shape and colour are integrated in memory. There is practical value in determining what conditions effect the integration of colour and shape in memory. Further work is needed to identify what circumstances affect this integration, and thus how it can be effectively utilised by a file retrieval system.

8.7 PRACTICAL IMPLICATIONS OF INCIDENTAL RECALL FOR THE DESIGN OF SYSTEMS

8.7.1 THE USE OF COLOUR CODING.

The experiments carried out in this thesis showed that colour was not recalled as well as either shape or location. Recall of colour was best when functionally combined with shape. It has noted that the distinctiveness of the colours used may have been at least partly responsible for their consistently poor recall. As a general view this needs further investigation. In a retrieval support system an increasing number of information items will require an equivalent number of distinct filing tags. Increasing the number of colour codes will result in reducing the distinctive quality of the unique colour codes. Using colour independently as a label for information items when a subject is not intentionally attending to it does not appear to be a productive option for the design of a retrieval support system. The matter takes on a different light when subjects attention is drawn to the colours as labels. It appears that recall of colour is affected by verbal

labels subjects apply to them (Davidoff and Ostergaard, 1984). Where colours can be given distinct verbal labels they are recalled well in comparison to colours that are difficult to label. A good semantic fit between the colour and colour label leads to improved recall of the colour. The implication is that when the subjects apply a verbal label to the colour, recall of that colour will be improved. The subjects were not asked to apply verbal labels to colours and since colour recall was poor in most of the experimental conditions it is possible that the subjects were not using verbal labels. Alternatively, the poor recall of the colour attribute may have originated from the experimental design used during this thesis. The colours were arbitrarily assigned to the information items. Evidence suggests that semantic fit between a file identification and the contents of the file leads to improved recall of the file identification (Schönplflug, 1988). The proposal is that if the colour coding has a good semantic fit with the information item being filed then the colour coding will probably prove memorable. An automated filing system would therefore have to assess the contents of the information being filed to evaluate whether colour coding was appropriate to the contents of the file. The value of colour coding as an independent attribute appears to depend upon features such as how distinctive the colour is, whether the subject's attention is drawn to it, whether the subject uses a verbal label for the colour, and the amount of semantic fit between the colour and the contents of the information being filed.

The results of Experiments I, II, and IV suggest that colour used in combination with shape may provide a means to support retrieval of information (See Section 8.6). Some studies have demonstrated that using colour as a redundant label provides little assistance to recognition (Davidoff and Ostergaard, 1985). However a set of experiments performed by Mazzoni et al (1988) concluded that subjects will make use of the colour coding in situations where the shape coding is ambiguous. These studies did not employ incidental learning paradigms. The evidence to suggest that colour is integrated with shape incidentally could provide a source for improving the design of filing systems. If the integration of colour and shape is not substantial then they are best employed as separate coding dimensions. More research is needed to investigate whether colour is integrated with shape in memory, and under what conditions this integration occurs.

Davidoff (1987) produced a fairly comprehensive review of the potential use of colour for VDUs. Davidoff suggests that the advantages provided by colour tend to be obtained at the expense of locational information. In general colour is not the most efficient coding method. Despite this fact the use of colour is appreciated regardless of the fact that it may not help performance (Narborough-Hall, 1985). Remembering colour codes appears to be effortful (Park and Mason, 1982). Davidoff advocates the use of "meaningful units" to organise a visual display and suggests that for most tasks these meaningful units must be objects. This suggestion supports the notion discussed earlier that colour is best used when there is a high degree of "semantic fit" between the colour and the item being coded.

The findings of this thesis suggest that recall of colour in the context of these methods is more effortful than recall of shape or location. Recall of colour was only evident when it was displayed functionally in association with a varying shape attribute. The use of colour coding in an incidental paradigm appears to be reliant on the subjects being oriented toward the colour. There is room for further investigation into how the use of distinct colours displayed in conjunction with distinct shapes affected the findings.

8.7.2 THE USE OF LOCATION CODING.

The use of locational coding in an incidental paradigm appears a promising avenue of application for retrieval support systems. In the two experiments where location is a functional attribute recall is substantially higher for location than either shape or colour. In the two experiments where location is the circumstantial attribute comparing the distribution of recall to the binomial distribution indicates that some subjects recalled the location. Consequently, the use of locational coding in an automated file support system appears constructive. However, the manner in which incidental locational codes can best be employed is not immediately obvious. For example, the findings of Crolla's (1990) study suggested that location is not necessarily recalled incidentally. The disparity between Crolla's findings and those of this thesis can suggest some of the

factors that affect the nature of incidental recall for location. In Crolla's study there were 16 locations in a 4x4 matrix. The experiments in this thesis used 12 locations in a 3x4 matrix, the locations were larger and were spread over a larger region than those in Crolla's study. One potential explanation for the disparity lies in how easy the subjects found the task of differentiating between the locations. Another potential explanation for the inconsistency between Crolla's findings and those of this thesis lies in design of the subjects task. In Crolla's experiment the subjects only accessed each document (by the location) once. The experimental paradigm used in by this thesis enabled the subjects to access and re-access documents. Consequently the subjects were able to use the locations frequently and choose which location they wished to use. The incidental recall evident in the experiments of this thesis could be due to a factor relating to the subjects ability to use the locations. In short, there are content and task variables which affect how well the locational attribute is recalled incidentally. For example there is evidence suggesting that spatial retention is more likely to accompany correct item recall than when information is not retrieved (e.g, Zechmeister and M^CKillip, 1972). An understanding of the nature of these variables will enable limits upon the use of location as an incidental code for filing information to be evaluated.

The application of an automated location coding system might be affected by how distinguishable the locations are, whether the subject is physically oriented towards the locations during the filing task, and how the subject uses the locations during the filing task. Investigating the effects of these variables will enable a clearer picture to be drawn of the conditions that support incidental memory for location.

8.7.3 THE USE OF SHAPE CODING.

In the incidental paradigm used the icon shape attribute was not recalled as well as location but was recalled better than the colour. The different shapes used in Experiments I and IV suggest that the intricacy of the shape affects the structure of recall for the shape and colour where more intricate shapes lead to less integration of colour and shape. The recall of shape was evident separately from the colour as well as in conjunction with it. This implies that shape could be used successfully as an

independent incidental coding dimension. Shape could also be used to exploit the potential of colour as an incidental coding dimension and thus improve the overall precision of the system.

8.8 CONCLUSIONS

This section summarizes the results of the experiments together with their implications for the design of an automated filing system and future research. The thesis has found evidence that the icon attributes of location, shape, and colour are all recalled incidentally to various degrees. Two procedurally different forms of incidental recall have been investigated. One in which the incidental attributes are central to the subjects task (functional), and one in which they are not (circumstantial). Recall for attributes which are displayed circumstantially is generally minimal and evident in how the distribution of the correctly recalled attributes varies from the binomial distribution. This indicates that some subjects recall the circumstantial attributes. The generally low recall for the circumstantial attributes suggests that their use as coding methods in an automated file support system is marginal where the exposure of the attributes to the user is minimal and is of no direct use to the task.

When functional, each attribute shows more evidence of being recalled than the circumstantial attributes. Since the same attributes were displayed as functional, and circumstantial in different experiments the difference between recall for circumstantial and functional attributes is very clear. Also, in each experiment recall for one of the two functional attributes appears to be superior to the other. There are a number of possible reasons for this imbalance all of which have implications for the design of an automated file support system. Explanations for the imbalance in the recall of the attributes could include the fact that one attribute is redundant as a means of accessing the documents. However redundancy does not explain why there is recall for both attributes. There may be an incidental learning factor involved where the attributes are learnt with exposure even though recall is not expected. The possibility that the redundant attributes are learned incidentally could be investigated within this paradigm by loading the functional dimensions as described in Section 8.3. An alternative

explanation of the different levels of recall for the functional attributes is the distinctiveness of each attribute variable. With the attribute sets that are most distinctive being more easily recalled.

Recall for location is always more substantial than shape or colour when combined with either of these attributes as a functional attribute. Incidental recall for location may simply be more prominent than incidental recall for the other attributes. Superior recall of the locational attribute could be task dependent and stem from the motor activity involved in moving the cursor to the location as a means of identifying the documents. These aspects of incidental recall need to be investigated.

There is also some evidence to suggest that the attributes of colour and shape are integrated in memory. The conditions which encourage this integration need to be investigated to distinguish whether an automated file support system would benefit using unique variations of each attribute to identify files or whether a unique combination of attributes would be more efficient.

The fact that incidental recall for colour, shape and location exists suggests that information workers would not necessarily have to generate the complete file identification themselves to ensure that their recall was effective. Merely being oriented towards the filing attributes and exposed to the relationship between the icons and their associated information item will lead to the associations being learnt incidentally. The generally low levels of recall for the circumstantial attributes in comparison to the functional attributes suggests that the dimensions would be best employed in situations where they are used as part of the filing activity. Therefore, the use of location, shape, and colour as information retrieval aids is recommended as a support to other filing activities rather than the main form of access. Further research is required to evaluate how variations in the design of each dimension affects incidental recall. This research will lead to a clearer picture of the relationship between the optimum application and use of colour, location, and shape in a retrieval system, and the specific relation to the subject's task.

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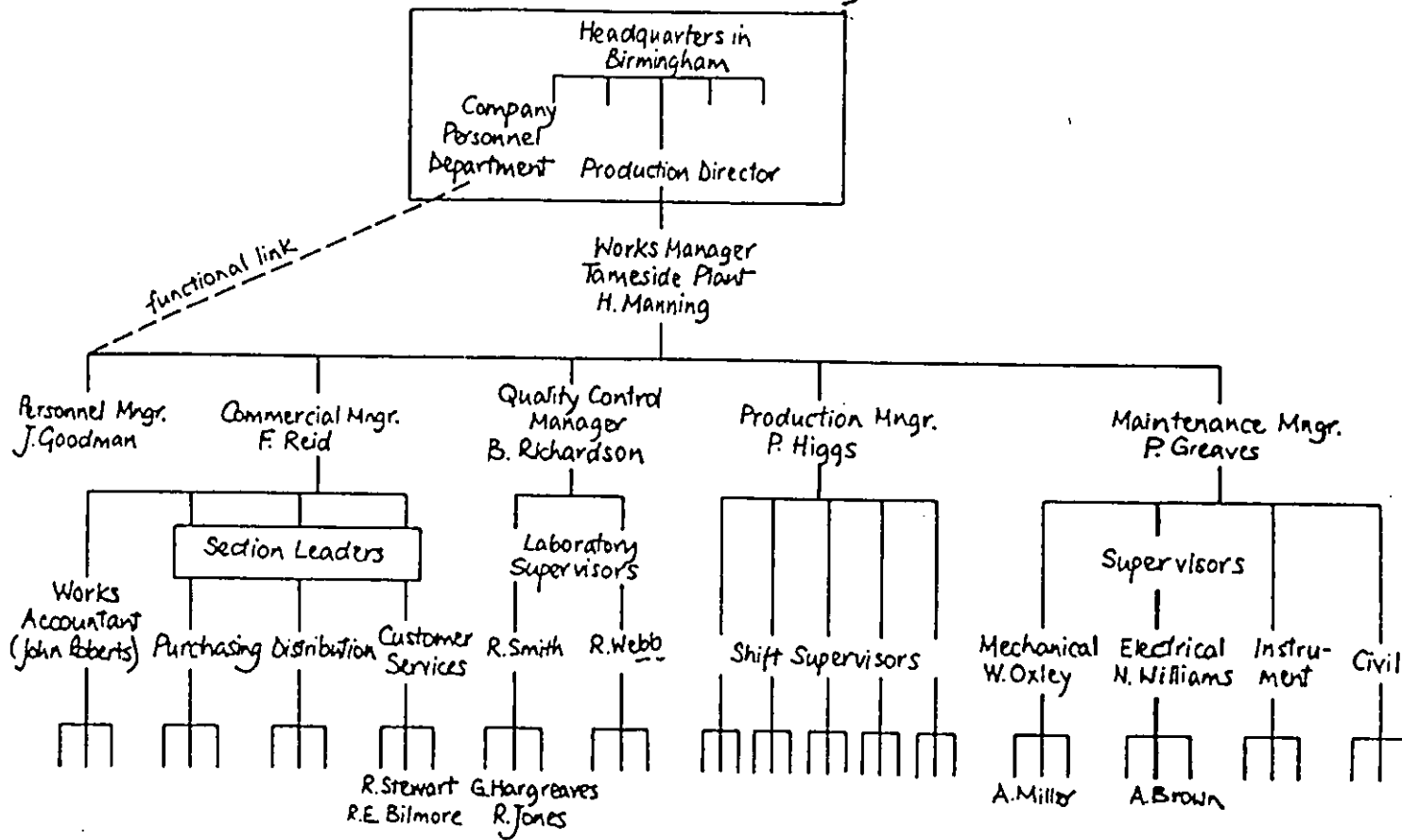
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APPENDIX 1**THE INTRAY EXERCISE**

Contents

The appendix contains the sheet of background information about the company "Plastic Products" and the 12 information items that constitute the personnel manager's incoming mail.

Plastics Products Limited – Organisation Chart



Plastics Products Limited

Background

Plastics Products Ltd has its headquarters in Birmingham and four outlying factories. One of these is the Tameside plant in North Cheshire which was established in 1951 during the post war expansion. The company prospered and developed a reputation of good employee and customer relations. However in the last ten years increased competition arising from excess production capacity world wide had put greater pressures on managers and employees to improve productivity. The reduction of costs while maintaining security of employment and regard for the community has now become a major issue and the onset of the recession has made this both more important and more difficult.

The Tameside plant produces plastic materials in the form of powder and small chips. Customers use these as raw materials for a variety of finished goods, eg. mouldings, rain water pipes, electrical wire insulation etc. The factory employs 350 people and runs continuously on shifts. About 100 of the staff are management and office/laboratory staff and there are 250 factory workers. All the weekly paid staff belong to an appropriate trade union (GMWU, AUEW, EEP TU) and are represented by Shop Stewards elected by their workmates. 30% of the monthly paid staff are in a white collar union (ASTMS) and are represented by Accredited Representatives.

The site is situated on the outskirts of a small town of some 40,000 people. Other local industry is small in comparison and covers a broad field. The social amenities in the town are excellent and secondary education is somewhat stretched but there are plans for extension in the future. The local College of Further Education has a poor reputation. In nearby larger towns, however, these facilities are extensive.

Unemployment in the area is high but it is still comparatively difficult to get and retain good laboratory staff, secretaries and instrument artificers.

The local council is very co-operative to schemes of expansion and will readily discuss problems about local services ie. sewage disposal, water supply, social services, etc. Unions are strong but generally not militant. The Shop Stewards have a joint Consultative Committee; there is also a (monthly-paid) Staff Committee, and the Company is very proud of its enlightened policies in joint consultation generally.

Five Section Managers responsible for functions at the factory report to H. Manning, Works Manager, and they all have technical links to equivalent departments at HQ.

H. Manning, Works Manager, reports to the Production Director in Birmingham. Manning is 54, and had experience of technical service as a physicist with other companies before joining Plastics Products' Research and Development Department in Birmingham. He has been Works Manager at Tameside for four years and likes to seek views from his management group.

F. Reid, Commercial Manager, is 57. He has been 33 years with the Company, being one of the first to move to the new factory in 1951. As Commercial Manager he deals with works accounts, distribution, purchasing and customer liaison. He has four section leaders and 20 monthly staff working for him.

B. Richardson, Quality Control Manager, is an analytical chemist by training and is primarily interested in technical problems. He is responsible for two areas of work - Quality Control and Process Investigation. He is responsible for the operation of two laboratories. One laboratory covers analysis of raw materials, finished product and plant samples. There is a Supervisor, eight shift lab assistants and one day lab assistant. The other lab deals with technical problem solving, development of new techniques and the development of new equipment. There is a Supervisor and three day lab assistants.

P. Higgs, Production Manager, is responsible for the safe and economic running of the Production Plant. Four Shift Supervisors and one day Supervisor report to him and each are responsible for about 40 weekly paid Process Operators.

P. Greaves, Maintenance Manager, is responsible for mechanical, electrical, instrument and civil maintenance of the plant and subsidiary buildings, labs and offices. Working for him are four day Supervisors covering each area, a small drawing office team, engineering storemen, fitters, electricians, instrument artificers, plumbers, riggers, bricklayers, painters and boilermen. The total number of weekly staff is 90. He is meticulous at following company procedures.

J. Goodman, is Personnel Manager.

From : P.Greaves
Maintenance Manager
To : J.Goodman
Personnel

It has been reported to me that Alan Miller was recently discovered to have carried matches in the flammable solvent reception area. As you know this area is covered by the Statutory Petroleum Regulations so Millers action is an offence at law. In reply to the routine question at the security gate he denied having either matches or a cigarette lighter. Later however, he returned to the gate and handed in a full box of matches, stating that he had "forgotten" they were in his pocket. In the past people committing similar offences have been dismissed. I should be glad to know, as soon as possible, the course of action you wish me to take in this case.

P.Greaves

From : W. Oxley
Mechanical Maintenance
To : P. Greaves
Maintenance Manager
Copy To: J. Goodman
Personnel

MEDICAL RESTRICTIONS - Craftsmen

As you know, tight manpower controls necessitate full and productive utilisation of those people we already have. Unfortunately, there seems to be a spate of notes coming out of the medical centre telling us to put our people on "lightwork". While some of these are temporary problems, two are of a long term nature and the fact is that they are not now physically capable of doing the jobs for which they were employed. The Union is very sensitive about this subject, because of all the emotional arguments are being put about - " casting people aside in their hour of need ", moral obligations etc,etc,... but the fact is that the work needs to be done. We are not a welfare centre. Perhaps you would advise me how to tackle such cases now and in the future?

W. Oxley

From : F. Bullock
Chairman of the Shop Steward Representatives on
the
Joint Consultative Committee
To : J. Goodman
Personnel

JOINT CONSULTATION

I have to inform you that the Shop Stewards on the Works committee are not satisfied with the way Joint Consultation is working in this factory. Management only tells us about decisions after they are made and does not take any notice of our views. The Company keeps on boasting about it's joint consultation policy and talks about being "pioneers in participation". We therefore demand real participation on all decisions in this factory especially business decisions, the introduction of new technology, manpower planning decisions, and decisions on facilities. If the management is not prepared to apply what it keeps boasting about in public we, the shop stewards, shall withdraw from the works committee and cease all co-operation. I have also spoken to Mr. Meads, the chairman of the monthly staff of ASTMS branch and understand that they feel the same way and will also be withdrawing from the staff committee.

F. Bullock

From : N. Williams
Electrical Maintenance Supervisor

To : P. Greeves Copy to : J. Goodman
Maintenance Manager Personnel

Last night, I received a telephone call at 3.00 am concerning a technical difficulty on site. While I was investigating the problem I found that the shift electrician was absent from the place he was supposed to be working. I could not find him, although I did not conduct an exhaustive search. He says he was not absent from the site, although several people had not seen him. It is only three months since we found this character drinking in the local during the evening shift, and we told him then that he would be dismissed if ever again he left the premises during working hours. As he is the Shop Steward, and bearing in mind the generally sensitive climate, (in which the chairman will be touring the site next week) I thought you would wish to consider this one.

N.Williams

From : F. Reid
Commercial Manager
To : J. Goodman
Personnel

CONFIDENTIAL

Bob Stewart the Customer Liason Representative was "breathalysed" one evening last week when driving home after having dinner with some customers following a visit to their factory. He was found to be some 20mg over the limit and his case comes up next month. He spends about 70% of his time on the road visiting customers. I know that we sacked a lorry driver who is a member of the union last week when he was convicted for driving one of our lorries whilst being over the alcoholic limit and would appreciate your advice. I would like to emphasise the following points which I think you should consider very carefully. Stewart is 42 years old, with 20 years' service and he has four children under the age of 15. He is superb at his job and, as you know, has saved us a lot of money over the past 18 months. With competition increasing we have even more need to maintain this service and I have no-one to replace him. This is the first slip after 20 unblemished years and it took place outside normal working hours. The customers with whom he was dining were also by way of being personal friends of Bob's. Would you please advise me on the action we should take on this unfortunate case?

F. Reid

From : P. Greaves
Maintenance Manager
To : J. Goodman
Personnel

The workers who operate the boilers, as you know, have felt for sometime that they are underpaid. In accordance with the company's practice, they were asked to write up a description of their current duties for formal job evaluation. They are now saying that they will not take the chance of including new duties in the description, and subsequently being committed to those duties, should they fail to get a higher grade. They will not do any extra work without additional reward, and so have stated that from the end of this week they will work solely to their old job description. As you know the introduction of the new boiler capacity was of considerable importance to us, and it is essential that the boilermen operate the new boilers if we are to keep the factory going. The boilermen are on a grade which was fixed years ago, but as their marks are low in the band, they probably will not achieve a higher grade on this occasion. I think they know this which explains their action. Some are more militant than others, but all are resolved to take whatever action is required to either get a higher grade or make sure that they do not continue to perform the new duties introduced since the last assessment.

P. Greaves

From : F. Reid
Commercial Manager
To : J. Goodman
Personnel

The works accountant John Roberts, came to see me today to tender his resignation having been offered a more lucrative post outside the company. Needless to say this was a bit of a shock and we can ill afford to lose him. I told him that there was a good chance in the near future of a promotion into H.Q. Accounts department at which he expressed surprise but said that he had made up his mind and wished to leave in a month's time at the end of this quarter (i.e. 2 months before his contractual notice expires). Please could you advise me on this?

Incidentally , I note that my other three section leaders are all due to retire over the next three years and, quite frankly, I do not know how we shall replace them - your help in this matter would also be appreciated.

F. Reid

From : H. Manning
Works Manager
To : J. Goodman
Personnel

STRICTLY

CONFIDENTIAL

As you know, I attended an emergency meeting with the Production Director yesterday on the business situation. The competition is now starting to have an adverse effect on sales and if, as looks very likely, the situation does not improve before the end of the quarter we shall need to reduce the shop floor numbers by at least 20%. Would you please come to see me at 3.00pm and let me have your views on how we could handle this situation.

H. Manning

From : P. Higgs
To : J. Goodman

RE: ERNEST SEED - DECEASED

You will remember that Seed collapsed and died on night shift some weeks ago. He left a widow and two children. The eldest was due to go to university this year. His widow says that this may not be possible for financial reasons. She is extremely bitter towards the company since she ascribes overwork as a cause of her husbands death. What, if anything, can we do in this case?

P. Higgs

From : F. Reid
Commercial Manager
To : J. Goodman
Personnel

CONFIDENTIAL

P. BILMORE, CLERK

This man has worked for us for 26 years, and for many of those he's been more of a liability than an asset. His workpace is ponderous and the quality is awful. He couldn't care less about this, and because he's convinced that he's bullet proof he never tries to improve even when he's given a good talking to. I doubt that he is capable of improving. It is time to put away sentimental ideas about the length of service and the fact that he's 52, and put this section in order. The customer service can be dramatically improved only by getting rid of him, and then we'll all take less "stick" than has been the case in the past. I am not just talking about management, but also about the unfair load Bilmore's presence imposes on everyone else.

F. Reid

From : A. Brown
EEPTU Shop Steward
To : P. Greaves
Maintenance Manager
Copy To: J. Goodman
Personnel

PROMOTION

Mr. Stillson (AUEW) tells me that the instrument section supervisor is to retire in three month's time. I have been instructed by my members to advise you that we expect full consultation in the new appointment and expect the decision on his replacement to be made on a fully participative basis as we are not prepared to be supervised by another AUEW man.

A. Brown

From : B. Richardson
Works Manager
To : H. Manning
Quality Control Manager
Copy To: J. Goodman
Personnel

RE : G. HARGREAVES

I am having problems with Graham Hargreaves & have made the following notes on his case; Graham (19 yrs) joined us from the midlands branch. Recommended as promotion potential, this move was intended to broaden his experience. He planned to stay with relations at weekends, so the company helped find him 5 day digs. He enrolled at college under the our FE Scheme to take his HNC. Hargreaves works for Smith (a junior supervisor), Smith delegates a fair measure of responsibility & is well liked. After a few weeks Hargreaves complained to me that he did not have enough work to do, or encouragement. Smith stated that he treats all his assistants the same way, that Hargreaves had not complained to him, that Hargreaves' work was not up to standard in quality or quantity, & he was distracting the other assistants. Consequently, I warned Hargreaves to apply himself. His work, & behaviour, improved for a while, then a gradual deterioration in his appearance, & passive, resentful attitude to those about him, was noticed. Hargreaves has only attended college once this term, he was not on site & has claimed expenses for full attendance. Hargreaves admitted his absences & defaultations, was very upset, & attempted to justify himself on the grounds that: a. As his first time away from home, he was very lonely. b. After 6 weekends his relatives moved & he took pub accommodation, while seeking a social life in Manchester. He told no-one of his accommodation & financial difficulties, due to pride. What do you think we should do about this case?

B. Richardson

APPENDIX 2**THE INSTRUCTIONS GIVEN TO THE SUBJECTS**

Contents

This appendix contains copies of the written instructions that the subjects recieved prior to each performing the In-Tray exercise, and the memory test.

EXPERIMENT I, and IV : The presentation program instructions

EXPERIMENTAL AIMS

The layout of information on a screen, and limitations imposed by equipment, will affect performance of a task. I am investigating how different screen layouts and equipment changes affect the practical use of the equipment.

SORTING THE MAIL

Your task is to pretend that you are J.Goodman, the personnel manager of "Plastic products Ltd." As the personnel manager you will read your morning mail and sort it into an order ready for dealing with. For sorting the letters consider:

- possible time constraints.
- the necessity of gathering further information.
- the possible consequences of any action taken.

PERSONNEL MANAGEMENT

General Background on Personnel Management: the main task of the personnel manager is to ensure that the members of an organisation contribute as effectively as possible towards its objectives. This involves considering

- the best fit of person with job,
- provision of good working conditions,
- fair reward for effort,
- proper training,
- and sometimes providing a sympathetic ear.

Inevitably there will be occasions when the interests of the organisation and the employee are not the same. Because a personnel manager is a manager he/she must always have the needs of the organisation as a whole in mind. There is an accompanying sheet of background information on the Plastic Products company which you might find useful. Read, and arrange the letters in an order indicating the priority you would assign to dealing with the information that they contain.

The program will enable you to read and re-arrange the letters by using the "mouse". Instructions on how to operate the mouse are on the reverse side of this sheet.

When sorting the letters place the letter you give the highest priority to on the top of the pile (i.e. the right hand side of the screen)

MOUSE OPERATION

The mouse moves a cursor (a small arrow shaped pointer) around the screen. It has three buttons and each button performs a different operation on the screen.

THE LEFT HAND BUTTON

(for reading)

can be used to read the letters, and to put them away after they've been read. When you point the cursor at one of the letters and press this button the full size letter will be displayed so that it can be read. Pressing this button a second time will return the letter to its smaller representation on the screen amongst the other letters.

THE MIDDLE BUTTON

(for selecting)

When you press this button it "selects" the letter the cursor is pointing at, ready to be moved (for sorting).

THE RIGHT HAND BUTTON

(for shuffling)

When you have selected a letter (with the middle button) point the cursor at the position in the pile that you would like to place the letter and press this button. The result will be that the letter you selected is now in the position that the cursor is pointing at, and all the other letters have been shuffled along one position.

Start when you are ready, and when you are satisfied with the arrangement of the letters place the cursor in the box at the lower left hand side of the screen and click any button.

MEMORY TEST

The instructions used in all four experiments.

INTRODUCTION

The aim of this second part of the study is to discover whether people remember features that were not related to the information content of the letters they read. The features are the shape, colour and location of the logos that were on each letter.

The program for this part of the study will show you the letters that you have just read. The letters will be shown one at a time. With the presentation of each letter there will be two displays. One display will show all the colours that were originally used for the logos. The other display will show all the original logo shapes. The possible locations for the icons are highlighted by broken-line boxes drawn over the letters.

Your task is try and recall which icon was originally displayed on the letter. Choose a colour, a shape, and then place this on the letter using the mouse. When you can not remember which shape, colour, or position the logo was, guess. The instructions for using the mouse are on the reverse side of this sheet.

MOUSE OPERATION

LEFT HAND BUTTON

(selection)

Is a selection button. If you point the cursor at a colour and press this button, it selects the colour - like dipping a paintbrush into a paint pot. If you point the cursor at a shape and press this button it will colour, and select that shape. You can then point the cursor at one of the positions marked on the letter and the coloured shape will appear in this location.

THE MIDDLE BUTTON

(clear logos from letter)

Pressing this button (the position of the cursor is irrelevant) re-presents the letter without any logos you may have placed on it.

RIGHT HAND BUTTON

(next letter)

This button shows you the next letter. When you are satisfied with your choice of colour, shape, and location on the letter already showing, use this letter to move on. This button will not work unless there is a logo on the letter. You cannot go back to change any logo's you have already placed, but you can use them more than once.

EXPERIMENTS II and III: The presentation program instructions

EXPERIMENTAL AIMS

The layout of information on a screen, and limitations imposed by equipment, will affect performance of a task. I am investigating how different screen layouts and equipment changes affect the practical use of the equipment.

SORTING THE MAIL

Your task is to pretend that you are J.Goodman, the personnel manager of "Plastic products Ltd." As the personnel manager you will read your morning mail and sort it into an order ready for dealing with. For sorting the letters consider:

- possible time constraints.
- the necessity of gathering further information.
- the possible consequences of any action taken.

PERSONNEL MANAGEMENT

General Background on Personnel Management: the main task of the personnel manager is to ensure that the members of an organisation contribute as effectively as possible towards its objectives. This involves considering

- the best fit of person with job,
- provision of good working conditions,
- fair reward for effort,
- proper training,
- and sometimes providing a sympathetic ear.

Inevitably there will be occasions when the interests of the organisation and the employee are not the same. Because a personnel manager is a manager he/she must always have the needs of the organisation as a whole in mind. There is an accompanying sheet of background information on the plastic products company which you might find useful. read, and arrange the letters in an order indicating the priority you would assign to dealing with the information that they contain.

The program will enable you to read and re-arrange the letters by using the "mouse". Instructions on how to operate the mouse are on the reverse side of this sheet.

These are the mouse instructions used for Experiment II. They are identical to those used during Experiment III if the words relating to "colour" are replaced with "shape".

USING THE MOUSE

As you move the mouse around the board it moves a cursor (arrow shaped pointer) around the screen. The twelve coloured squares represent the twelve letters that you are going to sort. The numbers beneath the letter representations (coloured squares) are the rankings. When you have read the letters, rank them in an order that you think a personnel manager would choose to deal with them. The letter you think is most important should be ranked with a 1, the next with a 2. etc.

READING A LETTER

To read a letter:

- (i) Move the cursor to point at (in) a colour,
- (ii) press any mouse button,
To replace the letter when you have read it
- (iii) move the cursor to point at the box marked "point here to close the letter" at the middle
left-hand-side of the screen.
- (iv) press any mouse button.

RANKING the letters

- (i) move the cursor to point at the rank number you wish to select.
- (ii) press any mouse button
the rank that you have just selected will be displayed in a small box on the left hand side of the screen.
- (iii) move the mouse to point at the box beneath the letter representation you wish to re-rank
- (iv) press any mouse button.

The result will be that the rank from the first selection (displayed in the box on the left hand side of the screen) will now be under the letter representation you have just selected.

APPENDIX 3**THE PROGRAMS**

Contents

The programs written for running the In-Tray exercise and the memory test.

The presentation program for Experiment 1:

```

PROGRAM EXPER1 (Input, Output) ;

LABEL L1, L2, L3;

VAR {public}
x, x1, x2, x3, x4, x8, x9, xc, xc2, arindex, xb, cx, cellx, ox      : INTEGER;
y, y1, y2, y3, y4, y8, y9, yc, yc2, yy, yx, lhm, bx, yb, cy, celly, oy : INTEGER;
ic, ax, currx, curry, oldw, height, selected_colour, clickNo      : INTEGER;
bone, btwo, bthree, b, d, e, f, h, n, o, p, q, r, s, t, u, w, z    : INTEGER;
one, two, three, four, eight, twenty, thirty, sedge, part, jz     : INTEGER;
iconx, icony, iconno, COL, PIXCOL, iconstore, blackiconx          : INTEGER;
store_old_position, store_new_position, blackicony                : INTEGER;
Black, green, blue, cyan, red, yellow, magenta, white             : INTEGER;
aargen, bbrgen, ccrgen, srgen, srgenpl, srgenml, trgen, rmax       : INTEGER;
store_aargen, store_bbrgen, store_ccrgen                          : INTEGER;
argen, brgen, crgen                                                : INTEGER4;
hrgen, jrgen, jjrgen                                              : REAL;
reading                                                            : BOOLEAN;
ftext, DATA                                                        : TEXT;
ff                                                                    : FILE OF INTEGER;
rr                                                                    : CHAR;
filnam, resultstring, st                                           : LSTRING(62);
instring                                                            : LSTRING(3);
matrix, randcol, randfil                                           : ARRAY[0..12] OF INTEGER;
randicon, isort1, isort2                                           : ARRAY[0..12] OF INTEGER;
randlocs, filsort1, filsort2                                       : ARRAY[0..12] OF INTEGER;
locsort1, locsort2                                                 : ARRAY[0..12] OF INTEGER;
Buttonpress : ARRAY[0..3000] OF INTEGER;
grey        : ARRAY[0..40] OF INTEGER;
colour      : ARRAY[0..5] OF ARRAY[0..5] OF ARRAY[0..5] OF INTEGER;

{The procedures below are those provided by the Pluto graphics system}
PROCEDURE AUX_IN (VARS X : LSTRING);                               EXTERNAL;
PROCEDURE AUX_OUT (VARS Y : LSTRING);                             EXTERNAL;
PROCEDURE Allocp (VAR width, height, nsyms, p : INTEGER);         EXTERNAL;
PROCEDURE Copy (VAR w, h, pl, x1, y1, p2, x2, y2 : INTEGER);      EXTERNAL;
PROCEDURE Cops (VAR n : INTEGER);                                  EXTERNAL;
PROCEDURE CLrCWP;                                                  EXTERNAL;
PROCEDURE Pinit;                                                    EXTERNAL;
PROCEDURE Plot (VAR x, y : INTEGER);                               EXTERNAL;
PROCEDURE Lineto (VAR x, y : INTEGER);                             EXTERNAL;
PROCEDURE MoveTo (VAR x, y : INTEGER);                             EXTERNAL;
PROCEDURE RFill (VAR W, H : INTEGER);                              EXTERNAL;
PROCEDURE RPix (VAR X, Y, C : INTEGER);                            EXTERNAL;
PROCEDURE SCCol (VAR c : INTEGER);                                 EXTERNAL;
PROCEDURE STCol (VAR c : INTEGER);                                 EXTERNAL;
PROCEDURE SCDP (VAR cdp : INTEGER);                                EXTERNAL;
PROCEDURE SCSP (VAR csp : INTEGER);                                EXTERNAL;
PROCEDURE SCWP (VAR cwp : INTEGER);                                EXTERNAL;
PROCEDURE Sstyle (VAR style : INTEGER);                            EXTERNAL;
PROCEDURE SLUTWP (VAR lwp : INTEGER);                              EXTERNAL;
PROCEDURE SLUTDP (VAR ldp : INTEGER);                              EXTERNAL;
PROCEDURE SHiRes;                                                  EXTERNAL;
PROCEDURE Wlut (VAR index, gbr : INTEGER);                         EXTERNAL;
PROCEDURE Rlut (VAR index, gbr : INTEGER);                         EXTERNAL;

```


{The procedures below found in the module "modone"}

```
PROCEDURE modone;                external;
PROCEDURE colent1;               external;
PROCEDURE colent2;               external;
PROCEDURE messbox;               external;
PROCEDURE clearscrn;             external;
PROCEDURE setscrn;               external;
PROCEDURE changescreen;          external;
PROCEDURE getname;               external;
PROCEDURE paper;                 external;
PROCEDURE creturn;               external;
PROCEDURE stripstring;           external;
PROCEDURE loadfiles;             external;
PROCEDURE border;                external;
PROCEDURE end_box;               external;
PROCEDURE Sheet;                 external;
PROCEDURE Shuffle;               external;
PROCEDURE Presetrand;            external;
PROCEDURE Rgen(var max : integer); external;
PROCEDURE Loctn_array;           external;
PROCEDURE file_array;            external;
PROCEDURE col_array;             external;
PROCEDURE icon_array;            external;
PROCEDURE Set_colours;           external;
PROCEDURE draw_icon;             external;
```

{The procedures below found in the module "modmouse"}

```
PROCEDURE Modmouse;              external;
PROCEDURE First_cursor;          external;
PROCEDURE Init_mouse;            external;
PROCEDURE Mousein;               external;
PROCEDURE Movecursor;            external;
PROCEDURE Drawcursor;            external;
PROCEDURE Replace_cursor;         external;
PROCEDURE Hide_cursor;           external;
```

```
PROCEDURE ell2[public];
BEGIN
GOTO L2;
END;
```

{This procedure needs to be declared in EXPER1 because it is declared as external in modone, though it is not actually used in EXPER1}

```
PROCEDURE read_letter[public];
BEGIN
END;
```

{This procedure identifies the shape from the "bwicon.pic" file by it's location in the frame buffer then identifies the colour that is to be associated with this shape}

```
PROCEDURE Check_srgen;
BEGIN
  IF (ax>99) and (ax<150) THEN srgen := 1;
  IF (ax>149) and (ax<200) THEN srgen := 2;
  IF (ax>199) and (ax<250) THEN srgen := 3;
  IF (ax>249) and (ax<300) THEN srgen := 4;
  IF (ax>299) and (ax<350) THEN srgen := 5;
  IF (ax>349) and (ax<400) THEN srgen := 6;
  IF (ax>399) and (ax<450) THEN srgen := 7;
  IF (ax>449) and (ax<500) THEN srgen := 8;
  IF (ax>499) and (ax<550) THEN srgen := 9;
  IF (ax>549) and (ax<600) THEN srgen := 10;
  IF (ax>599) and (ax<650) THEN srgen := 11;
  IF ax>649 THEN srgen := 12;
  IF (ax>99) and (ax<700) THEN arindex := randcol[srgen];
END;
```

{This procedure loads the shapes into the frame buffer and colours them as it loads them}

```
PROCEDURE Loadfont;
VAR a,b,colour,x,y : INTEGER;
BEGIN
  a := 15;
  ALLOCP(sedge,sedge,a,part);col := white;
  SCSP(part); SCWP(part);
  writeln('now loading the icons');
  filnam := 'G:BWICON.pic';
  ASSIGN(ff,filnam);
  RESET(ff);
  READ(ff,x,y);
  ax :=0;
  WHILE ax<x DO BEGIN
    CHECK_SRGEN;
    SET_COLOURS;
    b := 0;
    WHILE b<y DO BEGIN
      READ(ff,colour);
      IF colour=white THEN
        BEGIN
          SCCOL(colour);
        END
      ELSE
        BEGIN
          SCCOL(COL);
        END;
      PLOT(ax,b);
      b := b+1;
    END;
    ax := ax+1;
  END;CLOSE(FF);
  writeln('finished loading the icons');
END;
```

{This procedure clears the screen by drawing one box on top of a larger box, hence making a border}

```
PROCEDURE Clrscrn2;
BEGIN
x4 := 756;  y4 := 550;  SCCOL(GREEN);
MOVETO(four,four);  RFILL(X4,Y4);  x4 := 590;
MOVETO(four,y4);    RFILL(X4,twenty);
END;
```

{This procedure holds the order of the displayed files, and the coordinates of their associated icons when the documents are opened for reading}

```
PROCEDURE Ffiles;
BEGIN
arindex := filsort1[srgen];
CASE arindex OF
  1 : filnam := 'g:fmail1.tex';  2 : filnam := 'g:fmail2.tex';
  3 : filnam := 'g:fmail3.tex';  4 : filnam := 'g:fmail4.tex';
  5 : filnam := 'g:fmail5.tex';  6 : filnam := 'g:fmail6.tex';
  7 : filnam := 'g:fmail7.tex';  8 : filnam := 'g:fmail8.tex';
  9 : filnam := 'g:fmail9.tex'; 10 : filnam := 'g:fmail10.tex';
 11 : filnam := 'g:fmail11.tex'; 12 : filnam := 'g:fmail12.tex'
END;
arindex := locsort1[srgen];
CASE arindex OF
  1 : iconx := 105;  2 : iconx := 295;
  3 : iconx := 485;  4 : iconx := 105;
  5 : iconx := 295;  6 : iconx := 485;
  7 : iconx := 105;  8 : iconx := 295;
  9 : iconx := 485; 10 : iconx := 105;
 11 : iconx := 295; 12 : iconx := 485;
END;
CASE arindex OF
  1 : icony := 55;  2 : icony := 55;
  3 : icony := 55;  4 : icony := 201;
  5 : icony := 201; 6 : icony := 201;
  7 : icony := 337; 8 : icony := 337;
  9 : icony := 337; 10 : icony := 473;
 11 : icony := 473; 12 : icony := 473;
END;
END;
```

{This procedure draws the 12 diminished representations of the letters on the screen}

```
PROCEDURE Allsheets;
VAR i : INTEGER;
BEGIN
X9 := 10;  Y9 := 10;  X8:= 100;  Y8 := 190;  SLUTWP(one);
SLUTDP(one);
CLRSCRN2;  SLUTWP(jz);  SLUTDP(jz);
  FOR i := 1 TO 12 DO
    BEGIN
      SHEET;
      X9 := X9+55; Y9 := Y9+20;
    END;
  END_BOX;
END;
```

{This procedure holds the coordinates of the coloured shapes for the sorting mode, not the coordinates when the icons are displayed on their associated letters}

```
PROCEDURE icon_place;
BEGIN
  arindex := srgen;
  CASE arindex OF
    1 : iconx := 13;      2 : iconx := 70;
    3 : iconx := 127;    4 : iconx := 184;
    5 : iconx := 240;    6 : iconx := 297;
    7 : iconx := 354;    8 : iconx := 411;
    9 : iconx := 469;   10 : iconx := 526;
   11 : iconx := 583;   12 : iconx := 640;
  END;
  CASE arindex OF
    1 : icony := 20;      2 : icony := 45;
    3 : icony := 70;      4 : icony := 95;
    5 : icony := 120;     6 : icony := 145;
    7 : icony := 170;     8 : icony := 195;
    9 : icony := 220;    10 : icony := 245;
   11 : icony := 270;    12 : icony := 295;
  END;
END;
```

{Displays one document to be read by the subject}

```
PROCEDURE OneDoc;
BEGIN
  HIDE_CURSOR;  SSTYLE(jz);  STCOL(jz);
  SLUTWP(one);  SLUTDP(one);
  PAPER;
  FFILES;
  ICONNO := isort1[srgen]*50+50;
  DRAW_ICON;
  currx:=x2+20;  curry:=y2+20;
  LOADFILES;
  SLUTWP(jz);  SLUTDP(jz);
  STCOL(white);
  REPLACE_CURSOR;
  SSTYLE(jz);
END;
```

{This procedure interprets the position of the cursor on the documents in terms of the virtual switches on the screen - the twelve document representations}

```
PROCEDURE CuOnDoc;
BEGIN
  IF (((xc<140) AND (xc>40)) AND ((yc<540) AND (yc>440))) THEN Goto L1;
  IF (xc> 10) AND (xc< 68) THEN srgen := 1;  IF (xc> 67) AND (xc<125)
  THEN srgen := 2;
  IF (xc>124) AND (xc<182) THEN srgen := 3;  IF (xc>181) AND (xc<239)
  THEN srgen := 4;
  IF (xc>238) AND (xc<296) THEN srgen := 5;  IF (xc>295) AND (xc<353)
  THEN srgen := 6;
  IF (xc>352) AND (xc<410) THEN srgen := 7;  IF (xc>409) AND (xc<469)
  THEN srgen := 8;
  IF (xc>468) AND (xc<526) THEN srgen := 9;  IF (xc>525) AND (xc<583)
  THEN srgen := 10;
  IF (xc>582) AND (xc<640) THEN srgen := 11; IF (xc>639) AND (xc<794)
  THEN srgen := 12;
END;
```

{This procedure defines the operations performed by each button on the mouse in relation to the position of the cursor on the main display screen}

```

PROCEDURE CursorOp;
LABEL Loop1;
VAR doc_move : INTEGER;

BEGIN
doc_move := 0;
DRAWCURSOR;
FIRST_CURSOR;

Loop1:
STCOL(white);
MOUSEIN;
MOVECURSOR;
IF (bONE AND 7) = 0 THEN Goto Loop1;
IF (bONE AND 4) = 4 THEN BEGIN {OPEN/CLOSE BUTTON}
    CuOnDoc;
    clickNo := clickNo+1;
    buttonpress[clickNo] := 21;
    IF reading=false THEN BEGIN
        ONEDOC;
        clickNo := clickNo+1;
        buttonpress[clickNo] :=
filsort1[srgen];

        reading:= true;
        Goto loop1;
    END
    ELSE BEGIN
        CHANGESCREEN;
        ALLSHEETS;
        FOR srgen:= 1 TO 12 DO BEGIN
            ICON_PLACE;

iconno:=isort1[srgen]*50+50;

            DRAW_ICON;
            END;
            reading := false;
            Goto Loop1;
        END;
    END;
END;
IF (bONE AND 2) = 2 THEN BEGIN {this button picks up a document ready to move it}
    CuOnDoc;
IF (((xc<140) AND (xc>40)) AND ((yc<540) AND (yc>440))) THEN Goto L1;
    clickNo := clickNo+1;
    buttonpress[clickNo] := 22;
    clickNo := clickNo+1;
    buttonpress[clickNo] := srgen;
    store_old_position := srgen;
    doc_move := 1;
    goto loop1;
END;
IF (bONE AND 1) = 1 THEN BEGIN {this button places the document previously picked up
and operates the shuffle}
    CuOnDoc;
IF (((xc<140) AND (xc>40)) AND ((yc<540) AND (yc>440))) THEN Goto L1;

```

```

IF doc_move= 1 THEN BEGIN
    clickNo := clickNo+1;
    buttonpress[clickNo] := 23;
    clickNo := clickNo+1;
    buttonpress[clickNo] := srgen;
    IF store_old_position=0 THEN Goto loop1;
    store_new_position := srgen;
    SHUFFLE;
    HIDE_CURSOR;  SSTYLE(jz);
    STCOL(jz);
    FOR srgen:= 1 TO 12 DO BEGIN
        ICON_PLACE;

iconno:=isort1[srgen]*50+50;

        DRAW_ICON;
        END;
    STCOL(white);  REPLACE_CURSOR;  SSTYLE(jz);
    doc_move := 0;
    Goto Loop1;
    END;
goto loop1;
END;
END;

```

{This procedure creates the datafile}

```

PROCEDURE Storage;
LABEL loop1,Loop2;
VAR  a : INTEGER;
BEGIN
a := 0;

Loop2:
WRITELN('Under which subject name will these results be stored ?');
writeln('Use the format D:"subjectname".PT1 ');
READLN(resultstring);
filnam := resultstring;
WRITELN('is this correct ? ',filnam);
READLN(rr);
IF rr='n' THEN Goto loop2;
ASSIGN(Data,Filnam);
REWRITE(Data);
WRITELN(Data,resultstring);
st := ' '; WRITELN(Data,st);
st := ' the three numbers used by the random generator were : ';
WRITELN(Data,st);
WRITELN(data,STORE_aargen,store_bbrgen,store_ccrgen);
st := ' '; WRITELN(Data,st);
st :='          final presentation      location      icon      colour';
WRITELN(Data,st);
st :='          Order      order      of icon      number      of icon';
WRITELN(Data,st);
FOR srgen := 1 TO 12 DO BEGIN arindex := randicon[srgen];
WRITELN(DATA,filsort1[srgen],randfil[srgen],randlocs[srgen],randicon[
srgen],randcol[arindex]);
END;
st := ' ';
WRITELN(DATA,st);

```

```

st := 'Documents opened : 1-12, Buttons pressed : 21,22,23 ';
WRITELN(DATA,st);
FOR clickNo:= 1 TO 3000 DO
  BEGIN
    a := a+1;
    IF buttonpress[clickno]=0 THEN Goto Loop1;
    WRITE (DATA,buttonpress[clickno]);
    IF (a=5) THEN BEGIN
      a := 0;
      WRITELN(DATA, ' ');
      END;
    END;

loop1:
st := ' ';
WRITELN(DATA,st);
CLOSE (Data);
END;

```

{The main body of the program}

```

BEGIN
X1 := 0;          Y1 := 0;          ox :=600; oy :=555;
x2 := 55;         x3 := 520;        x4 := 764; cx := 644; cy :=555;
y2 := 20;         y3 := 536;        y4 := 576;
lhm := 20;        sedge := 50;      part := 4; cellx := 8; celly := 4;
jz := 0;          height := 10;     bx := 55; clickNo := 0;
black := 216; green := 225; blue := 18; cyan := 255;
red := 76; yellow := 13; magenta := 175; white := 250;
one := 1; two := 2; four := 4; eight := 8; twenty := 20; thirty :=
30;
store_old_position :=0;

SETSCRN;
WRITELN('enter three integers between 1 and 30000 for random
numbers');
READLN(aargen); READLN(bbrgen); READLN(ccrgen);
store_aargen := aargen; store_bbrgen := bbrgen; store_ccrgen :=
ccrgen;
LOCTN_ARRAY; FILE_ARRAY; ICON_ARRAY; COL_ARRAY;
WHILE clickNo<3001 DO BEGIN
  buttonpress[clickNo] := 0;
  clickNo := clickNo+1;
  END;

clickNo := 0;  srgen := 1;
WHILE srgen<13 DO BEGIN
  filsort1[srgen] := randfil[srgen];
  filsort2[srgen] := randfil[srgen];
  locsort1[srgen] := randlocs[srgen];
  locsort2[srgen] := randlocs[srgen];
  isort1[srgen] := randicon[srgen];
  isort2[srgen] := randicon[srgen];
  srgen := srgen+1;
  END;

LOADFONT;

L3:
SCWP (JZ);
READLN(filnam);
X4 := 45;
Y4 := 70;

```

```
ALLSHEETS;
srgen := 1;
WHILE srgen<13 DO BEGIN
    iconno := isort1[srgen]*50+50;
    ICON_PLACE;
    DRAW_ICON;
    srgen := srgen+1;
END;
Reading := false;
CURSOROP;

L1:
STORAGE;
CLEARSCRN;

L2:
END.
```


The presentation program for Experiment II:

```

PROGRAM exper2 (Input, Output);

LABEL L1, L2, L3;

VAR [PUBLIC]
x, x1, x2, x3, x4, cx, xc, xc2, cellx, currx, x8, x9, lx, bx, xb : INTEGER;
y, y1, y2, y3, y4, cy, yc, yc2, celly, curry, y8, y9, yy, yx, yb : INTEGER;
ox, oy, bONE, bTWO, bTHREE, b, d, e, f, h, n, o, q, qq, r, s, t, u, w, z : INTEGER;
arindex, oldw, height, lhm, ic, nextdoc, cw, ch, clickNo : INTEGER;
tox, toy, boxw, boxh, oox, ooy, iix, iiy : INTEGER;
jz, one, two, three, four, eight, twenty, thirty, sedge, part : INTEGER;
store_old_position, store_new_position, selected_colour : INTEGER;
icons, iconno, pixcol, iconx, icony, iconstore, blackiconx : INTEGER;
blackicony, check : INTEGER;
black, green, blue, cyan, red, yellow, magenta, white, col : INTEGER;
argen, brgen, crgen : INTEGER4;
aargen, bbrgen, ccrgen, srgen, trgen, rmax, srgenml, srgenpl : INTEGER;
store_aargen, store_bbrgen, store_ccrgen : INTEGER;
hrgen, jrgen, jjrgen : REAL;
reading : BOOLEAN;
rr : CHAR;
ftext : TEXT;
ff : FILE OF INTEGER;
data : TEXT;
filnam, resultstring, st : LSTRING(62);
instring : LSTRING(3);
matrix, randlocs, randcol, randicon, randfil : ARRAY[0..12] OF INTEGER;
filsort1, filsort2, isort1, isort2, locsort1 : ARRAY[0..12] OF INTEGER;
locsort2, locxm, locym, locxj, locyj, locxml : ARRAY[0..12] OF INTEGER;
locym1, locxm1, locymo : ARRAY[0..12] OF INTEGER;
grey : ARRAY[0..40] OF INTEGER;
colour : ARRAY[0..5] OF ARRAY[0..5] OF ARRAY[0..5] OF
INTEGER;
buttonpress : ARRAY[0..3000] OF INTEGER;

{These procedures are supplied by the pluto grphics system}
PROCEDURE RPix (VAR X, Y, C : INTEGER); EXTERNAL;
PROCEDURE AUX_IN (VARS X : LSTRING); EXTERNAL;
PROCEDURE AUX_OUT (VARS Y : LSTRING); EXTERNAL;
PROCEDURE Allocp (VAR width, height, nsyms, p : INTEGER); EXTERNAL;
PROCEDURE Copy (VAR w, h, pl, x1, y1, p2, x2, y2 : INTEGER); EXTERNAL;
PROCEDURE Copys (VAR n : INTEGER); EXTERNAL;
PROCEDURE CLrCWP; EXTERNAL;
PROCEDURE Pinit; EXTERNAL;
PROCEDURE Plot (VAR x, y : INTEGER); EXTERNAL;
PROCEDURE Lineto (VAR x, y : INTEGER); EXTERNAL;
PROCEDURE MoveTo (VAR x, y : INTEGER); EXTERNAL;
PROCEDURE Rfill (VAR W, H : INTEGER); EXTERNAL;
PROCEDURE SCCol (VAR c : INTEGER); EXTERNAL;
PROCEDURE STCOL (VAR c : INTEGER); EXTERNAL;
PROCEDURE SCDP (VAR cdp : INTEGER); EXTERNAL;
PROCEDURE SCSP (VAR csp : INTEGER); EXTERNAL;
PROCEDURE SCWP (VAR cwp : INTEGER); EXTERNAL;
PROCEDURE Sstyle (VAR style : INTEGER); EXTERNAL;
PROCEDURE SLUTWP (VAR LWP : INTEGER); EXTERNAL;
PROCEDURE SLUTDP (VAR LDP : INTEGER); EXTERNAL;
PROCEDURE SHiRes; EXTERNAL;

```

```
PROCEDURE Wlut (VAR index,gbr :INTEGER);          EXTERNAL;
```

{The following procedures are found in the module "Modone"}

```
PROCEDURE modone;          EXTERNAL;
PROCEDURE loctn_array;     external;
PROCEDURE file_array;     external;
PROCEDURE icon_array;     external;
PROCEDURE col_array;      external;
PROCEDURE colent1;        external;
PROCEDURE colent2;        external;
PROCEDURE messbox;        external;
PROCEDURE clearscrn;      external;
PROCEDURE setscrn;        external;
PROCEDURE getname;        external;
PROCEDURE paper;          external;
PROCEDURE creturn;        external;
PROCEDURE stripstring;    external;
PROCEDURE loadfiles;      external;
PROCEDURE Border;         external;
PROCEDURE Rgen(var max : integer); external;
PROCEDURE presetrand;     external;
PROCEDURE draw_icon;      external;
PROCEDURE set_colours;    external;
PROCEDURE posicon;        external;
PROCEDURE line_box;       external;
PROCEDURE Draw_locations; external;
PROCEDURE End_Box;        external;
PROCEDURE Shuffle;        external;
```

{The following procedures are found in the module "Modmouse"}

```
PROCEDURE Modmouse;          EXTERNAL;
PROCEDURE First_cursor;     external;
PROCEDURE Init_mouse;       external;
PROCEDURE Mousein;          external;
PROCEDURE Movecursor;       external;
PROCEDURE Drawcursor;       external;
PROCEDURE Replace_cursor;   external;
PROCEDURE Hide_cursor;      external;
```

```
PROCEDURE Ell2[public];
BEGIN
Goto L2;
END;
```

{This procedure draws the coloured boxes}

```
PROCEDURE pre_color;
BEGIN
arindex := randcol[srgen];
set_colours; sccol(col);
messbox;
END;
```

{This procedure defines the 12 locations at which the coloured boxes are to be drawn}

```
PROCEDURE Color_Locations;
BEGIN
y4 := 50; x4 := 50; y1 := 55; x1 := 250; srgen := 1; pre_color;
srgen := 4; y1 := 201; pre_color;
srgen := 7; y1 := 337; pre_color;
srgen := 10; y1 := 473; pre_color;
x1 := 440;
```

```

srgen := 2; y1 := 55; pre_color;
srgen := 5; y1 := 201; pre_color;
srgen := 8; y1 := 337; pre_color;
srgen := 11; y1 := 473; pre_color;
x1 := 630;
srgen := 3; y1 := 55; pre_color;
srgen := 6; y1 := 201; pre_color;
srgen := 9; y1 := 337; pre_color;
srgen := 12; y1 := 473; pre_color;
sccol(white);
END;

```

{This procedure loads black and white shapes from the "bwicon.pic" file into the pluto memory buffer}

```

PROCEDURE Loadfont;
VAR a,b,colour,x,y : INTEGER;
BEGIN a := 15;
  ALLOCP(sedge,sedge,a,part);
  SCSP(part); SCWP(part);
  WRITELN('Loading the font');
  filnam := 'G:BWICON.pic';
  ASSIGN(ff,filnam); RESET(ff);
  READ(ff,x,y); a := 0;
  WHILE a < x DO BEGIN
    b := 0;
    WHILE b < y DO BEGIN
      READ(ff,colour);
      SCCOL(colour);
      PLOT(a,b);
      b := b+1;
    END;
    a := a+1;
  END;
  CLOSE(ff);
  WRITELN('Finished loading the font');
END;

```

{This procedure holds the file names for the twelve information items and enables access to the to be consistent, yet initially random}

```

PROCEDURE Ffiles;
BEGIN
  arindex := randfil[srgen];
  CASE arindex OF
    1 : filnam := 'g:fmail1.tex';
    2 : filnam := 'g:fmail2.tex';
    3 : filnam := 'g:fmail3.tex';
    4 : filnam := 'g:fmail4.tex';
    5 : filnam := 'g:fmail5.tex';
    6 : filnam := 'g:fmail6.tex';
    7 : filnam := 'g:fmail7.tex';
    8 : filnam := 'g:fmail8.tex';
    9 : filnam := 'g:fmail9.tex';
    10 : filnam := 'g:fmail10.tex';
    11 : filnam := 'g:fmail11.tex';
    12 : filnam := 'g:fmail12.tex';
  END;
END;

```

{This procedure colours the black and white icons}

```

PROCEDURE Color_icon;
VAR ys,ix,iy : INTEGER;

BEGIN
ys := icony;  ix := 0;
WHILE ix<sedge DO BEGIN
    iy := 0;
    icony := ys;
    WHILE iy<sedge DO BEGIN
        RPIX(iconx,icony,pixcol);
        IF pixcol<>white THEN
            begin
                PLOT(iconx,icony);
            end;
        iy := iy+1;
        icony := icony+1;
    END;
    ix := ix+1;
    iconx := iconx+1;
END;
iconx := iconx-sedge;
icony := icony-sedge;
sccol(white);
END;

```

{This procedure draws a the paper, selects the document number and draws the associated icon on the screen}

```

PROCEDURE Getfmail;
BEGIN
stcol(jz);
PAPER;
arindex := randicon[srgen];
iconno := arindex*50+50; draw_icon;
arindex := randcol[srgen];
set_colours; sccol(col); color_icon;
currx := x2+20; curry := y2+20;
FFILES;
LOADFILES;
stcol(white);
END;

```

{This procedure reads the value of the rating that the subject has selected}

```

PROCEDURE Read_the_Rating;{from the major- the NEW POSITION}
BEGIN
srgen := 0;
IF(((YC>125) and (yc<155)) AND ((xc>250) and (XC<280))) THEN srgen
:= 1;
IF(((YC>125) and (yc<155)) AND ((xc>440) and (XC<470))) THEN srgen
:= 2;
IF(((YC>125) and (yc<155)) AND ((xc>630) and (XC<660))) THEN srgen
:= 3;
IF(((YC>258) and (yc<288)) AND ((xc>250) and (XC<280))) THEN srgen
:= 4;
IF(((YC>258) and (yc<288)) AND ((xc>440) and (XC<470))) THEN srgen
:= 5;
IF(((YC>258) and (yc<288)) AND ((xc>630) and (XC<660))) THEN srgen
:= 6;
IF(((YC>391) and (yc<421)) AND ((xc>250) and (XC<280))) THEN srgen
:= 7;

```

```

IF(((YC>391) and (yc<421)) AND ((xc>440) and (XC<470))) THEN  srgen
:= 8;
IF(((YC>391) and (yc<421)) AND ((xc>630) and (XC<660))) THEN  srgen
:= 9;
IF(((YC>524) and (yc<554)) AND ((xc>250) and (XC<280))) THEN  srgen
:=10;
IF(((YC>524) and (yc<554)) AND ((xc>440) and (XC<470))) THEN  srgen
:=11;
IF(((YC>524) and (yc<554)) AND ((xc>630) and (XC<660))) THEN  srgen
:=12;
IF srgen<>0 THEN
  BEGIN   store_new_position := srgen;
  END;
END;

```

{This procedure reads the position at which the new rating is to be placed}

```

PROCEDURE readrating;
BEGIN
  srgen := 0;
  IF(((YC>125) and (yc<155)) AND ((xc>250) and (XC<280))) THEN  srgen
:= 1;
  IF(((YC>125) and (yc<155)) AND ((xc>440) and (XC<470))) THEN  srgen
:= 2;
  IF(((YC>125) and (yc<155)) AND ((xc>630) and (XC<660))) THEN  srgen
:= 3;
  IF(((YC>258) and (yc<288)) AND ((xc>250) and (XC<280))) THEN  srgen
:= 4;
  IF(((YC>258) and (yc<288)) AND ((xc>440) and (XC<470))) THEN  srgen
:= 5;
  IF(((YC>258) and (yc<288)) AND ((xc>630) and (XC<660))) THEN  srgen
:= 6;
  IF(((YC>391) and (yc<421)) AND ((xc>250) and (XC<280))) THEN  srgen
:= 7;
  IF(((YC>391) and (yc<421)) AND ((xc>440) and (XC<470))) THEN  srgen
:= 8;
  IF(((YC>391) and (yc<421)) AND ((xc>630) and (XC<660))) THEN  srgen
:= 9;
  IF(((YC>524) and (yc<554)) AND ((xc>250) and (XC<280))) THEN  srgen
:=10;
  IF(((YC>524) and (yc<554)) AND ((xc>440) and (XC<470))) THEN  srgen
:=11;
  IF(((YC>524) and (yc<554)) AND ((xc>630) and (XC<660))) THEN  srgen
:=12;
  IF srgen<>0 THEN
    BEGIN   store_old_position := srgen;
    hide_cursor; sstyle(jz);
    tox-:= locxmo[srgen]; toy := locymo[srgen];
    copy(boxw,boxh,jz,tox,toy,jz,iix,iiy);
    replace_cursor; sstyle(jz);
    END;
  END;
END;

```

{This procedure shuffles the ratings on the screen to display the new rating at the new position}

```
PROCEDURE redraw_junior;
BEGIN
  hide_cursor;  sstyle(jz);
  shuffle;
  FOR srgen := 1 TO 12 DO
    BEGIN
      tox := locsort1[srgen]; toy := isort1[srgen];
      oox := locxm[srgen];  ooy := locym[srgen];
      copy(boxw,boxh,jz,tox,toy,jz,oox,ooy);
    END;
  replace_cursor; sstyle(jz);
  buttonpress[clickNo] := 22; clickNo := clickNo+1;
  buttonpress[clickNo] := store_old_position; clickNo := clickNo+1;
  buttonpress[clickNo] := 23; clickNo := clickNo+1;
  buttonpress[clickNo] := store_new_position; clickNo := clickNo+1;
END;
```

{This procedure displays the document that has been selected for reading}

```
PROCEDURE OneDoc;
BEGIN
  PosIcon;
  IF reading=true THEN
    BEGIN
      hide_cursor; sstyle(jz);
      slutdp(one); slutdp(one);
      Getfmail;
      buttonpress[clickNo] := randfil[srgen];
      clickno := clickNo+1;
      replace_cursor; sstyle(jz);
      slutdp(jz); slutdp(jz);
    END
  ELSE
    BEGIN
      IF store_old_position=0 THEN READRATING
      ELSE
        IF store_new_position=0 THEN
          READ_THE_RATING;
        IF ((store_old_position<>0) and
        (store_new_position<>0)) THEN
          BEGIN
            IF store_old_position=store_new_position THEN
              redraw_junior;
            ELSE
              REDRAW_JUNIOR;
              sccol(white);
              moveto(iix,iiy); rfill(boxw,boxh);
              store_old_position := 0;
              store_new_position := 0;
            END;
          END;
        END;
    END;
  END;
```

{This procedure copies the ratings from the main display to a small one so that they are not lost when a letter is being read}

```
PROCEDURE Copy_Ratings; {from junior to major}
BEGIN
  boxw := 20; boxh := 20;
  SSTYLE(jz);
  FOR srgen := 1 TO 12 DO
    BEGIN
      tox := locxmo[srgen]; toy := locymo[srgen];
      oox := locsort1[srgen]; ooy := isort1[srgen];
      COPY(boxw,boxh,jz,oox,ooy,jz,tox,toy);
    END;
  END;
```

{this procedure copies the ratings from the small display to their original positions on the main display when a document is closed after reading}

```
PROCEDURE ReDraw; {the major}
BEGIN
  hide_cursor; sstyle(jz);
  slutdp(one); slutdp(one);
  reading := false; white := 245; paper; white := 250;
  color_locations;
  COPY_RATINGS;
  replace_cursor; sstyle(jz);
  slutdp(jz); slutdp(jz);
  END;
```

{this procedure defines the actions of the buttons, whether to open a document, or close one}

```
PROCEDURE AllButtons;
BEGIN
  IF ((XC>240)and(xc<750))AND ((yc>45) and (yc<555)) THEN
    BEGIN
      IF reading= false THEN ONEDOC;
    END;
  IF ((xc<140) and (xc>40)) AND ((yc<540) and (yc>440)) THEN goto L1;
  IF ((xc<140) and (xc>40)) AND ((yc<340) and (yc>240)) THEN
    BEGIN
      IF reading=true THEN
        BEGIN
          Reading := false;
          REDRAW;
        END;
    END;
  stcol(white);
  END;
```

{this procedure sets up the mouse operation enabling the three buttons to be used for sepearte functions if required}

```
PROCEDURE CursorOp;
LABEL Loop1;

BEGINLoop1:
MOUSEIN;
MOVECURSOR;
IF (bone AND 7) = 0 THEN Goto Loop1;
IF (bone AND 4) = 4 THEN BEGIN
  ALLBUTTONS;
  Goto loop1;
END;IF (bone AND 2) = 2 THEN BEGIN
  ALLBUTTONS;
```

```

                                goto loop1;
                                END; IF (bONE AND 1) = 1 THEN BEGIN
                                ALLBUTTONS;
                                goto loop1;
                                END;
END;

```

{this procedure sets up the small display where the ratings are maintained while the subject is reading a document}

```

PROCEDURE Chosen_Rating;
BEGIN
  STCOL(JZ);
  x1 := 30; x4 := 120; y1 := 35; y4 := 110;
  SCCOL(magenta); MESSBOX;
  x1 := 35; x4 := 110;
  y1 := 40; y4 := 100;
  SCCOL(white); MESSBOX;
  currx := 0; curry := y1+20;
  filnam := 'G:NUMBERS.TEX';
  bx := 45; lhm := 0;
  LOADFILES;
  bx := 55;
  x1 := 81; x4 := 30; y1 := 175; y4 := 30;
  SCCOL(thirty); MESSBOX;
  x1 := 85; x4 := 20; y1 := 180; y4 := 20;
  SCCOL(white); MESSBOX;
END;

```

{this procedure reads the final order that the subjects gave the document rankings}

```

PROCEDURE Final_order;
Var XX,yy : INTEGER;

BEGIN
  xx:= locsort1[srgen]; yy := isort1[srgen];
  IF xx+yy=94 THEN arindex:= 1; IF xx+yy=134 THEN arindex:= 2;
  IF xx+yy=174 THEN arindex:= 3; IF xx+yy=109 THEN arindex:= 4;
  IF xx+yy=149 THEN arindex:= 5; IF xx+yy=189 THEN arindex:= 6;
  IF xx+yy=124 THEN arindex:= 7; IF xx+yy=164 THEN arindex:= 8;
  IF xx+yy=204 THEN arindex:= 9; IF xx+yy=139 THEN arindex:=10;
  IF xx+yy=179 THEN arindex:=11; IF xx+yy=219 THEN arindex:=12;
END;

```

{this procedure draws the screen display which acts as a virtual switch to close any letter that is being read}

```

PROCEDURE Close_Letters_Box;
BEGIN
  STCOL(JZ);
  x1 := 30; x4 := 120;
  y1 := 235; y4 := 110;
  SCCOL(magenta); MESSBOX;
  x1 := 35; x4 := 110;
  y1 := 240; y4 := 100;
  SCCOL(white); MESSBOX;
  x1 := 10; currx := x1+10; curry := y1+20;
  filnam := 'g:closeL.mes';
  lhm := 0; bx := 50;
  LOADFILES; bx := 55;
END;

```


{this procedure stores the data collected from the sorting task}

```

PROCEDURE Storage;
LABEL loop1, Loop2;
VAR   a : INTEGER;

BEGIN
a := 0;

Loop2:
WRITELN('Under which subject name will these results be stored ?');
WRITELN('Use the format  D:"subjectname".PT1 ');
READLN(resultstring);
filnam := resultstring;
WRITELN('is this correct ? ', filnam);
READLN(rr);
IF rr='n' THEN Goto loop2;
ASSIGN(Data, Filnam);
REWRITE(Data);
WRITELN(Data, resultstring);
st := ' '; WRITELN(Data, st);
st := ' the three numbers used by the random generator were : ';
WRITELN(Data, st);
WRITELN(data, STORE_aargen, store_bbrgen, store_ccrgen);
st := ' '; WRITELN(Data, st);
st := ' initial document   location      icon      colour   final';
WRITELN(Data, st);
st := '                Order                        doc. order';
WRITELN(Data, st);
FOR srgen := 1 TO 12 DO
    BEGIN
        final_order;

WRITELN(DATA, randfil[srgen], srgen, randicon[srgen], randcol[srgen], arin
dex);
        END; st := ' ';
WRITELN(DATA, st);
st := 'Documents opened : 1-12, Buttons pressed : 21,22,23 ';
WRITELN(DATA, st);
FOR clickNo:= 1 TO 3000 DO
    BEGIN   a := a+1;
        IF buttonpress[clickno]=0 THEN Goto Loop1;
        WRITE(DATA, buttonpress[clickno]);
        IF (a=5) THEN BEGIN
            a := 0;
            WRITELN(DATA, ' ');
            END;

        END;

loop1:
st := ' '; WRITELN(DATA, st);
CLOSE(Data);
END;
```

```
BEGIN    { the main program }
```

```
x1 := 0;      y1 := 0;      x2 := 200;      y2 := 20;
x3 := 520;    y3 := 536;    x4 := 764;      y4 := 576;
sedge := 50;  part := 4;    cellx := 8;      celly := 4;
jz := 0;      height := 10;  bx := 55;
q := 0;       qq := 0;      r := 0;
iix := 85;    iiy := 180;    clickNo := 0;
blackiconx := 0; blackicony := 0;
```

```
black := 216; green := 230; blue := 18; cyan := 255; selected_colour
:= 0;
red := 76; yellow := 13; magenta := 174; white := 250; col := 250;
```

```
one := 1; two := 2; four := 4; eight := 8; twenty := 20; thirty
:= 30;
```

```
reading := false; store_old_position := 0; store_new_position := 0;
```

```
SETSCRN;
```

```
WRITELN('enter 3 numbers between 1 and 30000 for randomising the
files');
```

```
READLN(aargen); readln(bbrgen); readln(ccrgen);
```

```
store_aargen := aargen;
```

```
store_bbrgen := bbrgen;
```

```
store_ccrgen := ccrgen;
```

```
loctn_array; icon_array;
```

```
file_array; col_array;
```

```
WHILE clickNo<3001 DO BEGIN
```

```
    buttonpress[clickNo] := 0;
```

```
    clickNo := clickNo+1;
```

```
    END;
```

```
clickNo := 0; srgen := 1;
```

```
locsort1[srgen] := 42; isort1[srgen] := 52; locxm[srgen] := 250;
```

```
locym[srgen] := 130; srgen := 2;
```

```
locsort1[srgen] := 82; isort1[srgen] := 52; locxm[srgen] := 440;
```

```
locym[srgen] := 130; srgen := 3;
```

```
locsort1[srgen] := 122; isort1[srgen] := 52; locxm[srgen] := 630;
```

```
locym[srgen] := 130; srgen := 4;
```

```
locsort1[srgen] := 42; isort1[srgen] := 67; locxm[srgen] := 250;
```

```
locym[srgen] := 263; srgen := 5;
```

```
locsort1[srgen] := 82; isort1[srgen] := 67; locxm[srgen] := 440;
```

```
locym[srgen] := 263; srgen := 6;
```

```
locsort1[srgen] := 122; isort1[srgen] := 67; locxm[srgen] := 630;
```

```
locym[srgen] := 263; srgen := 7;
```

```
locsort1[srgen] := 42; isort1[srgen] := 82; locxm[srgen] := 250;
```

```
locym[srgen] := 396; srgen := 8;
```

```
locsort1[srgen] := 82; isort1[srgen] := 82; locxm[srgen] := 440;
```

```
locym[srgen] := 396; srgen := 9;
```

```
locsort1[srgen] := 122; isort1[srgen] := 82; locxm[srgen] := 630;
```

```
locym[srgen] := 396; srgen := 10;
```

```
locsort1[srgen] := 42; isort1[srgen] := 97; locxm[srgen] := 250;
```

```
locym[srgen] := 529; srgen := 11;
```

```
locsort1[srgen] := 82; isort1[srgen] := 97; locxm[srgen] := 440;
```

```
locym[srgen] := 529; srgen := 12;
```

```
locsort1[srgen] := 122; isort1[srgen] := 97; locxm[srgen] := 630;
```

```
locym[srgen] := 529; srgen := 13;
```

```
WHILE srgen<13 DO BEGIN
```

```
    filsort1[srgen] := randfil[srgen];
```

```
    filsort2[srgen] := randfil[srgen];
```

```
    locsort2[srgen] := locsort1[srgen];
```

```
    isort2[srgen] := isort1[srgen];
```

```

        locxj{srgen] := locsort1{srgen];
        locyj{srgen] := isort1{srgen];
        locymo{srgen] := locym{srgen];
        locxmo{srgen] := locxm{srgen];
        locym1{srgen] := locym{srgen];
        locxm1{srgen] := locxm{srgen];
        srgen := srgen+1;
    END;

LOADFONT;

L3:
SCWP(JZ);
SLUTWP(one); SLUTDP(one);
READLN(filnam);
CLOSE_LETTERS_BOX;
CHOSEN_RATING;
END_BOX;
lhm := 165;
x8 := 20; x9 := 72;
y8 := 385; y9 := 427;
white := 245;
PAPER;
white := 250;
COLOR_LOCATIONS;
COPY_RATINGS;
STCOL(JZ);
DRAWCURSOR;
FIRST_CURSOR;
STCOL(white);
slutwp(jz); slutdp(jz);

L2:
CURSOROP;

L1:
CLEARSCRN;
STORAGE;
END.

```

The presentation program used for Experiment III.

```
PROGRAM exper3(Input,Output);
```

```
LABEL L1,L2,L3;
```

```
VAR[PUBLIC]
```

```

x,x1,x2,x3,x4,cx,xc,xc2,cellx,currx,x8,x9,lx,bx,xb      : INTEGER;
y,y1,y2,y3,y4,cy,yc,yc2,celly,curry,y8,y9,yy,yx,yb     : INTEGER;
ox,oy,bONE,bTWO,bTHREE,b,d,e,f,h,n,o,q,qq,r,s,t,u,w,z : INTEGER;
arindex,oldw,height,lhm,ic,nextdoc,cw,ch,clickNo       : INTEGER;
tox,toy,boxw,boxh,oox,ooy,iix,iyy                     : INTEGER;
jz,one,two,three,four,eight,twenty,thirty,sedge,part  : INTEGER;
store_old_position,store_new_position,selected_colour   : INTEGER;
icons,iconno,pixcol,iconx,icony,iconstore,blackiconx    : INTEGER;
blackicony,check                                       : INTEGER;
black,green,blue,cyan,red,yellow,magenta,white,col      : INTEGER;
argen,brgen,crgen                                       : INTEGER4;
aargen,bbrgen,ccrgen,srgen,trgen,rmax,srgenml,srgenpl  : INTEGER;
store_aargen,store_bbrgen,store_ccrgen                 : INTEGER;
hrgen,jrgen,jjrgen                                     : REAL;
reading                                                  : BOOLEAN;
rr                                                       : CHAR;
ftext                                                   : TEXT;
ff                                                       : FILE OF INTEGER;
data                                                     : TEXT;
filnam,resultstring,st                                : LSTRING(62);
instring                                                : LSTRING(3);
matrix,randlocs,randcol,randicon,randfil              : ARRAY[0..12] OF INTEGER;
filsort1,filsort2,isort1,isort2,locsort1               : ARRAY[0..12] OF INTEGER;
locsort2,locxm,locym,locxj,locyj,locxml                : ARRAY[0..12] OF INTEGER;
locym1,locxmo,locymo                                    : ARRAY[0..12] OF INTEGER;
grey                                                    : ARRAY[0..40] OF INTEGER;
colour                                                  : ARRAY[0..5] OF ARRAY[0..5] OF ARRAY[0..5] OF INTEGER;
buttonpress: ARRAY[0..3000] OF INTEGER;
```

{External commands supplied by the Pluto graphics system}

```

PROCEDURE RPix (VAR X,Y,C : INTEGER);                  EXTERNAL;
PROCEDURE AUX_IN (VARS X : LSTRING);                   EXTERNAL;
PROCEDURE AUX_OUT (VARS Y : LSTRING);                   EXTERNAL;
PROCEDURE Allocp(VAR width,height,nsyms,p : INTEGER);  EXTERNAL;
PROCEDURE Copy(VAR w,h,p1,x1,y1,p2,x2,y2 : INTEGER);  EXTERNAL;
PROCEDURE Copys(VAR n : INTEGER);                       EXTERNAL;
PROCEDURE CLrCWP;                                       EXTERNAL;
PROCEDURE Pinit;                                       EXTERNAL;
PROCEDURE Plot (VAR x,y : INTEGER);                     EXTERNAL;
PROCEDURE Lineto (VAR x,y : INTEGER);                   EXTERNAL;
PROCEDURE MoveTo (VAR x,y : INTEGER);                   EXTERNAL;
PROCEDURE RFill (VAR W,H : INTEGER);                   EXTERNAL;
PROCEDURE SCCol (VAR c : INTEGER);                     EXTERNAL;
PROCEDURE STCOL (VAR c : INTEGER);                     EXTERNAL;
PROCEDURE SCDP (VAR cdp : INTEGER);                    EXTERNAL;
PROCEDURE SCSP (VAR csp : INTEGER);                    EXTERNAL;
PROCEDURE SCWP (VAR cwp : INTEGER);                    EXTERNAL;
PROCEDURE Sstyle (VAR style : INTEGER);                 EXTERNAL;
PROCEDURE SLUTWP (VAR LWP : INTEGER);                   EXTERNAL;
PROCEDURE SLUTDP (VAR LDP : INTEGER);                   EXTERNAL;
PROCEDURE SHiRes;                                       EXTERNAL;
PROCEDURE Wlut (VAR index,gbr : INTEGER);               EXTERNAL;
```

{External procedures that are found in the module "modone"}

```

PROCEDURE modone;           EXTERNAL;
PROCEDURE loctn_array;      external;
PROCEDURE file_array;       external;
PROCEDURE icon_array;       external;
PROCEDURE col_array;        external;
PROCEDURE colent1;          external;
PROCEDURE colent2;          external;
PROCEDURE messbox;          external;
PROCEDURE clearscrn;        external;
PROCEDURE setscrn;          external;
PROCEDURE getname;          external;
PROCEDURE paper;            external;
PROCEDURE creturn;          external;
PROCEDURE stripstring;      external;
PROCEDURE loadfiles;        external;
PROCEDURE Border;           external;
PROCEDURE Rgen(var max : integer); external;
PROCEDURE presetrand;       external;
PROCEDURE draw_icon;        external;
PROCEDURE set_colours;      external;
PROCEDURE posicon;          external;
PROCEDURE line_box;         external;
PROCEDURE Draw_locations;   external;
PROCEDURE End_Box;          external;
PROCEDURE Shuffle;          external;

```

{External procedures for operating the summa-mouse that are found in the module "modmouse"}

```

PROCEDURE Modmouse;         EXTERNAL;
PROCEDURE First_cursor;     external;
PROCEDURE Init_mouse;       external;
PROCEDURE Mousein;          external;
PROCEDURE Movecursor;       external;
PROCEDURE Drawcursor;       external;
PROCEDURE Replace_cursor;   external;
PROCEDURE Hide_cursor;      external;

```

```

PROCEDURE Ell2[public];
BEGIN
  Goto L2;
END;

```

{This procedure colours the black and white icons in the pluto memory buffer before copying a coloured icon onto the main display screen}

```

PROCEDURE pre_color;
BEGIN
  iconno := randicon[srgen]*50+50; SSTYLE(eight);
  DRAW_ICON;
  SSTYLE(jz);
END;

```

{This procedure associates the colour with the location of a particular icon, where srgen represents the number of the location, iconx and icony are the coordinates where the top left hand corner of the icon is placed on the main display screen}

```
PROCEDURE Icon_Locations;
BEGIN
  icony := 55;  iconx := 250;
  srgen := 1;  pre_color;
  srgen := 4;  icony := 201; pre_color;
  srgen := 7;  icony := 337; pre_color;
  srgen := 10; icony := 473; pre_color;
  iconx := 440;
  srgen := 2;  icony := 55; pre_color;
  srgen := 5;  icony := 201; pre_color;
  srgen := 8;  icony := 337; pre_color;
  srgen := 11; icony := 473; pre_color;
  iconx := 630;
  srgen := 3;  icony := 55; pre_color;
  srgen := 6;  icony := 201; pre_color;
  srgen := 9;  icony := 337; pre_color;
  srgen := 12; icony := 473; pre_color;
  SCCOL(white);
END;
```

{This procedure loads the file of pre-drawn icons into the pluto frame-buffer}

```
PROCEDURE Loadfont;
VAR a,b,colour,x,y : INTEGER;

BEGIN
  a := 15;
  ALLOCP(sedge,sedge,a,part);
  SCSP(part); SCWP(part);
  WRITELN('Loading the font');filnam := 'G:BWICON.pic';
  ASSIGN(ff,filnam);RESET(ff);
  READ(ff,x,y);a := 0;
  WHILE a<x DO BEGIN
    b := 0;
    WHILE b<y DO BEGIN
      READ(ff,colour);
      SCCOL(colour);
      PLOT(a,b);
      b := b+1;
    END;
    a := a+1;
  END;
  CLOSE(ff);
  WRITELN('Finished loading the font');
END;
```

{This procedure applies a textfile name to the randomly arranged set of numbers ranging from 1-12 held in the array "randfil"}

```
PROCEDURE Ffiles;
BEGIN
  arindex := randfil[srgen];
  CASE arindex OF
    1 : filnam := 'g:fmail1.tex'; 2 : filnam := 'g:fmail2.tex';
    3 : filnam := 'g:fmail3.tex'; 4 : filnam := 'g:fmail4.tex';
    5 : filnam := 'g:fmail5.tex'; 6 : filnam := 'g:fmail6.tex';
    7 : filnam := 'g:fmail7.tex'; 8 : filnam := 'g:fmail8.tex';
    9 : filnam := 'g:fmail9.tex'; 10 : filnam := 'g:fmail10.tex';
    11 : filnam := 'g:fmail11.tex'; 12 : filnam := 'g:fmail12.tex';
  END;
END;
```

{This procedure colours the icon by plotting every pixel in the colour selected}

```
PROCEDURE Color_icon;
VAR ys,ix,iy : INTEGER;

BEGIN
ys := icony; ix := 0;
WHILE ix<sedge DO BEGIN
    iy := 0;
    icony := ys;
    WHILE iy<sedge DO BEGIN
        RPIX(iconx,icony,pixcol);
        IF pixcol<>white THEN
            begin
                PLOT(iconx,icony);
            end;
        iy := iy+1;
        icony := icony+1;
    END;
    ix := ix+1;
    iconx := iconx+1;
END; iconx := iconx-sedge;
icony := icony-sedge;
SCCOL(white);
END;
```

{This procedure draws the paper with the coloured icon, before an fmail file is written onto it}

```
PROCEDURE Getfmail;
BEGIN
STCOL(jz);
PAPER;
arindex := randicon[srgen];
iconno := arindex*50+50;
DRAW_ICON;
arindex := randcol[srgen];
SET_COLOURS; sccol(col); color_icon;
currx := x2+20; curry := y2+20;
FFILES;
LOADFILES;
STCOL(white);
END;
```

{This procedure reads the value of the rating that the subject has selected}

```
PROCEDURE Read_the_Rating; {from the major- the NEW POSITION}
BEGIN
srgen := 0;
IF(((YC>125) and (yc<155)) AND ((xc>250) and (XC<280))) THEN srgen
:= 1;
IF(((YC>125) and (yc<155)) AND ((xc>440) and (XC<470))) THEN srgen
:= 2;
IF(((YC>125) and (yc<155)) AND ((xc>630) and (XC<660))) THEN srgen
:= 3;
IF(((YC>258) and (yc<288)) AND ((xc>250) and (XC<280))) THEN srgen
:= 4;
IF(((YC>258) and (yc<288)) AND ((xc>440) and (XC<470))) THEN srgen
:= 5;
IF(((YC>258) and (yc<288)) AND ((xc>630) and (XC<660))) THEN srgen
:= 6;
IF(((YC>391) and (yc<421)) AND ((xc>250) and (XC<280))) THEN srgen
:= 7;
```

```

IF(((YC>391) and (yc<421)) AND ((xc>440) and (XC<470))) THEN srgen
:= 8;
IF(((YC>391) and (yc<421)) AND ((xc>630) and (XC<660))) THEN srgen
:= 9;
IF(((YC>524) and (yc<554)) AND ((xc>250) and (XC<280))) THEN srgen
:=10;
IF(((YC>524) and (yc<554)) AND ((xc>440) and (XC<470))) THEN srgen
:=11;
IF(((YC>524) and (yc<554)) AND ((xc>630) and (XC<660))) THEN srgen
:=12;
IF srgen<>0 THEN
  BEGIN
    store_new_position := srgen;
  END;
END;

```

{This procedure reads the position at which the new rating is to be placed}

```

PROCEDURE readrating;
BEGIN
  srgen := 0;
  IF(((YC>125) and (yc<155)) AND ((xc>250) and (XC<280))) THEN srgen
:= 1;
  IF(((YC>125) and (yc<155)) AND ((xc>440) and (XC<470))) THEN srgen
:= 2;
  IF(((YC>125) and (yc<155)) AND ((xc>630) and (XC<660))) THEN srgen
:= 3;
  IF(((YC>258) and (yc<288)) AND ((xc>250) and (XC<280))) THEN srgen
:= 4;
  IF(((YC>258) and (yc<288)) AND ((xc>440) and (XC<470))) THEN srgen
:= 5;
  IF(((YC>258) and (yc<288)) AND ((xc>630) and (XC<660))) THEN srgen
:= 6;
  IF(((YC>391) and (yc<421)) AND ((xc>250) and (XC<280))) THEN srgen
:= 7;
  IF(((YC>391) and (yc<421)) AND ((xc>440) and (XC<470))) THEN srgen
:= 8;
  IF(((YC>391) and (yc<421)) AND ((xc>630) and (XC<660))) THEN srgen
:= 9;
  IF(((YC>524) and (yc<554)) AND ((xc>250) and (XC<280))) THEN srgen
:=10;
  IF(((YC>524) and (yc<554)) AND ((xc>440) and (XC<470))) THEN srgen
:=11;
  IF(((YC>524) and (yc<554)) AND ((xc>630) and (XC<660))) THEN srgen
:=12;
  IF srgen<>0 THEN
    BEGIN
      store_old_position := srgen;
      HIDE_CURSOR; SSTYLE(jz);
      tox := locxmo[srgen]; toy := locymo[srgen];
      COPY(boxw,boxh,jz,tox,toy,jz,iix,iiy);
      REPLACE_CURSOR; SSTYLE(jz);
    END;
  END;
END;

```


{This procedure copies the ratings from the main display to a small one so that they are not lost when a letter is being read}

```

PROCEDURE redraw_junior;
BEGIN
  HIDE_CURSOR; SSTYLE(jz);
  SHUFFLE;
  FOR srgen := 1 TO 12 DO
    BEGIN
      tox := locsort1[srgen]; toy := isort1[srgen];
      oox := locxm[srgen];    ooy := locym[srgen];
      copy(boxw,boxh,jz,tox,toy,jz,oox,ooy);
    END;
  REPLACE_CURSOR; SSTYLE(jz);
  buttonpress[clickNo] := 22; clickNo := clickNo+1;
  buttonpress[clickNo] := store_old_position; clickNo := clickNo+1;
  buttonpress[clickNo] := 23; clickNo := clickNo+1;
  buttonpress[clickNo] := store_new_position; clickNo := clickNo+1;
END;

```

{This procedure draws a document on the screen so that the subject can read it, reads the ratings, or shuffles them depending on what is required}

```

PROCEDURE OneDoc;
BEGIN
  POSICON;
  IF reading=true THEN
    BEGIN
      HIDE_CURSOR; SSTYLE(jz);
      SLUTDP(one); SLUTDP(one);
      GETFMAIL;
      buttonpress[clickNo] := randfil[srgen];
      clickno := clickNo+1;
      REPLACE_CURSOR; SSTYLE(jz);
      SLUTDP(jz); SLUTDP(jz);
    END
    ELSE
    BEGIN
      IF store_old_position=0 THEN READRATING
        ELSE
        IF store_new_position=0 THEN
          READ_THE_RATING;
        IF ((store_old_position<>0) and
          (store_new_position<>0)) THEN
          BEGIN
            IF store_old_position=store_new_position THEN
              REDRAW_JUNIOR
            ELSE
              REDRAW_JUNIOR;
            SCCOL(white);
            MOVETO(iix,iiy); RFILL(boxw,boxh);
            store_old_position := 0;
            store_new_position := 0;
          END;
        END;
    END;
  END;
END;

```

{This procedure copies the ratings from the main display to a small one so that they are not lost when a letter is being read, by being overwritten}

```
PROCEDURE Copy_Ratings; {from junior to major}
BEGIN
  boxw := 20; boxh := 20;
  SSTYLE(jz);
  FOR srgen := 1 TO 12 DO
    BEGIN
      tox := locxmo[srgen]; toy := locymo[srgen];
      oox := locsort1[srgen]; ooy := isort1[srgen];
      COPY(boxw,boxh,jz,oox,ooy,jz,tox,toy);
    END;
  END;
```

{This procedure copies ratings from the small display back to their original positions on the main display when a document is closed after reading.}

```
PROCEDURE ReDraw; {the major}
BEGIN
  HIDE_CURSOR; SSTYLE(jz);
  SLUTDP(one); SLUTDP(one);
  reading := false; white := 245; PAPER; white := 250;
  ICON_LOCATIONS;
  COPY_RATINGS;
  REPLACE_CURSOR; SSTYLE(jz);
  SLUTDP(jz); SLUTDP(jz);
  END;
```

{this procedure defines the action of the buttons, whether to open a document or close one}

```
PROCEDURE AllButtons;
BEGIN
  IF (((XC>240)and(xc<750))AND ((yc>45) and (yc<555))) THEN
    BEGIN
      IF reading= false THEN ONEDOC;
    END;
  IF (((xc<140) and (xc>40)) AND ((yc<540) and (yc>440))) THEN goto L1;
  IF (((xc<140) and (xc>40)) AND ((yc<340) and (yc>240))) THEN
    BEGIN
      IF reading=true THEN
        BEGIN
          Reading := false;
          REDRAW;
        END;
    END;
  STCOL(white);
  END;
```

{This procedure sets up the mouse operation of the buttons}

```
PROCEDURE CursorOp;
LABEL Loop1;

BEGIN

Loop1:
MOUSEIN;
MOVECURSOR;
IF (bone AND 7) = 0 THEN Goto Loop1;
IF (bone AND 4) = 4 THEN BEGIN
  ALLBUTTONS;
  Goto loop1;
END;
```

```

IF (bONE AND 2) = 2 THEN BEGIN
    ALLBUTTONS;
    goto loop1;
END;
IF (bONE AND 1) = 1 THEN BEGIN
    ALLBUTTONS;
    goto loop1;
END;
END;

```

{This procedure sets up the small display where the ratings are maintained while a subject is reading a document}

```

PROCEDURE Chosen_Rating;
BEGIN
    STCOL(JZ);
    x1 := 30; x4 := 120;
    y1 := 35; y4 := 110;
    SCCOL(magenta); MESSBOX;
    x1 := 35; x4 := 110;
    y1 := 40; y4 := 100;
    SCCOL(white); MESSBOX;
    currx := 0; curry := y1+20;
    filnam := 'G:NUMBERS.TEX';
    bx := 45; lhm := 0;
    LOADFILES;
    bx := 55;
    x1 := 81; x4 := 30;
    y1 := 175; y4 := 30;
    SCCOL(thirty); MESSBOX;
    x1 := 85; x4 := 20;
    y1 := 180; y4 := 20;
    SCCOL(white); MESSBOX;
END;

```

{This procedure reads the final order that subjects allocate the documents}

```

PROCEDURE Final_order;
Var xx,yy : INTEGER;

BEGIN
    xx:= locsort1[srgen]; yy := isort1[srgen];
    IF xx+yy=94 THEN arindex:= 1;
    IF xx+yy=134 THEN arindex:= 2;
    IF xx+yy=174 THEN arindex:= 3;
    IF xx+yy=109 THEN arindex:= 4;
    IF xx+yy=149 THEN arindex:= 5;
    IF xx+yy=189 THEN arindex:= 6;
    IF xx+yy=124 THEN arindex:= 7;
    IF xx+yy=164 THEN arindex:= 8;
    IF xx+yy=204 THEN arindex:= 9;
    IF xx+yy=139 THEN arindex:=10;
    IF xx+yy=179 THEN arindex:=11;
    IF xx+yy=219 THEN arindex:=12;
END;

```

{ This procedure draws the screen display which acts as a virtual switch to close any letter that is being read}

```
PROCEDURE Close_Letters_Box;
BEGIN
  STCOL(JZ);
  x1 := 30; x4 := 120;
  y1 := 235; y4 := 110;
  SCCOL(magenta); MESSBOX;
  x1 := 35; x4 := 110;
  y1 := 240; y4 := 100;
  SCCOL(white); MESSBOX;
  x1 := 10; currx := x1+10; curry := y1+20;
  filnam := 'g:closeL.mes';
  lhm := 0; bx := 50;
  LOADFILES;
  bx := 55;
END;
```

{This procedure stores the data collected from the task}

```
PROCEDURE Storage;
LABEL loop1, Loop2;
VAR a : INTEGER;

BEGIN
  a := 0;

  Loop2:
  WRITELN('Under which subject name will these results be stored ?');
  WRITELN('Use the format D:"subjectname".PT1 ');
  READLN(resultstring);
  filnam := resultstring;
  WRITELN('is this correct ? ', filnam);
  READLN(rr); IF rr='n' THEN Goto loop2;
  ASSIGN(Data, Filnam);
  REWRITE(Data);
  WRITELN(Data, resultstring);
  st := ' '; WRITELN(Data, st);
  st := ' the three numbers used by the random generator were : ';
  WRITELN(Data, st);
  WRITELN(Data, STORE_aargen, store_bbrgen, store_ccrgen); st := ' ';
  WRITELN(Data, st); st := ' initial document location icon
colour final';
  WRITELN(Data, st); st := ' Order '
doc. order';
  WRITELN(Data, st);
  FOR srgen := 1 TO 12 DO
    BEGIN
      FINAL_ORDER;

  WRITELN(DATA, randfil[srgen], srgen, randicon[srgen], randcol[srgen], arin
dex);
    END;
  st := ' '; WRITELN(DATA, st);
  st := 'Documents opened : 1-12, Buttons pressed : 21,22,23 ';
  writeln(DATA, st);
  FOR clickNo:= 0 TO 3000 DO
    BEGIN
      a := a+1;
      IF buttonpress[clickno]=0 THEN Goto Loop1;
      WRITE(DATA, buttonpress[clickno]);
      IF (a=5) THEN BEGIN
        a := 0;
```

```

WRITELN(DATA, ' ');
END;

END;

loop1:
st := ' '; WRITELN(DATA,st);
CLOSE(Data);
END;

BEGIN { the main program }
x2 := 200;      y2 := 20; x1 := 0;      Y1 := 0;      x3 := 520;
x4 := 764;
y3 := 536;      y4 := 576; sedge := 50;      part := 4; cellx := 8;
celly := 4;
jz := 0;      height := 10;      bx := 55;
q := 0;      qq := 0;      r := 0;
iix := 85; iiy := 180; clickNo := 0;
blackiconx := 0; blackicony := 0;

black := 216; green := 230; blue := 18; cyan := 255; selected_colour
:= 0 ;
red := 76; yellow := 13; magenta := 174; white := 250; col := 250;

one := 1; two := 2; four := 4; eight := 8; twenty := 20; thirty := 30;
reading := false; store_old_position := 0; store_new_position := 0;

SETSCRN;
WRITELN('enter 3 numbers between 1 and 30000 for randomising the
files');
READLN(aargen); readln(bbargen); readln(ccargen);
store_aargen := aargen; store_bbargen := bbargen; store_ccargen :=
ccargen;
loctn_array; icon_array; file_array; col_array;
WHILE clickNo < 3001 DO BEGIN
      buttonpress[clickNo] := 0;
      clickNo := clickNo + 1;
END;

clickNo := 0; srgen := 1; locsort1[srgen] := 42; isort1[srgen] := 52;
locxm[srgen] := 250; locym[srgen] := 130; srgen := 2; locsort1[srgen]
:= 82; isort1[srgen] := 52;
locxm[srgen] := 440; locym[srgen] := 130; srgen := 3; locsort1[srgen]
:= 122; isort1[srgen] := 52;
locxm[srgen] := 630; locym[srgen] := 130; srgen := 4; locsort1[srgen]
:= 42; isort1[srgen] := 67;
locxm[srgen] := 250; locym[srgen] := 263; srgen := 5; locsort1[srgen]
:= 82; isort1[srgen] := 67;
locxm[srgen] := 440; locym[srgen] := 263; srgen := 6; locsort1[srgen]
:= 122; isort1[srgen] := 67;
locxm[srgen] := 630; locym[srgen] := 263; srgen := 7; locsort1[srgen]
:= 42; isort1[srgen] := 82;
locxm[srgen] := 250; locym[srgen] := 396; srgen := 8; locsort1[srgen]
:= 82; isort1[srgen] := 82;
locxm[srgen] := 440; locym[srgen] := 396; srgen := 9; locsort1[srgen]
:= 122; isort1[srgen] := 82;
locxm[srgen] := 630; locym[srgen] := 396; srgen := 10; locsort1[srgen]
:= 42; isort1[srgen] := 97;
locxm[srgen] := 250; locym[srgen] := 529; srgen := 11; locsort1[srgen]
:= 82; isort1[srgen] := 97;
; locxm[srgen] := 440; locym[srgen] := 529; srgen := 12;
locsort1[srgen] := 122; isort1[srgen] := 97;
locxm[srgen] := 630; locym[srgen] := 529; srgen := 1;

```

```

WHILE srgen<13 DO BEGIN
    filsort1[srgen] := randfil[srgen];
    filsort2[srgen] := randfil[srgen];
    locsort2[srgen] := locsort1[srgen];
    isort2[srgen] := isort1[srgen];
    locxj[srgen] := locsort1[srgen];
    locyj[srgen] := isort1[srgen];
    locymo[srgen] := locym[srgen];
    locxmo[srgen] := locxm[srgen];
    locym1[srgen] := locym[srgen];
    locxm1[srgen] := locxm[srgen];
    srgen := srgen+1;
END;

LOADFONT;
L3:
SCWP(JZ);
SLUTWP(one); SLUTDP(one);
READLN(filnam);
CLOSE_LETTERS_BOX;
CHOSEN_RATING;
END_BOX;
lhm := 165;
x8 := 20; x9 := 72; y8 := 385; y9 := 427;
white := 245;
PAPER;
white := 250;
ICON_LOCATIONS;
COPY_RATINGS;
STCOL(JZ);
DRAWCURSOR;
FIRST_CURSOR;
STCOL(white);
SLUTWP(jz); SLUTDP(jz);

L2:
CURSOROP;

L1:
CLEARSCRN;
STORAGE;
END.

```

"Modone" is a module used by all of the programs containing procedures that they share.

```

MODULE modone;
VAR[extern]x,x1,x2,x3,x4,x8,x9,xc,xc2,arindex,xb,cx,cellx,ox      :
INTEGER;
y,y1,y2,y3,y4,y8,y9,yc,yc2,yy,yx,yb,cy,celly,oy,lhm,bx : INTEGER;
currx,curry,oldw,height,store_old_position,store_new_position : INTEGER;
bone,btwo,bthree,b,d,e,f,h,n,o,q,r,s,t,u,w,z             : INTEGER;
one,three,two,four,eight,twenty,thirty,sedge,part,jz      : INTEGER;
iconx,icony,iconno,col,pixcol,selected_colour              : INTEGER;
iconstore,blackiconx,blackicony                             : INTEGER;
Black,green,blue,cyan,red,yellow,magenta,white              : INTEGER;
aargen,bbrgen,ccrgen,srgen,trgen,rmax,srgenml,srgenpl       : INTEGER;
argen,brgen,crgen                                           : INTEGER4;
hrgen,jrgen,jjrgen                                          : REAL;
reading              : BOOLEAN;
ftext                : TEXT;
ff                   : FILE OF INTEGER;
filnam,st            : LSTRING(62);
instring             : LSTRING(3);
matrix,randcol,randfil : ARRAY[0..12] OF INTEGER;
randicon,isort1,isort2 : ARRAY[0..12] OF INTEGER;
randlocs,filsort1,filsort2 : ARRAY[0..12] OF INTEGER;
locsort1,locsort2      : ARRAY[0..12] OF INTEGER;
grey                   : ARRAY[0..40] OF INTEGER;
colour                 : ARRAY[0..5] OF ARRAY[0..5] OF INTEGER;

FUNCTION aisrqq(consts a:real4):real4;EXTERNAL;

```

{The procedures below are those provided by the Pluto graphics system}

```

PROCEDURE Allocp(VAR width,height,nsyms,p :INTEGER); EXTERNAL;
PROCEDURE Copy(VAR w,h,p1,x1,y1,p2,x2,y2 : INTEGER); EXTERNAL;
PROCEDURE Copys(VAR n : INTEGER); EXTERNAL;
PROCEDURE CLrCWP; EXTERNAL;
PROCEDURE Pinit; EXTERNAL;
PROCEDURE Plot (VAR x,y : INTEGER); EXTERNAL;
PROCEDURE Lineto (VAR x,y : INTEGER); EXTERNAL;
PROCEDURE MoveTo (VAR x,y : INTEGER); EXTERNAL;
PROCEDURE RFill (VAR W,H : INTEGER); EXTERNAL;
PROCEDURE RPix(VAR X,Y,C : INTEGER); EXTERNAL;
PROCEDURE SCCol (VAR c : INTEGER); EXTERNAL;
PROCEDURE StCol (VAR c : INTEGER); EXTERNAL;
PROCEDURE SCDP (VAR cdp : INTEGER); EXTERNAL;
PROCEDURE SCSP (VAR csp : INTEGER); EXTERNAL;
PROCEDURE SCWP (VAR cwp : INTEGER); EXTERNAL;
PROCEDURE Sstyle (VAR style : INTEGER); EXTERNAL;
PROCEDURE SLUTWP (VAR lwp : INTEGER); EXTERNAL;
PROCEDURE SLUTDP (VAR ldp : INTEGER); EXTERNAL;
PROCEDURE SHiRes; EXTERNAL;
PROCEDURE Wlut (VAR index,gbr :INTEGER); EXTERNAL;
PROCEDURE Rlut (VAR index,gbr :INTEGER); EXTERNAL;

```

{procedures found in modmouse}

```

PROCEDURE Hide_cursor; external;
PROCEDURE Replace_cursor; external;

```

{a procedure found in the main program that instructs a move to "L2"}

```

PROCEDURE ell2; external;

```

{This procedure draws a white sheet with a blue border, these sheets are the letter representations used in experiments I and IV}

```
PROCEDURE Sheet;
BEGIN
  SCCOL(BLue);   MOVETO(x9,y9);  RFILL(x8,y8);
  x9 := x9+2;   y9 := y9+2;
  SCCOL(white);  MOVETO(x9,y9);  RFILL(x8,y8);
END;
```

{This procedure shuffles the information items, or the rankings for experiments II and III}

```
PROCEDURE shuffle;
BEGIN
  IF store_old_position > store_new_position THEN
    BEGIN
      isort1[store_new_position] := isort2[store_old_position];
      filsort1[store_new_position] := filsort2[store_old_position];
      locsort1[store_new_position] := locsort2[store_old_position];
      FOR srgen := store_new_position TO (store_old_position-1) DO
        BEGIN
          srgenp1 := srgen+1;
          isort1[srgenp1] := isort2[srgen];
          filsort1[srgenp1] := filsort2[srgen];
          locsort1[srgenp1] := locsort2[srgen];
        END;
      FOR srgen := 1 TO 12 DO
        BEGIN
          isort2[srgen] := isort1[srgen];
          filsort2[srgen] := filsort1[srgen];
          locsort2[srgen] := locsort1[srgen];
        END;
      END
    ELSE
      BEGIN
        isort1[store_new_position] := isort2[store_old_position];
        filsort1[store_new_position] := filsort2[store_old_position];
        locsort1[store_new_position] := locsort2[store_old_position];
        FOR srgen := (store_old_position+1) TO store_new_position DO
          BEGIN
            srgenm1 := srgen-1;
            isort1[srgenm1] := isort2[srgen];
            filsort1[srgenm1] := filsort2[srgen];
            locsort1[srgenm1] := locsort2[srgen];
          END;
        FOR srgen := 1 TO 12 DO
          BEGIN
            isort2[srgen] := isort1[srgen];
            filsort2[srgen] := filsort1[srgen];
            locsort2[srgen] := locsort1[srgen];
          END;
        END;
      END;
    END;
  END;
```


{This procedure holds the colour identities for the icons}

```
PROCEDURE set_colours;
BEGIN
CASE arindex OF
  1 : COL:= 10; {dark green}  2 : COL:= 11; {lime green}
  3 : COL:= 31; {royal blue}  4 : COL:= 34; {turquoise}
  5 : COL:= 144; {brown}      6 : COL:= 170; {magenta}
  7 : COL:= 159; {beige}      8 : COL:= 177; {lilac}
  9 : COL:= 180; {red}        10: COL:= 183; {orange}
  11: COL:= 184; {yellow}     12: COL:= 210; {pink}
END;
END;
```

{This procedure copies one icon from the pluto frame buffer to the position iconx, icony on the main display screen}

```
PROCEDURE Draw_icon;
BEGIN
STCOL(white);  SCSP(part);
COPY(sedge,sedge,part,iconno,jz,jz,iconx,icony);
SCSP(cyan);
STCOL(jz);
END;
```

{This procedure reads the colour of a pixel, if the colour is not white it colours the pixel}

```
PROCEDURE Kolour;
BEGIN
RPIX(x,y,pixcol);
if pixcol<>white then
  BEGIN
    PLOT(x,y);
  END;
x:=x+1;
END;
```

{This procedure colours a black shape in the memtest display at the x coordinate 25}

```
PROCEDURE Highlight1;
BEGIN
r := 1;  x:= 25;
blackiconX :=X;
WHILE x<75 do KOLOUR;
y:=y+1;
END;
```

{This procedure colours a black shape in the memtest display at the x coordinate 85}

```
PROCEDURE Highlight2;
BEGIN
r := 1;  x:= 85;
blackiconX :=X;
WHILE x<135 do KOLOUR;
y:=y+1;
END;
```

{This procedure returns a coloured shape on the memtest shape-selection display to black - by highlighting in black- in the event of a subject selecting another shape. Consequently, a subject can only have one shape on the memory test display coloured at any one time}

```
PROCEDURE black_icon;
VAR a : INTEGER;
```

```
BEGIN
```

```
IF BlackiconY<>0 THEN
```

```
  BEGIN
```

```
    IF ((blackiconX=25) or (blackiconx=85)) THEN
```

```
      BEGIN
```

```
        HIDE_CURSOR;
```

```
        SSTYLE(jz);
```

```
        SCCOL(BLACK);
```

```
        y := blackiconY;
```

```
        a := y+50;
```

```
        WHILE y<a DO BEGIN
```

```
          if blackiconx=25 then highlight1;
```

```
          if blackiconx=85 then highlight2;
```

```
        END;
```

```
        REPLACE_CURSOR;
```

```
        SSTYLE(jz);
```

```
      END;
```

```
    END;
```

```
END;
```

{This procedure calculates the co-ordinates of the selected shape, if a colour has already been selected it blacks out any previously selected shape and proceeds to colour the newly selected shape}

```
PROCEDURE Iconpos;
```

```
BEGIN
```

```
BLACK_ICON;
```

```
IF ((xc>25) AND (xc<75)) and ((yc>25) and (yc<380))
```

```
  THEN BEGIN
```

```
    HIDE_CURSOR;
```

```
    SSTYLE(jz);
```

```
IF selected_colour<>0 THEN SCCOL(selected_colour)
```

```
  ELSE SCCOL(black); IF ((yc>25) AND (yc<80)) THEN
```

```
BEGIN y:= 25;
```

```
  WHILE y<75 DO BEGIN
```

```
    HIGHLIGHT1;
```

```
  END;
```

```
  srgen := 1;
```

```
END;
```

```
IF ((yc>79) AND (yc<140)) THEN BEGIN y:= 85;
```

```
  WHILE y<135 do BEGIN
```

```
    HIGHLIGHT1;
```

```
  END;
```

```
  srgen := 2;
```

```
END;
```

```
IF ((yc>139) AND (yc<200)) THEN BEGIN y:= 145;
```

```
  WHILE y< 195 do BEGIN
```

```
    HIGHLIGHT1;
```

```
  END;
```

```
  srgen := 3;
```

```
END;
```

```
IF ((yc>199) AND (yc<260)) THEN BEGIN y:= 205;
```

```
  WHILE y<255 DO BEGIN
```

```
    HIGHLIGHT1;
```

```
  END;
```

```
  srgen := 4;
```

```
END;
```

```
IF ((yc>259) AND (yc<320)) THEN BEGIN y:= 265;
```

```

                                WHILE y< 315 DO BEGIN
                                    HIGHLIGHT1;
                                    END;
srgen := 5;                                end; IF ((yc>319) AND
(yc<380)) THEN BEGIN y:= 325;
                                WHILE y<375 DO BEGIN
                                    HIGHLIGHT1;
                                    END;
                                    srgen := 6;
                                    END;
                                    blackicony := y-sedge;
                                    Iconno := randicon[srgen]*50+50;
                                    REPLACE_CURSOR;
                                    SSTYLE(jz);
                                    END;
IF (((xc>85) AND (xc<135)) and ((yc>25) AND (yc<380))) THEN
    BEGIN
        HIDE_CURSOR;
        SSTYLE(jz);
    IF selected_colour<>0 THEN SCCOL(selected_colour)
        ELSE SCCOL(black); IF ((yc>25) AND (yc<80)) THEN
    BEGIN Y:= 25;
                                WHILE y<75 DO BEGIN
                                    HIGHLIGHT2;
                                    END;
                                    srgen := 7;
                                    END;
IF ((yc>79) AND (yc<140)) THEN BEGIN y:= 85;
                                WHILE y<135 DO BEGIN
                                    HIGHLIGHT2;
                                    END;
                                    srgen := 8;
                                    END;
IF ((yc>139) AND (yc<200)) THEN BEGIN y:= 145;
                                WHILE y<195 DO BEGIN
                                    HIGHLIGHT2;
                                    END;
                                    srgen := 9;
                                    END;
IF ((yc>199) AND (yc<260)) THEN BEGIN y:= 205;
                                WHILE y<255 DO BEGIN
                                    HIGHLIGHT2;
                                    END;
                                    srgen := 10;
                                    END;
IF ((yc>259) AND (yc<320)) THEN BEGIN y:= 265;
                                WHILE y<315 DO BEGIN
                                    HIGHLIGHT2;
                                    END;
                                    srgen := 11;
                                    END
; IF ((yc>319) AND (yc<380)) THEN BEGIN y:= 325;
                                WHILE y<375 DO BEGIN
                                    HIGHLIGHT2;
                                    END;
                                    srgen := 12;
                                    END;
                                    blackicony := y-sedge;
                                    Iconno := randicon[srgen]*50+50;
                                    REPLACE_CURSOR;
                                    SSTYLE(jz);
                                    END;
ell2;

```

END;

{This procedure draws the outline of a box on the screen}

```
PROCEDURE Line_box;
BEGIN
  x4 := x1+70; y4 := y1+70;
  MOVETO(x1,y1); LINETO(x1,y4); LINETO(x4,y4); LINETO(x4,y1);
  LINETO(x1,y1);
END;
```

{This procedure draws the outline of the twelve possible icon locations on the main display screen for the memtest program}

```
PROCEDURE draw_locations;
BEGIN
  SCCOL(magenta);
  X1 := 240 ; y1 := 45; LINE_BOX;
  Y1 :=191; LINE_BOX; Y1 :=327; LINE_BOX; Y1 :=463; LINE_BOX;
  X1 := 430; Y1 := 45; LINE_BOX;
  Y1 :=191; LINE_BOX; Y1 :=327; LINE_BOX; Y1 :=463; LINE_BOX;
  X1 := 620; Y1 := 45; LINE_BOX;
  Y1 :=191; LINE_BOX; Y1 :=327; LINE_BOX; Y1 :=463; LINE_BOX;
  SCCOL(white);
END;
```

{This procedure draws an icon on the letter the subject has selected to read}

```
PROCEDURE Read_Letter;
BEGIN
  srgen := iconstore;
  reading := true;
  SCCOL(white);
  SCWP(jz); SCDP(jz);
  HIDE_CURSOR; SSTYLE(jz);
  DRAW_ICON;
  REPLACE_CURSOR; SSTYLE(jz);
  SCCOL(selected_colour);
  q := 1;
END;
```

{This procedure converts the cursor position to an icon/letter identification and stores the identification of the letter that has been read}

```
PROCEDURE PosIcon;
BEGIN
  IF ((yc>55) AND (yc<95)) AND ((xc>250) AND (xc<300)) THEN BEGIN
    icony := 55;
    iconx := 250;
    iconstore := 1;
    READ_LETTER;
    END;
  IF ((yc>55) AND (yc<95)) AND ((xc>440) AND (xc<490)) THEN BEGIN
    iconx := 440;
    icony := 55;
    iconstore := 2;
    READ_LETTER;
    END;
  IF ((yc>55) AND (yc<95)) AND ((xc>630) AND (xc<680)) THEN BEGIN
    iconx := 630;
    icony := 55;
    iconstore := 3;
    READ_LETTER;
  END;
```

```

END;
IF (((yc>201) AND (yc<251)) AND ((xc>250) AND (xc<300))) THEN BEGIN
    icony := 201;
    iconx := 250;
    iconstore := 4;
    READ_LETTER;
END;
IF (((yc>201) AND (yc<251)) AND ((xc>440) AND (xc<490))) THEN BEGIN
    icony := 201;
    iconx := 440;
    iconstore := 5;
    READ_LETTER;
END;
IF (((yc>201) AND (yc<251)) AND ((xc>630) AND (xc<680))) THEN BEGIN
    icony := 201;
    iconx := 630;
    iconstore := 6;
    READ_LETTER;
END;
IF (((yc>337) AND (yc<387)) AND ((xc>250) AND (xc<300))) THEN BEGIN
    icony := 337;
    iconx := 250;
    iconstore := 7;
    READ_LETTER;
END;
IF (((yc>337) AND (yc<387)) AND ((xc>440) AND (xc<490))) THEN BEGIN
    icony := 337;
    iconx := 440;
    iconstore := 8;
    READ_LETTER;
END;
IF (((yc>337) AND (yc<387)) AND ((xc>630) AND (xc<680))) THEN BEGIN
    icony := 337;
    iconx := 630;
    iconstore := 9;
    READ_LETTER;
END;
IF (((yc>473) AND (yc<523)) AND ((xc>250) AND (xc<300))) THEN BEGIN
    icony := 473;
    iconx := 250;
    iconstore := 10;
    READ_LETTER;
END;
IF (((yc>473) AND (yc<523)) AND ((xc>440) AND (xc<490))) THEN BEGIN
    icony := 473;
    iconx := 440;
    iconstore := 11;
    READ_LETTER;
END;
IF (((yc>473) AND (yc<523)) AND ((xc>630) AND (xc<680))) THEN BEGIN
    icony := 473;
    iconx := 630;
    iconstore := 12;
    READ_LETTER;
END;
END;

```

{This procedure draws a border around the main display screen}

```
PROCEDURE Border;
begin
x4 := 768; y4 := 576;
SCCOL(red); MOVETO(JZ,JZ);
LINETO(X4,JZ); LINETO(X4,Y4); LINETO(Y4,JZ); LINETO(JZ,JZ);
x4 := 767; y4 := 575; MOVETO(one,one);
LINETO(X4,ONE); LINETO(X4,Y4); LINETO(ONE,Y4); LINETO(ONE,ONE);
x4 := 766; y4 := 574; SCCOL(yellow); MOVETO(two,two);
LINETO(X4,TWO); LINETO(X4,Y4); LINETO(TWO,Y4); LINETO(TWO,TWO);
x4 := 765; y4 := 573; MOVETO(THREE,THREE);
LINETO(X4,THREE); LINETO(X4,Y4); LINETO(THREE,Y4);
LINETO(THREE,THREE);
END;
```

{This procedure colours a box on the screen}

```
PROCEDURE Messbox;
BEGIN
MOVETO(X1,Y1); RFILL(X4,Y4);
END;
```

{This procedure colours the whole screen grey by filling it with grey pixels}

```
PROCEDURE Clearscrn;
BEGIN
x4 := 760; y4 := 568; SCCOL(GREEN); MOVETO(four,four); RFILL(X4,Y4);
END;
```

{This procedure copys the cursor picture from the pluto font when the screen has been redrawn}

```
PROCEDURE Changescreen;
VAR ch,cw, : INTEGER;
BEGIN
SCCOL(white);
CH := 13; cw := 15;
SSTYLE(jz);
COPY(cw,ch,part,sedge,jz,part,ox,oy);
SSTYLE(eight);
END;
```

{This procedure assigns a filename and resets a textfile in preperation for reading}

```
PROCEDURE Getname;
BEGIN
ASSIGN(ff,filnam);
RESET(ff)
END;
```

{This procedure draws a large white rectangle that represents the paper that the text files are written on}

```
PROCEDURE Paper;
BEGIN
SCCOL(blue);
x2 := x2-5; y2 := y2-5; x3:= x3+10; y3 := y3+10;
MOVETO(x2,y2);
RFILL(x3,y3);
SCCOL(WHITE);
x2 := x2+5; y2 := y2+5; x3:= x3-10; y3 := y3-10;
MOVETO(x2,y2);
RFILL(x3,y3);
END;
```

{A word processing procedure, it reads a carriage return in the text file and writes a carriage return on the screen}

```
PROCEDURE Creturn;
BEGIN
  currx := lhm+bx;  curry := curry+15;
  MOVETO(currx,curry)
END;
```

{A word processing procedure, it reads the strings of characters in the text files}

```
PROCEDURE StripString;
VAR index      : INTEGER;
    sChar      : CHAR;
    NoOfChars  : BYTE;
BEGIN
  W := 8; part := 255; height := 10;  scsp(part);  y := 0;
  SSTYLE(eight);  NoOfChars := st.LEN;
  FOR index := 1 TO NoOfChars DO
    BEGIN
      sChar := st[index];
      b := ORD(sChar);
      x := (b-32)*8;
      COPY(w,height,part,x,y,jz,currx,curry);
      currx := currx+8;
    END;
  CRETURN;
  part := 4;
END;
```

{Accessing the text files and writing them on the main display screen}

```
PROCEDURE Loadfiles;
BEGIN
  ASSIGN(ftext,filnam);
  RESET(ftext);
  WHILE NOT EOF(FTEXT) DO
    BEGIN
      READLN(ftext,st);
      STRIPSTRING;
    END;
  CLOSE(ftext)
END;
```

{Draws and defines an area on the main display screen which is a virtual switch that the subject's can use to indicate that they have finished their sort}

```
PROCEDURE End_Box;
BEGIN
  STCOL(jz);
  filnam := 'g:end.mes';
  lhm := 0;
  SCCOL(magenta);
  x1 := 30;  y1 := 435;  x4 := 120;  y4 := 110;  MESSBOX;  SCCOL(white);
  x1 := 35;  y1 := 440;  x4 := 110;  y4 := 100;  MESSBOX;
  x1 := 10;
  Currx := x1+10;  curry := y1+20;  LOADFILES;
  lhm := 20;
  STCOL(white);
END;
```

{A random number generating procedure}

```
PROCEDURE Rgen(var max : integer);
BEGIN
  argen := 171*aargen; brgen := 172*bbrgen; crgen := 170*ccrgen;
  argen := argen mod 30269;
  brgen := brgen mod 30307;
  crgen := crgen mod 30323;
  hrgen := float(argen)/30269.0+float(brgen)/30307.0+float(crgen)/30323.0;
  jrgen := hrgen-aisrqq(hrgen);
  jjrgen := jrgen*30000;
  ccrgen := bbrgen; bbrgen := aargen; aargen := trunc(jjrgen);
  jrgen := jrgen*max;
  trgen := round(jrgen);
END;
```

{Pre-setting the random generator so that it only generates the numbers 1-12 and does not duplicate them}

```
PROCEDURE Presetrand;
VAR p : INTEGER;
BEGIN
  p := 1;
  WHILE p<13 DO
    BEGIN
      matrix[p] := 1;
      p := p+1;
    END;
  END;
```

{Pre-setting the random numbers for accessing the locations in an array}

```
PROCEDURE loctn_array;
LABEL lend;
BEGIN
  presetrand;
  rmax := 12;
  srgen := 1;

  lend:
  WHILE srgen<13 DO BEGIN
    RGEN(rmax);
    IF matrix[trgen]=0 THEN Goto lend;
    randlocs[srgen] := trgen;
    matrix[trgen] := 0;
    srgen := srgen+1;
  END;
END;
```


{Pre-setting the random numbers for accessing the files in an array}

```
PROCEDURE file_array;
LABEL lend;
BEGIN
  presetrand;
  rmax := 12;
  srgen := 1;

  lend:
  WHILE srgen<13 DO BEGIN
    RGEN(rmax);
    IF matrix[trgen]=0 THEN Goto lend;
    randfil[srgen] := trgen;
    matrix[trgen] := 0;
    srgen := srgen+1;
  END;
END;
```

{Pre-setting the random numbers for accessing the shapes in an array}

```
PROCEDURE icon_array;
LABEL lend;

BEGIN
  presetrand;
  rmax := 12;
  srgen := 1;

  lend:
  WHILE srgen<13 DO BEGIN
    RGEN(rmax);
    IF matrix[trgen]=0 THEN Goto lend;
    randicon[srgen] := trgen;
    matrix[trgen] := 0;
    srgen := srgen+1;
  END;
END;
```

{Pre-setting the random numbers for accessing the colours in an array}

```
PROCEDURE col_array;
LABEL lend;
BEGIN
  presetrand;rmax := 12;
  srgen := 1;
  lend:
  WHILE srgen<13 DO BEGIN
    RGEN(rmax);
    IF matrix[trgen]=0 THEN Goto lend;
    randcol[srgen] := trgen;
    matrix[trgen] := 0;
    srgen := srgen+1;
  END;
END;
```

{Setting one of the pluto "look-up-Table's" to supply the necessary colour range}

```

PROCEDURE Colent1;
VAR a,b,c,i,j,k,lutind : INTEGER;
BEGIN
  SLUTWP(jz);  SLUTDP(JZ);  a := 0;
  WHILE a<6 DO
    BEGIN
      b := 0;
      WHILE b<6 DO
        BEGIN
          c := 0;
          WHILE c<6 DO
            BEGIN
              lutind := a*36+b*6+c;
              colour[a,b,c] := lutind;
              i := 21+a*42;
              j := 21+b*42;
              k := 21+c*42;
              WLUT(lutind,k);
              c := c+1
            END;
            b := b+1
          END;
          a := a+1
        END;
      a := 0;
      WHILE a<40 DO
        BEGIN
          lutind := 215+a+1;
          i := a*6; j := i; k := i;
          grey[a] := lutind;
          WLUT(lutind,k);
          a := a+1
        END
      END;
    END;
  END;

```

{Setting one of the pluto "look-up-Table"s to a uniform shade of gray, thereby enabling the screen to be blanked merely by changing the look-up-table. The screen border colours remain unchanged}

```

PROCEDURE Colent2;
VAR a,b,c,i,j,k,lutind : INTEGER;
BEGIN
  SLUTWP(one);  SLUTDP(one);  a := 0;
  WHILE a<6 DO
    BEGIN
      b := 0;
      WHILE b<6 DO
        BEGIN
          c := 0;
          WHILE c<6 DO
            BEGIN
              lutind := a*36+b*6+c;
              colour[a,b,c] := lutind;
              i := 85;
              j := 85;
              k := 85;
              WLUT(lutind,k);
              c := c+1
            END;
            b := b+1
          END;
          a := a+1
        END;
      a := 0;
    END;
  END;

```

```

a := 0;
WHILE a<40 DO
    BEGIN
        lutind := 215+a+1;
        i := 85; j :=85; k :=85;
        grey[a] := lutind;
        WLUT(lutind,k);
        a := a+1
    END;
lutind := 13;
i := 21;
j :=105;
k :=63;
WLUT(lutind,k);
lutind := 76;
i :=105; j :=21; k :=189;
WLUT(lutind,k);
END;

```

{Initialising the pluto screen, setting the resolution, clearing the working partitions and the screen, drawing the borders etc}

```

PROCEDURE Setscrn;
BEGIN
    Pinit;
    SHiRes;
    SCWP(jz); SCDP(jz);
    CLrCWP;
    COLENT2; COLENT1;
    SLUTWP(one); SLUtDP(one);
    CLEARSCRN;
    BORDER;
    SLUTWP(jz); SLUtDP(jz);
    SCCOL(WHITE);
END;
END.

```

