VISUO-SPATIAL WORKING MEMORY

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VISUO-SPATIAL WORKING MEMORY

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DECLARATION FOR THE DEGREE OF PHD

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PREFACE

It seems that most people one meets express an interest in memory. Everyone it appears has a "poor one" but knows someone who has a "good one"; and advertisements in the Guardian promise us better ones. My own interest in the subject began when, as an undergraduate at the University of Strathclyde I was introduced to the subject by Dr Terry Mayes. The intricacies of the experimental work fascinated me : how we began with this immense monster called memory and how Cognitive psychologists were attempting to devise means of investigating it; how vast amounts of experimental work would be carried out presenting seemingly convincing results for one theory only to be met by results which demanded that the theory be modified or abandoned. As the theories came and went our knowledge about memory continued to grow.

One of the theories presently in vogue is the Working Memory framework of Baddeley and Hitch (1974). I became interested in one particular aspect of this framework, namely the Visuo-Spatial Sketch Pad after reading the Baddeley and Lieberman (1981) paper. It appeared that this slave system had not been examined to any great extent. This was too much of a challenge for me to resist.

This thesis represents both my philosophy on exploring memory, and in fact any other area of psychology, and my attempts to investigate one area of human memory. It is essentially made up of two halves. In the first half a literature review is presented. The chapters presenting this review all take an essentially historical perspective. This does not stem from a belief that history can help us in our analysis of memory, but because it shows how we, as

Cognitive psychologists, have developed our ideas : how we view the work we are presently involved in, not as one more step to some Cognitive Nirvana or as another piece of a jigsaw that is nearing completion, but as part of a continually evolving outlook. The second half is my attempt to design and carry out a series of experiments which it is hoped will help evolve our view of one particular aspect of human memory, namely visuo-spatial short term memory.

ACKNOWLEDGEMENTS

I would like to express my thanks to SERC; to Dr J.G. Quinn,possibly the world's greatest devil's advocate; to B. Rothwell; to my friends and finally to my family.

To AILEEN AND SAM

A book attracts me straight away if it answers questions that I am asking myself....Just as the sight of an object begets the desire for it, so hearing about some unforeseen event often makes me want to know more and to understand it better. Or else fresh discoveries about facts that I either did not know or did not care about will arouse my interest.

Simone De Beauvoir (All Said and Done)

ABSTRACT

This study set out to investigate the visuo-spatial component of Baddeley and Hitch's (1974) Working Memory framework. The development of our understanding of this component has been less dramatic than that of its verbal counterpart, the Articulatory Loop. The primary reason for this can be said to be the lack of techniques for investigation (Logie, 1986). This thesis presents one attempt to try to explore the nature of this code and to reveal possible new techniques of investigation. The following are three possible areas of investigation :

1. Is the system spatially or visually based?

2. Does movement have a role in the system?

3. How is information stored?

The latter two issues are investigated here. Experiments 1-4 set out to explore the possibility that movement may be involved in the code. These experiments supported the idea that movement has a role to play in spatial coding and more specifically demonstrated that arm movements which are not compatible with the presentation of spatial material can cause disruption. In addition it was shown that when movement identical to that involved in presentation is encouraged at recall subjects show marked improvement in performance. Together these results very strongly suggest that movement should be given prominent reference in the definition of spatial coding and in the description of the visuo-spatial slave system.

Another development that came out of these experiments relates to the lack of investigative techniques in the field of visuo-spatial short term memory. The fact that movement has been shown to be important suggests that techniques employed to investigate kinaesthetic memory will aid us in exploring visuo-spatial coding.

The second issue in this thesis explored further the nature of the internal code. Research into the nature of coding in visuo-spatial memory had previously argued for the presence of a sequential component. Experiments 1-4 in this thesis had shown that movement had an important role to play in coding. The fact that movement by its very nature would appear to be sequential suggested that there was a strong sequential element in coding within visuo-spatial memory. However, concern was expressed that the materials and presentation format used may have led to sequential coding. This was first explored in experiments 5-8. The results supported the view that the material and presentation format used had led to sequential coding. This was further explored by Experiments 9 and 10 which illustrated that while it may be important under certain conditions, sequentiality is not always a dominant element in coding within the Visuo-Spatial Sketch Pad.

This thesis has explored two of the central issues currently interesting theorists of Working Memory and has put forward suggestions for techniques which may in the future help us to advance our knowledge of the visuo-spatial component of the Working Memory framework.

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CHAPTER 1 : THE EVOLUTION OF HUMAN MEMORY

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1.1 INTRODUCTION

In the Preface, it was suggested that in order to fully comprehend the evolution of cognitive research into human memory it is necessary to take a historical perspective. Thus, to introduce the Visuo-Spatial Sketch Pad (VSSP) and present the imagery research in this thesis in a coherent manner, we must begin with an indication of the reasons behind the original conceptualisation of multi-store models of human memory proposed by Atkinson and Shiffrin (1968), among others (Cf. Waugh and Norman, 1965). It will be shown that although these dichotomous approaches were originally convincing, a number of problems arose, and that these problems were sufficiently damaging to require a radical reconceptualisation. The two main alternative approaches that resulted from this reconceptualisation will then be discussed; first, the Levels of Processing Approach of Craik and Lockhart (1972) and in the following chapter the Working Memory framework of Baddeley and Hitch (1974).

1.2 A UNITARY SYSTEM OR A DICHOTOMY?

It was the question of whether memory should be viewed in terms of a unitary system or as a dichotomous one which was the biggest influence on memory research from the early 60s until the 70s. The dichotomous theory was originally postulated by Galton (1883), further proposed by James (1890) and brought into current vogue by Broadbent's 1958 formulation. These dichotomous theories argued for a functional separation of Long Term and Short Term Memory (LTM and STM). A strong counter-argument was adopted by Melton (1963) who put forward a unitary concept of memory. In the beginning, the vast amount of research that followed appeared to support the dichotomous approach. There were three main areas of corroborative evidence : The two component tasks; neuropsychological research; and coding.

1.2.1 TWO COMPONENT TASKS

The results from a number of tasks suggest that the solving of those tasks involves two memory components, a labile Short-Term component and a relatively stable Long-Term component. In the case of free-recall tasks, for example, the first reason for assuming two separate mechanisms may be found in a very prominent and reliable characteristic of free recall - the serial position curve or function. In a typical experiment subjects are asked to learn a list of twelve or thirteen items. When asked to recall, it has been found that performance is superior for items that are presented at the beginning or at the end of the list, compared with those presented in the middle. The greater recall shown for items presented at the beginning of the list is known as the "primacy" effect and the greater recall shown for items presented at the end of the list is termed the "recency" effect (e.g., Glanzer and Cunitz, 1966).

The dichotomous theory of memory appeared to provide a clear structural interpretation of this finding. If items are to achieve a long-term memory representation then it was felt that information must be maintained in the Short-Term Store (STS) by rehearsal. The hypothesis is that the recall of the most recently presented items in a list are most likely to be from the STS, while recall of items earlier in the list are most likely from the LTS. According to such an interpretation the primacy effect in serial learning is due to items at the beginning of a list having already been transferred to the LTS through rehearsal. The recency effect reflects the fresh storage of items from the limited capacity store. This hypothesis suggested that one might be able to obtain useful data about the nature of the STS by careful study of the serial position curve. If the primacy and recency effects in a serial position curve can be independently manipulated this would provide strong support for the idea that each is based on a different memory structure.

As a starting point one can examine the effects of rehearsal on the two ends of the serial position curve, since the assertion provided above would predict different results in these two cases. For example, since the transfer of information from STS to LTS requires rehearsal time, by manipulating the rate of presentation of the stimuli one could affect the amount of information stored and recalled from LTS, thus affecting the primacy part of the curve but not the recency part.

An early study by Murdock (1962) reports just this effect. Murdock explored the serial position effect of free-recall where subjects received lists of unrelated words of either 10,15,20,30, or 40 words long at two presentation rates. Each list was presented just once, and was followed by a recall period in which the subjects were asked to recall as many of the words from the list as possible. As one might expect from the foregoing assertion, there were major effects of both list length and presentation rate on the early and middle items in the list. For example, a 10-word list presented at a slower rate of one item every two seconds showed just under 70% recall accuracy for the first item in the list. This can be compared with the 25% accuracy for the first word of a 40-word list presented at the faster rate of one item per sec. Neither the length of the list nor the presentation rate had an effect on the later items in the lists.

List length (Murdock, 1963; Phillips, Shiffrin and Atkinson 1967) and presentation rate (Glanzer and Cunitz, 1966; and Raymond, 1969) have both been shown to be variables which are capable of influencing rehearsal. If only a few items are presented, the subject may have time between each presentation to re-rehearse the entire list up to that point in a cumulative fashion while waiting for the next item to occur. For the longer lists, however, there would not be time for this even at the slower rate of presentation. In general then, the longer the list, the less rehearsal we would expect each item to receive. Similarly, the faster rate of presentation would also decrease the opportunity for rehearsal as the list was being presented. The curves show the effects of rehearsal on LTS (the early portions of the curve) without a similar effect on STS (the recency portion of the curves). When rehearsal is affected by these variables the normal u-shape curve alters such that the primacy section flattens out while the recency effect remains unaltered. These later items would show a uniformly high level of recall, regardless of rehearsal opportunity, because they are still "fresh" in the STS and, being at the end of the list, do not require the maintenance of rehearsal to prevent their displacement by later items.

Several studies have also shown that recency effects can be manipulated without producing substantial effects on the earlier portions of the curve. One can do this, for example, simply by delaying recall (Glanzer and Cunitz, 1966; Raymond, 1969) or by filling the interval between the end of a list and a recall signal with a verbal task which would displace the most recent items from the STS. When this is done, one finds a loss of the recall advantage for items at the end of a list.

Another task which would appear to provide support for a dichotomous system is the short-term paired-associate learning task. This procedure is characterised by the fact that each item is really a compound; that is, it has two parts. For example, given room/car, the subjects learn to report the second part of the item when given the first. Thus given "room", they respond "car". Peterson and his colleagues (Peterson, Brewer and Bertucco, 1963; Peterson, Hillner and Saltzman, 1962) carried out a number of such tasks which were designed to explore the interaction of short-term storage and a long-term learning mechanism. They found that the primacy part of the curve was affected by the duration of presentations (Peterson, 1963), the number of repetitions (Peterson and Peterson, 1962) and the duration of the spacing interval between repetitions (Peterson, Peterson, Hillner and Saltzman, 1962; Peterson, Wampler, Kirkpatrick and Saltzman, 1963; Greeno, 1964), while the recency part decreases as a function of time and/or the action of other information (Peterson, 1963). The early and late sections of the retention curve were clearly differentially affected. Thus it was suggested (e.g., Peterson, 1966) that two components were operating within this task, namely a labile STS and a

Long-Term learning mechanism.

Other tasks such as the serial probe task (e.g., Waugh and Norman, 1965), the serial memory span (Baddeley and Levy, 1971; Craik, 1970) and the Brown/Peterson (1958/1959) task together with those described above, provide support for a labile STS as reflected in the recency part of the retention curve and a stable LTS as seen in the primacy part.

1.2.2 NEUROPSYCHOLOGICAL EVIDENCE

The most oft cited neuropsychological evidence supporting the dichotomous or duplex hypothesis comes from brain damaged patients who have been left with unique memory deficits. Possibly the most famous case is a patient known as H.M. (Milner, 1966; 1969; 1970). At the age of 28 H.M. underwent brain surgery for his epilepsy. This involved bilateral lesions of the hippocampus and parahippocampal gyrus on the medial aspect of the temporal lobes. The operation left H.M. with a severe, lasting and very generalised memory disorder which was unaccompanied by any other intellectual change (Milner, Corkin, and Teuber, 1968). The acquisition of new long-term traces was almost impossible. He could be introduced to the same person several times during the same day and still fail to recognise him/her. Neither was it possible for him to remember a simple list of numbers, nor even his new home address several years after he had moved. H.M. showed no loss of previously acquired knowledge or skill; nor did he have any perceptual difficulty. The immediate registration of new information appeared to take place normally yet he was not capable of adding new information to the LTS. The effects, then, of temporal lobe lesions it is argued are hard to reconcile with any unitary process theory of memory and point towards a dichotomy.

Further neuropsychological evidence for more than one memory system came from Drachman and Arbit (1966) who also studied patients with bilateral lesions of the hippocampal complexes in order to provide support for memory as a multiple process. Such patients had been shown to develop an isolated memory defect, with preservation of other cognitive functions (Scoville and Milner, 1957). Like H.M. not all aspects of memory were found to be equally affected. Although finding it impossible to undergo long-term learning, the subjects could quite easily recall relatively small quantities of information perfectly for several seconds or minutes, provided they were not distracted. As Drachman and Arbit (1966) said, this dissociation of intact and impaired memory functions suggests that one memory mechanism, dependent on the intactness of the hippocampal regions, is damaged while another anatomically independent mechanism is spared. They set out to establish whether there were indeed two phases of memory, one of which is markedly impaired by such lesions and the other left intact, or whether there is merely a general impairment of all memory functions. Confirmation of the "dualistic" concept of memory would be found if it could be demonstrated that there are different levels of performance in two distinct categories of memory tests. Five patients with memory defects due to bilateral lesions of hippocampal regions were compared with a group of twenty normal control subjects. Two memory tasks were devised in which the length of a "memorandum" could be gradually increased from subspan to supraspan lengths. They found that patients' immediate memory spans

(IMS) were normal compared to the control subjects. However, the learning of supraspan memoranda, even after multiple repetitions, yielded different results, with patients exhibiting severe impairments. Drachman and Arbit (1966) present these results as strong support for the dualistic concept of memory.

Further neuropsychological support for the two store view comes from an extensive study carried out by Baddeley and Warrington (1970). They set out to compare the performance of amnesic and normal control subjects using a number of standard laboratory memory tasks which vary in the degree to which performance is said to depend on STS and LTS. The central aim was to test the hypothesis that amnesic subjects have a normal STS, but impaired LTS. This would provide information about the relative contribution of STS and LTS to the various tasks and should thus help interpretation of the performance of normal subjects. Six patients were employed in this experiment with two criteria being used to select them. First, a clinically diagnosed amnesia - the patient did not remember such simple pieces of information as the day of the week, where they were and how long they had been in hospital. Second, patients with any sign of intellectual impairment other than a memory defect were excluded. Of these six patients four suffered from a disorder known as Korsakoff's syndrome. This is thought to be due to many years of chronic alcoholism and the inadequate diet associated with it which in turn leads to vitamin B deficiency, the result being brain damage. Baddeley and Warrington (1970) found that when examining the recency effect in free recall, the rate of short-term forgetting, short-term paired-associate retention and digit span, there was no difference in performance between amnesic patients and comparable controls. Thus amnesic patients are no more distractable than normal subjects and are no more dependent on rehearsal. Their level of performance was impaired on the free-recall task employed but only in the early portion of the curve. There was no recency effect. The amnesic subjects were also impaired on a questionnaire they filled out concerning recall of recent events and on other experiments involving long-term learning and recall leading Baddeley and Warrington to conclude that they had an LTS defect. Baddeley and Warrington (1970) state, then, that their amnesic subjects do appear to have normal STS and impaired LTS, a result consistent with the studies of Drachman and Arbit (1966) and those involving H.M., all of which support a dichotomous view of memory.

1.2.3 CODING

Conrad (1962, 1964) investigated intrusion errors in the immediate recall of lists of six letters drawn from the following 10 letters : BCPTV,FMNSX. He found that confusions were high within the two groups and relatively low between them. This was true even though the letters were presented VISUALLY at the rate of .75sec/letter, under conditions where the probability of perceptual error was known to be negligible. Three conclusions were drawn from this study : (a) Short-Term storage is acoustic (or speech-motor). (b) Acoustically similar items are represented by similar traces. (c) Partial forgetting of an item is possible, producing intrusion errors that share the unforgotten property common to both the original item and the intrusion. Wickelgren (1965) set out to investigate these ideas. He extended Conrad's study, employing all 26 letters in the English alphabet and the digits 1-9. If the conclusions were valid, he argued, there should be a significant tendency for confusions among letters, and between letters and digits, based on ANY vowel or consonant acoustic similarity. In support of Conrad's conclusions Wickelgren found that intrusions among letters, and letters and numbers, tended to follow acoustic similarity. From this he concluded that STS appears to use an "auditory or speech-motor code" (p.102).

Baddeley (1966a) substantiated this claim in three experiments when he examined STM for word sequences as a function of acoustic, semantic and formal similarity. The first experiment compared acoustic and semantic similarity for auditorily presented word sequences. The second compared what he termed formal similarity (i.e., similar letter structure, e.g., rough/cough) with acoustically similar but formally dissimilar word sequences (e.g., brought, sort, taut). Finally, the third experiment used visual instead of auditory presentation to replicate experiment one. In all of these experiments a large and significant adverse effect of acoustic similarity was shown and neither semantic nor formal similarity had an effect of comparable magnitude. The relative unimportance of semantic similarity shown in Baddeley's experiment together with the failure of Baddeley and Dale (1966) to find an effect of semantic similarity among stimuli on STM for paired-associates suggests that subjects show remarkable consistency and uniformity in using an almost exclusively acoustic coding system for the short-term remembering of disconnected words.

The evidence presented thus far is exclusively related to coding in STS, indicating a speech based system, but what of coding in LTS? Baddeley (1966b) set out to test the hypothesis that LTS would be affected in a similar fashion to STS. That is, that acoustic similarity would cause impairment, but semantic similarity would have no effect. In his first experiment subjects attempted to learn one of four lists of 10 words. List A was comprised of ten acoustically similar words (e.g., man, can, cab, cad). List B was a control list comprising acoustically relatively dissimilar words which were matched with List A for frequency of occurrence in the language using the Thorndike and Lorge (1944) norms (e.g., pit, few, cow, pen). List C comprised ten semantically similar adjectives (e.g., great, large, huge, big) and List D, adjectives of equal frequency of occurrence but with dissimilar meanings served as a control list (e.g., good, huge, hot, safe). These lists were learned for four trials, after which subjects spent twenty minutes on a task involving immediate memory for digits. They were then asked to recall the word list. It was found that the acoustically similar list was learned relatively slowly, but, unlike the other three lists, showed no forgetting. Experiment II showed that this latter paradox, a result which is in conflict with previous studies (Underwood, 1949; Baddeley, 1966a), can be explained by assuming that the learning score depends on both LTS and STS, but the subsequent retest depends only on LTS. This suggested that the testing procedure adopted confounded the effects of LTS and STS during the learning phase, and that this, in turn, may influence the subsequent recall score. Baddeley (1966b) concluded that such conventional procedures cannot be expected to give a satisfactory answer to the question of the relative importance of semantic and acoustic factors in LTS. The final experiment thus repeated Experiment I but attempts were made to minimize the effects of STS during learning by interposing a task to prevent rehearsal between the presentation and testing of the word sequences. Unlike STS, LTS proved to be impaired by semantic similarity but not by acoustic similarity a result also found by Underwood (1951), among others (Underwood and Goad, 1951; Baddeley and Dale, 1966; Kintsch and Buschke, 1969).

It was suggested that this effect could be generalised beyond serial and paired-associate learning. This task was taken up by Sachs (1967, 1974). In the 1967 study, Sachs reported an experiment in which subjects listened to passages and then attempted to recognise changes in sentences they had heard. With this method, subjects are instructed to try to remember as much about the original form of the sentences as they can, while at the same time to perform the semantic processing necessary to succeed at recognising semantic changes in the sentences. By comparing recognition for semantically changed sentences and for various sorts of paraphrases of the original sentences, conclusions can be reached about the wording in memory and about the characteristics of the encoding of the linguistic material at different points in time. Sachs found that paraphrases of sentences were poorly identified as different from the original sentences after 80 syllables of interpolated linguistic material had been heard. Changes in the meaning of the sentence, on the other hand, were well recognised at that and longer intervals. These findings were taken as support of the idea that linguistic material becomes semantically encoded. In that study, however, the shortest time interval between the original presentation and recognition test was 27sec. Sachs (1974) therefore suggested that no conclusion could be reached about the characteristics of the encoding between these two points. In her subsequent study Sachs (1974) had intervals between the original presentation and test ranging from 1 to 23 sec. She found as before that paraphrases were poorly detected within 10 secs of interpolated discourse, which suggests that formal aspects of discourse do not normally enter LTS. Thus, there would appear to be more evidence for the dichotomous argument in Short-Term and Long-Term Memory.

1.3 THE MODAL MODEL

The evidence generated throughout the 1960s seemed then to indicate a clear dichotomy between Long-Term and Short-Term Memory. Many different models were developed (e.g, Waugh and Norman, 1965; Norman, 1970), all of which had common themes. The most detailed and explicit of these models was one which arose from Broadbent's 1958 formulation and was postulated by Atkinson and Shiffrin (1968) (see Figure 1.1). According to Atkinson and Shiffrin's model the basic structural features comprise three memory stores. These are the Sensory Register (SR), the STS and the LTS. All of these stores are felt to be structurally distinct because they preserve information in different formats, for different durations and also because they lose information in different ways.

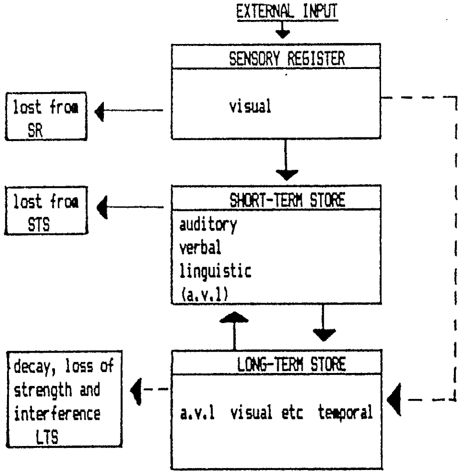

FIGURE 1.1. Flow diagram of the three memory stores in Atkinson and Shiffrin's (1968) model of episodic memory.

1.3.1 THE SENSORY REGISTER

According to this model when external information enters the memory system via the various senses it proceeds first to the SR. While they made provision for other systems, Atkinson and Shiffrin (1968) only postulated the visual system, gathering support from the work of Sperling (1960) among others (Averbach and Coriell, 1961; Estes and Taylor, 1964; 1966). They argued that the particular features of visual registration allows us to positively identify this system as a distinct component of memory. Information is neither recognised nor identified until after it has passed through the register. They felt that the entry of information into the register is passive and that such entry is obligatory as it cannot be avoided if the senses are functioning properly. Furthermore, there are no control processes involved in the register and although all sensory information is accepted in a complete and "more or less photographic trace" (p.95) it decays during a period of several hundred milliseconds. Information, it is surmised, may be lost in one of two ways. It may either decay spontaneously, simply dissipating with the onslaught of time; or new information from the senses writes over already registered information, erasing it. But what of transfer to higher order systems? In the case of the transfer of visual information Atkinson and Shiffrin (1968) postulated that it goes to an auditory-verbal-linguistic STS by means of a selective scanning process carried out at the discretion of the subject. While the elements in the register are scanned, a "matching program of some sort" (p.96) is carried out against information in the LTS and the verbal "name" of the element is sought from LTS and relayed to the

STS. However, the links between the SR and the LTS do not, Atkinson and Shiffrin (1968) stress, indicate that information is transferred directly to the LTS from the register. The function of the SR is to preserve incoming information for a sufficient period allowing the cognitive system, meanwhile, to run off subroutines that select from its sensory inputs those that will be further processed and entered into the STS. The idea that information travelled from the SR into the STS before gaining access to the LTS will later be revealed as a fatal flaw in the argument for flow diagram models of the fractionation of Short- and Long-Term memory systems.

1.3.2 THE SHORT-TERM STORE

The STS is presented by Atkinson and Shiffrin (1968) as a "working memory", by which they mean that conscious mental activities are performed there. Information enters the STS from both the SR and the LTS. Consciousness is viewed as a function that is unique to the STS and it is argued that information cannot undergo conscious processing in either the sensory register or the LTS. Unlike the sensory register, information in the STS can be maintained indefinitely provided it is given constant attention through rehearsal. The degree of transfer to LTS and the amount of learning correlates highly, Atkinson and Shiffrin (1968) say, with the length of maintenance rehearsal. In order to manipulate information the STS was believed to have a number of control processes or strategies available to it. Although a range of such strategies was postulated, empirical investigation was largely confined to the single process of subvocal rehearsal. However, as soon as attention is shifted from information in the STS it begins to decay and it will be gone completely in 15 to 30 secs. What function does the STS serve that contrasts it with the Sensory Register and the LTS? The function of the STS is best described by Lachman, Lachman and Butterfield (1979) "it is to briefly hold small amounts of carefully selected information from the SR and the LTS in order for people to execute the optional conscious processes necessary to tailor their behaviour to the changing demands of their environment" (p.222).

1.3.3 THE LONG-TERM STORE

This store differs from the preceding ones in that information stored here does not decay and become lost in the same way. Although information stored in the SR and STS is eventually lost, information in the LTS is felt to be permanent, even though it may be temporarily irretrievable. Atkinson and Shiffrin (1968) emphasised that although most of the studies in the field had been concerned with storage in the auditory-verbal-linguistic mode, it is intuitively obvious that there is long-term memory in each of the other sensory modalities, as one can recognise stimuli presented to those senses. They even allowed for the possibility that there may be information in the LTS which is not classifiable into any of the sensory modalities, an example being temporal memory. In order to do their mental work people must have recourse to a vast repository of information, and they must be able to call on mental rules. The function, then, of the LTS is to keep information and rules for its processing when they are not being used. This storage need not be conscious since we do not need to use all our knowledge nor all of our cognitive subroutines all of the time. However, these have to be maintained so that they can be called up to "working memory" when they are needed.

1.4 COMPLICATIONS WITH THE DICHOTOMOUS VIEW

In the early 1970s through extensive empirical research a number of problems arose with the modal model. Three phenomena are commonly viewed as combining to cause the gravest difficulties for an Atkinson and Shiffrin flow type formulation of human memory : Neuropsychological evidence, Long-Term recency effects and coding findings (Baddeley, 1983).

1.4.1 NEUROPSYCHOLOGICAL EVIDENCE

Within the dichotomous view of human memory as presented by Atkinson and Shiffrin (1968) the STS was viewed as essential to Long-Term learning. The evidence presented earlier in section 1.2.2 shows that the "classical amnesic syndrome" patient (Warrington and Wieskrantz, 1973) has a normal STS and an impaired LTS, evidence which is not inconsistent with the Atkinson and Shiffrin (1968) type formulation. However, there is also evidence from the neuropsychological literature which undermines such a view of memory. This comes in the guise of another form of amnesia which results in an impaired STS and normal LTS! The work carried out on this type of amnesia is exemplified by research conducted by Warrington and Shallice (Warrington and Shallice, 1969; 1970; Shallice and Warrington, 1972) with a single patient K.F., work that is supported by the results of studies carried out with other patients by Warrington, Logue and Pratt (1971) and Saffran and Marin (1972). K.F. incurred damage in the left parieto-occipital region from a motorcycle accident. This resulted in his being mildly aphasic with word selection problems when speaking, an effect which increased when he was reading. K.F. did not suffer from general amnesia and he was quite capable of discussing events of current interest. His disability is described by Shallice and Warrington (1970) as a defect of STS capacity. They found that with both a free recall experiment and the Brown/Peterson task the "STS involvement was close to zero"(p.268). The results indicated a dramatic reduction in the recency effect in free-recall and no decline in performance in the Brown/Peterson experiment. Warrington and Shallice (1969) have shown that K.F.'s performance on several LTM tasks, the Wechsler P.A task, a 10-word learning task (Stevenson, 1968) and the Warrington and Weiskrantz(1968) incomplete word learning task, is approximately normal. This would appear to indicate that his LTS is unaffected. Overall, the findings from these experiments indicate that K.F. has a defective STS while his performance on LTM tasks is normal. Warrington, Logue and Pratt (1971) in their study also conclude that K.F has a STS impairment. They also investigated this phenomenon in two further patients (J.B and W.H), finding comparable data which supported and confirmed their interpretation of an STS deficit. Further support from case studies comes from Saffran and Marin (1975) with their patient I.L. who suffered from mild conduction aphasia. They conducted four experiments to explore the immediate memory for word lists and sentences with this patient. They found that I.L's performance mirrored the performance one would expect with delayed rather than immediate recall. There was a primacy effect present but no evidence for a recency effect. They also found that the subject's shortened memory span was sensitive to familiarity and meaningfulness, factors normally attributed to LTS, suggesting that this subject's immediate memory is primarily LTS dependent.

In summary, then the neuropsychological evidence presented above shows there are subjects like K.F. who have defective STS systems while their performance on LTM tasks is normal. This provides very damaging evidence for flow diagram models (Waugh and Norman, 1965; Atkinson and Shiffrin, 1968; Murdock, 1967; Bower, 1967) in which information must enter STS before reaching the LTS. According to such models, if the STS system were defective one would expect impairment on LTM tasks, since the input to the LTS would be reduced. Clearly then flow-diagram models are fatally flawed. However, such neuropsychological evidence does not on its own necessarily sound the death knell for dichotomous approaches to memory. While the evidence presented here spells the end of the flow-diagram postulation it, along with the evidence presented in section 1.2.2, provides strong support for a double dissociation of function : that is, that there are at least two stores, the STS and LTS, which are able to operate independently. In fact Shallice and Warrington (1970) put forward a dichotomous model, in which the inputs to STS and LTS are in parallel rather than in series.

1.4.2 RECENCY EFFECTS IN LTM

As discussed earlier evidence presented by Glanzer and his colleagues (1969, 1972) suggested that the serial position curve for free recall was actually a composite of two curves, reflecting output from two memory systems. It was argued that the recency portion of the serial position curve reflects short-term processes, while the initial and middle positions of the curve were considered to reflect long-term processes. A number of reports appeared, however, which showed recency effects occurring under conditions that would seem to have precluded an explanation in terms of STS. Tzeng (1973) employed a procedure that was a mixture of Brown/Peterson and free-recall paradigms. Subjects were presented with four lists, each of which consisted of 10 unrelated words. Before and after the presentation of each to-be-recalled word, there was a 20-sec period of counting backward activity, a task generally assumed to displace any information in STS. At the end of each 10-word list, subjects were asked to free-recall the words in the list. After four lists, they were asked to free recall all the words from the four lists. It was found that not only did the initial recall show a pronounced positive recency effect, but so did the final recall! Similar phenomena were observed by Bjork and Whitten (1974), Dalezman (1972), (reported in Baddeley and Warrington, 1974), Aldridge and Farrell (1977), Poltrock and Mcleod (1977), Baddeley and Hitch (1977) and also the unpublished data from a study on anagram solving (Baddeley, 1963, reported in Baddeley and Hitch, 1974). A more ecologically valid example of this effect has been shown in the well-known Baddeley and Hitch (1977) "Rugby Club and Beer" experiment. They chose to ask members of a rugby club to name the teams they had played against that season. Since most games were not organised on a league basis and were not obviously associated with a specific geographical location, it was felt that complex modes of retrieval of information would be less common than, say, ordinal retrieval. Subjects were offered what they called an "Honorarium" of one pint of beer for participating and strangely enough virtually all members of the team volunteered. The results showed that there was a clear tendency for the most recent games to be the best recalled, once again illustrating the presence of long-term recency effects.

1.4.3 CODING

From the work of Conrad (1964) and Baddeley (1966) among others it was initially thought that the STS coded speech based information and the LTS maintained semantic information. However, experiments by Shulman (1970, 1971, 1972) suggested that semantic codes could also be held in the STS. In Shulman's studies, subjects were presented with a list of 10 words. Following this list, a "probe" word was presented, and the subject's task was to say whether it was identical with one of the list items, a synonym or a homonym. Shulman's studies are based on Glanzer's (1972) account of the serial position curve. That is, accuracy of recalling the last few items was supposedly an index of the contents of the STS, while recall of the earlier items supposedly came only from the LTS. Shulman assumed that correct identification of a homonym requires the use of acoustic information - presumably from the STS. Similarly, he assumed that correct identification of a synonym requires the use of semantic information which, according to multistore theory, should only be available from the LTS. If all this were true, homonym probes should have been judged more accurately for the later than the earlier ones. Synonym probes should have been judged more accurately for earlier than later ones. These predictions from the three-store model were not supported by Shulman's data. The serial position effects were quite similar for homonyms and synonyms, and a pronounced recency effect for synonyms suggested that people retrieve semantic information from the STS as well as from the LTS.

Shulman's studies are therefore cited as evidence against a distinction between the short- and long-term stores (Craik and Lockhart, 1972; Postman, 1975). But the three store formulation's problems relating to coding however, did not end there. Although the STS was supposed to hold acoustic codes alone, Kroll, Parkinson and their associates found evidence that it holds visual codes (Kroll, 1972; Kroll and Kellicut, 1972; Kroll, Parks, Parkinson, Beiber and Johnson, 1970; Parkinson, 1972; Parkinson, Parks and Kroll, 1971; Salzberg, Parks, Kroll and Parkinson, 1971). Their subjects were asked to remember a letter while repeating other letters that were spoken to them - that is, while shadowing the other letters. According to the three-store model, the to-be-remembered letter should be transferred to the STS for rehearsal, and this transfer would require conversion to an acoustic code regardless of how the letter is presented. If that were true, shadowing ought to have had the same effect on memory for letters presented visually as for those presented verbally. The experiments by Kroll and Parkinson and their colleagues showed that shadowing interfered less when the to-be-remembered letter was presented visually. This suggests that visually presented letters need not be recoded into pure acoustic information.

The original claim of the STS theory was satisfyingly strong. The STS required an exclusively acoustic code. By 1972, the data required that the claim be hedged. In addition to acoustic codes, the STS had to accept semantic and visual codes, and there was evidence for articulatory coding as well (Levy, 1971; Peterson and Johnson, 1971). As a distinguishing characteristic of the STS was said to be its dependence on the acceptance of acoustic codes alone, the suggestion that it accepted semantic, visual, and articulatory codes as well cast doubt on the idea that it was a separate entity at all.

To summarise then, initially a great deal of evidence from the work on coding, on neuropsychological research and from two component task studies appeared to strongly support the dichotomous approach. After a time, however, certain anomalies in these areas led to serious criticism of this approach. While the Atkinson and Shiffrin (1968) type model could withstand each of the criticisms directed against it individually, the combination of so many major problems associated with it each requiring a radical reworking of the approach if it was to survive, eventually necessitated a change in direction theoretically. Thus the criticisms illustrated here led to the discussion of new models and frameworks. One of these, the Levels of Processing approach of Craik and Lockhart (1972) is presented in the next section.

1.5 LEVELS OF PROCESSING

It has been postulated by Triesman (1964) and Sutherland (1968) among others (e.g., Selfridge and Neisser, 1960) that perception involves the rapid analysis of stimuli at several different levels. Craik and Lockhart (1972) have proposed a more flexible approach to memory adopting just such a levels analysis and rejecting the multistore concept. This framework is termed the Levels of Processing paradigm. While they believe that the multistore approach is unsatisfactory in many respects they accept that studies investigating such models have indicated certain basic findings which any model or framework of memory must encompass. For example, it would appear that stimuli are encoded in different ways within the memory system, with a word being coded at different times in terms of its visual, phonemic or semantic features. It is also clear that differently coded representations exist for different lengths of time. They also believe in the importance of a limited capacity mechanism operating within the system and finally that we should not forget the parts played by perceptual, attentional and rehearsal processes. While they concede that the inconsistencies described earlier could be accommodated by a multistore theory, through allocating additional stores to the model (Morton, 1970; Sperling, 1970) they argue that it is more useful to concentrate on the encoding operations themselves and to consider the notion that rates of forgetting are a function of the type and depth of encoding.

Within this framework the initial stages deal with physical or sensory analysis, while later stages deal with pattern recognition and the extraction of meaning. The basic tenet of this framework is that of a series of stages (or levels) of processing. This is referred to as "depth of processing, where the deeper the information is processed the greater the amount of semantic analysis. Once the information has been coded it may be subject to further analysis through what Craik and Lockhart (1972) term enrichment or elaboration. The example they provide is of a word, that when recognised, activates various associations and images from the subject's past learning. Such elaboration, it is stressed, is not restricted to verbal material. Craik and Lockhart (1972) argue that similar stages of processing exist in the perceptual analysis of taste,touch,smell and so on. The analysis passes through a series of sensory levels to stages dealing with perception of pattern recognition and finally to semantic levels.

It is argued that one of the results of such a perceptual analysis is the memory trace. Its coding and its life expectancy are essentially byproducts of perceptual processing (Morton, 1970). The persistence of the memory trace is thought to be directly related to the depth to which it is analysed. More specifically, the deeper the trace is analysed, the more enriched or elaborate and persistent it turns out to be. However, one may wish to ask why this is seen as different from a multistore approach, for, as Craik and Lockhart (1972) themselves point out, we could simply draw a box around primary analysis and call it sensory memory and a box around intermediate analysis and call it short-term memory. This, however, they say, is over simplistic.

Craik and Lockhart (1972) refer to perception as a continuum of analysis which extends from a physical level through pattern recognition and stimulus elaboration to semantic levels. Since memory is viewed as a byproduct of the perceptual analysis it is also viewed as a continuum which extends from "the transient products of sensory analysis to the highly durable products of semantic-associate operations" (Craik and Lockhart, 1972, p.676). The memory trace is believed to be a function of depth, the amount of attention allocated to the stimulus, its compatibility with the existing cognitive structures and the time available for processing at each level. Each of these factors plays a part in determining the depth to which information is processed. Thus stimuli that are highly familiar and meaningful are, by definition, compatible with the present cognitive structures. As a result such stimuli will be processed to a deep level more rapidly than less meaningful stimuli and will be well retained. There is, however, another way in which stimuli can be retained, which is by recirculation of information at a certain level of processing. Craik and Lockhart (1972) view phrases such as "retention of the items in primary memory", "keeping the items in consciousness", "continued attention to certain aspects of the stimulus" and "holding the items in the rehearsal buffer" as all referring to the same concept : that of maintaining information at one level on the processing continuum. They refer to this as primary memory. The idea of a limited-capacity central processor, discussed by Moray (1967), is incorporated into the levels framework. When the processor is deployed to maintain information at one level, the phenomenon of short-term memory will appear. This processor is felt to be neutral in terms of coding characteristics and the primary memory code is dependent on the modality within which the processor is operating at the time. It is also noted that while limited capacity is said to be a function of the processor itself, its capacity is dependent on the particular level at which the processor is operating. Put simply, at deeper levels it is possible for the subject to employ the learned rules and past knowledge and, as such, the material is more efficiently dealt with and more can be retained. That is, the rate of forgetting will be slower for information that was coded at a deeper level. Thus, although primary memory retention is continuous processing, such processing merely prolongs an item's current level of analysis without leading to a move to a deeper level of processing. The repetition of a phone number to oneself while waiting to dial is an example of this type of processing. While the number is read, perceptual analysis extracts an acoustic code and repeating the number to oneself amounts to recirculating its acoustic code, thereby lengthening its normal life. If a person were to form a mnemonic while recirculating the number, so that they could remember it far into the future, the levels approach would state that they had processed the number at a semantic level. The recirculation itself would have been said to contribute nothing to the increased memorability of the number. This recirculation was termed Type I processing and is contrasted with Type II which involves the deeper analysis of the stimulus. It is only this second type of processing which leads to improved memory performance.

To summarise then, there was a move away from conceptualising memory in terms of a series of rigid separate boxes dealing mainly with the storage of information. The need to see memory not as existing in a vacuum, but as a concept which is functionally integrated with other information processing tasks, such as pattern recognition and perception was recognised.

One basic paradigm was employed to explore the Levels of Processing framework, with slight variations adopted for certain experiments. This involves asking subjects a series of questions. Three types of question may be asked in this initial encoding phase : (a) e.g., "Is the word printed in capital letters?"; (b) e.g., "Does the word rhyme with TRAIN?"; (c) e.g., "Would the word fit the following sentence frame : "The girl placed the .... on the table?". The purpose of such questions are to induce the subjects to process the words presented subsequently to one of several levels of analysis : Thus the questions were chosen to necessitate processing to a relatively shallow level (e.g., questions about the word's physical appearance); to a phonemic level (e.g., questions about rhyming); or to a relatively deep level (e.g, questions about the words meaning). The comparison of retention of the presented words across different orienting tasks, it is argued, "provides a relatively pure measure of the memorial consequences of different processing activities" (Craik and Lockhart, 1972, p.677).

Experiments involving the incidental learning of sentences (Bobrow and Bower, 1969; Rosenberg and Schiller, 1971) have shown that recall after an orienting task that required processing the sentence to a semantic level was substantially superior to recall of words from equivalently exposed sentences which were processed nonsemantically. Schulman (1971) had subjects scan a list of words for targets defined either structurally (such as words containing the letter A) or semantically (such as words denoting living things). After the scanning task, subjects were given an unexpected test of recognition memory. Performance for the semantically defined target words was significantly better than that for the structurally defined words.

Such findings support the notion that memory performance is a positive function of the level of processing required by the orienting task. From such findings it is also stated that the better memory performance is, the deeper the stmulus must have been processed. However these suggestions present the Levels of Processing approach with its first major problem, namely circularity. If one is employing the performance at recall to indicate the depth to which the information is processed, and then using the supposed depth of processing to explain the recall performance, one is most definitely indulging in an exercise in circularity. What is required if the framework is to have any opportunity to extend its influence within human memory research is an adequate index of depth.

In the initial postulation of this theory Craik and Lockhart (1972) suggested that, when other things were held constant, deeper levels of processing would require longer processing times. Thus, processing time was put forward as a possible index of depth. Craik and Tulving (1975) set out to explore this idea in greater detail. They employed the orienting task paradigm described above with subjects making their decisions by pressing one key for YES and another for NO. In several of the experiments the subjects were given an incidental memory test, while in others they were aware that a memory test would be given.

Experiments 1 and 2 showed that with an incidental and recognition paradigm (a) different encoding questions were associated with different response latencies (b) positive and negative responses were equally fast, (c) recognition increased to the extent that the encoding questions deals with more abstract, semantic features of the word, and (d) words given a positive response were associated with higher recognition performance, but only after rhyme and category questions. This pattern of data supported the notion that memory performance may simply be a function of processing TIME. Experiments 3 and 4 extended the generality of these findings by showing that the same pattern of results holds in recall and under intentional learning conditions. Craik and Tulving (1975) found that intentional recall was superior to incidental recall, but that decision times did not differ between intentional and incidental conditions. This was contrary to the TIME hypothesis since if recall is a function of depth of processing and depth is indexed by decision time, then clearly differences in recall should be associated with differences in initial response latency. Another finding which was inconsistent with the hypothesis was that words given a YES response in the initial task were better recalled and recognised than words given a NO response, although reaction times to YES and NO responses were identical. This suggests that reaction time is not an adequate index of depth.

Craik and Tulving (1975) carried out another experiment, to directly test the TIME hypothesis. Subjects were given either a complex structural task or they had to compare a vowel consonant pattern, CVVC, with a word, e.g., cool, to see if they matched. The semantic task was the sentence task employed previously. They found that the non-semantic task took longer to accomplish but that the deeper sentence task gave rise to higher levels of recognition. This showed that it is the depth of processing and not the amount of processing time which determines memory performance.

One constant feature of Experiments 1-4 was the superior recall or recognition of words given a YES response in the initial perceptual phase. This result was also reported by Schulman (1974). If high levels of retention are associated with "rich" or "elaborate" encodings of the word (rather than deep encodings), the differences in retention between positive and negative words become understandable. In many cases where a positive response is made, the encoding question and the target word can form a coherent, integrated unit, e.g., "A four footed animal?" (bear). However, integration of the question and target word would be much less likely in the negative case : "A four footed animal?" (cloud). Greater degrees of integration, what

Baddeley (1978) terms Compatibility, (or, alternatively, greater degrees of elaboration of the target word) may lead to better retention in the subsequent test. This factor of integration or congruity (Schulman, 1974) between target word and question would also apply to rhyme questions but not to questions about typescript : If the target word is in capital letters (a YES decision), the words' encoding would be elaborated no more than if the word had been presented in lowercase type (a NO decision). This analysis is based on the premise that effective elaboration of an encoding requires further descriptive attributes which are salient, or applicable to the event, or specify the event more uniquely. While positive semantic and rhyme decisions fit this description, negative semantic and rhyme decisions and both types of case decision do not. In line with this analysis was the finding from Experiments 1-4 that while positive decisions are associated with higher retention levels for semantic and rhyme questions, words eliciting positive and negative decisions are equally well retained after typescript judgements. If the preceding argument is valid, then questions leading to equivalent elaboration for positive and negative decisions should be followed by equivalent levels of retention, e.g., "Is the object bigger than a chair?" (house-positive, mouse-negative). In the experiment designed to explore this, eight descriptive dimensions were used (e.g., length, weight). Craik and Tulving (1975) found that when positive and negative decisions are equally well encoded, the respective sets of target words are equally well recalled. The results of this study suggest that it is not the type of response given to the presented word that is responsible for differences in subsequent recall and recognition, but rather the richness or elaborateness of the encoding.

This finding was supported by another experiment which demonstrated that more complex and elaborate sentence frames lead to higher recall, but only in the case of positive target words.

This series of results, then, confirm and extend the findings of other investigators, notably the series of studies by Hyde, Jenkins and their colleagues (Hyde, 1973; Hyde and Jenkins, 1969; 1973; Till and Jenkins, 1973; Walsh and Jenkins, 1973) and by Schulman (1971, 1974). It is clear that the level of recall or recognition of a word event is not dependent upon the intention to learn, the amount of time spent making judgements about the items, or even the amount of rehearsal the items receive (Craik and Watkins, 1973). The crucial variables are qualitative nature of the task and the kind of operations carried out on the items; that is, the DEGREE OF STIMULUS ELABORATION and semantic coding.

The Levels of Processing framework then provided an innovative way of conceptualising memory. It shifted the emphasis away from viewing memory in terms of rigid stores, to stressing its importance in relation to other information processing tasks. But while doing this the Levels of Processing approach itself came under heavy attack.

1.6 CRITICISMS OF THE LEVELS OF PROCESSING FRAMEWORK

Although the Levels of Processing framework provided a welcome addition to experimental research in human memory it did start to receive some very damaging critiques, both in terms of its underlying assumptions, and its value as a theoretical framework (Nelson, 1977; Eysenck, 1978; Baddeley, 1978). Within this section several of the most poigniant criticisms will be illustrated.

The most serious of the criticisms levelled at the Craik and Lockhart (1972) formulation is undoubtedly that it lacks an independent index of depth. As seen in the previous section Craik and Tulving (1975) explored the possibility that TIME may be this index. This was not found to be the case and further, the Levels of Processing framework was seen to require the inclusion of concepts of compatibility and elaboration for which there are also no means of independent assessment. These are major flaws of the Levels of Processing approach as a theoretical framework. As Popper(1959) states "All statements of empirical science...must be such that TO VERIFY THEM AND TO FALSIFY THEM must both be logically possible". Falsification is impossible if one of the empirical orderings is defined in terms of the other (i.e.,circular ordering). As has been noted above the only ordering for depth of processing so far has been circular, with various kinds of processing being ordered in TERMS OF THEIR EFFECT ON MEMORY. As a result of this ordering it is not possible to falsify, and thus impossible to test, the principle that deeper processing facilitates memory. In brief, "until such falsification becomes possible, statements about such-and-such a result being in accord with the deeper-processing principle are scientifically meaningless" (Nelson, 1977, p.165). While this is a crushing blow to the levels theorists their problems don't end there, as Baddeley (1978) points out. Research has revealed doubts about several prominent principles in this theory. Two of these will be examined here:

1.Memory is unaffected by repetition at a constant depth of processing.

2.Memory increases as the depth of processing increases.

One of the central foundations of the Levels of Processing framework concerns the relationship between rehearsal and learning. In the original levels approach maintenance rehearsal did not increase memory performance. However, if the material presented is processed to a deeper level then learning does occur. This is made clear by Craik and Lockhart (1972): "Type I processing, that is, repetition of analyses which have already been carried out, may be contrasted with Type II processing which involves deeper analysis of the stimulus. Only this second type of rehearsal should lead to improved memory performance" (p.676). The evidence for this is quite extensive (Craik and Watkins, 1973; Jacoby, 1973; Jacoby and Bartz, 1972; Woodward,Bjork and Jongward, 1973; Modigliani and Seamon, 1974), evidence which supports various versions of the principle that sheer repetition, especially at the phonemic depth of processing, has no effect on memory.

A number of studies have shown, however, that repetition can enhance learning. Mechanic (1964) in a study comparing intentional and incidental learning, where subjects were presented with nonsense syllables and instructed to read each syllable as many times as possible within a set time interval, found subsequent recall to be a function of the number of repetitions performed.

The enhancement of learning through repetition has been further explored by Nelson (1977). In his first experiment an incidental learning task required the subject to make a YES-NO classification for a series of words (e.g., "Does the word contain an n sound?"). The major finding from this experiment is that incidental recall increases with the number of repetitions at the phonemic depth of processing. This result is inconsistent with the principle that repetition at a constant depth of processing has no effect on memory performance. Moreover, although Tulving (1966) found no effect of phonemic repetition, two other studies found a trend in the direction of facilitation (Postman and Adams, 1958; Salzman and Atkinson, 1954) and several other experiments have found reliable facilitative effects of phonemic repetition on incidental recall (Brown, 1954; Craik and Tulving, 1975 ; Mechanic, 1962; Mechanic and D'Andrea, 1966; Mechanic and Mechanic, 1967).

It is possible to explain the results of Mechanic (1964) and Nelson (1977) from within a Levels Framework. Craik and Tulving (1975) have stated that any word that is presented is likely to access its semantic representation in LTM, even though the subject is only required to make phonemic judgements. It is not beyond the bounds of possibility that repetitions may gain entry to a different component of the complex network of semantic associations that probably represent the full meaning of any given word to a particular subject. This may then generate a more elaborate code for that item, which in turn would make it easier to recall. One may then wish to postulate that Mechanic's (1964) subjects were involuntarily generating more meaningful associations to the nonsense syllables they were vocalising; the greater the number of repetitions, the greater the probability of a meaningful association occurring. As Baddeley (1978) points out, the lack of an independent method of measuring involuntary semantic elaboration makes circularity a major weakness of this argument. Although the literature review by Craik and Lockhart (1972) is quite impressive, they do appear to have overlooked all of the pre-1972 studies of phonemic repetition in incidental recall (except for Tulving, 1966). As Nelson (1977) suggests, this is rather unfortunate because knowledge of those results (of facilitation via phonemic repetition) would have meant that Craik and Lockhart would not have included the principle that same-depth repetitions has no effect on memory performance.

The other major assumption that has come under attack is the fact that in the original formulation deep coding was thought to be necessary for durable traces. There were a number of studies which appeared suggesting that superficial aspects of the to-be-recalled information may also be retained. Kirsner (1973) gave subjects a continuous recognition memory test in which each word was presented twice, either in the same print or in different print on two different occasions. Her results showed that recognition performance was facilitated to a small but statistically significant extent in the same-print condition. This result was extended to nonsense strings of 5 to 7 letters instead of words. This manipulation increased the same-print advantage. Craik and Kirsner (1974) in an experiment examining the effect of speaker's voice on word recognition found that words are recognised faster and more accurately when they are re-presented in the same voice. These two experiments indicate that in some circumstances the physical features of verbal stimuli do persist in memory for several minutes. This has been substantiated by studies on interference in long term learning (Nelson and Borden, 1973; Nelson and Brooks, 1973) and on studies on the reading of orthographically transcribed text (Kolers, 1975, 1976).

It is clear that simple generalisations about the relation between encoding and subsequent retention are unlikely to prove adequate.

How, then, do Craik and Lockhart (1972) deal with the criticisms directed against their formulation? Their main defence consists of stating that depth of processing should be regarded not as a theory, but instead as a theoretical framework or paradigm (Craik and Tulving, 1975, p.269). This would apparently allow major alterations to take place without causing problems for the overall formulation. However, a paradigm typically is viewed as PRESUPPOSING a theory. Kuhn writes, "I take a paradigm to be...in the first place, a fundamental scientific achievement...which includes... a theory.... " (1963, p.358). Although the depth of processing view has displayed some of the characteristics of a paradigm, such as contributing to a change in language (from structure language to process language) and a change in research topics (from investigations of serial position curves to investigations of incidental memory), the crucial issue concerns the degree to which the depth of processing view contributes to scientific theory. From the points raised above this must be seen as being limited.

As was said earlier the Levels of Processing approach as suggested by Craik and Lockhart (1972) and extended by Craik and Tulving (1975) has avoided many of the problems associated with the too rigid Atkinson and Shiffrin (1968) flow-type models. However, while this approach did offer a useful statement for looking at levels in the coding of memory the criticisms led several researchers to call for a return to the detailed analysis of specific subcomponents of human memory, one such approach being the Working Memory model of Baddeley and Hitch (1974), the framework adopted in this thesis. It should be noted, however, that this formulation is not in direct competition with the Levels approach since it is largely concerned with rather different problems, as will be seen in the following chapter.

CHAPTER 2 : WORKING MEMORY

CHAPTER 2 : WORKING MEMORY

2.1 INTRODUCTION

This chapter will begin with a description of the formulation of the working memory framework of Baddeley and Hitch (1974), followed by an overview of how it has developed to date. This development will centre on the verbal component of this system. The progress made in the non-verbal system will be discussed in Chapter 4. This overview will illustrate that this framework has been continually evolving and that the future will undoubtedly bring more changes to its present state.

The previous chapter presented over a decade's work on the topic of STM. It was in 1974, during this lengthy period of research, that Baddeley and Hitch set out to explore what one might have thought by that time would be a simple question : what is STM for? The suggestion had been made that the STS, a hypothesised memory system which Atkinson and Shiffrin (1968) said was responsible for performance in tasks involving STM paradigms, had an integral part to play in a number of information processing tasks. The STS was assigned the major role of a central controlling mechanism. It was hypothesised that this store was concerned with the organisation of many of the processes that were involved in the learning of new material and the storage of previously learned material. Intuitively, this appeared to many theorists as a valid hypothesis. However, when Baddeley and Hitch (1974) examined the evidence from such studies as Coltheart's (1972) work on concept formation, Patterson's (1972) work on retrieval and the neuropsychological literature presented in the previous chapter, they found that the evidence did not confirm this hypothesis. That is, the evidence did not warrant the claims of a common working memory system.

Baddeley and Hitch (1974) set out to generate empirical evidence which would provide theorists with a stronger basis for positing such a common working memory system. They had two aims in the study : first, to test whether a series of information processing tasks share a common working memory system; and second, how, if such a system exists, it relates to our present conceptions of STM.

2.2 BADDELEY AND HITCH (1974)

In this study Baddeley and Hitch adopted similar techniques across a series of tasks to see if a pattern would emerge. This idea revolved around the commonly held belief in human memory research that STS had a limited capacity or memory span. This stems from a number of studies which set out to determine exactly how much is retained in an immediate memory task (Norman, 1976) and which found that subjects can usually recall only a limited number of items that have been presented to them, 7+-2 as stated by Miller (1956). Baddeley and Hitch (1974) said that if such a limited capacity system existed then subjects required to perform a memory task while carrying out an information processing task should show a dramatic deficit in memory performance. For a given task this capacity may be considered to be fixed. If a primary task requires less than the total processing capacity, then a residual amount of capacity is reflected in the performance of a concurrent secondary task. If the primary task is performed at a nearly optimal level, then secondary task performance may be used to infer the amount of processing expended while performing the primary task.

The following series of experiments explores this idea of a limited capacity system by asking subjects to perform a number of information processing tasks while concurrently doing a memory task involving recall of a number of digits.

2.2.1 WORKING MEMORY AND VERBAL REASONING

The first task explored was the reasoning task originally devised by Baddeley (1968) and employed extensively by Wason and Johnson-Laird (1972). This task involves presenting subjects with a sentence followed by the two letters referred to in the sentence. The subject's task is to answer "true" or "false" as to whether the sentence describes the order in which letters are presented. An example would be : "the letter A is preceded by B - AB", in which case the subject would respond "false". A large number of different sentences can be produced varying as to whether they are active or passive, positive or negative and whether the word "precedes" or "follows" is used. In the first two experiments subjects had to carry out this reasoning task while concurrently holding a digit load. In experiment I they had to hold 0, 1, or 2 digits and in experiment II a load of 6 digits was used. Together the first two experiments indicated that the reasoning task does not seem to require all available short-term storage space as subjects can recall a two letter preload without delaying reasoning time. A possible problem with these two experiments was that subjects may be time sharing. That is, switching their attention from the memory task to the reasoning task.

While such time sharing may be the result of competition between the tasks for a limited storage capacity, this may not be the case. Experiment III attempted to rule out the time sharing phenomenon by employing a concurrent rather than a preload procedure. In this experiment subjects had to carry out a reasoning task while concurrently performing an articulatory suppression task, repeating "the", counting "1....6", or repeating 6 randomly presented digits. The random digits sequence caused greater slowing in reasoning times than any other condition. This experiment indicates that the more difficult a task the greater the effect of an additional short-term storage load. Together these experiments suggest that the trade-off between reasoning speed and additional storage load is due to the fact that the interference occurs within a limited capacity "workspace", which can be given over to storage or to processing. While experiment III did not show a significant effect of articulatory suppression work by Hammerton (1961) had shown articulatory suppression to produce interference in a similar task. This led Baddeley and Hitch to suggest that reasoning may resemble the memory span task in having an articulatory component. Experiment IV explored the relation between the memory span and working memory further by taking a major feature of the verbal memory span, namely its susceptibility to the effects of phonemic similarity, and testing for similar effects in the verbal reasoning task. Memory span's susceptibility to phonemic similarity was revealed by the deficits in recall with the sequences of phonemically similar items (Baddeley, 1966b) and the nature of intrusion errors (Conrad, 1962). Experiment IV revealed a main effect of phonemic similarity. The verbal reasoning task does appear to require the use of phonemically coded information.

Essentially these experiments show that an information processing task such as the reasoning task employed here is effected by; a concurrent storage load, but only one of 6 items; of articulatory suppression and of phonemic similarity. Taken together these results support the view that such information processing tasks rely on the use of a short-term store which has the features exhibited in the memory span paradigm. What is also clear from the size of these effects is that the system that deals with memory span is but one part of working memory.

2.2.2 COMPREHENSION AND WORKING MEMORY

It has often been suggested that in the comprehension of spoken language the STS had an important role (Norman, 1972). However, as Baddeley and Hitch (1974) say the evidence for such a suggestion is sparse. Experiments V and VI both set out to explore the importance of STS in comprehension using the memory preload and the concurrent memory load techniques. In the first two experiments of this series the comprehension task involved subjects listening tp prose passages under different memory-for-numbers conditions. Subjects were subsequently tested for retention of the passages and for the numbers. The first experiment had two conditions. The experimental condition involved subjects listening to sentences of a passage each of which was preceded by a sequence of 6 digits. After each sentence subjects had to recall the numbers by writing them down in the correct order. In the control condition the number sequence followed the sentence and was recalled immediately afterward. Once the passage was completed three minutes were allotted for recall. Recall was based on the Cloze technique. This technique involved subjects attempting to fill in every fifth word which is blanked out in a type script of the passage. Results show that performance on the comprehension test is impaired when digits have to be maintained during presentation of the passage. These results suggest that comprehension is impaired by an additional short-term storage load. However, such a conclusion is not without its problems. The Cloze technique it can be argued may not be a test of comprehension but of verbatim recall. It was also suggested that the control condition of the experiment may have been subject to interference. It may be that the time between sentences is important for comprehension of meaning. Since subjects had to write digits down between sentences this may have led to interference.

Experiment VI overcomes these objections by using a concurrent memory load procedure instead of a preload technique and employing the Neale Analysis of Reading Ability instead of the Cloze technique. This test examines comprehension without using the specific words employed in the initial presentation. It is not therefore a test of verbatim recall but rather of retention of the gist of the passage. There were three conditions in this experiment. The two experimental conditions required subjects to recall three and six digits respectively while concurrently listening to the prose passage. In the control condition subjects were presented with sequences of three and six digits in alternation. They were simply required to copy down the digits as they were presented while listening to the prose passage. The results revealed a similar picture to that shown with the verbal reasoning task. It was clearly shown that comprehension is not reliably affected by a three item memory load, but is depressed by a six item load. The evidence supported the view that working memory has a role in comprehension . However, Baddeley and Hitch (1974) felt that those experiments presented above may have been testing retention rather than comprehension. While accepting that these two processes are closely related they tried to separate them in order to provide firmer conclusions. The logic for Experiment VII stated that if comprehension employs working memory then it should be possible to disrupt performance on comprehension tasks by introducing phonemic similarity into the test material. In this experiment subjects were required to judge whether a single sentence was possible or impossible. Possible sentences were both grammatical and meaningful, while impossible sentences were both ungrammatical and relatively meaningless. The results of this experiment indicated that phonemic similarity increased the judgement times for both possible and impossible sentences. To summarise this section, a concurrent digit load of six items impairs comprehension of verbal material but not one of three or less. It has also been shown that verbal comprehension can be disrupted by phonemic similarity. The tasks studied here appear to employ a short-term working memory system. This system, as was the case in the previous section, appears to be disrupted by a near span memory load and by phonemic similarity.

Baddeley and Hitch suggested that the reasoning task employed may simply be a measure of sentence comprehension. It may be that working memory has only been studied in one class of activity. As a result of this, Baddeley and Hitch moved away from studying sentence material to study the retention and free recall of lists of unrelated words.

2.2.3 FREE RECALL AND WORKING MEMORY

The move to study free recall also allowed Baddeley and Hitch to observe the relationship between working memory and the recency effect. The recency effect as studied in the previous chapter was often taken as indicating the presence of an STS. The first experiment in this series had two aims. One was to explore the effect of a memory preload of 0, 3 or 6 items on free recall, and the other to study the effect of a preload on the LTS component of the free recall task. Since, up to this point, the view of the STS was that the digit span and the recency effect were a reflection of STS, one would expect a dramatic reduction of recency when a preload is imposed. Subjects were given the preload and were required to recall the word list immediately or after a delay of 30 secs during which subjects copied down letters spoken at a one-second rate. In both cases, subjects were given 60 seconds to write down the words they could recall, after which they were instructed to write down the preload digits at the left- or right-hand side of their response sheets. The results showed that the overall percentage of words recalled declined with increased preload. This load effect, however, was restricted to the long-term component of recall and did not substantially influence the recency effect. There were two possible interpretations of these results. The first was that a preload does not interfere with the mechanism that involves the recency effect. This would require a radical reconceptualisation of the STS, since the "normal" account of recency assumes that the last few items are retreived from the same store that would be used to hold the preload items. The second interpretation put forward assumed that subjects rehearse the preload items at the beginning of the list, and by the end of the list have succeeded in transferring them into LTS, freeing STS for other tasks. The next experiment attempted to control subjects' rehearsal strategies by employing a concurrent memory load. Procedures were identical with the last experiment except that a concurrent rather than a preload technique was used. The results showed that an additional concurrent memory load, even of 6 items, does not significantly alter the standard recency effect. This suggests that the previous interpretation, that recency is independent of memory span, is the more valid.

In the previous experiments in this study, those involving verbal reasoning and comprehension, evidence of phonemic coding was found. This was revealed by effects of acoustic similarity and articulatory suppression in the reasoning task, and by acoustic similarity effects in comprehension. While Baddeley and Hitch state that there is evidence that subjects may use phonemic similarity in long-term learning, this in itself is not strong evidence they say, for a phonemically based working memory. The final experiment in this series attempted to examine the role of articulatory coding in long-term learning using the articulatory suppression technique. Subjects were presented with lists of ten words, either auditorily or visually. A total of 40 lists were used. During half of the lists presented subjects were instructed to remain silent and during the other half they were told to whisper "hiya" at a rate of two utterances per second throughout the presentation of the word list. After each list of words had been presented subjects were required to recall them immediately, unless they were presented with a three digit number. In this case they had to count backwards from that number by three's. Half the lists in each block of ten were tested immediately and half after the 20-second delay, in each case subjects were allowed 40 seconds for recall. The results of this experiment indicated that articulatory suppression does impair retention of word lists. This effect was especially marked with visual presentation. Articulatory suppression impaired early serial positions, consistently regarded as dependent on LTS, to the same degree as the recency component. Such a pattern was taken as support for the view that working memory operates on phonemically coded information, transferring it to LTS.

2.2.4 CONCLUSIONS

Baddeley and Hitch (1974) set out to examine the possible role STS may have in carrying out several information processing tasks. They studied verbal reasoning, language comprehension and the free recall of unrelated words and found that while a digit load of 6 impairs performance, one of 3 does not. In the case of phonemic similarity they found a series of results that substantiate the idea that there exists a working memory system which has characteristics in common with the digit span. They also found that articulatory suppression, which is known to cause a decrement in digit span, caused an impairment in the reasoning task and the free recall task.

Baddeley and Hitch (1974) incorporated similar experimental designs across these experiments to see if some consistency would be revealed, a consistency which would lend support for the idea of a common working memory system prominent in all of these cognitive tasks. A consistent pattern did emerge. From the results it was clear that this system has similarities with the mechanism concerned with digit span, although the fact that disruption was not complete when this was accompanied by these cognitive tasks indicates that there is a section of this system that does not deal with digit span. The idea that there is more than one component to STS is substantiated by the fact that there are only small effects of phonemic coding and articulatory suppression. Baddeley and Hitch (1974) posit the idea that the centre of the working memory system consists of a limited capacity flexible "work space", later termed the Central Executive (CE) and a component that deals with storage, known as the Articulatory Loop (AL). They also tentatively suggested that there may be a parallel non-verbal, perhaps visual, system operating along similar lines to the AL. The possibility that a non-verbal system exists was originally a secondary issue and research tended to concentrate on the AL. However, the non-verbal component eventually began to generate a number of studies and will be elaborated on in Chapter 4. The remainder of this chapter will concentrate essentially on the development of the AL.

The original form that this common working system was thought to take may be made clearer by analysing its role in memory span. Baddeley and Hitch (1974) was surmised that memory span requires the use of a phonemic store, i.e., the AL, and the more flexible "work space" or CE. This phonemic store was capable of dealing with a limited amount of speech-like material in the appropriate serial order. Provided the capacity of the AL is not exceeded, then it makes very few requirements of the central processor. The CE activates phonemic rehearsal routines and is only required to set up the AL and retrieve information from it when required. It is only when the capacity of the phonemic store is exceeded that the central executive component must allocate part of its processing time to cope with storage. Immediate memory span appears to be subject to two factors: the capacity of the phonemic store, which is believed to be relatively invariant; and the ability of the CE component to support this, both by recoding at input and reconstruction at the recall stage. It is also clear from this study that the working memory system does not underlie the recency effect in free recall.

2.3 WORKING MEMORY AND THE RECENCY EFFECT

Before going on to explore this Working Memory framework in greater detail, it is necessary to come to some understanding of the recency effect. Baddeley and Hitch (1977) set out to investigate recency in three groups of experiments. The first group was concerned with recency in incidental learning, in which, since the subject is not aware that they will subsequently be tested, it is unlikely they will adopt special learning or rehearsal strategies. Three experiments were carried out, the first two employed intentional and incidental memory tasks and the third combined these with a filled delay interval. In each of these experiments clear evidence of recency was found. Taken together, these experiments suggest that although the recency effect may be enhanced by the subjects' strategy during input, it is not dependent on such a strategy. They found that both primacy and recency effects occur under conditions in which the subject has no reason to rehearse the incoming material, or to encode it in such a way as to facilitate subsequent recall. The second group of experiments explored the view that recency represents the output of a short-term phonemically based store. If this was the case then one might expect it to show a phonemic similarity effect. In three experiments there was no evidence for impaired recency with phonemically similar items. They also showed that there was no evidence that storage load disrupts the recency effect in the way one would expect if digits were taking up storage space in the limited capacity STS, which is commonly assumed to be responsible for the recency effect. Given the results from both the storage load and the articulatory suppression studies, it was decided to abandon earlier speculations that recency represents the output of a limited-capacity STS. They adopted Tulving's (1968) idea that recency reflects a retrieval strategy which relies heavily on ordinal retrieval cues. The suggestion was that such a strategy may be applied within any range of memory stores, and, indeed, within LTS to any given class of items, provided they are readily distinguishable as a class, and have been presented in a clearly defined order. From this one should be able to observe recency effects in LTS. The third and final group of experiments explored this possibility. This involved performing two experiments, one a replication of Baddeley's (1963) anagram experiment and the other the "rugby club and beer" experiment, both of which were discussed in the last chapter. As will be recalled, both showed evidence of long-term recency effects. To summarise then, the presence of recency effects in incidental learning experiments points out that encoding strategy interpretations cannot provide a complete answer, although, as Shallice (1975) indicates, it can alter the recency effect. The claim that the recency effect has an integral role in the Working Memory system is weakened when one sees that, while Working memory and memory span appear to be heavily dependent on phonemic coding, recency does not appear to be sensitive to such phonemic factors as articulatory suppression or acoustic similarity. This claim is also questioned by the fact that such concurrent tasks as digit span, card sorting (Baddeley, Scott, Dryan and Smith, 1969; Murdock, 1965) and arithmetic (Shiffrin, 1970; Silverstein and Glanzer, 1971) appear to involve working memory but they do not effect the recency effect. Finally, the evidence for Long-Term recency effects in the absence of an STS requires that the recency effect be interpreted differently from before. Baddeley and Hitch (1974) suggest then as others have done,(Craik and Jacoby, 1975; Sanders, 1975; Tulving, 1968) that the recency effect is based on an ordinal retrieval strategy.

In 1980 Hitch developed this idea further by suggesting that the standard short-term recency effect is a result of this retrieval strategy applied to an STS. In order to support this notion he set out to illustrate that there are differences between short-term and long-term recency effects. There would appear to be several differences. The standard recency effect disappears when a filled delay is incurred prior to recall, while the long-term effect is not influenced by this (Bjork and Whitten, 1974). Dalezman (1976) has shown another difference whereby the standard recency effect is obtained only when the last items in the list are recalled first, whereas long-term recency is present regardless of whether recall starts with the beginning, middle or final items of the list (Whitten, 1978). Hitch (1980) has also shown that the short- and long-term recency effects are different in the way they reflect the effects of varying list-length in standard free recall and the continuous distractor task (Tzeng, 1973). The short-term recency effect retains a constant profile across different list lengths, whereas long-term recency becomes weaker as list length increases. This, Hitch (1980) argues, is support for the operation of a buffer store in the case of short-term recency and not long-term recency. He concludes that the recency effect is a temporary storage phenomenon, not a special case of the principle that more recently experienced episodes are more easily recovered from LTS. This effect, then, is interpreted in terms of retrieval from a "passive input register" from which the last two or three meaningful items or "chunks" are available. This limited capacity input buffer is said to be distinct from the other components of Working Memory and is responsible for the recency effect in immediate, but not long-term, recall. While this is a plausible explanation it has still to receive critical support (Hitch and Halliday, 1983).

2.4 DEVELOPMENT OF WORKING MEMORY

It was clear from the Baddeley and Hitch (1974) study that there exists a common working memory system. A system which was thought to comprise of a CE and an AL, with the distinct possibility that at least one other component existed, a non-verbal component perhaps carrying out activites similar to those performed by the AL. Having provided evidence to tentatively support this hypothetical framework Baddeley, Thomson and Buchanan (1975) set out to investigate this STM system in greater detail. Given the evidence presented already that the system has a phonemic base it was surmised that the basic units with which the capacity of the AL is measured may be syllables or phonemes. A number of experiments within the Baddeley et al (1975) study set out to study the influence of word-length on memory span. If words constitute the units in STS then words of differing lengths should not alter performance. An examination of the possible importance of number of syllables and temporal duration of a word as determinants of span was undertaken. As regards word length and memory span, they performed two experiments comparing long and short words over a range of verbal materials. They found that memory span is sensitive to word length. Three experiments were then carried out to investigate the number of syllables and the temporal duration. They found that when the number of syllables and the number of phonemes are held constant, words of short temporal duration are better recalled than words of long duration. The final group of experiments in this study explored the time based system further. It was further found that when articulation is suppressed by requiring the subject to articulate an irrelevant sound, the word length effect disappears with visual presentation, but remains when presentation is auditory (Levy, 1971; Peterson and Johnson, 1971). How do these results fit into the working memory framework? The previous sections of this chapter have combined to put forward a tentative formulation which posits a working memory system comprising a Central Executive (CE), which is the controling mechanism, and is supported by a number of subsidiary slave systems. One of these slave systems, the Articulatory Loop (AL), gains support if one accepts the assumption that the word length effect is the result of the limited capacity of the AL. The results of Baddeley et al (1975) indicate that the AL is in fact not item based but time based. It has a temporally limited capacity. When articulatory suppression prevents the use of the AL then memory performance for verbal material depends on the CE, a system which is not phonemically based and, as such, does not have the same temporal limitation.

The phonemic similarity effect (Conrad, 1964; Conrad and Hull, 1964; Baddeley, 1966) can also be accounted for by the operation of the articulatory rehearsal system. The phonemic similarity effect, as was the case with the word length effect, disappears when articulatory suppression occurs with visually presented material (Levy, 1971).

Taken together, the working memory framework can account for the neuropsychological literature of Shallice and Warrington and their colleagues (see Chapter 1), which caused so many problems for earlier models of human memory. This evidence is accounted for if one assumes that such patients are defective in the operation of the articulatory rehearsal system, while having the executive component of the working memory system intact.

Up to this point, then, the working memory framework appeared to be developing without any problems. The AL, in particular, appeared to be able to account for a number of results. Specifically it could account for the word length effect, the phonemic similarity effect, and the effect of articulatory suppression. Baddeley et al (1975) as was stated, illustrated that memory span for short words is superior to long, an effect that can be attributed to the fact that short words are spoken quicker and as a result 1.5 sec of short words will be greater in number than 1.5 sec of long words. The phonemic similarity effect as shown by Conrad and Hull (1964), among others, can be attributed to the fact that since items have similar articulatory codes, then confusion will arise, resulting in poor recall for phonemically similar items. Articulatory suppression impairs performance since suppressing articulation stops the AL functioning, preventing the maintenance of items in memory. Combining these effects one would expect that if both the phonemic similarity effect and the word length effect are attributed to an articulatory loop, then the prevention of its use through articulatory suppression would see the elimination of both these effects. Both Murray (1968) and Baddeley et al. (1975) showed that this was what happened, provided visual presentation was employed.

However, this last finding by Murray (1968) and Baddeley et al. (1975) provided one of the first problems for the concept of the AL. If the word length and phonemic similarity effects are a result of the articulatory process, then preventing articulation should eliminate these effects no matter whether visual or auditory presentation is employed. Murray (1968) with the phonemic similarity effect and Baddeley et al. (1975) with the word length effect found, however, that auditory presentation does not result in the elimination of these effects. This would appear to support the suggestion made by Warrington and Shallice (1972), Shallice (1979) and Shallice and Butterworth (1977) that there are separate auditory and visual memory stores and that articulation allows information to be transferred from the visual to the auditory store.

Another problem for the AL, and one which can also be viewed as support for some form of acoustic or auditory code, stems from the findings of Colle and Welsh (1976). They presented subjects with sequences of letters which they had to remember while "ignoring" a continuous prose passage, spoken in German, a language the subjects were not familiar with. They found that the presence of this irrelevant noise reduced recall performance. These anomalous results were explored in a number of studies, which will be discussed below.

2.5 EVOLUTION OF THE ARTICULATORY LOOP

The irrelevant speech effect shown by Colle (Colle and Welsh, 1976; Colle, 1980) was investigated by Salame and Baddeley (1982). They carried out a series of five experiments designed to explore the role of semantic factors, subvocal articulation and phonemic factors in the AL. From this they hoped to provide a clearer picture of the Working Memory hypothesis. In investigating semantic factors they performed two experiments, both involving visual presentation of digits. One compared meaningful and nonsense words as irrelevant speech and the other meaningful words and white noise. They found that the AL system was unaffected by the semantic content of the irrelevant speech nor was it affected by the non-speech material, white noise. In their examination of subvocal articulation Salame and Baddeley (1982) found that the irrelevant speech effect disappears under articulatory suppression. Finally they found that the system was affected by the phonological characteristics of the irrelevant material. They explored the role of similarity by comparing the influence on memory for visually presented digit sequences of irrelevant spoken digits, irrelevant words made up from the same phonemes as digits, and irrelevant disyllabic words, selected so as to be phonologically dissimilar to the monosyllabic digits. The results indicated that memory for digit sequences suffers greater disruption from irrelevant digits, or items made up from the same phonemes as digits, than by disyllabic words selected to be phonemically dissimilar to digits. Salame and Baddeley proposed that the concept of the AL system should be altered from a single system to a two component one. It was suggested that it comprised a phonological store and a control process involving articulatory rehearsal. This articulatory rehearsal process is thought to have two functions : it can maintain a memory trace which may otherwise fade, and it provides the means of translating a visual stimulus into a phonological code. The phonological store is capable of storing material for a limited period of time. When information is presented auditorily it has obligatory access into this store. If, on the other hand, material is presented visually, then access may be provided by subvocal rehearsal. How does this help explain the unattended speech effect? This effect is a result of the irrelevant speech having obligatory access to the phonological store which is used to store the subvocally rehearsed visual material. As a result of their being in the same store, interference can occur between the relevant visual material and the irrelevant spoken items.

This evolved version of the AL was explored further by Baddeley, Lewis and Vallar (1984) and Vallar and Baddeley (1984). Baddeley et al. (1984) sought to find whether this extended AL concept could account for the anomalous results found by Murray (1968) and Baddeley et al. (1975). It will be recalled that while the phonemic similarity and word length effects are eliminated by articulatory suppression when presentation is visual, Murray (1968) found that with auditory presentation articulatory suppression does not eliminate the phonemic similarity effect, and Baddeley et al. (1975) found the same with the word length effect. Baddeley et al. (1984) set out to explore the revised AL. They began by replicating the observation reported by Murray (1968). They found over three experiments a substantial effect of phonemic similarity regardless of whether the subject is or is not suppressing articulation. Thus under conditions of auditory presentation the phonemic similarity effect is undiminished by articulatory suppression. To explain these results one needs to take account of the revised AL concept. In this version of the AL system, the phonemic similarity effect reflects the nature of the coding in a phonological input store. When material is presented auditorily it is automatically registered in this store, regardless of whether or not the subject is allowed to articulate. With visually presented material, however, the store can be used only if the subject is allowed to articulate the items; hence suppression during visual presentation removes the similarity effect. While the phonemic similarity effect is assumed to stem from the phonological store, the word length effect is assumed to reflect the control process of articulatory rehearsal. Long words are assumed to be remembered more poorly than short simply because the rate at which they can be rehearsed, and hence the rate at which the phonological trace can be refreshed, is less for long than for short words. Since the word length effect is assumed to depend on the process of articulation per se, it should be abolished if subvocal rehearsal is prevented by articulatory suppression, regardless of whether the material is presented visually or auditorily. Experiments 4 and 5 required subjects to articulate irrelevant sequences of items both during input and recall and found that there was no effect of word length. Together these results provide strong support for the revised AL model.

Vallar and Baddeley (1984) also explored this evolved version of the AL by examining a single STM patient, P.V. P.V, a thirty year old Italian woman, suffered a stroke with a transient loss of consciousness. She underwent a detailed neuropsychological study which provided evidence for a defective auditory verbal STS (Basso, Spinnler, Vallar and Zanobio, 1982). The findings were as follows: P.V's auditory span was grossly defective with a striking auditory/visual dissociation; her performance did not improve when memory span was assessed using a recognition-by-pointing technique, (which was devised in order to rule out the possibility that covert deficits of speech production might be impairing her performance in this situation, where overt articulation is not required,) her auditory span remained poor; short-term retention of individual items was studied using the Peterson technique with a delay of a few seconds filled by a distracting activity producing a selective dramatic forgetting of the auditory items; visuo-spatial STM as assessed by the Block Tapping Test (De Renzi, 1977), visuo-spatial LTM as assessed by the Block Tapping Test and visual maze (De Renzi, 1977) and long-term verbal memory as investigated by a word learning test, a paired-associate learning test and by the learning of a short story (De Renzi, 1977) all showed P.V 's performance was well within the normal range. This pattern of results was interpreted as suggesting that P.V has a defective auditory-verbal STM. The auditory/visual dissociation suggests that the defect selectivity involves the auditory store. The defective performance when span is assessed by recognition ruled out the possibility that the defect could be attributed to covert expressive deficits. The Peterson experiment clearly supports the hypothesis of a storage deficit. P.V's performance on verbal LTM tasks, and on visuo-spatial short-term and long-term memory tasks suggest that she has no general cognitive deficits.

Vallar and Baddeley (1984) employed the method of converging operations in their study in order to attempt to specify the nature of P.V's deficit. They initiallly considered the phonological similarity effect. The evidence thus far suggests that this reflects the presence of a phonological store. As stated above (Salame and Baddeley, 1982) auditory information has obligatory access to this system, and, as such, a phonological similarity effect occurs, an effect which is not erradicated by articulatory suppression. If P.V shows a similarity effect with auditory presentation then one can assume that she employs the phonological store. There is also evidence which indicates that with visual presentation one finds no phonological similarity effect if subvocal rehearsal is prevented by articulatory suppression (Murray, 1968; Levy, 1971; Estes, 1973). Thus, with visual presentation the effect of similarity would only show if P.V were to use subvocal rehearsal. The lack of a phonological similarity effect with visual presentation would suggest that P.V was either unable or unwilling to subvocalise the items to be remembered.

As a further converging operation, articulatory suppression was used as a variable. With a normal subject and auditory presentation, suppression would be expected to produce a slight reduction in performance, but leave the similarity effect undisturbed. In the case of visual presentation, a normal subject would be expected to show a clear decrement in performance and an absence of an effect of phonological similarity. If P.V is not employing subvocal rehearsal, one would expect no effect of suppression.

Three experiments were carried out. The first explored the phonological similarity effect and found that P.V showed the standard phonological similarity effect with auditory presentation. With visual presentation, however, she showed neither phonological similarity nor suppression effects. These results support the idea that P.V has the use of a phonological store. The fact that there is no phonological similarity effect with visual presentation indicates that visually presented letters are not encoded phonologically. This view is substantiated by the absence of a suppression effect. If a subject is not subvocally rehearsing then preventing such rehearsal would not be expected to impair their performance. The evidence then suggests that with visually presented material, the strategy of subvocal rehearsal is not used by P.V. However, it is possible that subvocal rehearsal will be used with auditory presentation. The word length effect was used to see whether P.V uses an articulatory rehearsal strategy with auditory presentation. There is clear evidence that memory span for long words is poorer than that for short if, and only if, the subject uses a subvocal rehearsal strategy. If such rehearsal is prevented by articulatory suppression during both input and recall, then the word length effect disappears with both visual presentation (Baddeley et al. 1975) and with auditory presentation (Baddeley, Lewis and Vallar, 1984), showing that the word length effect depends on the process of subvocal rehearsal, rather than on the phonological store per se. If P.V is using subvocal rehearsal, then she would be expected to show a poorer immediate memory for longer words; if, on the other hand, a verbal rehearsal strategy is not adopted, no difference would be expected since the phonological store does not appear to be sensitive to word length. There was no effect of word length. This result supports the conclusion of Experiment 1 that P.V is not using sub-vocal rehearsal. The final experiment investigated whether this is because P.V has some articulatory problem. If her articulation is normal then her failure to use subvocal rehearsal would appear to stem from its dependence for effectiveness on the phonological store. If the store is not functioning adequately, then subvocal rehearsal might be expected to offer no advantage and hence not to be used. P.V was shown <u>not</u> to have an articulation deficit, indicating that rate of articulation per se is not responsible for her STM deficit. The authors concluded that the deficit lay in the phonological store.

It is clear from the work of Baddeley and his colleagues that the development of the AL is proceeding at a steady pace and is now capable of explaining a great deal of memory research. However little has been said concerning the CE. As Baddeley (1981) admits, this represents the most important but least understood of the three initial components of Working Memory, presenting the most difficult problems both technically and conceptually. Any explanation of this part of Working Memory would include details of its method of manipulating control processes and integrating the growing number of peripheral systems and also an understanding of selective attention and probably of the role and function of consciousness. In an attempt to make some progress, theorists within this area have concentrated on the peripheral components of Working Memory, gradually attempting to separate out further subcomponents of the executive, thus limiting the functions that need to be assigned to the central processor. As a result, the CE is described as the "area of residual ignorance" (Baddeley, 1983 p.315).

2.6 CONCLUSION

The previous chapter and the present one have combined to illustrate the development of thought within the expansive field of human memory. One of the most popular frameworks presently employed to explain and explore memory phenomena is the Working Memory model, originally postulated by Baddeley and Hitch (1974). In its original form it was claimed to comprise of a centralised "work space" and a number of slave systems. Two of these slave systems were put forward initially, one the AL, was said to deal with verbal information and the second, a non-verbal system, was initially thought to deal with visual information. The present chapter has indicated that this is a framework which is continually developing. This development has tended to concentrate on the AL component of the system, although, as will be seen from Chapter 4, theorists working in the non-verbal system have recently begun to produce a number of interesting findings.

Although restrictions on space did not allow for it here, one of the important contributions of the concept of Working Memory lies in its concern with its workings in cognitive tasks such as reasoning, comprehension and learning. Thus while research into the actual theory has taken place, at the same time research into understanding other more ecologically relevant information processing tasks has also been carried out. This has involved the study of both fluent reading, learning to read (Baddeley, 1978, 1982; Baddeley and Lewis, 1981; Baddeley et al. 1981; Lieberman, Shankweiler, Lieberman, Fowler and Fischer, 1977), simple arithmetic (Hitch, 1978), breakdown of normal cognitive functioning (Vallar and Baddeley, 1983) and the development of Working Memory through childhood (Hitch and Halliday, 1983).

The Working Memory framework, then, is clearly developing in its own right and with this, it is helping us develop a clearer understanding of a number of information processing tasks.

CHAPTER 3 : IMAGERY

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3.1 INTRODUCTION

The previous chapter presented a framework of human short-term memory which postulated a Central Executive, an Articulatory Loop and a system that deals with visuo-spatial information, known as the Visuo-Spatial Scratch or Sketch Pad (VSSP). Initially work carried out within this framework centred on the verbal component, the AL. However, while the visuo-spatial component appeared originally to be neglected, in recent years a number of theorists have become increasingly involved in exploring it. Before the VSSP is examined in detail in the next chapter it is necessary to provide a brief description of the general field of mental imagery.

This chapter has five main sections. First, a precis of the history of Imagery will be presented. This will indicate how imagery was initially widely accepted as an important area of study, how it was subsequently banished to obscurity with the advent of Behaviourism and how finally it was recalled and accepted into modern-day psychology. The next section will present a description of the central debate that has immersed the field for over a decade. There are two sides in this debate : one which suggests that all internal representations are coded in terms of "abstract propositions", the other which argues for the existence of a surface image with emergent properties. The third section will explore the early criticisms levelled at the supporters of the emergent properties theory, and their responses to them. In the fourth section the development of the criticisms in the area will be described and the fifth section examines the results of two major areas of research on imagery, and two explanations are offered for their results based on the two sides of the debate. This section also examines a critical aspect of the current debate, namely the influence of Tacit Knowledge. Finally, some conclusions about the relative merits of both accounts will be drawn.

3.2 HISTORICAL OVERVIEW

The concept of "imagery" has had an extensive and varied history. It has often been the case that the foundations of scientific interest in imagery have been attributed to Sir Francis Galton (1880, 1883). However exploration in this subject was underway long before Galton. The ancient Greeks carried out a series of forays into the area of mental imagery. Long before the well documented ideas of Plato and Aristotle there was the tradition of Simonides of Ceos, a tradition followed by early Greek teachers of oratory and rhetoric, which sought to achieve increased memory capacity through the systematic and disciplined use of visual imagery. Plato, carrying on the intellectual tradition of the Greeks, developed an extensive study of the psychology of memory which involved the notion of imagery differences. The involvement of Aristotle can be found in both dream imagery and "memory" imagery. He highlights, in both De Memoria and De Anima, the central importance of imagery in thinking, going as far as to say that thinking cannot occur without imagery. This early interest in imagery by the Greeks was taken up by Galton in his famous "breakfast table experiment". In Galton's experiment we come across his scientists, many of whom protested that mental imagery was not an integral part of their thinking : "they had no more notion of its true nature than a blind man who has not discerned his defect has of the nature of colour" (Galton, 1880, p.302). Galton states that he came across many good visual and other imagers in the general population but not in "the great majority of the men of science to whom I first applied" (Galton, 1883, p.58). Since Galton there have been many studies carried out which have found it almost impossible to discover any non-imagers. Corey (1915) in a study of visual imagery in a group of London school children could not find any who had no imagery. More recently Marks (1972) studied 190 students on his Vividness of Visual Imagery Questionnaire (VVIQ) and found only one gave a rating of "5", this being an indication of "no imagery at all" for all 16 items of the scale. An earlier investigation on an even larger subject sample of 500 carried out by McKellar (1965), showed the following : No less than 97% reported visual imagery; 93% auditory imagery and 74% motor imagery. There was also substantial incidence reported for other forms of imagery : tactile 70%; gustatory 67%; olfactory 66%; pain (algesic imagery) 54%; and temperature imagery 43%. It is clear then that for children, students and nonstudent adults imagery seems to be an common occurrence. McKellar (1972) suggests that perhaps through time there has been a change of incidence. "The tendency to overlook and to forget imagery experiences is certainly still with us; perhaps this tendency was stronger in Galton's day and age than our own" (p.38).

The study of imagery, which had enjoyed widespread acceptance for many years, began to come under direct attack with the advent of Behaviourism. This attack centred on the fact that up until that point research into imagery had tended to rely on the method of introspection. The Behaviourists argued that since mental phenomena could not (at that time) be examined in an objective, systematic and scientific manner then it should be abandoned in favour of the study of directly observable behaviour. Behaviourism went to even greater extremes and stated that all the terms employed must be defined in terms of behaviour and as such all "mental" vocabulary was forbidden from any discussion of psychology, this point being stressed by J.B Watson (1914) :

> "Psychology, as the behaviourist views it, is a purely objective, experimental branch of natural science, which needs introspection as little as do the sciences of chemistry and physics. It is granted that the behaviour of animals can be investigated without appeal to consciousness. The position is taken here that the behaviour of man and the behaviour of animals must be considered on the same plane....It is possible to define [psychology] as "the science of behaviour" and never to go back upon the definition: nor to use the terms consciousness, mental states, mind, will, content, imagery, and the like..." (p.27).

Watson, then, sees mental images as nothing more than mere ghosts of sensations and of no functional significance whatsoever.

Behaviourism caused a massive upheaval in psychology although it didn't go unchallenged, McDougall being one of the earliest and most vehement of its opponents. McDougall's comments concerning Watson and the Behaviourists are particularly scathing : "I regard Dr Watson as a good man gone wrong... a bold pioneer whose enthusiasm in the cause of reform in psychology has carried him too far....and landed him in a ditch....And his followers continue to jump into the ditch after him, shouting loud songs as they go..." (McDougall,1929)

Behaviourism dominated the psychological literature for several decades and it was not until the mid 1950s that its popularity began to decline. Many factors contributed to the growing dissatisfaction with Behaviourism. Primarily, there was a need to describe mental states as something other than intervening variables. The brain stimulation research of Penfield (Penfield and Rasmussen, 1950) required mentalistic terms to correlate with neurophysiology. Similarly, researchers of verbal learning were finding that complex processes mediated even simple learning tasks (Bugelski, 1953; Tulving, 1963). This dissatisfaction developed into a full scale regeneration of psychology's interest in mental experiences. The new approach adopted the strict scientific approach initiated by the behaviourists and, as such the methodology employed has been termed variously behavioural mentalism, objective mentalism, neomentalism, and experimental mentalism. Paivio (1975) claims that neomentalism represents an integration of prebehaviouristic and behaviouristic views concerning the nature of thought.

The history of imagery illustrates that it has gone full circle in that it began on the whole with positive acceptance, suffered obscurity through the behaviourist years and is now experiencing a widespread resurgence. In spite of its return to centre stage in the world of psychology its theoretical status still remains equivocal. The next section aims to provide a representation of the central debate around imagery's status, a debate that has stimulated the field for the past 10-15 years.

3.3 IMAGERY DEBATE

This debate centres on the dispute between the Imagery theorists and the Propositional theorists. It has been an intellectual battleground where as soon as one side produces what they take to be a damaging result the other side finds a way to compensate for this by adjusting the process that accesses the representation while leaving fixed the assumed properties of the representation itself (Pylyshyn, 1981). Some have even taken the view that the debate is, in principle, not capable of resolution (Anderson, 1978). The complexity of the issues is quite considerable but an attempt will be made here to provide as clear and concise a view of the central themes as possible.

The issue under discussion concerns the nature of imagery. The question being asked is not whether images exist, or more specifically the experience of images, but what their nature and their operational status is. Kosslyn and his colleagues (Kosslyn and Pomerantz, 1977; Kosslyn, Smith and Shwartz, 1979), the leading proponents of the Imagist view, have put forward a computational theory of imagery. This theory suggests that visual mental images are transitory data structures that occur in an analogue spatial medium. The "surface" representations are generated from more abstract "deep" representations, incorporating literal and propositional encodings in LTM and, once formed, can be operated on in various ways. Objects imaged are said to have size, orientation and position properties which are instantiated in the image. Paivio (1969, 1971) was one of the founders of the quasi-pictorial view. From the early work he carried out showing an improvement of memory performance with imagery, he posited the idea of two codes in memory representation, one of which is concerned with verbal information, the other with imagery. The Propositionalists, on the other hand, led by Zenon Pylyshyn (1973, 1981) suggest that visual information is to be defined in terms of abstract structures that express relationships, and truth values. A set of propositions may represent regional features of a compound array, and several sets of propositions may be interrelated to constitute a structural description of the whole.

Criticisms of the Imagist position emanate most vehemently from Pylyshyn. In his original critique (1973), he attacked the view that mental imagery could be employed as a construct for explaining the then available results. Pylyshyn is at pains to stress that the existence of the experience of imagery is not under question. It is clear that imagery is a powerful experience and one whose importance he is not denying. He goes further and states that the mere mention of consciousness necessitates the acceptance of the presence of images. It is not the existence of these experiences, nor imagery either as a subject of study or as scientific evidence that is being challenged. The crucial point is whether the concept of imagery can be used as a primitive explanatory construct (i.e., one not requiring further reduction) in psychological theories of cognition. Pylyshyn puts forward several criticisms of mental imagery, some of which are dealt with by the imagists better than others. The next section will present three criticisms arising from his original 1973 paper, namely the Picture Metaphor; the Brain Capacity argument and the Notion of an Interlingua. The section following this, Section 3.5, will illustrate the elaborated criticisms that Pylyshyn (1981) has recently put forward. That is, the question of Tacit Knowledge and its corollary, Cognitive Penetrability.

3.4 EARLY CRITICISMS OF IMAGIST APPROACH

3.4.1 THE PICTURE METAPHOR

The criticism of the use of the picture metaphor by imagists stems from Gilbert Ryle (1939). Ryle's principal objection to the study of imagery was that he viewed questions such as "Where do things and happenings exist which people imagine existing?" as spurious. The crucial problem is that of describing what is seen in the mind's eye and what is heard in one's head. What are spoken of as "visual images", "mental pictures", "auditory images" and in one use of "ideas" are commonly taken to be entities which are genuinely found existing elsewhere than in the external world. Thus, Ryle states we have presented minds as being theatres. The concept of picturing, visualising, or "seeing" is viewed as a proper and useful concept, but its use does not entail the existence of pictures which we contemplate or the existence of a gallery in which such pictures are ephemerally suspended.

Pylyshyn (1973) takes up this point and suggests that "the whole vocabulary of imaging uses a language appropriate for describing pictures and the process of perceiving pictures. We speak of clarity and vividness of images, of scanning images, of seeing new patterns in images, and of naming objects or properties depicted in images" (p.8).

The implication involved in employing such phrases is that what we retrieve from memory when we image, is some sort of undifferentiated (or at least not fully interpreted) signal or pattern, a major part of which is simultaneously available. This pattern is subsequently scanned perceptually in order to obtain meaningful information about the presence of objects, attributes, relations, etc. It would appear that using this metaphor implies that images are perceived as we perceive pictures.

Eysenck (1984) argues that this is in fact erroneous, since basic perceptual processing is called for when dealing with pictures but images, on the other hand, are already highly organised. Image representations resemble those that underlie the experience of seeing something, but in the case of imaging these representations are retrieved from LTM and do not stem from sensory stimulation. In other words, images are similar to percepts, and thus share the highly organised structure of most percepts. As a consequence, it is misleading to criticise image theorists for postulating the existence of uninterpreted images. Pylyshyn (1973) accepts this; however he states that "if retrieval can address perceptually interpreted context, the network of cross-classified relations must have interpreted objects (i.e., concepts) at its nodes. Thus storing images at these nodes is functionally redundant" (p.10).

Kosslyn and Pomerantz (1977) together with Paivio (1970) and Bugelski (1977) agree with Pylyshyn (1973) that the picture-in-the-head hypothesis is untenable. They regard it as a straw man, arguing that no serious student of imagery holds this view. They conclude that the picture metaphor is not defensible. As Paivio of points encoding the location in 2-D space of the contour points of an imaged object. This is clearly pictorial in Anderson's sense.

The critical point that the picture metaphor has brought to light is that the Imagery theorists must be more specific about what they mean. It is clear what they don't mean : they do not view images as pictures in the head in any literal sense. But do they mean pictures in the head in Anderson's sense, and if they do not, how do they answer his point?

3.4.3 THE BRAIN CAPACITY ARGUMENT

The second phase of Pylyshyn's thesis argues that employing mental images as representations entails "an incredible burden on the storage capacity of the brain. In fact, since there is no limit to the variety of sensory patterns which are possible (since no two sensory events are objectively identical), it would require an unlimited storage capacity."(p.9)

The most apt retort to this point is presented by Kosslyn and Pomerantz (1977). They reply on three levels. Initially they state that there is no reliable guage to measure the amount of information contained in an image or percept of a scene. Following on from this point, any argument concerning capacity limits only generates credence against the imagists approach if the image itself is believed to comprise relatively unprocessed sensations. However, if one accepts that images are thought of as being composed of relatively large, interpreted "chunks", then encoding capacity may not be a problem. Their major criticism of a capacity argument is that while the brain may well have a capacity limitation, it may not, and as the science

(1976) writes,

> "The wax tablet of picture metaphor is open to the kinds of criticisms that were directed at it over the ages. Today, however, they are largely directed at a straw man because no imagery researcher accepts the metaphorical view as a working theory." (p.2)

However, the problem is that imagery theorists have failed to say precisely what an image is. Anderson (1978) claims that the picture metaphor IS the imagery theory. He considers the alternative explanations of an image offered by Kosslyn and Pomerantz (1977):

> "Images are like surface displays generated on a cathode ray tube by a computer" (p.70).

> "Images, once formed, are wholes that may be compared to percepts in a template-like manner" (p.66).

and asks : what is a display on a cathode-ray tube or a template but another name for a spatial array of light information? What is a spatial array of light information but a picture? He believes that the picture metaphor is the only available model of imagery. When using the term "picture" he is referring to some format that represents information as a spatially structured array of light information. This fits well with the original model of Kosslyn and Shwartz (1977). They postulated a computer simulation model to account for imagery. In this model, an image is represented by a set stands at the moment we would not appear to be close to finding such a limitation. Finally, it must be said that the objection of a brain capacity limitation can be leveled at alternative theories with similar emphasis. There is no criterion for deciding which of an indefinite number of sets of propositions best represents the scene or event depicted by a given mental image. Nevertheless vast numbers of propositions seem to be necessary to represent even relatively simple configurations of objects.

3.4.3 THE NOTION OF AN INTERLINGUA

Paivio (1971) argues for a close interrelationship between the verbal and visual codes in his dual-coding theory. However Pylyshyn (1973) states that this necessitates an interlingual code in order to initiate translation. He goes further and suggests that such a code should be amodal and propositional in nature:

> "But the need to postulate a more abstract proposition - one which resembles neither pictures nor words and is not accessible to subjective experience - is unavoidable. As long as we recognize that people can go from mental pictures to mental words or vice versa, we are forced to conclude that there must be a representation (which is more abstract and not available to conscious experience) which encompasses both. There must, in other words, be some common format or interlingua." (p.5)

The idea is not unique to Pylyshyn and has in fact been put forward by several theorists such as Anderson and Bower (1975), Clark and Chase (1972) and Moscovitch (1973). However there is a major difficulty with the interlingua argument, as illustrated by Anderson (1978). If, as the propositionalists suggest, all translation between codes requires an intermediary code then one is left with an infinite regress. The translation between the visual or the perceptual and the propositional code requires yet another code, and the translation between the perceptual code and the new code necessitates a further code, and so on ad infinitum. Kosslyn and Pomerantz (1977) suggest that to solve the translation problem one must have a set of transformational rules with specific world knowledge. These rules would take the form of processes or routines, which when applied to information coded in one format would produce a corresponding representation in another format. No intermediate third form of representation need be involved. Janssen (1976) takes a different view, a view which is essentially Rylian. He believes Pylyshyn is correct in his formulation that a common code must underlie both mental pictures and mental words, since we can go from one to the other. Yet he says it is difficult to see for what logical reasons it should follow from this that the concept of mental imagery should be abandoned or replaced by a symbolic mode of representation. He sees the issue as being the familiar one of levels of analysis. Suppose that images were actually isomorphic to some type of underlying symbolic representation. It could still be worthwhile to treat imagery at a separate theoretical level. This is because the format a representation takes may become critically important under some circumstances. For example, if a representation at some level would involve a motor component as part of its structure it might suffer from concurrent motor activity when at that level. Another example he presents is the isomorphism between a map and the geographical environment it portrays. While there is isomorphism between them there are still things one can do with the one but not with the other, such as setting fire to the map. Thus, to the extent that images can be shown to have properties of their own, it is theoretically necessary to distinguish a level at which representation is by means of images. And, of course, the issue of whether images have such distinctive properties can only be solved by a suitable combination of theorising and empirical research.

Recently Pylyshyn (1981) has extended his critique of the imagery position. This seems to have been prompted by two factors. First, a considerable amount of new empirical data has been generated about images since the publication of his classic 1973 paper and a lot of this work has been directly addressed to contentious issues in the imagery debate. Second, in an effort to refine their own models and to respond to criticism, image theorists such as Kosslyn (1980) have produced more sophisticated systems. The direction of the debate has moved towards discussing the adequacy of specific theories and the collection of new data which will set constraints on such theories.

3.5 RECENT DEVELOPMENTS

Pylyshyn's (1981) criticisms have developed and are now viewed as being both a concession and a challenge to pictorial theorists (Morris and Hampson, 1984). He admits that because of its links with perception, imagery may well in some sense mimic or model operations with objects. The main point of disagreement, as he sees it, is whether certain aspects of the way in which images are transformed should be attributed to intrinsic knowledge-independent properties of the medium in which images are instantiated, or the mechanisms by which they are processed, or whether images are typically transformed in certain ways because subjects take their task to be the simulation of the act of witnessing certain real events taking place. It is possible that subjects use their TACIT KNOWLEDGE of the imaged situation to cause the transformation to proceed as they believe it would have proceeded in reality.

To examine the involvement of tacit knowledge Pylyshyn (1981) incorporates the cognitive impenetrability criterion. Essentially the penetrability condition is as follows :

> "Suppose subjects exhibit some behaviour characterised by a function, f (say, some relation between reaction time and distance or angle or perceived size of an imagined object), when they believe one thing, and some different function, f2, when they believe another. Suppose further that which particular f they exhibit bears some logical or rational relation to the content of their belief : for example, they might believe that what they are imaging is very heavy and cannot accelerate rapidly under some particular applied force, and the observed f might then reflect slow movement of that object on their image. Such a logically coherent relation between

> the form of f and their belief (which is referred to as the "cognitive penetrability of f") must be explained somehow." (p.21).

Pylyshyn's claim is that to account for this sort of penetrability of the process, the explanation of f itself will have to contain processes that are rule governed or computational, such as processes of logical inference, and that make reference to semantically interpreted entities (i.e., symbols).

To explore the issue of tacit knowledge it is necessary to examine two major areas of research viewed as supportive of the Imagists position, namely mental scanning and mental rotation. Within this analysis of these empirical findings it will be clear that aside from the possible influence of tacit knowledge the results presented can be explained equally well by both an Imagist and a Propositional account.

3.6 ANALYSIS OF EMPIRICAL RESULTS

3.6.1 MENTAL SCANNING

Kosslyn and his colleagues (e.g., Kosslyn, 1973; Kosslyn, Ball and Reiser, 1978) have carried out an extensive series of experiments on mental scanning. The results of this work have illustrated that there is a close relationship between processes of perceiving, and the reports based on inspecting or scanning images. Essentially these experiments require subjects to image an object and to indicate whether there are certain properties present in the image. The time taken to begin the scan and press the response key is the dependent variable. Results from such studies have consistently found a systematic relation between reaction time and the distance, size and complexity of the objects imaged (Kosslyn, 1980; Pinker, 1980). There are generally seen to be three types of mental scanning experiments.

<u>The Image Distance Effect</u> - In a typical experiment of this type subjects study a fictional map of an island (Kosslyn, et al.1978). On this island are several objects, a tree, a hut, a lake, and a well, at different locations. Subjects are instructed to memorize the map by closing their eyes and forming an image of it and then comparing it with the image of the actual map. Once the map is memorised a location name is then presented, and the subject has to "focus" on this location while keeping the entire map in view in the mental image, and then to wait for a second name. Upon hearing this name, the subject has to "look for" the item on the imaged map. If the item was on the map, the subject scans to it. Scanning is accomplished by imaging a small black speck moving in a straight line as fast as possible to the object. When the speck hits the second object the subject presses one button if the object was present and another if it was not. Results have consistently shown that reaction times increase linearly with distance. It takes longer for the speck to get to its location the further away the object is from the starting point. This is taken as evidence that imagery occurs in a spatial analogue where the object imaged has size, orientation and position properties instantiated within it.

Propositionalists can account for such results with relative ease by simply positing that subjects are consulting not a spatial image, but a network of propositions with distance represented in terms of degree of relatedness. However, Kosslyn responded to this possibility by repeating the experiment without instructions to use imagery. It is only when subjects image that reaction time is related to distance. When subjects are asked "Is there a hut on the island?" there is no such relationship.

Pylyshyn (1981) claims that subjects in this experiment are simply responding in terms of their tacit knowledge. An alternative explanation advanced by Intons-Peterson (1983) is that these results are a product of "experimenter expectancy effects". That is when experimenters are aware of the predictions under investigation they might unwittingly and unintentionally influence the subjects' performances. The phenomenon of experimenter expectancy effects was put most aptly by that early English psychologist William Shakespeare :

> Hamlet: Do you see yonder cloud that's almost in shape of a camel?
>
> Polonius: By the mass, and 'tis like a camel, indeed.
>
> Hamlet: Methinks it is like a weasel.
>
> Polonius: It is backed like a weasel.
>
> Hamlet: Or like a whale?
>
> Polonius: Very like a whale. Hamlet, Act III, Scene 2.

These are damaging criticisms which are difficult to totally rebut, and clearly require further experimental work.

The Image Size and The Image Complexity Effects - Kosslyn (1975) has found that subjects take longer to verify that an imaged object has a certain property if they are instructed to make the image of the object small. He argues that there is a "grain" limitation on the mental image and that it is difficult to properly represent the details of a small image. This is related to the supposed perceptual fact that it is difficult to discriminate details of small objects when presented. Kosslyn has shown that there is a complexity limitation on an image - that it takes longer to verify that an object has a certain property when it is imaged along with a more complex object.

These results can be accounted for by a propositional model which assumes that a subject activates fewer propositions to represent an object when instructed to image it small and that they can activate fewer propositions when they must represent another complex object. Kosslyn and Pomerantz (1977) argue that this explanation is ad hoc. However, as Anderson (1978) points out, it is no less ad hoc to propose that small images suffer a grain limitation. Interestingly however, Kosslyn (1975) has illustrated that if one does not instruct subjects to image, response times are governed not by size but by conjoint frequency. For example, the question "Does a cat have claws?" was responded to more quickly than "Does a cat have a head?". With imagery instructions, verification times were affected by size and "head" was verified faster than "claws". These results are still open to the challenge directed at the distance effect, namely that of the demand characteristics of the task.

3.6.2 MENTAL ROTATION

One of the most interesting phenomena that has come out of research in cognitive psychology is that of mental rotation (Metzler and Shepard, 1974; Shepard, 1975). The basic finding is that the time taken to decide that one object is a rotation of another object is a monotonic and often linear function of the amount (degrees) of rotation. The suggestion is that one object has to be mentally rotated until it is in a corresponding orientation to the other. A mental rotation study employing alphanumeric characters was carried out by Cooper and Shepard (1973). In this study the characters were either normal (F), or reversed, mirror-image forms (ꟻ). These alphanumerics were presented to subjects at various degrees of rotation and the task for the subject was to respond as to whether the character was "normal" or "reversed". Cooper and Shepard (1973) found that there was a linear increase in response times such that, the degree of rotation was the longest for the 180 degree inverted presentation, (Ⱶ or ⅎ). Response time is interpreted as showing the time taken to rotate the character back to the upright before making the judgement. In a follow-up experiment to this, subjects were given prior knowledge of the identity of the alphanumeric and at what degree of rotation it would be presented. They were thus able to image the expected character at the expected orientation, and make the judgement at a speed which was uniformly rapid, and did not vary with rotation. Briefly then, when no prior information is provided an F at 180 degrees has to be rotated back to the upright before it can be judged normal or reversed, and the time for rotation depends on the angular distance. When prior knowledge is advanced, the subject can image a normal F at the 180 degree rotation before the stimulus appears, and then make a rapid, direct comparison between the image and the stimulus. In the no prior information condition, the mental rotation has to be performed on the perceived stimulus and inflates the reaction time; in the advance information condition, the mental rotation is performed prior to presentation and is thus not included in the response time. Further experiments have shown that the subject must go through all of many intermediate states in rotating the object. In Kosslyn and Shwartz (1977) simulation, the image is moved through a series of small changes in orientation.

As Anderson (1978) suggests, one can quite simply postulate a propositional model that mimics this image model. The systematic alteration of the relations that hold between propositions could produce the same results. Kosslyn and Shwartz (1977) argue that the propositional account is less satisfactory. Essentially their criticism of the propositional account is that it is hard to see why it should necessarily involve more changes to convert Ⅎ to F than to convert ℿ to F . In order to explain why the 180 degree figure takes longer to transform, propositionalists have to make the arbitrary and ad hoc assumption that a series of stepwise transformations are carried out, converting the propositional representation successively to each intermediate state until it reaches the upright form. This assumption, as Cohen (1983) rightly states, seems implausible. However the image account itself is not immune from this criticism. One can also ask why rotation of the image must be gradual. Why should it be computationally harder in the

180 degree step than a 1 degree step? In terms of number of CPU cycles, Anderson (1978) states there would be no differences in a simulation program like that of Kosslyn and Shwartz (1977). It is no less ad hoc, then, to suggest this restriction on the image model than it is to suggest it for the propositional model.

The imagery account comes under further attack with Kosslyn's proposal, arising from his 1981 model, that spatial images may be transformed in two different ways. The shift transform is said to operate by incremental stages on the existing display. The blink transform lets the initial image fade and then generates another image of the object at a new size or location. In order to explain why subjects in the Cooper and Shepard type of experiment appear to use the incremental shift strategy rather than the blink transform, Kosslyn makes the assumption that it is less effortful to use shift transforms unless a large change is required. The blink transforms are reserved for large changes. These assumptions again appear to be just as arbitrary and ad hoc as the propositional explanation.

The possibility of the involvement of cognitive penetration has also been suggested to be present in mental rotation studies (Pylyshyn, 1979, 1981). Pylyshyn (1981) claims that

> "the operation of mentally rotating a whole image is not one of the functions that is instantiated by the knowledge-independent functional capacities of the brain and should not be explained by appealing to properties of some analogue medium." (p.29)

He based this conclusion on the empirical findings of two experiments (1979). In these experiments subjects saw two stimuli simultaneously, one a geometric figure (containing internal lines dividing it into subpatterns) and the other possibly a part of the figure. The part was presented at different angular disparities from the orientation of the figure. The subject was to decide whether the part was a component of the figure, rotating the figure into congruence with the part if necessary. The main result of interest here was the rate of increase in time with the amount of rotation : The amount of time required with greater amounts of rotation increased more sharply when the part was not a "good" (in the Gestalt sense) subpattern. That is, "bad" parts were apparently rotated at a slower rate. Pylyshyn argues that because subjects' knowledge of part goodness affected rotation, rotation is not an analogue process.

Kosslyn (1981) responds to these experiments by suggesting that Pylyshyn's results may not have anything to do with "goodness" per se. He suggests that because Pylyshyn used different patterns for his "good" and "bad" parts (instead of constructing sets of figures such that the same pattern could serve in both conditions), one cannot know whether this result is due to peculiarities of the individual patterns per se, or to the relationship between the pattern and the figure in which it was embedded. He also suggests that Pylyshyn's results may simply reflect task-specific strategies that have nothing to do with mental rotation as occurs when stimuli are not presented simultaneously (as in Cooper and Shepard, 1983) and hence are not available for successive visual comparisons. A third possibility is that subjects' results are due to a visual comparison process, where subjects never rotate a mental image - even in part. If this is the case then the results simply indicate that the detection task becomes increasingly difficult for "bad" parts when the subpattern is rotated further. A final possibility, Kosslyn postulates, is that even if subjects did encode the entire figure and then mentally rotated it into congruence with the part, the results may be due to the image's becoming increasingly degraded with more rotation because it has had more time to fade. If so, "good" parts may still be relatively easily detectable at amounts of degradation that make it difficult to detect "bad" parts, resulting in detection times for "bad" parts that increase more sharply with increasing amounts of rotation.

It is clear that no definite conclusion can be drawn regarding tacit knowledge and its influence on mental rotation results. What is clearly required is an extensive exploration of the involvement of tacit knowledge and the effects it has on mental rotation as well as an examination of the boundaries of mental rotation itself.

3.7 CONCLUSION

This chapter has illustrated that imagery theorising has had a chequered history. It gained popularity with the ancient Greeks, developing into a dominant force in psychology up until the advent of Behaviourism. Through the Behavourist years imagery found itself banished to the wilderness. However, when it was gradually adopted back into the fold it quickly established itself as a central topic within psychology. While it was gradually accepted as a legitimate area for investigation, its theoretical status was still equivocal. This equivocation is amply displayed in the prominence of the

Imagist/Propositionalist debate currently dominating the study of imagery. It has been shown here that both of these approaches can adequately account for the results generated in all mental scanning and mental rotation imagery research to date. So where does this leave the study of imagery? Anderson (1978) has argued that the question of whether we should adopt an Imagist or Propositionalist approach may not be one that can be answered sufficiently, and that our energies as cognitive psychologists should be directed elsewhere. While the complexity of the issues involved, as one can glimpse from this chapter, seems to negate the possibility of a quick end to the debate, it would seem rather hasty to accept this as justification for deserting the area. There has undoubtedly been some progress because of the debate. The earlier theorising was very abstract and presently there is a move toward developing specific theories. It is also clear that a massive amount of empirical data is being produced which is placing constraints on theories and causing theorists to continually refine their arguments. This scientific analysis augurs well for future resolution.

Finally, there has been an interesting suggestion made by Baddeley (1980) about the relation between the non-verbal component of the Working Memory theory, the VSSP, and the general imagery debate. He has suggested that the VSSP may be the centre for the transfer of "propositional codes from LTM and manipulating and displaying them via an analogical peripheral system" (p.21). In approaching this possibility, as will be shown by the following chapter, the theorists involved in examining the VSSP have decided initially to explore its characteristics and components in isolation: the idea being that once its details have been worked out then its relationship to the Imagist/Propositionalist debate will be greatly clarified.

CHAPTER 4 : THE VISUO-SPATIAL SCRATCH PAD

CHAPTER 4. THE VISUO-SPATIAL SCRATCH PAD

4.1 INTRODUCTION

There has, in the past, been a call for a separation of visual and verbal processes arising from normal memory research (Paivio,1971) and neurological studies (Milner,1971; De Renzi et al,1975,1977). In order to account for the research on the processing of visuo-spatial images the Working Memory theorists have posited another slave system, which is thought to correspond to the equivalent subsystem for verbal material, the Articulatory Loop. The VSSP is described as a slave system for the maintenance of visuo-spatial information. In terms of empirical work the VSSP has until recently been the poor relation of the WM family. In investigating the nature of this system three interrelated issues have arisen :

1. Is the system spatially or visually based?

2. Does movement have a role in the system?

3. How is information stored?

The present thesis is an investigation of the latter two issues, but the majority of research thus far has centred on the first question and the remainder of this chapter will involve describing this research.

4.2 THE ORIGINS OF THE VSSP

Current work on the nature of the code is based largely on the work of Baddeley, Grant, Wight and Thomson (1975) and Baddeley and Lieberman (1980) which derived from Brooks (1967,1968). In the first of the Brooks studies, a modified memory span procedure was developed. Two types of sequences were used, one easily visualised and termed the spatial material, the other formally equivalent but not easily visualised, termed the nonsense material. The subject was instructed to imagine a 4x4 matrix and was taught that one particular square (the second square in the second row) would be designated the starting square. Each message described the location of the digits 1 to 8 within the matrix, and in each case the digit 1 was in the starting square and successive digits appeared in adjacent squares. Since the message was always presented in the sequence 1 to 8, it was possible to remember it in terms of a path through the matrix, with each successive digit being located as above , below, to the right, or to the left of the previous location (e.g., in the starting square put a 1; in the next square up put a 2; in the next square to the right put a 3; etc). The nonsense material was derived from the spatial material by replacing the words right, left, up, down, with the words quick, slow, good, bad (e.g, in the starting square put a 1, in the next square to the slow put a 2; in the next square to the bad put a 3). In this way, material was obtained that was formally equivalent : it is identical to the spatial material in length and form of presentation, and it involved strings of polar opposites with the same sequential restraints. However, Brooks and subsequently Baddeley and Lieberman (1980) found that the nonsense sequences were more difficult than the spatial but that reducing them from 8 to 6 items gave an approximately equivalent probability of correct reproduction (See

Figure 4.1).

		3	4
	1	2	5
		7	6
		8	

NONSENSE MATERIAL

In the starting square put a 1.
In the next square to the quick put a 2.
In the next square to the good put a 3.
In the next square to the quick put a 4.
In the next square to the bad put a 5.
In the next square to the bad put a 6.
In the next square to the slow put a 7.
In the next square to the bad put 8.

SPATIAL MATERIAL

In the starting square put a 1.
In the next square to the right put a 2.
In the next square up put a 3.
In the next square to the right put a 4.
In the next square down put a 5.
In the next square down put a 6.
In the next square left put a 7.
In the next square down put an 8.

FIGURE 4.1 A SAMPLE OF THE EXPERIMENTAL MATERIAL

Brooks described four experiments which demonstrate a conflict between reading verbal messages and imagining the spatial relations described by those messages. In contrast, when the subject was induced to treat the messages as rote strings of words instead of visualising their referents, reading was a more effective means of presentation than listening. It was suggested from this that visualisation and reading were competing for the neural pathways specialised for visual perception. In a subsequent study Brooks (1968) carried out a spatial task which involved showing the subject a block capital letter, with the bottom left hand corner marked with a star (see Figure 4.2)

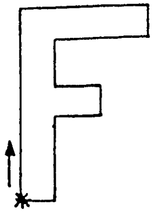

FIGURE 4.2. A sample of the simple block diagram used by Brooks (1967). The asterisk and arrow showed the subject the starting point and direction for both reproduction and categorization.

The subjects' task was to look away from the letter and, holding it in their mind's eye, to go around the letter from the star responding "yes" if the corner in question was at the top or bottom, and "no" otherwise. Hence for the letter F, the responses would be "yes,yes,yes,no,no,no,no,no,yes". The verbal task devised by Brooks involved presenting the subject with a sentence, for example A BIRD IN HAND IS NOT IN THE BUSH. The subjects' task was to hold this in memory, and then successively categorise each word as either a noun (in which case they should respond "yes"), or a verb ("no"). Hence for that particular sentence the sequence would be "no,yes,no,yes,no,no,no,no,yes". Brooks used two methods of responding, either spoken or manual. The manual task involved pointing to a series of "yes's" or "no's" scattered irregularly down the response sheet. He observed that a task that involved processing the visual image of the letter was performed more slowly when subjects were required to respond by pointing to a visually displayed response than when the response was spoken. When the subject had to make linguistic judgements about a sentence held in immediate memory, however, exactly the opposite occurred, with pointing being more efficient than speaking the response. Brooks suggests that this is because both the visual imagery task and the pointing response depended on the visual system, whereas both the immediate sentence memory and the spoken response depended on the verbal system.

The VSSP discussed only briefly by Baddeley and Hitch (1974) in their initial working memory proposal, began to be explored directly by Baddeley, Grant, Wight and Thomson (1975). who adopted the disruption technique pioneered by Brooks. In Experiment 1 the possible interaction between visual tracking and visualisation was explored by employing a pursuit rotor and the Brooks letter visualisation task. Subjects were required to perform the visual and verbal Brooks (1968) tasks both alone and while pursuit tracking. The results showed that performance on a visual tracking task is impaired by a task requiring the processing of a visual memory image (the F-type task), with little if any impairment produced by a verbal processing task (noun/non-noun task) which Brooks (1968) has shown to be of roughly comparable difficulty.

The second experiment investigated the converse question of whether tracking will impair imagery. The effects of tracking were tested using the visualisable and nonsense material used by Brooks (1967). Both types of material were presented with and without tracking. Performance on the matrix sequences was markedly impaired by tracking in all 12 subjects while the nonsense sequences showed no such decrement. These results confirm those of Experiment 1 in showing a clear interaction between tracking and memory when a visual imagery component is present. It extends the original finding to a different memory span task, and in doing so confirms the conclusions of Brooks using the same tasks.

Experiment 3 again applied the visual pursuit tracking task which had proved a convenient and sensitive technique for studying visualisation. This experiment studied abstract and concrete verbal material, for which large learning differences are typically observed and interpreted in terms of visual imagery. If such imagery does account for the enhanced learning of the concrete material, one might expect learning to be grossly disrupted by visual tracking. Subjects learned and recalled two lists of 15 noun-adjective pairs in each of four conditions, namely (1) abstract pairs while tracking, (2) abstract pairs without tracking, (3) concrete pairs while tracking and (4) concrete pairs without tracking. The results were unequivocal in showing that the visual tracking task, which was found to interact strongly with tasks requiring visual imagery, impairs the learning and retention of concrete imageable and abstract word pairs to the same extent. On the basis of these results it was suggested that a distinction should be drawn between the abstract/concrete distinction and imagery as a control process whereby material is manipulated in a visuo-spatial working memory. The former, it was suggested, represents the manner in which a given type of material is registered in semantic memory. Its manner of registration will influence performance whether or not the control process of visuo-spatial imagery is employed in learning or recall.

4.3 A SPATIAL SLAVE SYSTEM ?

The evidence from Baddeley et al (1975) and Brooks (1967,1968) provided strong support for the other slave system suggested by Baddeley and Hitch, initially assumed to be of a visual nature. It was Kahneman (cited in Baddeley and Lieberman, 1980) who first asked whether in fact the evidence implied a visual system or a spatial one. As the evidence to date did not warrant reaching a conclusion one way or the other he suggested that the system could in fact be spatial. Baddeley and Lieberman (1980) reported a series of experiments designed to explore this question. A dual-task approach was again adopted. In one experiment the influence on imagery of a spatial nonvisual task was examined, whereas in the second the disrupting effect of a task involving visual but nonspatial processing was studied. In the first study subjects carried out the immediate memory tasks that had previously been shown by Brooks (1967) and Baddeley et al (1975) to stress either visuo-spatial or verbal coding. Subjects performed both tasks alone and while performing an auditory tracking task. The tracking task involved pointing to a moving sound source while blindfolded. This task was deemed to have a clear spatial component which was not dependent on visual input. The results revealed that not only was the visuo-spatial task more vulnerable to tracking, but also that tracking itself was more vulnerable to the effect of the spatial task, findings which combine to rule out a speed error trade-off interpretation of the results. These data "are clearly consistent with the assumption that the memory task relying on imagery has a spatial component that does not depend on direct visual input" (p525). The possibility that there may also be a purely visual component at work was examined in experiment 2. In this experiment the Brooks (1967) spatial and nonsense memory tasks were again used, but this time the effect on performance of using a concurrent visual task thought to have minimal spatial demands was investigated. The concurrent visual task involved subjects judging the brightness of a series of light patches on a screen. The results of this experiment clearly showed that the concurrent visual task of judging brightness was sufficient to cause a significant decrement in performance on the memory task, but that this was not specific to the spatial condition. In fact the evidence suggested that the disruption was rather less on the spatial than the nonsense conditions.

Baddeley and Lieberman (1980) carried out several other experiments, all of which suggested that the system relies on spatial rather than visual input, because it can be disrupted by a spatial task that is free from visual input and is relatively resistant to disruption by a visual task said to make only a slight processing demand. Comparable findings were presented by Den Heyer and Barrett (1971) and Meudell (1972).

The distinction between spatial coding and visual coding has become a major theoretical issue (Eysenck,1984). Consider the well known work on mental rotation carried out by Shepard and his colleagues (Shepard and Metzler, 1971; Cooper, 1975; Cooper and Podgorney, 1976). Shepard and Metzler originally formulated the mental rotation paradigm in 1971. In its initial form it involved presenting two pictorial cube-like structures. These figures, which differed in their orientations, were presented to subjects whose job was to indicate whether the two structures were the same or mirror images. Mental rotation was reflected in the response times, which increased linearly with the angular disparity between the orientation of the two figures. This rotation process is also visible in the pattern of eye fixations during the task, as shown by Just and Carpenter (1976). In their study subjects made a series of fixations looking back and forth between the corresponding features on the two figures, with approximately one additional comparison for every 45 degrees of angular disparity.

Due to the fact that there is a large visual component present in this type of task it was primarily thought that this indicated that the underlying representations were visual. However, an alternative possibility for the mental rotation results, as with the selective interference studies presented earlier, is that the representations may be simply spatial. There is no definitive evidence to suggest that an underlying representation is necessarily defined by the modality of the presentation stimulus. As Hampson and Duffy (1984) suggest, a visual or spatial representation could be generated from a verbal description, from haptic input, or retrieved from semantic memory.

Evidence to support the possible spatial coding comes from a series of mental rotation studies involving congenitally blind subjects. Blind people know a considerable amount about the visual world despite their obvious handicap. This knowledge can be employed to aid them in familiarising themselves with new environments, depth, concealment and describing familiar surroundings. Such ability must have been gained by nonvisual means and recently it has been suggested that the blind, compared to the sighted, rely heavily on haptics and verbal instruction in the acquisition of these abilities (Kennedy, 1980; Zimler and Keenan, 1983). A number of studies suggest mental rotation can be undertaken by blind people. Marmor and Zaback (1976) employed a haptic version of the Shepard and Metzler (1971) task and found that there was only a quantitative difference between the sighted and blind subjects. Two nonsense shapes were haptically presented to subjects who had to judge whether they were same or different. Subjects who were blind from birth had a slower rate of rotation than those who had become blind about age 15; they, in turn, were slower than blindfolded sighted subjects.

Does this mental rotation involve mainly visually based coding or spatial processing? Evidence to support the view that there is not necessarily a visual component in mental rotation, was obtained by Carpenter and Eisenberg (1978). They investigated mental rotation in blind children using a haptic version of the letter matching task. As in the standard mental rotation experiment, subjects, both blind and blindfolded sighted, were presented with letters in some orientation between 0 and 300 degrees from the vertical and were timed while they judged whether the stimuli were normal or mirror image versions. Both groups' responses, as in the Marmor and Zaback (1976) study, showed a linear increase in reaction time with departure from the vertical.

It has been reported by Zimler and Keenan (1983) that there are many imagery tasks on which blind and sighted subjects do not differ qualitatively. They have shown that in a paired associate learning task both blind and sighted adults recalled a greater number of high visual imagery pairs. It was also shown that both these groups could organise their free recall on the basis of words grouped by colour. Finally, after hearing descriptions of objects that were either visible in the picture plane or concealed by other objects, the blind, like the sighted, recalled more pictorial than concealed targets. Kerr (1983) however, found no better recall of pictorial versus concealed items, and a consistent and significant difference in formation times, with the blind taking longer than the sighted. Nevertheless, the overall pattern of responding of the blind was similar to that of the sighted in this and in two other experiments that Kerr reports involving image scanning and property detection.

There are two possible reasons that immediately spring to mind to explain the results of these studies. One is that the sighted and the blind may employ different strategies for processing information when carrying out such tasks, and somehow, in some unspecifiable manner, these two strategies produce exactly the same effects. The second and more plausible explanation is that both groups use similar mental methods. The latter view finds favour with many theorists in this field. Carpenter and Eisenberg (1978), for example, conclude that, "mental rotation is an operation that requires a representation with spatial components rather than specifically visual components", and more recently Hampson and Duffy (1984) who investigated verbal and spatial interference effects in congenitally blind and sighted subjects, suggest that there are many imagery tasks that involve a heavy dependence on spatial information processing.

The evidence reported thus far strongly supports the idea of a spatially based WM system. However, the existence of such a system does not rule out the possibility that there may be a parallel system or component relating to nonspatial visual information. In the next section the evidence for just such a system is reported.

4.4 A NON-SPATIAL VISUAL MEMORY SYSTEM ?

As early as 1971 Atwood demonstrated the existence of selective interference between high and low imagery sentences and a visual processing task. He used an unconventional paired associate task which involved the memorisation of phrases and sentences containing the two nouns to be associated. Interference was in the form of a digit presented visually or auditorily immediately after a phrase or sentence was presented. A number of studies have subsequently attempted to replicate Atwood's experiment without much success (e.g., Baddeley et al, 1975; Quinn, cited in Baddeley, 1975)). Janssen (1976 a,b) on the other hand, found evidence for selective interference both during the memorisation of noun pairs and of isolated nouns, under auditory and visual perceptual interference as in the Atwood study. These inconsistencies are put down by Janssen to a basic difference in procedure relating to the interference tasks employed. For example, in the Baddeley et al (1975) study, the visual pursuit tracking task involved employing an important spatial component; that is, the visual guidance of movements of the subjects fingers and hands. According to Janssen, it might for this reason have been inappropriate to cause interference with an imagery task lacking a spatial aspect. This latter type of task, it is claimed, would be more vulnerable to interference consisting of a relatively non-spatial task, such as the recognition of digits presented in a fixed position relative to the subject. Janssen consistently succeeded in producing the Atwood effect over several experiments which does support the idea of a visual component.

A more recent paper by Beech (1984) again suggests the possibility of a visual and a spatial component. He replicated the Baddeley and Lieberman (1980) study under broadly similar circumstances. The spatial and verbal primary tasks were again those discussed by Brooks which involved remembering descriptions of spatially arranged or nonsense sequences of digits respectively. The secondary visual and spatial tasks involved either judging the level of brightness or pressing an unseen matrix of buttons in a predetermined sequence (Moar, 1978). In contrast to the finding of Baddeley and Lieberman (1980), both the visual and spatial secondary tasks significantly impaired spatial WM. Neither of these secondary tasks significantly interfered with concurrent verbal processing. Beech suggests that spatial WM draws on resources from both visual and spatial quarters.

Another study which appears to support the proposed involvement of both spatial and visual components is one by Mayes and Ralston (unpublished). They set out to replicate and extend Baddeley and Lieberman's (1980) study. A major concern of theirs was the secondary tasks employed by Baddeley and Lieberman, in that they differed on several dimensions other than the visual or spatial nature of the information to be judged. While one was visual, the other involved auditory feedback; their temporal characteristics were quite different; so was the mode of response : one required discrete judgements, while the other required continuous tracking. To identify the visual-spatial distinction here as the crucial factor in determining the observed pattern of interference with memory tasks, they suggest, is to leap too far ahead of the results.

In their study Mayes and Ralston devised secondary tasks that were formally equivalent in terms of an information theory transmission rate in bits per second. Their temporal characteristics were identical, so were their responses. The same computer program delivered the stimuli in both tasks. As far as they could ensure, the only difference between the tasks lay in the way in which the information to be judged was presented to the subject. In one case it was in the form of sequences of different coloured flashes from what was virtually a point source of light. This was referred to as a visual, non-spatial task and was termed the Colour Sequence Discrimination (CSD) task. In the other case a series of taps were delivered to the index and middle fingers of the subject's right hand and this was referred to as a non-visual task and was termed the Finger Sequence Discrimination (FSD) task.

In the first experiment the above tasks were required to be performed concurrently with the spatial memory task (Brooks matrix task) employed by Baddeley and Lieberman. No verbal memory task (the "nonsense" version) was included here; this simply represented an attempt to demonstrate the expected result that spatial memory would be disrupted by the FSD task but not by the CSD task. The pattern of results generated by this experiment were exactly the opposite to those reported by Baddeley and Lieberman. Spatial memory performance was significantly impaired when the CSD task was concurrently run; when the FSD task was performed, however, there was no significant difference from the memory task alone.

A second experiment was carried out to see if the results of Experiment 1 could be replicated. The CSD and FSD tasks used were those employed in Experiment 1. Two memory tasks were used this time, the method of loci and rote learning with each subject performing the three task combinations (memory/alone, memory/CSD, memory/FSD) on both memory tasks (method of loci and rote) and with both high and low imageability words. The results from this experiment showed that the CSD task again produced significantly more disruption on the imagery task than the FSD task but on this occasion the FSD task had itself proved a source of significant interference.

A final study that should be mentioned was carried out by Logie (1986) who attempted to develop a simple technique for the study of visuo-spatial processing based along the lines of the articulatory suppression technique. In each of his four experiments Logie employed the selective interference paradigm. The first experiment involved the matching of successively presented random matrix patterns, as a secondary visual suppression task. This was coupled with rote rehearsal or a visual imagery mnemonic for learning lists of concrete words presented auditorily and the results showed that the visual mnemonic was differentially affected. Experiment II involved the elimination of the decision part of this secondary task, with the patterns being presented but "not attended to". The use of the visual mnemonic was again found to be significantly affected. This result was replicated in a further experiment which involved presenting simpler plain coloured squares as the unattended material. The final experiment presented subjects with line drawings or lists of words presented visually, with or without unattended speech. This experiment showed that the unattended pictures disrupt use of a visual mnemonic, while unattended speech disrupts rote rehearsal. Taken as a whole these experiments show interference with a visual secondary task, a result which one would not have expected if the system is purely spatially based.

From this section and the previous one it is clear that there is strong evidence for both a spatial working memory system and a visual working memory system. While this is clear the relationship between these two components has yet to be examined.

4.5 COMPETITION FOR RESOURCES ARGUMENT

This chapter, in its reporting of the possible form the VSSP may take, has assumed that the results of the experiments reported here, and by others elsewhere (Rollins and Thibadeau, 1973; Salthouse, 1974; 1975) involving the selective interference phenomenon, support the existence of independent verbal and visuo-spatial information processing systems. It has also been suggested by Salthouse (1975) that there is an anatomical basis for such an argument in the distinction between the two cerebral hemispheres since many investigators (e.g., Gazzanga, 1970; Kimura, 1973; Newcombe, 1969) have reported that the right hemisphere is apparently specialised for processing spatial information, while the left is specialised for handling verbal information. Segal and her colleagues (Segal and Fuesella, 1969; Segal and Gordon, 1969) found a clear modality-specific effect in a series of experiments they carried out. However, there was also a generalised effect of mental imagery on perceptual similarity. They found that a subject's sensory sensitivity in a detection experiment is reduced when they maintain a mental image and that the reduction in detection is roughly twice as great when the signal and the mental image are in the same sensory modality. Thus, auditory imagery interferes more with the detection of auditory signals, but visual imagery interferes more with the detection of visual signals (Segal and Fuesella, 1970; 1971). The modality effect they found may be taken to support the idea present throughout this chapter, but it has been surmised (Bower, 1972) that it might merely reflect peripheral effects of mental imagery upon modality-specific attentional mechanisms.

The major alternative explanation to this separation of processing systems arises from the work of Phillips and his collaborators at Stirling who have examined the existing results from a different perspective. Phillips and Christie (1977a,b) have suggested that the conventional interpretation of Brooks (1967, 1968) can be faulted. Phillips and Christie (1977b) take as an example the finding that visualising is interfered with more by pointing than by speaking. If it were the case that verbalisation did not interfere at all with visualisation, then it would seem reasonable to conclude that they use separate resources. Phillips and Christie (1977b) argue against the usual interpretation of Brooks' findings, that visualization and perception compete for special purpose visual processing resources. They state that visualization requires general purpose resources, and the interference between visualization and perception might be due to competition for these resources. While Working Memory theorists would not deny the importance of a general resource system, nor the emphasis Phillips and Christie ascribe to details of the task itself (e.g., Mayes and Ralston, unpublished), they would undoubtedly question the limitation of their argument. How, for example, can a general purpose resources argument account for selective interference effects? It would appear that even if one specifies a general purpose system then in order to explain these effects one still needs separate subsystems specialised for dealing with verbal and visuo-spatial information. Interestingly, while Phillips and his collaborators (1977a,b, 1979, 1983) argue for general purpose resources, Barnard (1986) suggests that we should not assume a general purpose system. Rather, the functional capability of the total cognitive system to represent and retrieve information should be regarded as a product of the operating characteristics of individual subsystems, their constituent processes, and their potential interactions. It is clear that there are a number of alternative views currently expressed concerning STM and no doubt the debate will continue. However at present the Working Memory framework seems better adapted to explain the empirical evidence.

Before moving on to discuss and explore the second central issue stated in the Introduction, the evidence for another "visual" system should be mentioned. The relationship of this system to the VSSP is as yet unclear. The notion of this system has arisen from the work of Phillips and his colleagues. The paradigm they have developed stems originally from Schnore and Partington (1967) and subsequently employed in various forms by Yuille and Ternes (1975) among others (e.g., Phillips and Baddeley, 1971; Adamowicz and Hudson, 1978). Essentially it involves memory for sequences of matrix patterns where selected cells are randomly filled. Phillips and Christie (1977a) have shown a form of the standard serial position curve for visual recognition memory. They found that there was a pronounced recency effect here, but only for the last item. This effect was shown to be removed by interference through mental addition (Phillips and Christie, 1977b). Phillips and Christie (1977a and b) carried out several experiments which clearly indicate that "visualization", as they refer to it, cannot be attributed to sensory or LTM. They found that it is not subject to masking, that it has a duration of approximately 15 secs to sensory storage's 0.5 sec and that, whereas reaction time increases with pattern complexity in "visualization", large changes in pattern complexity cause no changes in reaction time with sensory memory. In comparing "visualization" and LTM there are also several major differences which indicate that "visualization" cannot be interpreted in terms of either activated LTM or enhanced accessibility to LTM. "Visualization" is limited in its capacity, its duration and it is subject to interference from mental arithmetic. In addition it has been shown that a reduction in presentation time has little or no effect. Long-Term Visual Memory on the other hand has an indefinitely large capacity with little deterioration. It is not affected by mental arithmetic but reducing presentation time does cause impairment (Phillips, 1983). Thus results obtained with this technique lend fairly clear support for the idea of a specifically short-term component of visual memory. However, as stated previously, it is at present uncertain whether this system should be thought of as being equivalent to the VSSP investigated by Baddeley and his associates. One possible difference as suggested by Hitch (1984), is that evidence for the VSSP is based on memory involving spatial relations, while Phillips' technique appears to focus on memory for visual pattern information. There may be functional differences between the maintenance of these conceptually distinguishable types of visuo-spatial information. At this stage it is too early to provide any conclusive comments on the relation between the VSSP and "visualization" and this is obviously a critical issue which requires further research. However, such an issue is beyond the scope of this thesis and, as such, only the VSSP will be investigated although it is accepted that the findings presented here may well be of interest to those "visualization" theorists.

4.6 CONCLUSION

In conclusion, then although alternatives have been put forward to explain the present evidence this chapter has emphasised the existence of a separate VSSP system within the Working Memory framework. It has been further suggested that this system has a heavy spatial base and that, either it incorporates a visual component, or that there is a parallel system for visual information. Attempts to characterise this code have suggested the part played by movement. The next chapter will examine the evidence leading to such a view and Chapter 6 will explore the issue further through four experiments.

CHAPTER 5 : THE ROLE OF MOVEMENT IN VISUO-SPATIAL MEMORY

CHAPTER 5. THE ROLE OF MOVEMENT IN VISUO-SPATIAL MEMORY

5.1 INITIAL SUPPORT FOR A MOVEMENT HYPOTHESIS

It was illustrated in Chapter 4 that the bulk of research into the VSSP has been directed towards exploring whether the code is spatial and/or visual. It would appear from the evidence that a spatial code is present when the material to be encoded is spatially distinct within the visual field. In attempting to specify further the characteristics of such a code many authors have made preliminary suggestions that movement has a role to play, either eye movements as suggested by Hebb (1968) or a more abstract "move process" whose relationship to physical movement is not clear (Lea, 1975). The idea that movement is important has a commonsense appeal when one considers reports given by people of imaging. For example, Allan Paivio (1971) reports that "Occasionally, when I have to list the names of my colleagues from memory, I have found myself visualising the hallways in which their offices are located systematically moving past these offices, then picturing and naming the occupants (p3)." A well-known example is a request for the reader to enumerate the windows in their house (Shepard, 1966; Neisser, 1968). Most people report that they have to imaginally move around the house, visualising and counting the windows. Meudell (1971) presents evidence that when people are asked this question response latency increases linearly with the number of windows counted. Berlyne (1965), as another example suggests that, if a person is asked to name the states of the U.S.A. in a line from California to New York City, he/she would most likely do it in stages by successively imagining areas in a West to East direction and that the "...stages will be linked to one another by processes that are clearly equivalent to the eye movements... which he/she would have used if they had been examining an actual map of the U.S.A. and reading off the names of the states from it" (p.142). In these examples there seems to be a distinction between generating images of things (colleagues, windows) and engaging in a spatial search, a dynamic activity (moving along a hallway or around a house) that links these spatially distinct items. Of course introspective reports can only provide tentative support for any mental functioning and it is also possible that even if such movement activity does take place it is merely an epiphenomenon.

5.2 HISTORICAL PERSPECTIVE

The idea that movement operates on/with spatial aspects of the memorized material has received intermittent attention in the experimental literature on imagery since as long ago as the late 1880s (e.g.,Stricker, 1882; Ladd,1892). More recently, Lorens and Darrow (1962) found eye movements to be a consistent occurrence during mental multiplication and attributed them to visual imagery, and Aserinsky and Kleitman (1955) observed rapid eye movements occurring in cyclic clusters during sleep in adults and believed them to be involved in visual imagery during day dreaming. In subsequent studies (Dement and Kleitman, 1957; and Dement and Wolpert, 1958), evidence was presented to support the hypothesis that the rapid eye movements correspond to where and at what the dreamer was looking, a finding confirmed by Brady and Rosner (1966). Additional evidence was supplied by Berger et al (1962), who found that blind subjects who had retained visual imagery ability showed rapid eye movements during dreaming, but blind subjects who had never had visual imagery did not show eye movements.

Taken together these initial studies designed to explore this issue do suggest some form of involvement of movement with imagery. The late 60s and early 70s saw an increase in the empirical research into this phenomenon in an attempt to generate more evidence and thus provide a more coherent picture of what is actually happening. For example, Hebb (1968) attempted to analyse imagery in physiological terms and from this he proposed that eye movements have an organising function, an idea similar to the active construction proposal put forward by Neisser (1967).

Further support for a movement hypothesis was shown by Hall (1974) who examined the relationship between eye fixation and spatial organisation in imagery. He manipulated eye fixations to produce external patterns appropriate or inappropriate to an internal scanning pattern involved in the spatially organised recall of a visual stimulus. Geometric shapes were presented one at a time at one of a number of different locations on a screen. Subjects were instructed either to fixate a central light during stimulus presentation or to look around as they wished. Subsequently subjects were asked to recall the shapes by name, according to which of them had appeared at each spatially consecutive location. If the subject had looked around previously they could do so during recall, and if the subject had fixated the central light during stimulus presentation then they had to fixate the light during recall. There was a significant effect of conditions (fixation vs scanning) on the number of items recalled and on the latency of recall, the scanning condition leading to better performance on both variables. This indicated that movement does have a role in imagery. Janssen (1976) states that the involvement of movement is dependent on the relative weights spatial and nonspatial components have in tasks. Thus, he says, one would expect that eye movements play a much larger role during imagery of a set of objects positioned at several locations in space, or during movement imagery, than in a relatively nonspatial type of imaging.

The evidence as shown above would appear to support the involvement of movement in imagery. It is apparent that particular reference should be made to the spatialness of an imagery task and whether the movement involved in any particular task is compatible or not with the to-be-memorized material. If movement does have a role to play in imagery what are the consequences for our conceptions of the VSSP.? When the material to be encoded is spatially distinct within the visual field, is movement at the base of the code? Is the type and form of movement important? At this point, and with these questions in mind, some of the work directly relating to the VSSP. will be examined to see if there is any supporting evidence concerning the involvement of movement.

5.3 MOVEMENT AND THE VSSP

Lee Brooks' 1968 study was one of the earliest attempts to go beyond a general movement hypothesis to a more specific examination of the involvement of movement in imagery. Within this group of experiments he carried out four pertaining to movement and spatial processing. Initially he found that when subjects are instructed to recall a line diagram they can more readily signal information about that diagram by speaking than by spatially monitoring output, a task which required the subject to point to correct items in a column of symbols. This greater difficulty was attributed to conflict between simultaneously recalling the diagram and monitoring the pointing. However, it is possible that the conflict was due to disruptive effects of movement, quite independently of any monitoring of the movement with respect to spatial locations of patterns. Another experiment was therefore designed to assess the hypothesis that spatially monitored movement can be particularly destructive of spatial recall. Two groups of subjects performed in this experiment, one on the diagram condition and the other on the sentence condition. Subjects in each group carried out three output conditions (a) No movement : instructions were given to make /s and Xs roughly on top of one another (b) Unmonitored movement : subjects were asked to place their marks one under the other to form a rough column. In both these conditions subjects were told not to look at the page while performing and not to worry about making a neat column (c) Monitored movement: Subjects were given 8.5x11 in. piece of paper with a set of 15 small boxes (0.5 in. side) evenly placed in an exact column down the page. Subjects were asked to work from top to bottom and to make sure that their marks at least started in the box. Varying the movement and guidance of movement during output did not affect verbal recall BUT had a strong effect on recalling diagrams. An effect due to movement per se exists when recalling diagrams, BUT it is minor compared to the effect of making movements to precise locations not arranged in the same pattern as the diagram to be recalled. Another experiment in Brooks' study ruled out the possibility that the results of these two movement experiments could be due to the over-all difficulty of the tasks. In the final experiment it was suggested that the conflict shown between recalling the diagram and making visually monitored movements does not justify assuming that both of these activities are being executed in a specifically "visual" system. It is quite possible that one would suffer comparable impairment from marking in a series of tactually monitored locations. Brooks suggests that if this is so, it may be more appropriate to refer to a spatial non-visual system. In this experiment subjects in both groups were asked to perform on both output conditions for each item. (a) Unmonitored movement (as before) (b) Tactually monitored movement: An 8.5x11 in. sheet of cardboard was placed in front of the subject. A regular vertical column of fourteen holes 0.5x0.5 in. had been cut in the sheet at 0.5 in intervals. Subjects were asked to proceed down the sheet, placing a / in the hole if it corresponded to a positive instance of the category, and X if negative. The subjects were told to close their eyes while performing, and to use one hand to locate each hole while the other was marking. Both sets of subjects took longer to complete tactually monitored than unmonitored responses. The difference, however, was larger for the diagrams than for the sentences. Tactual monitoring of output apparently provides particular difficulty when the subject is recalling diagrams. It is clear from the Brooks study that the recall of spatial information conflicts with spatially monitored output that involves movement.

Byrne (1974) investigated further the hypothesised dynamic component operating on imagery. He used an adaptation of the selective interference technique employed by Brooks (1968). The subjects were asked to memorise a list of words such as pig, trunk, dog, fire, wheat, child, bale, insect, ocean, tulip, and then, from memory to successively categorise each item for the presence or absence of a certain characteristic (e.g., does the word refer to an animal). They were given two ways of responding, saying "yes" or "no" for each item in turn, or pointing to a column of Ys and Ns printed on a card before them. If recall of the word list requires imagery then the visually guided pointing response should disrupt recall. From his results Byrne concludes that a visually guided response does seem to disrupt recall of a list of items learned under conditions regarded as likely to induce mediating imagery. He also feels that because the visual conflict is most in evidence when the items are spatially organised and seems largely independent of item concreteness, the presence or absence of spatial organisation is an important characteristic of stimulus material when it comes to predicting whether the material will be coded imaginally and needs to be considered separately from item concreteness. Byrne explains the conflict by suggesting that "the (motor) mechanism" underlying the use of the imagined, spatially distributed, information was also required in responding to the spatially distributed output sheet, with the covert and overt distributions having different directional characteristics. In other words, subjects may have had trouble thinking in one direction and directing movement in another, because both orienting responses used the same equipment. Such a view is supported by various unpublished experiments conducted by Byrne (reported in 1974, p59).

The story of a movement based spatial code involved in imagery has been taken up and explored further by Baddeley and his co-workers. As was reported earlier, Baddeley et al(1975) carried out three experiments investigating imagery and visual memory. Concurrent visual pursuit tracking was used to study two memory tasks involving spatial visualisation (Brooks, 1968 and 1967 respectively) and a third involving highly visualisable verbal material. The first two concern us here in that they found that a visuo-spatial task involving movement (pursuit rotor) is impaired by a concurrent visuo-spatial imagery task (F-type task), while little, if any, impairment is produced by a verbal processing task which Brooks (1968) has shown to be of roughly comparable difficulty, and that a visuo-spatial imagery task is subject to interference from a concurrent visuo-spatial movement task (again the pursuit rotor was employed). Further support for the role of movement came in the 1980 Baddeley and Lieberman study. In four of the five experiments carried out in their study, the effect of a concurrent visuo-spatial task on imagery was investigated. In the first experiment, this required the subject to perform an auditory tracking task that involved pointing to a moving sound source while blindfolded and concurrently carrying out the Brooks (1967) visuo-spatial imagery and nonsense tasks. The visuo-spatial task was more vulnerable to tracking and tracking itself was more vulnerable to the effect of the spatial task, ruling out a speed-error trade-off interpretation of the results. Baddeley and Lieberman extended this finding by carrying out three more experiments which involved examining the effect of the pursuit rotor on three types of imagery mnemonics : pegword, method of loci, and alphabet. Each of these mnemonics was interfered with by the concurrent movement task - the pursuit rotor.

These studies discussed above were all designed to investigate imagery and have provided information that suggests the system involved in spatial information has a strong movement component. Such a view is supported by Johnson (1982). Using an interference paradigm he demonstrated that arm movements and imagined arm movements were functionally equivalent. A more recent study by Idzikowski, Baddeley, Dimbleby and Park (unpublished) explored the role of movement further. In their first experiment Idzikowski et al tested to see whether involuntary eye movement could selectively interfere with an imagery task. The involuntary movement task involved a post-rotational nystagmus induced by spinning subjects in an electrically powered chair. It was felt that if eye movements themselves are involved in imagery then this would be expected selectively to disrupt performance on a memory task involving imagery, whilst having little or no effect on tasks employing mainly verbal coding. There was no trace of the interaction that would occur if the induction of involuntary eye movements interfered selectively with imagery. The results suggested that eye movements per se do not play any important intermediate role in imagery.

It was then suggested that perhaps the crucial aspect may be the control processes involved in movement which may share processing capacities with the formation, "scanning", and maintenance of images. This was tested by instructing subjects to watch a moving spot on a monitor : if a common processing capacity notion held one would expect the task to selectively disrupt an imagery task whilst having no significant effect on a verbal task. Subjects at another stage were prevented from making free eye movements by fixating a stationary object to see whether this caused selective disruption on imagery tasks performed concurrently with the processing of visuo-spatial information caused by changes in the visual field. The results showed a significant decrement in performance on the imagery but not the verbal task when carried out concurrently with voluntary eye movements. No such differential impairment was found when movements comparable to the movements of the retinal image during eye movement occurred in the visual field. In addition, having to hold the eyes stationary had no effect on performance when compared with a free eye movement condition.

The final experiment in this series examined further the involvement of the processes in imagery used to control voluntary eye movements. This involved exploring whether the importance of the eye movement control processes lay in the encoding or retrieval of the image. If selective disruption occurs for eye movement during presentation of the material, then this would suggest that the involvement is during the formation of imaginal information. Alternatively, if disruption only occurs when subjects move their eyes during recall of the material, one would stress the involvement of eye movement control processes in the retrieval or "scanning" of imagery. If the disruption occurs during both presentation and recall of the material then one would say that it is possibly the maintenance of imaginal information that involves eye movement control processes. A comparable outcome would be shown if the processes involved in the voluntary control of eye movements were also involved in both encoding and retrieval of imaginal information. An impairment of performance on the spatial task was shown for voluntary eye movements during both presentation and recall of the memory material. The decrement during recall was restricted to the spatial task and it was felt that a system involved in the control of voluntary eye movements must either share capacity with both the encoding of imaginal information and the retrieval or scanning of it, or with processing involved in the maintenance of the image.

To summarise Idzikowski et al's results, they suggested that performance on a task involving imagery is selectively impaired by having to control voluntary movements of the eyes. This impairment occurs when the eyes move during either presentation or recall of the memory material, but does not occur when involuntary eye movements of a similar magnitude are induced, when the eyes are held stationary, or when movements of similar magnitude to movements of the retinal image during eye movements occur in the visual field.

5.4 EYE MOVEMENT OR A MORE ABSTRACT PROCESS

The evidence from investigation into imagery and the role of movement shows that initial support for the involvement of a dynamic component came from studies employing eye movement. Not surprisingly then, it was thought at the outset that eye movement was at the root of the code, a view expressed by Hebb (1968), Janssen (1976) and Hall (1974), among others. However, the research into the VSSP in recent years appears to direct us away from a strict examination of this code in terms of eye movement, and to posit the idea that a more abstract process is implicated. Indeed just such a process has been suggested by Lea (1975). He carried out a series of experiments using chronometric analysis of the method of loci. Chronometric analysis has been successfully applied in the study of imagery by Shepard and his associates (Carpenter and Shepard, 1973; Shepard and Metzler, 1971). By measuring the time required for subjects to mentally rotate stimuli they were able to relate reaction time to the number of degrees of rotation. The important outcome of this research was an objective measurement of the speed of mental rotation. In the variant of the method of loci Lea used, people first associate a list of items with a well-known set of loci. During recall they are probed with a starting locus, scan a certain number of loci, and respond with either the locus or the associated item. Three general processes are hypothesised by Lea to underlie performance in the task:

1. FIND: Given the name of the starting locus (the probe), the subject must activate the representation of this locus before scanning can begin.

2. MOVE: The subject must mentally move from locus to locus, keeping track of the number of loci scanned. The MOVE process generates successive loci. This process is operated until the locus a desired number of places away from the probe is reached. Lea proposes that this MOVE process is the dynamic component which Byrne (1974) suggests operates on the spatial material of an imaginal representation.

3. RETRIEVE: The locus-item association (image) must be decoded and the name of the item retrieved.

Having suggested that a more abstract move process is involved it must be said that to date the evidence for such a system is not without problems. In all the experiments reported above which incorporated gross movements, eye movement was not monitored in any way. It could be that eye movement is solely involved in these tasks and in the system itself and that arm movement, used in these experiments per se has no functional role. There is, then, still a need to clarify whether when movement is involved in imagery it is limited to eye movement. A major problem in delineating the role of movement in the past has been that movement per se and the subjects' attention to that movement are difficult to disentangle. For example, Idzikowski et al (unpublished) admit that the interference they found may not be due to directing the eyes but to directing attention and as such any conclusions from their results should, they say, be tempered with caution. This "attention" problem can be seen in other studies in this area, an example being the interference Byrne (1974) found due to directing one's attention to the response sheet containing the Y and N symbols. The pursuit rotor used in a number of studies (e.g.; Baddeley and Lieberman, 1980) is also subject to this problem, for again it may not be the movement per se, but the directing of attention to the movement requested. In the experiments carried out thus far the directing of movement and the directing of attention are confounded.

In the light of these comments, the following experiments have two aims. First, they were designed to examine whether the movement involved in spatial encoding is limited to eye movement or whether arm movements are relevant. Second, they were designed to produce a plausible separation of movement and attention. While the work of Posner and his associates (Posner et al, 1980) suggests that an experimental technique may be developed which will allow effective separation of these components when movement of the eyes are being considered, it is arguably easier to deal with the problem when employing gross arm movements.

CHAPTER 6 : INVESTIGATING THE ROLE OF MOVEMENT IN THE VSSP

CHAPTER 6. INVESTIGATING THE ROLE OF MOVEMENT IN THE VSSP

6.1 EXPERIMENT 1 - "ARM MOVEMENT"

6.1.1 INTRODUCTION

The evidence presented in the previous chapter provides strong support for the idea that movement has a role to play in visuo-spatial short-term memory. If this dynamic component (Byrne, 1974) involved in spatial coding is not the exclusive property of eye movement, but is a component of a more abstract mechanism such as the "MOVE" process posited by Lea (1975), it should be possible to demonstrate a fall in performance in the recall of spatially distinct items when it is accompanied by incompatible movement of various sorts during presentation. It is hypothesised, then, that incompatible arm movements during presentation will disrupt recall in circumstances similar to those where a fall in performance is associated with incompatible eye movements (e.g., Idzikowski et al, unpublished).

6.1.2 METHOD

DESIGN

The design adopted for this series of experiments is based on the Brooks (1967) task described earlier, which has found widespread use in investigations into the field of mental imagery (e.g, Baddeley et al, 1975; Beech, 1984). To recap, in this task subjects are presented with a series of verbal messages which relate the locations of the digits which the subjects are instructed to image within a mental matrix. In this first experiment there were two variables. The first, termed the matrix variable (the between subjects variable), required one group of subjects to recall the series of digits by writing them down in the correct formation on blank pages of a booklet. The other group had a matrix drawn on each page of the booklet and simply had to enter the digits into the matrix. The presence of the matrix was manipulated for methodological reasons. Errors in digit formation could be due to subjects going "off-matrix", so having the matrix present during the response period should ensure that that type of error, if common, is detected and performance improved. The second variable was called the "movement" variable and it involved four conditions, each of which is described in the procedure section.

SUBJECTS

24 right-handed undergraduates served as subjects in this experiment with each subject being tested individually.

MATERIALS

The materials in this experiment comprised : two response booklets; a sheet with 36 sets of nine sentences; a stop watch; a fixation point and a 5x5 "movement" (table) matrix with accompanying hood.

Each subject was given two booklets, one of 12 pages used in the practice trials and one of 24 pages used in the test trials. Half of the subjects had blank pages and half had a 5x5 matrix drawn on each page, each cell in the matrix measuring 0.5 sq in.

Each of the 36 sentence sets started with the sentence: "In the starting square put a one". From there it progressed: "In the next square to the right (left,up,down) put a two", and continued with sentences designating adjacent squares and using the digits 3-9 in ascending numerical order. All the squares designated were within a 5x5 matrix and within this there were never more than three squares sequentially designated within one row or column. Apart from these constraints the designation of the squares was random. The reader will note that, unlike previous researchers who have employed the Brooks (1967) task, the subjects receive 9 digits here, not 7, and they were instructed to image a 5x5 matrix rather than a 4x4. During pilot work for this experiment 7 digits were employed and a 4x4 matrix, but subjects performance was at 100% correct. Increasing the digit number to 8 made no difference since this generally meant that having received 7 digits, the 8th's location could be predicted because there was only one option left. This led to the decision to expand the matrix to 5x5 which meant there were a greater number of alternatives for the "next square". When this was done subjects still managed 100% recall levels with 8 digits. However, increasing the digit load to 9 combined with the 5x5, matrix led to the optimum presentation level. The stop watch was used to time the presentation of the sentences and a fixation point was present throughout the experiment, placed approximately four feet in front of the subject.

A 5x5 "movement" matrix made from masking tape was attached to the right hand half of a table 4ft by 2.5ft. The squares of the matrix were 2.5sq in and the tape was 1in wide. This "movement" matrix was covered with a hood which allowed the subject freedom of movement around the matrix but eliminated any visual contact with it. The hood was open at one end to allow the experimenter to monitor the subjects' movement ensuring that the correct procedure was being followed.

PROCEDURE

The subjects were seated at the left hand half of the table and the experimenter then presented them with their instructions. The Brooks type task was examined first. Subjects were told they were going to hear so many sets of sentences of the sort "In the starting square put a 1, in the next square to the...... put a 2" etc, and they were shown how the sentences related to the table matrix. The starting square, they were told, was always the second square of the second row. Subjects were told that they had to listen to the sentences under the four movement conditions while they continually kept their eyes on the fixation point. They had to endeavour to build up a visual image of the digits-in- position so that they could write the digits in the appropriate formation. During recall no time limit was put on the response period, nor were any instructions given about the order of recall.

The four movement conditions were as follows:

1. NO MOVEMENT. In this condition subjects were instructed to keep their hands still in front of them.

2. COMPATIBLE MOVEMENT. Here subjects were told to begin by placing their right hand in the starting square of the table matrix. They then, while visualising the mental matrix with its accompanying

digits, had to trace out the pattern designated by the sentences. It was emphasised that the movements had to be from square to adjacent square and always in time with the presentation of the sentences.

3. INCOMPATIBLE MOVEMENT. In this condition subjects were again instructed to visualise as above and to place their hand in the starting square but to move the three squares to the right which would take them to the end square in that row, go down to the square below and to move left through the squares until they arrive at the left end square of the row. Again it was stressed that all movements had to be in time with sentence presentation so that the subject had to reach the left end square as the ninth sentence was presented. This movement was selected because of its straight-forward nature and ease of learning, which it was believed would reduce the attentional capacity required.

4. TAPPING MOVEMENT. A form of control movement that was neutral in compatibility was sought. It was felt that a condition which required subjects to tap in the starting square at a rate of once per sentence presentation would be ideal.

Before each movement condition the hood was removed from the "movement" matrix to allow the subject to place their hand in the starting square. The hood was then replaced, allowing the experimenter who was seated at the opposite side of the table, to monitor the hand movement while making it impossible for the subject to employ vision to aid the movement. Each set of nine sentences was presented verbally by the experimenter in 36 secs with the subject responding immediately after the presentation of the last sentence.

There were 24 test trials made up of four blocks of six trials under each of the four movement conditions. To ensure that each block appeared equally often in each serial position the four blocks were presented according to a Latin square design. The 24 sentence sets appeared an equal number of times under each movement condition, ensuring that any peculiarities of a particular sentence set were not assocated with a particular movement condition. The 12 practice trials were presented in four blocks of three sentences. They were presented at the beginning of the session, with the blocks being given in the same order as the experimental trials. The practice sets helped the subjects become familiar with the general design and also made certain that they learned to move appropriately through the table matrix using the tape boundaries for guidance. At several points during the experiment it was again stressed how important it was to fixate and to move in time with sentence presentation.

6.1.3 RESULTS

The subjects' responses were scored by giving one point for each digit written in the appropriate relative position. These scores were then analysed using a 2(response matrix presence) x 4(movement condition) anova with subjects nested within matrix condition. There was a significant main effect of movement ($F(3,66)=5.4, p=0.002$) and a significant interaction between movement and matrix presence ($F(3,66)=3.54, p=0.019$). Table 6.1 shows the main effect of movement. Newman-Keuls tests show that the incompatible condition is different from all others and that there are no other significant differences ($p<0.05$ in all cases).

The interaction between movement and matrix presence is illustrated in Figure 6.1. Here the matrix present incompatible condition differs from others : the absent tapping; present compatible; and both present and absent control (Newman-Keuls, $p<0.05$ in all cases).

Control	43.42	(7.62)
Tapping	40.75	(8.83)
Compatible	40.83	(8.05)
Incompatible	35.13	(11.96)

TABLE 6.1. Mean number correct under the four movement conditions.

Note : Standard deviations are shown in parentheses.
Perfect score = 54.

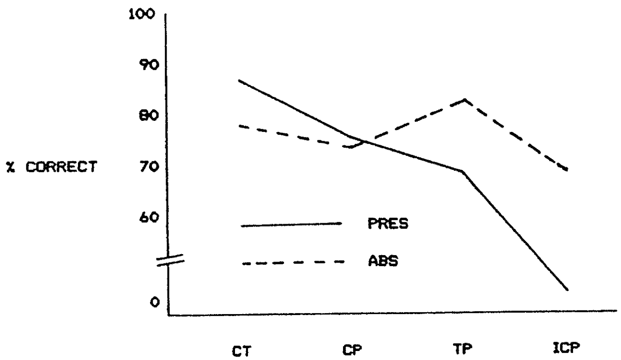

FIGURE 6.1. The interaction between the four movement conditions and the matrix presence conditions in Experiment 1. CT=Control; CP=Compatible; ICP=Incompatible; ABS=Matrix absent during the response; PRES=Matrix present during the response.

6.1.4 DISCUSSION

The Newman-Keuls tests have supported the hypothesis stated in the Introduction in that they indicate that incompatible movement alone causes a significant drop in performance. These results support the interpretations suggested earlier of the work of Idzikowski et al (1983) who it was suggested had shown that eye movements incompatible with directions indicated by sentences interfere with memory performance. The lack of external movement, movement that is compatible with the sentences or movement such as tapping which it is accepted may be trivial in amount, has no significant effect on performance. However, caution is required when discussing the effect of movement, as can be seen from the movement x matrix presence interaction. The fact that there was no main effect of the matrix presence condition and no apparent theoretical background with which to interpret the interaction makes it difficult to explain this result fully. Nevertheless, Figure 6.1 illustrates that the incompatible condition is significantly worse than the other movement conditions, largely because of the particularly poor performance when the response matrix is present. When the response matrix is absent, the incompatible condition is non-significantly poorer than the other movement conditons. There appears to be a lack of any sufficiently stringent theoretical framework with which to interpret this interaction, a fact which lies very heavily on this study since it questions the strength of the main effect of movement, which is the central thrust of the present series of experiments. It is therefore necessary to test the reliability of the effect of movement. Under the present circumstances this can best be achieved by excluding the response matrix variable in the next experiments, and, as such, the subjects only receive blank response booklets. By eliminating the condition where the effect of movement was previously shown to be at its strongest the odds are being weighed heavily against finding such an effect, if the response matrix variable is crucial. As a result of this alteration it is believed that the main effect of movement can be more stringently tested.

At present two plausible interpretations can be put forward to explain this main effect of movement. On the one hand, incompatible movement may establish an internal representation which interferes with the code established by the requirement of imaging the sentence instructions, on the other hand it is possible that attention has to be shared between the two tasks to a degree not present in the other movement conditions. In the compatible condition, the sentences determine both the correct recall location and the correct arm movement, whereas in the incompatible condition the sentences do not determine the arm movements. As was emphasised earlier, it is important that we move towards an empirical separation of attention and movement. Experiments 2 and 3 were therefore formulated to limit the attentional component in subjects' performance. It was felt that with less attention required to perform the tasks a more accurate assessment of the effects of movement per se should be possible.

6.2 EXPERIMENT 2 -"PRACTICE AND ATTENTION"

6.2.1 INTRODUCTION

Experiment 2 manipulated the amount of attention required by the movement tasks by varying the number of practice trials. It has been suggested (Spelke, Hirst and Neisser, 1976) that one of the key phenomena within dual-task experiments is the dramatic impact that practice typically has on performance. While there are several possible explanations of this phenomenon, the consensual view is that, as a result of lengthy practice, some processing activities cease to make substantial demands on central capacity or attention; they become increasingly automatic (Mackworth, 1970). This idea has been extensively explored by Schneider and Shiffrin (Schneider and Shiffrin, 1977; Shiffrin and Schneider, 1977) and supported by the work of Poltrock, Lansman and Hunt (1982) and Logan (1979). In the previous experiment it was noticeable that the arm movements in the incompatible movement condition were more cautious than in the other movement conditions. This caution suggested that more attentional capacity was required and thus it was considered that increasing the number of practice trials would be particularly helpful in this condition.

6.2.2 METHOD

DESIGN

The design of this experiment was similar to that employed in Experiment 1 with the following alterations : as the tapping movement provided no insights over and above the control and compatible movement conditions, it was eliminated, leaving three conditions; in the previous experiment all practice trials were presented en masse before the test trials began. In order to minimise any forgetting of the type of movement required as a possible result of such a procedure, each set of practice trials now immediately preceded the appropriate test trials. And finally, for the reasons mentioned earlier, subjects were presented with only blank response booklets.

The 18 sets of 9 sentences were formulated using the same procedure as in experiment 1. These sets were put into three blocks of six sentences with each block appearing equally often in each serial position and all 18 sets appearing an equal number of times under each movement condition. The number of practice trials varied between subjects : 12 subjects received nine practice trials and 12 received three practice trials immediately before the appropriate movement condition. The practice sets were constructed using procedures identical to those used with the test sentences.

SUBJECTS

24 right-handed undergraduates served as subjects in this experiment, none of whom had taken part in Experiment 1.

PROCEDURE

With the exception of the changes mentioned above the procedure in this experiment followed that of Experiment 1.

6.2.3 RESULTS

Subjects' responses were scored in the same manner as that used in Experiment 1, with the scores analysed using a 2(practice conditions) x 3(movement conditions) anova with subjects nested within practice conditions. The only significant effect was the main effect of movement ($F(2,44)=6.836, p=0.0045$). There was no other main effect and no interaction approached significance. The effects of movement is shown in Table 6.2 and Newman-Keuls tests confirmed the results of Experiment 1. The incompatible movement condition differs from the other two ($p<0.05$) which did not differ significantly from each other.

Control	42.96	(7.12)
Compatible	40.10	(5.94)
Incompatible	37.00	(10.42)

TABLE 6.2. Mean number correct under the three movement conditions.

Note : Standard deviations are shown in parentheses. Perfect score = 54.

6.2.4 DISCUSSION

The results of this experiment confirm those of Experiment 1 in that there was a main effect of movement, thus allaying any fears concerning the significance of the matrix presence variable. But what of the possible confounding of movement and attention? In an attempt to curtail the possible attentional factor as a major component in the performance deficit caused by the incompatible movement in Experiment 1, it was proposed, following the work of Shiffrin and Schneider (1977,1977) and others (Poltrock et al. 1982; Logan,1979), that the increase in practice trials and the positioning of these trials immediately before the corresponding test trials would significantly reduce the attentional component. This was thought especially likely in the simple forward and backward incompatible movement condition. This reduction in the attentional demands of the task would allow a more accurate assessment of movement per se. The failure of the increase in the number of practice trials to cause any significant difference to the movement results could suggest that attention did not cause the decrement in the recall under the incompatible condition. However, one difficulty with this interpretation is that it is based on essentially negative results. Without any statistical effects of practice, it is possible that its variation did not have the desired effect and that the demands of attention remained the same under both practice conditions. For example, it could be the case that under the three practice trial conditions the subjects counted the movement along the squares of the table matrix, a possibility previously voiced by Laabs (1975). Given this possibility, it cannot be argued with sufficient certainty that an increase in practice would change this strategy. Consequently, Experiment 3 was designed involving a technique which it was thought would more dramatically alter the attentional component of the movement.

6.3 EXPERIMENT 3 - "ACTIVE/PASSIVE"

6.3.1 INTRODUCTION

Within the field of motor short-term memory strong support has been generated for the notion that the reproduction of kinaesthetic extent information is very poor. Although this has been disputed

(Keele and Ells, 1972) the bulk of the evidence does favour such a view, as shown by Posner (1967) and others (Williams, Beaver, Spence and Rundell, 1969; Marteniuk and Roy, 1972; and Laabs, 1973). These authors interpreted their results as showing that extent information does not gain access to central processing capacity (Diewart, 1975), a term synonymous with attention (Posner and Konick, 1966; Posner, 1967). While it remains true that attention is used during the production of movement, it is possible that its contribution is especially weak if movement is passive. Marteniuk and Roy (1972), in their study of the codability of kinaesthetic location and distance information, provide evidence that little or no central capacity is involved with passive movement. Experiment 3, in an attempt to reduce - and plausibly abolish - the contribution of attention to the performance decrement, employs the technique of passive movement. The hypothesis behind this states that if the drop in performance is a result of movement per se then a continued drop in incompatible movement should take place, whether the movement involved is active or passive.

6.3.2 METHOD

DESIGN

There were two variables in this within-subject experiment. The first variable was called the movement variable and comprised of the compatible and incompatible movements. The second variable, termed the activity variable, was also made up of two conditions, active and passive. These are described fully in the procedure section.

SUBJECTS

24 right-handed undergraduates served in this experiment none of whom had taken part in the previous experiments.

MATERIALS

The materials employed in this experiment were similar to those used in the previous experiments. The same 36 sets of nine sentences used in Experiment 1 were employed. However, since the practice sets for each of the four movement conditions immediately preceded the corresponding test condition the 24 test sets and 12 practice sets were distributed differently. The fixation point and the covered matrix were as before.

PROCEDURE

The four movement conditions used were as follows : Compatible and incompatible active movement which were the same as those used in Experiments 1 and 2; compatible and incompatible passive movement similar to the active movement conditions. The difference concerned movement in that here the subjects did not move their own hands over the table matrix. Instead they were asked to relax their hands and to allow the Experimenter to hold their right hand. The Experimenter would then move their hand from location to location in the direction required by the sentences in the compatible condition and in the right then left direction required by the incompatible movement condition.

Apart from the changes consequent upon the changes in the movement conditions, the instructions to subjects were the same as in Experiment 2. The 24 test sentences were made up of blocks of six sentences under each of the four combinations of activity (2) and movement (2) conditions. The four blocks were presented as in Experiment 1, according to a Latin square design with the 24 sentence sets appearing an equal number of times under each of the four conditions. Following the procedure in Experiment 2, the three practice trials associated with each condition immediately preceded the appropriate condition.

6.3.3 RESULTS

Subjects' responses were scored by adopting the procedure employed in Experiments 1 and 2. The results were analysed using a 2(movement) x 2(active) x 24(subjects) within-subject anova. The only significant effect was the main effect of movement ($F(1,23)=6.8266, p=0.015$). Table 6.3 shows clearly that incompatible movement whether active or passive, leads to a fall in performance.

	ACTIVE	PASSIVE
Compatible	41.25 (9.98)	42.21 (8.56)
Incompatible	38.75 (10.82)	37.13 (13.22)

TABLE 6.3. Mean number correct under the four combinations of movement conditions and active or passive movement.

Note : Standard deviations are shown in parentheses.
Perfect score = 54.

6.3.4 DISCUSSION

From this series of experiments it is clear that arm movements, like eye movements, can cause disruption in the recall of spatial materials if the arms are moved simultaneously with, and are incompatible with, the spatial material. The importance of movement in spatial encoding as viewed by Hebb (1968) among others (Idzikowski et al, 1983; Johnson, 1982) has been substantiated. It is also clear from the results that the characteristics of spatial encoding may be profitably investigated using large scale arm movements which are likely to be more empirically tractable than small scale movements of the eyes. The results indicate that either eye movements or arm movements separately affect the code or that interference is caused by a more abstract process that is involved in both arm and eye movement.

The results of Experiments 2 and 3 indicate that central control of arm movements is not necessary to cause disruption of the spatial code and that disruption can be caused by peripheral mechanisms. This result appears to clash with the results of Idzikowski et al (1983), who found that only when the movement of the eyes was under voluntary control was there disruption of the spatial code. When the movement was involuntary, recall was not affected. It was suggested that this indicates that imaginal information processing shares processing capacity with voluntary eye movements. Two points must be stressed before the results are viewed as conflicting. It was stated earlier that eye and arm movement may separately affect the code and that involuntary movement of the eyes, as induced by post-rotational nystagmus (Idzikowski et al, 1983), may not be an appropriate analogue of passive movement. Since the arms were being moved in a set direction in time with the presentation of the sentences and since these aspects of movement are not present in post-rotational nystagmus, it remains a critical issue as to whether these differences are of significance.

In conclusion, this series of experiments has confirmed that movement has a role to play in spatial encoding and has specifically demonstrated that arm movements which are incompatible with the spatial recall can cause disruption. In addition, it has been shown that when attention is minimised, there is no significant reduction in disruption. To fully rule out the possibility of subjects "assisting" the experimenter in the passive condition future experiments could include the verbal control, or nonsense condition as used by Baddeley and Lieberman (1980).

6.4 EXPERIMENT 4 - "INVESTIGATING COMPATIBLE MOVEMENT"

6.4.1 INTRODUCTION

Experiments 1,2 and 3 in this study have confirmed that movement has a role to play in spatial encoding and have specifically demonstrated that arm movements which are incompatible with spatial recall can cause disruption. This would seem to indicate that spatial memory and movement must share a common representation. It is interesting to note, however, that no effect of compatible movement was found. If movement acts as some form of memory aid, as has been suggested by Hebb (1949,1968) and Neisser (1967) among others (Janssen, 1976; Lea, 1975), one may have expected compatible movement to show an increase in performance above simply fixating. Hall (1974) found evidence to support such an expected result. He showed that when subjects were allowed to scan in recall as they had done during presentation, performance for memory of geometric shapes and their locations was superior in conditions under which they had to fixate in presentation and recall. As the research stands at the moment there are felt to be three possible reasons why no improvement was found in the previous experiments in this thesis.

Firstly, if as Hebb (1949, 1968) and Neisser (1967) maintain, movement aids image construction, then an improvement in performance may only occur when the image to be remembered is complex. When the image is a simple path format then imagery alone may be sufficient and compatible movement may be redundant. This is thought to be somewhat unlikely in the present context, since subjects' performances were at such a level as to suggest the task although not complex, was far from easy.

Another suggestion concerns what has been termed the possible qualitative difference in the internal representation. In Experiments 1,2 and 3 there was no difference in recall for the compatible and control conditions, suggesting that movement was not an aid to memory. However, although in its original experimental form this may be the case, there may still be a qualitative difference in the representation that does not show up with immediate recall. If there is this qualitative difference favouring the compatible movement condition one way it may show up is with delayed recall. More specifically, it is felt that compatible movement may substantiate the image, making it more durable and possibly more resistant to interference.

The third possibility, and the one to be examined here, concerns the form of recall required of the subjects. In the previous experiments subjects were instructed to write down the numbers in the appropriate spatial relationship at recall. It may be that asking subjects to employ movement during recall, that is a reconstruction form of testing rather than written recall, would lead to improved recall.

The following experiment is designed to extend the evidence from the previous three experiments for a movement component by investigating compatible movement and the effects that recall formats have on its role in imagery. More specifically, it is hypothesised that when subjects are asked to produce the movement path, performance will show a significant improvement over the written recall used in Experiments 1,2 and 3. If this is the case, then it is consistent with the suggestion that movement is involved in the retrieval or "scanning" of imaginal information. If movement was solely involved in the encoding or formation of the image, then performance would have been affected only when movement occurs during presentation of the material. It could be that the maintenance of the imaginal information involves movement in which case performance could be affected when movement occurs during presentation and recall of the material. A similar result would be expected if the processes involved in movement were also involved in both encoding and retrieval of imaginal information.

6.4.2 METHOD

DESIGN

This experiment is a repeated measures design. The first variable, the Presentation variable, required subjects in one condition to move around the spatial path with their hand while imaging the numbers in the visualised matrix and in the other condition subjects were required to keep their hands still in front of them while they carried out the visualising task. The second variable was known as the Recall variable. In one condition subjects were instructed to move their hand in the same sequence as they had visualised while saying the digits out loud. The other condition required subjects to write down the digits as a spatial sequence in the response booklets provided, again saying the digits out loud.

SUBJECTS

24 undergraduate students acted as subjects in this experiment with each subject being tested individually.

MATERIALS

The materials in this experiment consisted of a sheet of 36 sets of 7 sentences; a blank response booklet which was only used for "No movement"; a stop watch used to time the presentation of the sentences; and a 5x5 table matrix with accompanying hood as used in the previous experiments. Several changes took place. A pilot study showed that using 9 digits presented constantly in the order 1,2,3,...9 resulted in subject performance of 100% correct. Thus it was decided to increase the difficulty level by randomising the order of presentation of the digits and reducing the number to 7.

PROCEDURE

Subjects were run individually and were seated at the left hand half of the table and they were shown the movement matrix. The subjects were told they would hear so many sets of sentences of the sort "In the starting square put a 5,in the next square up put a 3..."etc and were shown how the sentence related to the movement matrix. The starting square was always the second square from the left of the second row. The subjects were instructed to listen to the sentences and to attempt to build up a visual image of the digits in position while fixating on a point on the wall, so that they could write the digits down in the appropriate formation in the booklet in one condition and retrace the path in the other. Each set of seven sentences was presented verbally by the experimenter at a rate of one sentence per 4 seconds, with the subject responding immediately after the presentation of the last sentence. The 24 test trials were split into 6 movement presentation/6 movement recall(M/M), 6 movement presentation/6 written recall(M/W), 6 no movement presentation/6 movement recall(N/M), and 6 no movement presentation/6 written recall(N/W). The 12 practice trials were also presented before each condition, in blocks of 3 sentence sets. In addition to familiarising the subjects with the general experimental design, the practice sets ensured that they learned to move appropriately through the table matrix using the tape boundaries to guide them from square to square. Periodically throughout the experiment subjects were reminded of the imagery instructions, of the fixation point and also, when necessary, to move in time with the sentence presentation.

6.4.3 RESULTS

One point was awarded for each digit reported in the appropriate relative position. These scores were analysed using a 2(Presentation) x 2(Recall) within-subject anova. There was no significant main effect of presentation ($F(1,23)=0.2780, p=0.6030$) but there was a significant main effect of recall ($F(1,23)=13.2, p=0.0014$) and a significant interaction between the presentation and recall variables ($F(1,23)=11.2534, p=0.0027$). The main effect of recall indicated that recall involving movement results in superior performance to written recall (means of 27.16 vs 26.16 and standard deviations [SDs] of 7.92 vs 8.07).

The interaction as illustrated in Figure 6.2 showed that movement at recall only leads to better performance than written recall when it is accompanied by movement at presentation. The results of the Newman-Keuls ($p<0.05$) indicated that M/M differs from all others with no other significant differences.

6.4.4 DISCUSSION

The results of this experiment confirm the hypothesis that instructing subjects to adopt a movement reconstruction form of recall leads to an increase in performance, providing movement was employed in presentation of imagery material. A similar finding was previously reported by Hall (1974) who showed that when subjects were allowed to move in recall as they had done during presentation their performance levels were higher than those subjects instructed to fixate both at presentation and recall.

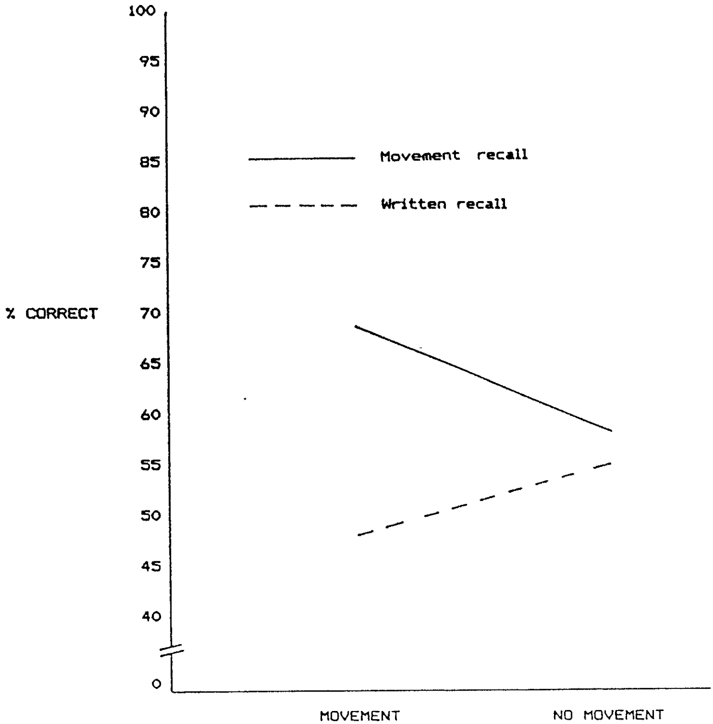

Figure 6.2. The interaction between the Presentation variable and the Recall variable.

Supplying a plausible explanation for these results involves adopting the reasoning of Idzikowski et al (1983). If movement had affected performance on the Brooks (1968) task only when subjects moved during recall of the material, then this would have suggested that movement is involved in the retrieval or "scanning" of imagined information. Conversely, if performance is affected only when movement occurs during presentation of the material, then this would suggest that the involvement is during encoding or formation of the image. If maintenance of the image information involves movement, then performance could be affected when movement occurs during presentation and recall of the material. A similar result would be expected if the processes involved in movement were also involved in both encoding and retrieval of imagery information.

The Results section clearly illustrates that performance is only subject to improvement when movement at presentation and movement at recall are combined. It would appear, from what had been said above, that since performance is affected when movement occurs during presentation and recall, then movement is involved in the maintenance of the imagery information and/or both encoding and retrieval of imagery information.

Another possibility should be mentioned and that is congruency. The superior performance found here when movement is employed at presentation and recall could be due not to movement per se, but to the congruency of presentation and recall (e.g., Encoding specificity hypothesis, Tulving and Thomson, 1973). That is, one may always generate an improvement in performance when the subjects do similar tasks at presentation and recall. Although this is possible it seems unlikely in the light of the evidence previously mentioned relating to work by Hall (1974). In his experiment he found that when subjects were allowed to move during recall as they had done during presentation then performance was better than if the subjects had made no movement during presentation and recall.

6.5 CONCLUSION

This and the previous chapter have endeavoured to investigate one of the questions currently generating considerable interest in the VSSP, namely does movement have a role to play in this system? The series of experiments presented here confirmed that movement has a role to play in spatial coding and has, further, specifically demonstrated that arm movements which are incompatible with the presentation of spatial material can cause disruption. In addition, it has been shown that when attention is minimised, there is no significant reduction in disruption. It is also clear that when movement identical to that involved in presentation is encouraged at recall subjects show marked improvement in performance. Together these results strongly suggest that movement should be given prominent reference in the definition of spatial coding and in the description of the properties of the VSSP.

CHAPTER 7 : FURTHER EXPLORATION OF THE NATURE OF THE INTERNAL CODE IN VISUAL WORKING MEMORY

CHAPTER 7. FURTHER EXPLORATION OF THE NATURE OF THE INTERNAL CODE IN VISUAL WORKING MEMORY.

7.1 INTRODUCTION

At the beginning of chapter 4 it was stated that within the visuo-spatial system of the Working Memory framework there are three central issues that are under investigation. The first is whether the system is spatially or visually based. While it was demonstrated that there was a considerable spatial component to this system, the possibility that there may also be a visual component was not ruled out. Chapters 5 and 6 both addressed themselves to the second issue, which was concerned with whether movement has a role in this system. The conclusion reached was that movement DOES have a role to play, but that the specific details have still to be clarified. This chapter and the two that follow address themselves to the third major issue : how information is stored within this system. More specifically, whether information is encoded sequentially (temporally).

This chapter intends to demonstrate through a review of the relevant literature the current view of the part played by a sequential element within the system. It will be shown that while there are many situations where sequentiality is a dominating characteristic of the system, there are others where its influence is less obvious.

7.2 THE STORY SO FAR

While the majority of work on the VSSP has been concerned with the visuo-spatial distinction, such an emphasis has not been without its critics. It is possible that this distinction oversimplifies matters.

Mayes and Ralston (unpublished) take up this point in their study, (described in Section 4.4), stating that the visual-spatial distinction is only one topic of several that one might wish to explore. Their two secondary tasks known as the Colour Sequence Discrimination (CSD) and the Finger Sequence Discrimination tasks (FSD), which corresponded to a visual non-spatial task and a spatial non-visual task, may involve the perception of a temporal pattern. The possibility arises then, that whether the elements of the pattern are themselves coded as events with a spatial or visual identity may not be a consideration that would wholly determine which part of the Working Memory system would be called into operation. Coding of a sequence here involves the storage of information over time. The fact that the FSD task did not significantly disrupt the concurrent performance of the apparently spatially-based matrix recall task, but did interfere significantly with the loci mnemonic, which they argued had a smaller spatial component, led them to conclude that the temporal or sequential nature of the coding may be the most important factor. It may be that the requirement to remember a particular order of "visiting" the loci is the source of the interference. While it is possible to envisage a slave system specialised for the maintenance of temporal patterns and indifferent to other aspects of the code, it is possible to reduce the contrast between Mayes and Ralston's results and those of Baddeley and Lieberman (1980) by extending the meaning of the term "spatial" to embrace time as well as space. The relationship between the maintenance of a static image and the maintenance of a sequence of such images is far from clear at present. Yet the way in which sequences of images are maintained can be as important for the process of comprehending the meaning of events as is the way in which sequences of words are held in comprehension of speech. Once temporal or sequential coding is involved, then it may be that any secondary task also involving such coding will disrupt memory for a series of images regardless of its visuo-spatial characteristics.

The idea that the spatial code has something in common with a sequential code is not an idea unique to the study by Mayes and Ralston. As far back as 1976 Quinn argued that the early work interpreted in terms of a visual representation should be reinterpreted in terms of a spatial/sequential representation. Quinn (1976) carried out a study designed to investigate the cognitive processes involved when subjects are instructed to visualise digits within a spatial framework using the Brooks technique. The crucial point to note from Quinn's study is that it indicates the presence of a sequential component in coding by showing that recall order which does not reflect the input order leads to a decrement in performance. From this he argues that the internal representation is closely linked to the sequence of input and is heavily disrupted if recall order is different from the initial encoding sequence. This would suggest that the internal code is not structurally analogous to the external stimulus. If it was, then input order would not be important and subjects would be able to read off the image in any order requested. Quinn (1976) also postulated the involvement of motor processes underlying the spatio-temporal code.

The previous chapter as has been noted above, illustrated the strong possibility of a movement component of some description being involved in the VSSP. Since movement is by its very nature sequential these experiments support the view of Mayes and Ralston and Quinn (1976) that visual short-term memory comprises a strong temporal element. However, it is possible that such evidence as generated from these experiments may not have been the result of a sequential component but may in fact have been an artefact of memory materials and their presentation format. The series of experiments in the following two chapters are designed to explore this further, but before that a review of the central themes in the literature to date will be undertaken. This review will illustrate that while the evidence for a sequential component is undoubtedly strong there are many situations which show that it is not a cut and dried issue.

Research into the nature of coding in visual STM has often argued for the presence of a sequential component. For example, Murdock (1969) set out to explore the modality effects as a function of temporal and spatial distribution of information. His earlier work (1966; 1967; 1968) had indicated that when comparing memory for materials presented auditorily or visually, auditory presentation consistently resulted in higher performance. He then set out to investigate whether STM had some inherent sequential component that would be advantageous to auditory presentation which, by its very nature, is sequential. He decided to provide both a spatial and temporal distribution which could be used either for auditory or visual presentation. A double classification scheme was employed; a given item was specified in one of two ways, by time of presentation and by place of presentation. Thus it was possible to probe for retention of spatial information independent of temporal information. To effect this separation, the experiments made use of a spatial display of eight slide projectors, each focused on the grill cloth of one of eight loudspeakers. A list consisted of the successive presentation of eight words, each in a different location. Each item thus had a unique temporal and spatial position, and retention of spatial information independent of temporal information could be tested following auditory or visual presentation. From the three experiments carried out, which all showed auditory presentation superiority even when the question asked was "where" rather than "when", Murdock postulated two coding possibilities. The first is that some direct spatial representation is being formed, with the words being visualised as occupying the eight clock positions of the array. On each trial one such representation would be formed and, given the probe, the subject would scan their memory of the array to extract the necessary information. The second possibility is that the temporal order in which the clock positions are filled is the information "stored"; then spatial information is extracted through a temporally-mediated reconstruction. The error distributions favoured the latter alternative. Errors were randomly distributed in space though the errors were very clearly not randomly distributed in time. There were, instead, sharp adjacency effects in error distributions that are characteristic of short-term serial tasks with sequential presentation.

Mandler and Anderson, in their 1971 study, also emphasise the importance of temporal coding. They set out to investigate whether temporal structure is the main factor in serial learning. Three experiments were reported on the differential acquisition of temporal and uni-dimensional spatial structures. The general method involved presenting a series of words in a horizontal array. These words could be exposed one item at a time in the apparatus which consisted of a series of twelve windows of a metal screen. Thus it was possible to vary where a particular word appeared in the left to right array, and, as a result, vary the spatial ordering. It was also possible to vary the temporal order by varying when a word was presented. In the first two experiments, they showed that recall of a temporally structured series is superior to that of a spatially structured series, both when subjects are informed before, and when they were informed after presentation of the required mode of recall. In the third experiment, a probe technique also showed superior recall of temporal structures. The fact that they found that temporal structures were more easily remembered than spatial ones, whether presentation was brief (one trial), or lengthy (four trials), and when recall was either for the whole list, or for specific items, led them to suggest that temporal ordering is easier because of the contiguity of temporally ordered items as they arrive at some central processing mechanism. The ordering of spatial items, on the other hand, presumably requires some construction and contiguity of items is a synthetic product of ordering the items within the structure. Such a view would also predict the improvement of spatial recall when subjects are given more time to process the items.

Healy (1975b) accepts that previous studies such as those described above, and others (Healy, 1975a; Lundberg and Book, 1969) have indicated that within STM temporal coding is primary and spatial is derivative. However, as she points out, there is an asymmetry present in these studies. Specifically, in both temporal and spatial order recall within these studies, the subjects' task was, in effect, to learn a list of paired associates. That is, each of the to-be-remembered items had to be associated with its respective serial position. In temporal recall the subject was always given the serial positions in a constant order. The aim of Healy's (1975b) study was to make a more adequate comparison of temporal and spatial order recall by removing this asymmetry. In particular, the type of order to be recalled (either temporal or spatial) was made a between-subjects variable, and for subjects who were to recall the temporal order of the items, the spatial order was held constant, whereas for the subjects who were to recall the spatial order of the items, the temporal order was held constant. From this one would have a better idea of the relationship between temporal and spatial order recall. Are the processes basically different, similar and parallel, or hierarchical, with one primary and the other derivative? In the first of four experiments the subjects were presented with a four consonant stimulus in a Bina view cell set-up, followed by an interval of 3, 8, or 18 intervening digits. Each subject was instructed to shadow, or read aloud each item as it appeared on the screen. At the end of each sequence of consonants and digits, the screen became blank and the subject had to write down the consonants in their proper order (the temporal order in the Temporal Order Recall conditions and the spatial order in the Spatial Order Recall condition). The percentage of correct responses for the Temporal and Spatial Order Recall conditions were not different at the shortest retention interval, but they were different at the longer intervals, with Spatial performance better than Temporal. The results indicated that phonemic coding is employed in Temporal Order Recall, as confusion-set errors were greater on phonemically similar letters than on phonemically dissimilar letters. This effect was shown to decline as the retention interval increased. There were, however, no confusion-set errors in Spatial Order Recall. Experiment 2 was the same as Experiment 1, except for the fact that the subjects were instructed to employ articulatory suppression. When phonemic coding had been eliminated through suppression, the Temporal Order Recall was poorer than Spatial at all the retention intervals.

In the third and fourth experiments the aim was to determine whether distractor tasks involving spatial processing would disrupt Spatial Order Recall more than did the distractor task of the previous experiments. In both these experiments the concurrent spatial task interfered with Spatial Order Recall.

On the surface it appears that Spatial Order Recall within this study is powerful and that if temporal coding has a part to play it is a secondary one. However, Healy (1975b) concludes that the question of whether temporal and spatial order recall can be described as parallel processes or processes that are hierarchical cannot be decided conclusively on the basis of the present facts. She in fact argues strongly for the importance of a temporal element. She states that the Spatial Order Recall conditions involve subjects coding information about the temporal-spatial patterns of consonant presentations. Healy (1975b) extends this by suggesting that if recall depends, at least in part, on these temporal-spatial patterns, then one would expect to find the patterns to have a consistent effect on recall across experimental conditions. She then calculated the percentage of correct responses for each of the 24 temporal-spatial patterns that had been presented to the subjects. Pearson product-moment correlation coefficients were calculated in order to compare the effect of temporal-spatial pattern on recall in the various Spatial Order Recall conditions of Experiments 1-4. Each coefficient was significant, indicating considerable consistency across Spatial Order Recall. This finding was taken as support for the proposal that subjects code information about the temporal-spatial patterns when their task is to recall the consonants in their spatial order. The low correlations between percentages of correct responses at each of the twenty-four patterns in Experiment 1 for Temporal Order Recall indicate that subjects do not code such information here, although when phonemic information is suppressed they can code information about temporal-spatial patterns.

While not denying the strength of the argument put forward by these theorists, the fact that Healy (1975) did find that spatial order recall was not inherently inferior to that of temporal does lead one to ask for further investigation. It was seen earlier that the previous experiments in this thesis are not considered substantive evidence for sequential dominance in coding in this system; this is because it is possible that the findings occurred as a result of the memory materials and their presentation format. It was felt that the Brooks (1967) task used, presenting digits in ascending numerical order, and the fact that only adjacent squares were successively designated may have ensured sequential coding. The idea that memory material and the presentation format may be of some import is not a new one.

Anderson's (1976) study aimed to find out whether temporal and spatial structures are independent of one another and whether this relationship varies as a function of the form class of stimuli, pictures and words in her case. She cites what she claims are the three most logical possibilities: (a) the structures are independent for both form classes; (b) spatial structures are derived from temporal structures for words, and temporal structures are derived from spatial structures for pictures; or (c) spatial structures are derived from temporal structures for both types of stimuli. All the experiments were variations on the basic methodology reported by Mandler and Anderson (1971). Eight items were presented one by one in a horizontal array. Typically, temporal order of presentation was uncorrelated with the spatial position of the items. Following a single presentation the subject attempted to reproduce either the temporal or the spatial structure of that trial. Each subject received an equal number of temporal and spatial reconstruction trials in a single session. In various experiments the stimuli were common nouns, line drawings of common objects, or line drawings of complex 3-D geometrical shapes. To eliminate the necessity for verbal encoding, a reproduction task was used. Anderson(1976) found that the retention of temporal and spatial structures WAS greatly affected by the form class of stimuli used in the test. Pictorial forms gave rise to equality of temporal and spatial retention regardless of base performance levels and the use of linguistic forms led to consistent temporal superiority.

While the materials and presentation have been put forward as important variables in coding, visual short-term memory has also been investigated in terms of simultaneous versus sequential presentation. As was shown above, recall of spatial information using a sequential presentation has, in the past, either shown no evidence of direct spatial recall (Murdock, 1969; Healy, 1975b), or, when there is evidence of spatial recall it is argued that it always involves temporal factors (Healy, 1975a; 1977). Frick (1984, 1985) points out that this may be due to the form of presentation. He indicates a study by Snodgrass and Antone (1974), the only study which found better recognition for spatial order than for temporal, employed simultaneous presentation. Frick (1985) thus set out to explore whether presenting stimuli simultaneously or sequentially was a major factor in how information was encoded. He conducted two experiments testing immediate ordered recall. The purpose of Experiment 1 was to investigate the use of visual short-term memory with and without articulatory suppression, testing both sequential and simultaneous presentation. Confusion errors were collected using consonants. In Experiment 1, when subjects engaged in articulatory suppression and the letters were presented simultaneously, more visual confusion errors occurred in recall than would be expected by chance. For a sequential presentation with articulatory suppression, the proportion of visual errors was not significantly greater than would be expected by chance. Experiment 2 again tested visual presentations with articulatory suppression and immediate ordered recall. For the simultaneous presentation, recall was lower in a written prefix condition than in the spoken condition, a result he states that would be expected if visual short-term memory was being used. In the sequential presentation, there was no difference between the written prefix condition and the spoken prefix condition. The conclusion Frick draws is that, in two different experiments, the results suggest that a simultaneous presentation (with articulatory suppression) elicited use of visual short-term memory, but that a sequential presentation (even with articulatory suppression) did not. Frick's (1985) results, then, support the importance of presentation formatting in specifying coding.

It is interesting to note that effects on coding have also been shown for different subject groups. For example, O'Connor and Hermelin (1973) investigated the spatial and temporal organisation of short-term memory across several different groups of children. The children were shown three visually displayed digits. These digits were exposed successively in three windows in such a way that the left-to-right order never corresponded with the temporal-sequential order. When asked to recall or recognise the digits, normal children responded in terms of temporal order. Deaf, autistic and some abnormal (sic) children, recalled or recognised the spatial, i.e., the left-to-right order.

7.3 CONCLUSION

A number of different approaches, then, have been employed to explore the influence of temporal and spatial elements on coding within STM. Approaches range from the examination of the modality effects (Murdock, 1969); materials and format (Anderson, 1976); simultaneous vs. sequential presentation (Frick, 1985) and different subject groupings (O'Connor and Hermelin, 1973). These studies indicate that there is still a great deal of debate within this area. Are there two coding systems, the "independence" of which indicate two components of equal importance, both dependent on particular memory materials and presentation formats as surmised by Metcalfe, Glavanov and Murdock (1981)? Or is one derivative of the other as has been suggested by Lee and Estes (1977) and Murdock (1969), who argues that spatial information is extracted through a temporally mediated reconstruction? The following two chapters and the experiments within them aim to explore the issue of sequentiality and its relation to visuo-spatial processing in greater detail.

CHAPTER 8 : DOES THE CODE HAVE A SEQUENTIAL (TEMPORAL) ELEMENT.

CHAPTER 8. DOES THE CODE HAVE A SEQUENTIAL (TEMPORAL) ELEMENT?

8.1 INTRODUCTION

The previous chapter, while indicating the possibility of a strong temporal element within the visuo-spatial system, also showed that there are a number of situations where this apparent involvement may be due to other factors. It was suggested, for example, that experiments employing the Brooks (1967) task may have ensured sequential coding because it involves presenting digits in ascending numerical order and designating adjacent squares. It is thus impossible to say whether sequentiality is a characteristic of spatial memory, or whether the results are merely a consequence of using the Brooks technique. The present study examines these experimental constraints in differing ways in order to investigate the nature of the internal representation further. The question is whether the internal representation is strongly sequential in nature as suggested by Lee and Estes (1977) or more visual as Shepard (1966) claims, where a stable pictorial representation is generated, maintained and the required information simply read off this image. If the representation of the to be remembered material (digits in this study) is visual and if the work of Bahrick and Boucher (1968) and Paivio (1971) has a general application, it follows that the subjects could maintain a visual image of the digits and read them off in any order. In contrast, if the sequential nature of the code is of predominant importance the order of recall should make a considerable difference. The material would be encoded in terms of the order of input and any recall which required abandonment of that order would cause a decrement in performance.

8.2 EXPERIMENT 5 -"NON-ASCENDING/NON-ADJACENT"

8.2.1 INTRODUCTION

The following experiment incorporated the points made above by requiring subjects to recall in the order of presentation in one condition and according to a spatial sequence round the diagram in another. It is hypothesised that if the code is sequential in nature then recall that is the same as order of presentation should show superior performance to recall that differs from order of presentation.

The point at which subjects were told the nature of the recall required, whether it was to be "as presentation" or "as spatial sequence" was also included as a factor. This was incorporated into the study to allow any possible strategy change and its effect to be monitored. It is possible that if the interpretation in terms of sequential encoding is correct, subjects would have two choices for information encoding when recall was according to the spatial sequence. First, they could follow instructions and visualise the digits in position according to the input order. Second they could ignore imagery instructions and code the material in a manner consistent with the required output. That is, they could code the digits in an order appropriate to the spatial sequence of the diagram by re-arranging their order immediately after input. By altering the time of being told the form of recall required it was felt that the circumstances under which strategies are, or can be, used would become clearer.

8.2.2 METHOD

DESIGN

For this study several changes were made to the previous experiment. A 3x3 as opposed to a 5x5 matrix was presented for visualisation. This allowed each block to be uniquely designated by a spatial term (e.g.,top left, middle right) rather than by terms which might encourage verbal processing (e.g.,third down and fourth left, fourth left and two down), and also ensured that non-adjacent blocks could be successively designated. A similar approach was adopted in a series of experiments by Quinn (1976). The subject may thus be presented with a series of sentences like those in Figure 8.1(a). The presentation of the digits was also changed. Normally when experiments employ the Brooks material digits are presented in ascending numerical order (e.g., Baddeley and Lieberman, 1980). However, as was mentioned in the Introduction, such experimental constraints may in previous experiments have helped ensure sequential processing. Thus this study presented sentences with numbers in non-ascending random order (Figure 8.1(a)).

There were two variables in this experiment, each incorporating two conditions. The first variable, known as the Recall variable, was concerned with the order in which subjects were required to recall. Condition A, the Order of Presentation (Sequential) condition, required subjects to recall in the order in which the digits were presented. Condition B, the Spatial Sequence (Row) condition, required subjects to recall in rows from left to right and from top to bottom in accordance with the visualised matrix. This is an arbitrary

In the bottom centre put a 1.	In the bottom right put a 4.
In the top left put a 5.	In the bottom centre put a 1.
In the middle centre put a 6.	In the bottom left put a 7.
In the top right put a 3.	In the middle left put a 2.
In the bottom left put a 7.	In the middle centre put a 6.
In the bottom right put a 4.	In the top centre put a 3.
In the middle left put a 2.	In the top left put a 5.
FIGURE 8.1(a)	FIGURE 8.1(b)

In the top left put a 1.	In the top left put a 1.
In the middle left put a2.	In the middle right put a 2.
In the middle centre put a 3.	In the bottom left put a 3.
In the bottom centre put a 4.	In the middle centre put a 4.
In the bottom right put a 5.	In the top right put a 5.
In the middle right put a 6.	In the bottom right put a 6.
In the top right put 7.	In the middle left put a 7.
FIGURE 8.1(c)	FIGURE 8.1(d)

FIGURE 8.1 SAMPLES OF THE EXPERIMENTAL MATERIAL.

format and one could have asked subjects to recall in another form e.g., in columns. It was hypothesised that if the internal representation is sequential in nature then condition A should lead to a superior performance level, because subjects recall in the same order as presentation, whereas condition B involves recall which is different from presentation.

The second variable, known as the Strategy variable, was employed to examine the strategies subjects adopt while performing the Brooks type task. Condition 1, the Before presentation condition, involved telling subjects before presentation whether they would be required to recall as Condition A above or Condition B. Condition 2 involved telling subjects After presentation what form of recall was required.

This variable it was believed would shine some light on the circumstances under which strategies are, or can be used.

SUBJECTS

Twelve undergraduates served as subjects in this experiment with each subject being tested individually.

MATERIALS

The materials in this experiment comprised of a blank response booklet, a stop watch, and a sheet of sets of sentences. Each subject was given a response booklet of twenty-eight pages, four for use in the practice trials and twenty-four for use in the test trials. The experimenter held a sheet with the twenty-eight sets of seven sentences, an example of which is shown in Figure 8.1(a). The stop watch was used to time the presentation of the sentences, each set of seven sentences taking twenty eight secs.

PROCEDURE

Each subject was told they were going to hear sets of seven sentences of the sort "In the top left put a 3, in the middle centre put a 6..." for the digits 1 to 7. The subjects had to listen to the sentences under each of four conditions (see Design section) and they were instructed to attempt to build up a visual image of the digits so that they could recall the digits in the order specified by the experimenter. In the RECALL variable subjects were told that in the Order of Presentation condition they were required to recall the digits and their locations in the same order as had been presented. Thus if the digit three was presented first, e.g., "In the top centre put a 3", then the first digit written down must be the 3... and so on. In the Spatial Sequence condition subjects had to recall as if they were reading from a book, i.e., if a digit was in the top left box of the visualised matrix then it must be recalled first, then the top centre, top right, middle left, middle centre... etc. Subjects were told that for both recall orders they should write down not in a straight line, but in a matrix format and an example was provided. The subjects were monitored continuously to ensure that they followed the recall instructions.

In the Strategy variable, the experimenter would say in the Before condition "sequential recall" in one trial and "row recall" in another. After presentation the subjects were instructed to "sequential recall" or "row recall". In the After condition the experimenter would say "sequential recall" or "row recall" as appropriate.

Each subject received four practice trials containing two sequential and two row recall trials before the test set. There was no limit on recall time. In the actual test set each subject received 24 sentence sets (6 row/before, 6 row/after, 6 sequential/before, 6 sequential/after) presented randomly.

8.2.3 RESULTS

One point was given for each digit written in the appropriate relative position. The results were analysed using a 2(Before/After presentation) x 2(Recall order) x 12(subjects) within-subject anova. The only effect to reach significance was the main effect of "Before/After presentation" ($F(1,11)=10.0675, p=0.0089$). It is clear that when subjects were told which form of recall was required Before presentation they performed better (means of 20.7 vs 16.8 and SDs of 6.64 vs 5.00). There was no main effect of recall order and no form of interactions.

8.2.4 DISCUSSION

The only significant effect was the Before/After presentation variable. Such an effect has been shown by Mandler and Anderson (1971) among others (e.g,Peterson, Peterson and Ward-Hull, 1977) who explain the superior recall for "Before" presentation as simply a rehearsal phenomenon. It is suggested that the reason for the difference found here is that in the "After" presentation condition subjects can and must monitor presentation for both the possibly required forms of recall, whereas in the "Before" presentation condition subjects need monitor for only one and so performance shows a marked improvement.

In the Introduction the hypothesis stated that if the code is sequential in nature then recall that is the same as order of presentation should show superior performance to recall that differs from order of presentation. However, the results of the present experiment show no main effect for form of recall. Thus the hypothesis was not confirmed. These results are contrary to the work done by Peterson, Peterson and Ward-Hull (1977) who showed sequential recall to be superior to spatial order recall. In an attempt to explain this a closer comparison of their study and the present one is required. There would appear to be four major differences between this experiment and that carried out by Peterson et al (1977): The time factor, the number of digits, the matrix make-up and the order of digits. Taking each in turn : 1) TIME FACTOR - Peterson et al (1977) employed eight digits which were presented in "about" 20 secs, whereas in Experiment 5 the seven digits were presented in 28 secs, a difference of eight secs. If coding is normally sequential with spatial coding available, but only if more time is allowed, then one could argue that this difference enabled subjects to code information spatially. As mentioned in Chapter 7 the influence of time has been suggested before by Mandler and Anderson (1971). They argue that temporal ordering is easier because of the contiguity of temporally ordered items as they arrive at some central processing mechanism. The ordering of spatial items, on the other hand, requires some constructed structure, and contiguity of items is a synthetic product of ordering the items within the structure. Such a view suggests the improvement of spatial recall when subjects are given more time to process the items. The time factor could then quite possibly be an important variable. However, while this argument is plausible, the implicit assumption is that more time benefits spatial recall because it enables information to be structured. One could just as easily argue that more time should lead to greater superiority for the sequential condition. It already has a structured form and the "extra" time could be used to substantiate this through rehearsal, leading to an even stronger memory code. Time, then, is not a critical factor in the difference between these two studies. 2) NUMBER OF DIGITS - There is a difference in the number of digits employed in these two studies : whereas seven were presented here, Peterson et al (1977) used eight. It is possible that a capacity variable may be critical here, perhaps similar to that put forward by

Weber and Harnish (1974). They interpreted the results of two experiments they carried out as indicating that there exists a visual image operating-memory with a fixed letter capacity of approximately five letters. While this is also a plausible explanation for not finding a sequential superiority it should be noted that while Peterson et al (1977) employed eight digits one was always in the same location, "the starting square", so essentially the subjects only have seven digits to recall. It should also be mentioned that Quinn (1976) used only seven digits and still found a main effect in favour of sequential recall. These factors, combine to cast doubts on digit capacity as the critical explanatory factor for the difference between the results of this experiment and those of Peterson et al. (1977) and Quinn (1976). These doubts will be tested as a minor variable in the next experiment. 3) THE MATRIX MAKE-UP - A 3x3 matrix was adopted here whereas Peterson et al (1977) used a 4x4 (and, incidentally, Quinn (1976) used a series of block shapes). It could be argued that the 3x3 matrix is more compact than either of the other matrix make-ups. One might suggest that as a consequence sequential coding becomes more difficult as the path created by the sentence sets becomes less clear, less "separate", whereas in a 4x4 and Quinn "block shape" this is less likely to occur. There is an implicit assumption within this argument which weakens its case somewhat. It is assumed that having spatial locations "less separate" makes matters difficult. However, one could justifiably argue that compactness should aid spatial recall, because it is easier to relate spatial locations and their digits to one another, providing closer links. At this stage it is not possible to rule out compactness as an important variable here. 4) ORDER OF THE DIGITS - The digits in the present study were presented in a non-ascending, random order, whereas in Peterson et al's study subjects always received digits in the same, ascending numerical order. It is argued that stimuli as employed by Peterson et al. (1977) has an inherent sequentiality. The stimuli are presented in a constant order and, in this case, an order that each subject has been familiar with for nearly 20 years, namely 1,2,3,4...etc. Having such an overlearned ordering may amount to inherent sequentiality leading to sequential coding. The present study employed unfamiliar orderings which were not constant over trials and so one would not get sequential dominance. The obvious question to ask is : what would happen if an experiment similar to Experiment 5 was carried out, but incorporating ascending numerical order?

There are clearly several explanations for the results generated by this experiment. It is beyond the scope of this thesis to attempt to explore each of these and their possible combinations in turn. For this reason the following experiment is restricted to an examination of only two of these possibilities. First, the Order of Digits and second, the Number of Digits.

8.3 EXPERIMENT 6 a and b - "ASCENDING/DIGIT"

8.3.1 INTRODUCTION

Experiments 6 a and b tested two hypotheses. Firstly, that the ascending nature of presenting the digits is a crucial variable, and as such there should be a significant difference between sequential and spatial recall, the advantage lying with the former. Secondly, that the difference of one digit between Peterson et al's (1977) study and Experiment 5 may be the cut-off point, such that the system can cope with both forms of recall at 7-digit span but at 8 the sequentiality of the code becomes critical. A limited capacity system for letters has already been suggested by Weber and Harnish (1974) and it is possible that a similar system exists for digits.

8.3.2 METHOD

DESIGN

The design of this experiment was the same as that of the Recall variable of the previous experiment. The only difference was that the digits were presented in ascending numerical order (see Figure 8.1(d)). The Before/After variable was excluded because it was felt that the rehearsal explanation was sufficient to explain the results found, and that the inclusion of this variable had failed to provide any information concerning the central issue of spatial versus sequential coding. Subjects were informed of which recall format was required both Before and After recall.

SUBJECTS

16 undergraduates served as subjects in this study, 8 in each experiment, with each subject being tested individually.

MATERIALS

The materials were exactly the same as those in the previous experiment, except in Experiment B where the subjects were presented with 8 digits and not 7.

PROCEDURE

The procedure for this study was the same as that used in the RECALL variable of the previous experiment, the only difference being the digits were presented in ascending numerical order.

8.3.3 RESULTS

One point was given for each digit written in the appropriate relative position. The results for both the experiments were analysed using two tailed t-tests. In both an effect of recall was found with sequential superior to row recall. The effect of increasing the number of digits from 7 in Exp A (means of 32.9 vs 29.4 and SDs of 9.01 vs 7.9 for sequential and row respectively) to 8 in Exp B (means of 32.5 vs 25 and SDs of 10.8 vs 10.56 for sequential and row respectively) was merely to increase the significance of the difference between sequential and row recall (7 digits - df=6, t value of 3.258> critical value of 3.133, 8 digits - df=7, t value of 7.918> critical value of 5.405) The proposal that 7 digits may be the cut off point of a limited capacity system, whereby the addition of one more digit would result in the system being unable to cope with recall different from presentation, thus showing a superior performance for sequential recall, was unfounded.

8.3.4 DISCUSSION

The first hypothesis stated in the Introduction has been confirmed. Presenting the digits in ascending numerical order causes a critical difference from the results of Experiment 5. The results of this present study are consistent with those of previous work (e.g.

Peterson et al, 1977) in that sequential ordering performance was shown to be superior to spatial ordering. There was, however, no evidence for the second hypothesis concerning a limited capacity system for numbers similar to the one for letters suggested by Weber and Harnish (1974). This does not negate the possibility that such a limited capacity system exists. It merely shows that at this load there is no cut-off point and that an alternative explanation for the difference between the present results and Peterson et al (1977) must be sought.

Ascending numerical order was also suggested as a critical variable (See Discussion of Experiment 5). The results of the present experiment support this suggestion. They indicate that when digits are presented in a constant, ascending numerical order there is a sequential recall performance advantage over row recall. This result differs from that of the previous experiment which employed non-ascending numerical order and found no advantage for sequential recall. While accepting the importance of ascendency it is possible that such an explanation is too simplistic. In examining the results of Peterson et al (1977) and Experiment 5, another possibly vital difference is the fact that the digits in her study were presented to adjacent squares as well as in ascending numerical order. The following experiment will examine the possible effects of ascendency and adjacency on recall order.

8.4 EXPERIMENT 7 - "ASCENDENCY/ADJACENCY"

8.4.1 INTRODUCTION

The previous experiment has shown that ascendency is a crucial factor in the difference in results generated by Experiment No.5 and those of Peterson et al (1977). Although it is clear that the presentation of digits in ascending order leads to an advantage in recall scores for sequential over row, it is by no means the only possible critical factor. Another difference in the two studies relates again to the format in which the memory material is presented. In Peterson et al (1977) the sentence sets presented all referred to adjacent squares in the Brooks (1967) matrix material, whereas in both Experiment 5 and 6 of the present study, the sentence sets all referred to non-adjacent squares. The use of adjacent squares allows the subjects to create an unimpeded path around the visualised matrix. On the other hand, allocating non-adjacent squares does not allow this, as there is the possibility that "crossing over" will occur. Subjects during these experiments talk about drawing paths (lines) linking up square to square. If they are required to draw a line through a square it is possible that this may interfere with the number allocated to that particular square. It is hypothesised that, in the following experiment, as in Experiment 6, there will be a main effect of Ascendency and a main effect of Adjacency.

8.4.2 METHOD

DESIGN

This experiment is a three factor mixed design, with repeated measures on two factors. The three variables each incorporated two conditions. The first variable, the Recall variable, was the same as its namesake of Experiments 5 and 6. The second was termed the Adjacency variable, condition 1 of which involved presenting the numbers to the subjects in adjacent (either vertical or horizontal) squares of the "to be visualised" matrix, while condition 2 required numbers to be allocated non-adjacent squares. The third variable, the between-subjects variable was known as Ascendency, and it involved, in one condition, presenting numbers for recall in ascending numerical order and in the other, presenting them in non-ascending numerical order. As the previous experiment showed no differential effect of presenting 7 or 8 digits it was decided to return to the procedure employed in Experiment 5 of presenting 7 digits.

SUBJECTS

16 undergraduate students acted as subjects in this experiment, 8 in each group, and all were tested individually.

MATERIALS

The materials in this experiment were again based on the Brooks (1967) memory matrices, with certain modifications. As before, a 3x3, as opposed to a 5x5, matrix was presented for visualisation. The presentation of digits was also altered. Normally when experimenters employ the Brooks material, digits are in ascending numerical order and in adjacent squares (e.g., Baddeley and Lieberman, 1980). However in this study one group of subjects received 7 digits in ascending numerical order, another group heard 7 randomly (non-ascending) ordered digits. Also, both sets had one condition where digits were presented to adjacent squares and another where non-adjacent squares were assigned.

A stop watch was used to time the presentation of the sentence sets.

PROCEDURE

The first group of subjects were told they were going to hear 24 sentence sets of the sort shown in Figure 8.1(a and b) and the second group of subjects were told they would be hearing sentences of the sort shown in Figure 8.1(c and d). Both sets of subjects were advised about the difference between allocating adjacent and non-adjacent squares. These variables were both randomised across trials. The subjects had to listen to the sentences and they were instructed to attempt to build up a visual image of the digits so that they could recall the digits in the appropriate order.

Each subject received 4 practice trials before each test set (1 adjacent/sequential, 1 adjacent/row, 1 non-adjacent/sequential, 1 non-adjacent/row) The digits were presented at a rate of 1 per 4 secs and there was no time limit on recall time. In the actual test set each subject received 24 sentence sets, 6 in each of the four conditions above.

8.4.3 RESULTS

One point was given for each digit written in the appropriate position. The data from the experiment was analysed using a 2x2x2 mixed anova. There was a main effect of : Ascendency ($F(1,14)=7.7595, p=0.0146$) with digits presented in ascending numerical order providing superior performance (means of 32.1 vs. 25.2 and SDs of 8.6 vs 7.3)); Adjacency ($F(1,14)=37.7219, p=0.0000$) with digits presented to adjacent squares showing superior performance (means of 33.6 vs. 23.8 and SDs of 6.4 vs 8.9); and Recall order ($F(1,14)=6.6217, p=0.0221$) with sequential recall showing superior performance to row recall (29.8 vs. 27.6 and SDs of 12.86 vs 12.94). There was also a significant interaction between the three variables ($F(1,14)=7.6631, p=0.0151$). The results of a Newman-Keuls on all comparisons are discussed below ($p<0.05$).

8.4.4 DISCUSSION

In the Introduction it was surmised that the critical variable was Ascendency. It was argued that numbers presented in ascending numerical order have an inherent sequentiality. The present experiment confirms that Ascendency is a critical variable, but it also suggests that Adjacency has a role to play. Ascendency did not always lead to better recall, as will be discussed below. The most plausible explanation put forward for the main effect of Adjacency comes from subjects' reports of what they did in this experiment. When adjacent squares were assigned subjects reported that it was easier to move around the visualised matrix in an ordered spatial pathway. On the other hand, non-adjacent allocation of squares meant "jumping about the matrix", which made visualising the ordered pathway more "difficult". When subjects are able to employ the "pathway" strategy it is argued that this makes sequential recall easier.

The interaction between the three variables is shown in Figure 8.2, and listed below for the sake of clarity.

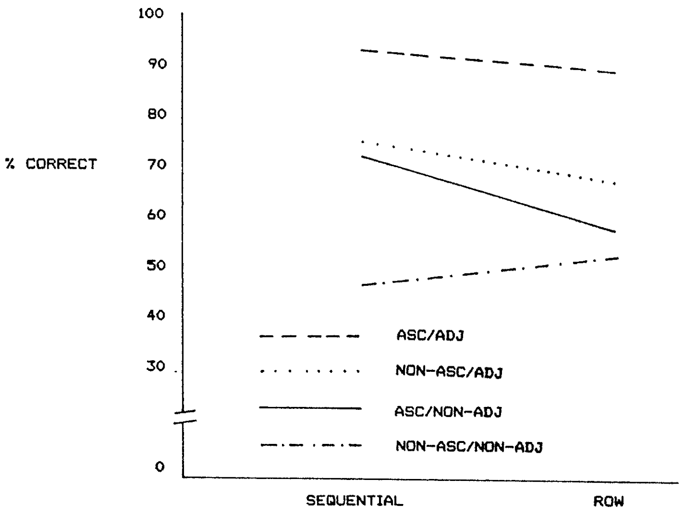

FIGURE 8.2. The interaction between the Recall conditions, the Adjacency conditions and the Ascendency conditions in Experiment 1. ASC=Ascendency; ADJ=Adjacency; NON-ASC=Non-Ascendency; NON-ADJ=Non-Adjacency.

(1) No difference between Row and Sequential if presentation is non-adjacent and non-ascending.

(2) No difference between Row and Sequential if presentation is both adjacent and ascending.

(3) No difference between Row and Sequential if presentation is adjacent and non-ascending.

(4) Significant difference between Row and Sequential if presentation is non-adjacent but ascending.

The question to be asked is : "Why are Row and Sequential only different under non-adjacent but ascending presentation ?"

It is argued here that whenever Ascending Numerical Order is employed subjects find it easy to latch onto the sequence. Adjacency it is felt can also be an aid to this "latching on" process, although its influence is not thought to be as strong as Acsendency.

(1) Here there is no contribution from Ascendency and so there is no sequence to latch onto, resulting in no difference in recall.

(2) Subjects here have Ascendency and Adjacency available. As was said, Ascendency allows subjects to latch onto the sequence and, in addition to this, they have Adjacency. Subjects report that Adjacency aids recall through the "pathway" strategy. Together these factors mean that recall is well within subjects' capacity so they can read off for recall in any order.

(3) Within this finding one can see that there is no Ascendency and so subjects cannot latch onto the sequence. Although Adjacency is available and has been shown to make some contribution it is obviously less powerful in respect of encouraging a difference in row and sequential recall than Ascendency.

(4) In this final result subjects have Ascendency but no Adjacency. They can thus latch onto the sequence which enables sequential coding to take place leading to better recall. The fact that Adjacency is not present but that this has no significant effect suggests again that the Adjacency contribution is not a dominating one.

The finding that Ascendency is of critical importance in enabling subjects to code information sequentially leads one to ask what would happen if the memory materials presented had no known ascendency formatting. Would there be any advantage for either row or sequential recall? This issue will be examined later, but before it is, one other possible explanation of the above results must be explored.

This explanation makes reference to possible floor and ceiling effects. It could well be that the failure to find a difference in (1) is due to floor effects : in itself this does not tell us much. The reason for this is that recall averages about 50%, which is about 3 out of 7. Figure 8.3 which shows the serial position curve generated by the recall conditions in Experiment 7, indicates that these were predominantly from the recency/primacy areas of the curve. This might suggest that the task was too difficult to allow the subject to follow the instructions and recall from a spatial code. Yet this condition replicates Experiment 5, so were the results of that experiment also due to floor effects? From Figure 8.4, the serial position curve generated by recall conditions in Experiment 5, one can see that once again four out of seven serial positions are below 50%. However, since in both these cases not all the recall scorings are so low, it is felt that although a floor effect is a possible explanation, it is, in many ways a borderline case. In order to clarify this situation it is necessary to eliminate any possibility

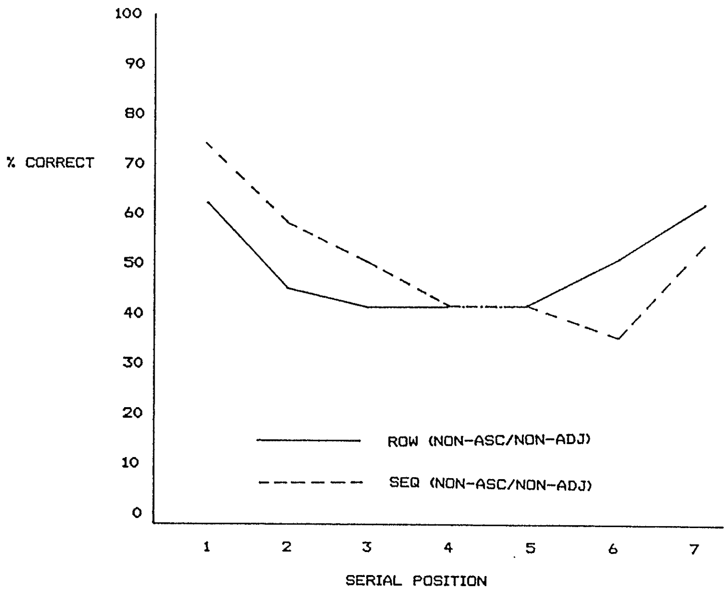

FIGURE 8.3. The serial position curve generated by the recall conditions in Experiment 7. SEQ=Sequential; ROW=Row; NON-ASC=Non-Ascendency; NON-ADJ=Non-Adjacency.

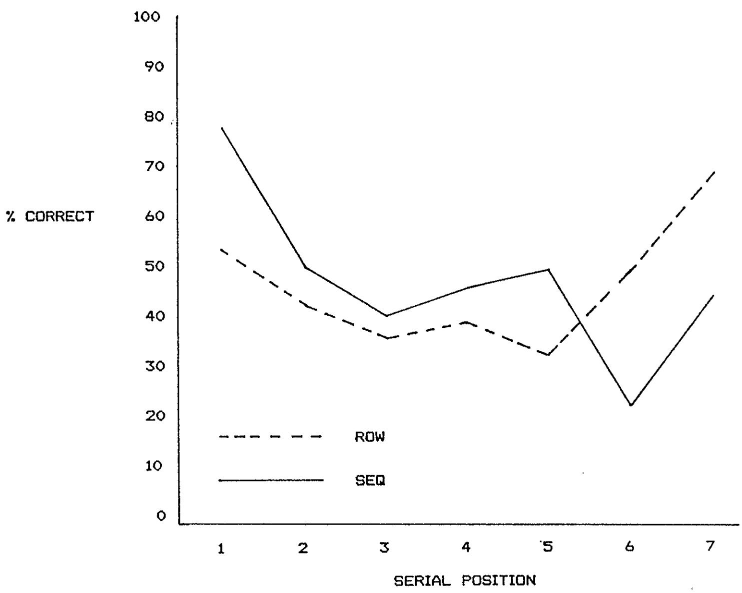

FIGURE 8.4. The serial position curve generated by recall conditions in Experiment 5. SEQ=Sequential; ROW=Row; NON-ASC=Non-Ascendency; NON=ADJ=Non-Adjacency.

that a floor effect may be present and the next experiment in this series will endeavour to do this.

The failure to find a difference in (2) could be due to ceiling effects, as the average recall score was just less than 90%, an average of just over 5 per trial. There is possibly a problem with this interpretation. After all, Peterson et al (1977) had both adjacent and ordered numerals and found a difference between the recalls. It could be said that this is because she used 8 digits; however, one was always the same i.e.,in the starting square. Having said this, reference to the first experiment in this thesis reveals that even when 8 digits and a 4x4 matrix were used concurrently with a movement task, subjects performance levels in a situation similar to the sequential variable here, were found to be as high as 100%. One way to examine ceiling effects, then, would be to increase the number of digits in ascending/adjacent conditions to eight. A ceiling effect is still likely for sequential recall from the results of pilot work carried out for Experiment 1, but 8 digits may be enough to eliminate the possibility of ceiling effects in row recall.

As for (3) and (4), two points have to be considered: first, although there is no difference between row and sequential in (3) it looks sufficiently like (4) to be nearly significant. There is less doubt about the robustness of the significance of (4) because it is a replication of Experiment 6. Second, the difference between (3) and (4) in terms of significance is real and suggests that adjacency may not be a dominant variable in itself, as far as encouraging reliance on sequential coding is concerned ,but ascendency is. To summarise then, there is a row/sequential difference only if the digits are in ascending order. However, this would indicate that there should have been a 2-way(row/sequential x ascendency) not a 3-way(row/sequential x ascendency x adjacency) interaction. Thus adjacency does have a significant role to play in encouraging reliance of sequential code in a 3x3 matrix.

The next experiment, by altering the number of digits presented, attempts to eliminate the possible ceiling and floor effects and, in so doing, provide a more accurate picture of what is actually happening.

8.5 EXPERIMENT 8 - "ASCENDENCY/ADJACENCY/DIGIT"

8.5.1 INTRODUCTION

Interpreting the results of Experiment 7 was seen to be problematic due to the possibility of floor and ceiling effects. Any conclusions drawn from the significant effects present must therefore be tempered. Nevertheless, it appeared that ascendency played a crucial role in this experiment, a result which was consistent with Experiments 6 a and b, and also that adjacency played a part, although the extent of its influence could not be determined. The following experiment will attempt to reduce the possibility of ceiling and floor effects occurring and influencing the data. This will be done by adding and reducing a digit to the total in the two conditions (2) and (1) respectively, where ceiling and floor effects are said to be present. Through such a procedure it is believed that these extraneous variables will be absent from our analysis, presenting a clearer view of what is happening and generating more support for any conclusions that may be drawn. It is thought that ascendency will again be shown to be the critical component in this experiment and that the effect of adjacency would be clearly visible.

8.5.2 METHOD

DESIGN

The design of this experiment is the same as the previous experiment with a minor change relating to the possible presence of floor and ceiling effects. It was decided to add one digit to the matrices presented in the Adjacent/Ascending condition and to reduce the number of digits from 7 to 6 in the Non-Adjacent/Non-Ascending condition to eradicate the possible ceiling and floor effects respectively.

SUBJECTS

16 undergraduate students acted as subjects in this experiment, 8 in each group and all were tested individually.

MATERIALS

With the exception of the digit alterations mentioned above the materials were also identical to those of Experiment 8.

PROCEDURE

The procedure in this experiment was as before, with the exception that one group of subjects were told that in a particular condition they would receive 6 digits and in another 7 digits. The other group were told they would receive 7 digits in one and 8 digits in another.

8.5.3 RESULTS

The method of scoring used in the previous series of experiments was adopted here. That is, one point was given for each digit written in the appropriate relative position and, because there were different numbers of digits presented in the conditions (see Procedure section above) the proportion of correct responses were analysed using a 2x2x2 mixed anova. There was a main effect of : Ascendency (AS)($F(1.14)=9.4821, p=0.0082$) with digits presented in ascending numerical order providing superior performance (means of 78.4 vs. 57.3 and SDs of 17.11 vs 20.36); and Adjacency (AD)($F(1,14)=12.0104, p=0.0038$) with digits presented to adjacent squares showing superior performance (means of 74.6 vs 61 and SDs of 21.19 vs 19.86). Unlike Experiment 8, there was found to be no main effect of Recall(RC) and no 3-way interaction between AS,AD and RC. There were significant interactions between AS and AD ($F(1,14)=5.5506, p=0.033$) and AS and RC ($F(1,14)=5.133, p=0.0399$). All comparisons were made in the Newman-Keuls analysis ($p<0.05$). With AS and AD, the ASC/ADJ condition differed from all others with no other significant differences. With AS and RC, the SEQ/ASC condition differed from all others as did ROW/ASC, and there were no other significant differences.

8.5.4 DISCUSSION

As in Experiment 8, the present experiment found a main effect of Ascendency and Adjacency; however, no main effect of Recall was found and there was no 3-way interaction. There were two significant interactions, namely ASxAD and ASxRC, which are clearly shown in Figures 8.5 and 8.6.

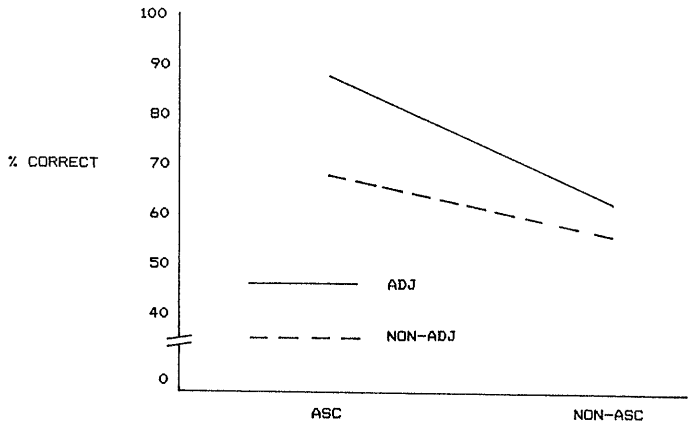

FIGURE 8.5 The interaction between the Ascendency conditions and Adjacency conditions in Experiment 8. ASC=Ascendency; NON-ASC=Non-Ascendency; ADJ=Adjacency; NON-ADJ=Non-Adjacency.

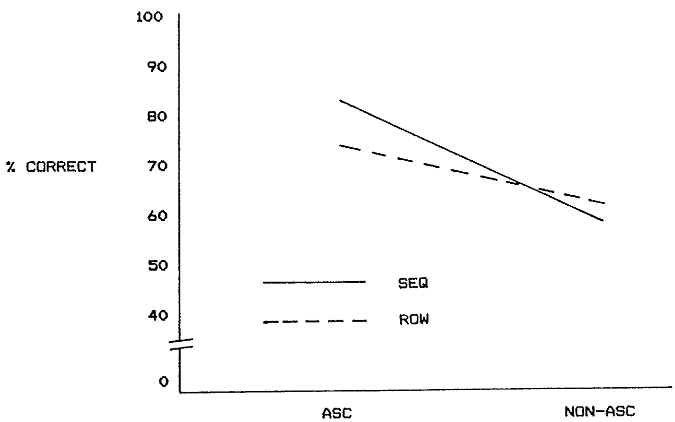

FIGURE 8.6. The interaction between the Ascendency conditions and the Recall conditions in Experiment 8. ASC=Ascendency; NON-ASC=Non-Ascendency; SEQ=Sequential; ROW=Row.

From Figure 8.5 one can see that adjacent presentation only leads to greater recall over non-adjacent when the digits are presented in ascending numerical order and that ascendency is only superior to non-ascendency when adjacent presentation is used. This would appear to indicate that these variables are only influential when the other is present. Figure 8.6 shows that the only time that sequential recall is superior to row is when numbers are presented in ascending numerical order. The importance of ascendency, then, is clear from the results presented above. This being the case, any work that is based on presenting numerals and that is used as support for the idea of sequential coding must be tested with some caution. It has been argued that there is some inherent sequentiality within digits, not present in other stimuli which do not have a "normal" order. What would happen if the memory materials presented had no known ascendency formatting? Would there be any advantage for either row or sequential recall? These issues will be discussed shortly.

At this point it is necessary to discuss the possible ceiling and floor effects. As was seen earlier it was thought that an increase in the number of digits would effect row recall but not sequential recall in reducing the influence of possible ceiling effects. Fig 8.7 goes some way to supporting this. It shows that for row recall 3 serial positions were above 90% in Exp 7 but only one in Exp 8, whereas sequential recall had 4 above 90% in Exp 7 and 8 in Exp 8. The possible floor effect suggested previously would also appear to have been resolved to a large extent. Now only 2 out of 7 and 1 out of 7 positions dropped below 50% for row and sequential respectively (see Fig 8.8).

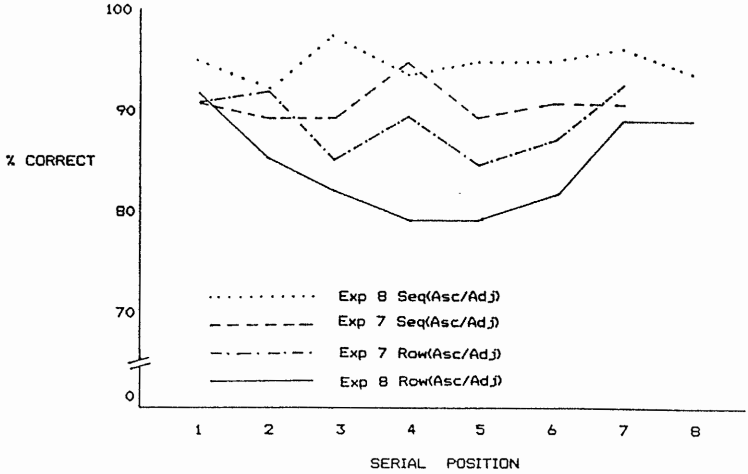

FIGURE 8.7. The serial position curve generated by the recall conditions in Experiment 7 and Experiment 8. SEQ=Sequential; ROW=Row; ASC=Ascendency; ADJ=Adjacency.

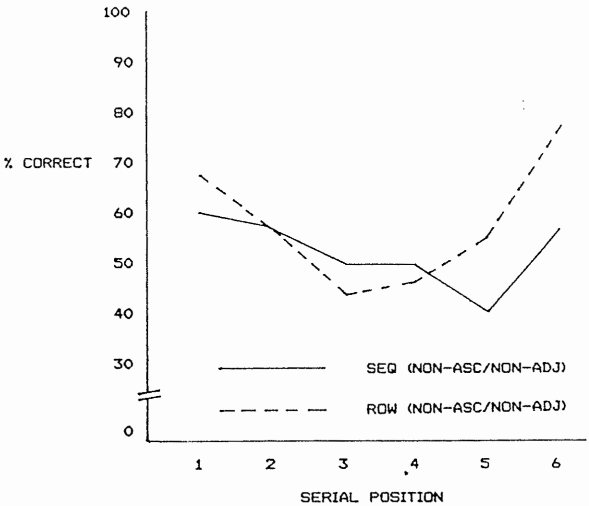

FIGURE 8.8. The serial position curve generated by the recall conditions in Experiment 8. SEQ=Sequential; ROW=Row; NON-ASC= Non-Ascendency; NON-ADJ=Non-Adjacency.

8.6 CONCLUSION

To summarise, this series of experiments was designed to investigate spatial memory and the nature of its code. The question asked was "Is sequentiality a characteristic feature of spatial memory, or is the evidence gathered thus far for such a code a reflection of the Brooks technique i.e., the use of adjacently presented locations and the ascending nature of the digits?" Experiment 5, which involved presenting the digits in non-ascending numerical order and to non-adjacent squares, found no difference in the two forms of recall. This, it was suggested, indicated that spatial memory does not have to be sequential. The results of Experiment 6 showed that presenting digits in ascending numerical order was crucial in suggesting a sequential aspect to spatial memory. Experiment 7 was designed to explore whether adjacency as well as ascendency has a part to play. The outcome of this experiment appeared to confirm the importance of ascendency and at the same time indicate that adjacency is also influential, although the extent of its influence could not be determined. This view of the importance of both AS and AD was substantiated by Experiment 8 which was designed to eliminated possible extraneous variables at work in Experiment 7.

As was stated in the Discussion to Experiment 7, the fact that Ascendency is of critical importance in enabling subjects to code information sequentially leads one to ask what would happen if the memory materials presented had no known ascendency formatting? The next step in this thesis would appear to be to carry out a study in which the possibility of Ascendency being important will be eliminated by not using numbers which, because of the reasons specified, may be inherently sequential. The next chapter will present two experiments designed to do just this and, as a result, it is hoped will provide us with a more stringent examination of the involvement of a sequential element in visuo-spatial memory.

CHAPTER 9 : IMPORTANCE OF MATERIALS AND FORMAT

CHAPTER 9. IMPORTANCE OF MATERIALS AND FORMAT

9.1 INTRODUCTION

Chapter 7 suggested that the evidence generated from the previous four experiments in this thesis and the work of Murdock (1969) and Healy (1975a) among others (e.g., Hitch and Morton, 1975; Nelson, Brooks and Borden, 1973; and Quinn, 1976), may not, as it was originally posited have been the result of a sequential component. It may in fact have been an artefact of memory materials and their presentation format. Experiments 5, 6, 7 and 8 presented in Chapter 8, were thus designed to explore this possibility. They concluded that the evidence generated thus far, at least that based on numerical stimuli, for a sequential code, is due not to the sequentiality of the code, but to the materials and format used. Following on from this, it has been decided that different materials should be employed. Materials which, unlike numbers cannot be categorised in terms of ascendency which was shown to be a crucial factor, and are not by their very nature sequential, not normally being presented in a sequential manner.

The following experiments are designed to explore this issue further by examining whether the form class of stimuli presented is important in determining what form of coding is employed, and if the presentation format itself is of significance.

9.2 EXPERIMENT 9 - "COLOUR"

9.2.1 INTRODUCTION

Colours are employed to eliminate any inherent sequentiality which may exist within numbers. Colours are not normally presented in any specific order, and are not associated with any concept of ascendency. As such, colours have no "natural" sequential component. It is hypothesised that, as a result of this, spatial recall (row) and sequential recall will show similar performance levels (Anderson, 1976). The suggestion has been made that the presentation modality may also be of some importance (Metcalfe et al. 1981). More specifically, it has been said that while visual presentation leads to spatial dominance, auditory presentation shows greater sequential performance. The previous four experiments undermine this suggestion in that auditory presentation was employed, and it was only under certain conditions that sequential led to greater recall over row. However, it should be noted that in the previous four experiments subjects were instructed to image, no such instructions were given in the other studies, with the exception of one experiment by Anderson (1976). She had an experiment involving a verbal and an image condition which found that the effects of imposed encoding strategies were minimal. The problem with this experiment was that subject cooperation may well have been a factor. The aspects of subject cooperation that are critical were not discussed by Anderson. However, the fact remains that in the vast majority of studies no instructions to image were used. So while the visual-spatial imagery system may be flexible enough to deal with temporal and spatial information it may not be dependent on the modality of presentation.

This will be examined directly in the next experiment where different types of presentation will be employed to see if this prejudices recall one way or another.

9.2.2 METHOD

DESIGN

This experiment is a two-factor design with repeated measures on the first variable. The first variable, the Recall variable, is the same as that used in the previous study. The second variable, the between-subjects variable, was termed the Presentation variable and it contained three conditions. Condition 1, the Verbal condition, involved presenting the sentence sets auditorily as had been the case in the previous study. The Verbal/Visual condition, condition 2, involved presenting the colour and its location verbally and visually. In the third condition, termed the Visual condition, the memory material was presented visually, i.e.,the matrix on the computer screen would flash up colours in the appropriate box.

SUBJECTS

24 undergraduate students acted as subjects in this experiment and each was tested individually.

MATERIALS

Taking each condition in turn:

VERBAL- A sheet with 12 sets of 9 sentences depicting the spatial location and the colour to be remembered was read out by the experimenter, who had a stop watch to time the presentation of the sentences. The colours were red, green, blue, magenta, cyan, yellow and white. Pilot work had indicated that 9 sentences was the optimal difficulty level. Each subject had a 3x3 matrix taped to the 4ft x 2.5ft table directly in front of them. The squares of the matrix were 2.5 sq in. with the masking tape an additional 1in thick. The colour response cards, four of each colour, were situated in piles to the left of the table matrix. Each card was 2.5 sq in so that they fitted neatly into the table matrix. Seven colours were employed because the BBC micro computer employed here did not have a "colour chip" and was only operating with this number of colours. As a result of this some colours were presented more than once in each trial. This repetition of colours was randomised across all trials. This, of course, has no differential effect over form of presentation or recall. The subjects sat 1m in front of the computer which had a 3x3 matrix permanently displayed on it, each cell of which measured 4cm by 4cm.

VERBAL/VISUAL- The materials here were the same as above, although the colours and their location were also presented visually on a 3x3 matrix on the computer screen.

VISUAL- The appropriate colours and their spatial locations were presented in the boxes of a 3x3 matrix by the computer as in the VERBAL/VISUAL condition. A response matrix and cards were as above.

The matrix on the computer screen was present in all conditions in order to avoid matrix presence becoming a differentially important variable.

PROCEDURE

Again taking each condition in turn:

VERBAL- In this condition the subjects were told they were going to hear 8 sets of 9 sentences of the sort "In the top left put RED,in the bottom centre put BLUE...etc."

VERBAL/VISUAL- Here the subjects were told they would hear sentences as above and at the same time the location and colour would be flashed onto the screen.

VISUAL- Here the subjects were told that they would see 9 colours individually flashed up onto the screen at 4 sec intervals in different boxes of the already visible matrix.

The subjects were told to attempt to build up a visual image of the colours in their appropriate locations so that they could recall them in the required formation (either row or sequential) which was always specified before the set of the messages were presented. In order to get the subjects used to the procedure a familiarisation period was allowed. Since subjects in each condition were required to do slightly different tasks these familiarisation periods were also slightly different. In the Verbal condition subjects were familiarised with the square designations. The appropriate designations were read out to the subject to ensure that they knew both the verbal descriptions and the spatial layout of the diagrams.

Only after an error free repetition of the block designations and only after the subject was otherwise sure of the spatial layout did the experiment begin. For the Visual condition it was ensured that subjects were familiar with the computerised colours, their differences and their corresponding response colour cards. The familiarisation period for the Visual/Verbal condition involved a combination of the above two and subjects were shown how the Verbal and Visual presentations referred to the same squares and colour.

Each subject received 4 practice trials before the start of the experiment. The colours were allocated random squares and presented successively with a display time of 4sec and an ISI of 4sec with no time limit on recall. The subjects would respond by entering the appropriate colour cards in the appropriate boxes of the table matrix in the required recall format. Thus, if row recall was asked for then the subject would enter a colour card in the top left box of the matrix, then the top centre and so on, ignoring the presentation order. If, on the other hand, the subject was asked to recall sequentially then they would enter the colour cards into the boxes of the table matrix in the order in which they were presented. The verbal presentation rate involved each message being given over a 4 sec period with an ISI of 4 sec. In each of these three conditions subjects were instructed during presentation to look at the computer screen which had the 3x3 matrix continually displayed. The subjects were monitored throughout the experiment to ensure that this instruction was followed.

9.2.3 RESULTS

The method of scoring used in the previous series of experiments was adopted here. That is, one point was given for each colour card presented (entered) in the appropriate position. The data from the experiment was analysed using a 3x2 mixed anova. There was a main effect of Presentation ($F(2,21)=4.3386, p=0.0265$) with Newman-Keuls indicating that both Verbal/Visual and Visual presentation (means of 35.68 and 35.3 vs 27.5 and SDs of 6.39 and 7.9 vs 8.24) provided an advantage over Verbal ($p<.05$), and no effect of Recall ($F(1,21)=2.3229, p=0.1424$) and there was no interaction.

9.2.4 DISCUSSION

As can be seen from the Results section there was a main effect of Presentation with both Visual and Verbal/Visual leading to higher performance levels than Verbal alone. Unlike with Anderson's (1976) results, it was found that presentation format did not differentially effect form of recall. Although this appears to conflict with the findings of Metcalfe et al. (1981) and Murdock (1969) it is not as surprising as it initially appears. Since in each of our conditions subjects were encouraged to image the matrix and the stimuli, one would not expect to find qualitative differences unless different image systems/processes were involved. How can one account for the fact that Verbal/Visual and Visual led to better recall than Verbal alone? From the literature on list learning one may have expected the reverse, since the modality of presentation, whether it is visual or auditory, has been shown to have a major influence on the results. Auditory presentation seems to show an advantage even if items are also presented visually. Thus a reversal of the outcome one would expect from list learning has been found when stimuli are employed which have no sequentiality. Why then is visualising easier here? What does this tell us about the VSSP? One hypothesis is that information presented visuo-spatially directly accesses the VSSP, whereas auditory information needs to undergo some translatory process before it gains entry. Thus, the fact that more time may be required and/or the need for the translation itself, may weaken the representation constructed from the auditory stimuli. What would happen if one asked subjects to vocalise when recalling? This may encourage an emphasis on auditory coding leading to superior performance for Verbal and perhaps Verbal/Visual over Visual.

To move onto the Recall variable. The previous set of experiments had suggested that evidence for a sequentially based code taken from studies employing numerals must be approached with some caution. It was argued that such stimuli have an inherent sequential component. Colours were employed in the present experiment in order to eliminate this possibility, allowing the dominance of sequential recall to be more stringently examined. The results of this experiment, as shown above, indicate that when stimuli are used which do not have any inherent sequentiality then there is an equality of performance over the two recall conditions. The hypothesis stated in the Introduction has been confirmed. It is clear from this experiment that subjects can read off information in an order that differs from the order of presentation, indicating that the coding within VSSP is not necessarily sequentially based.

The next experiment will employ different stimuli in order to test the reliability of this finding. Shapes will be adopted as they, like colours, have no "natural" order that they are presented in, nor do they have any concept of ascendency associated with them.

9.3 EXPERIMENT 10 "SHAPE"

9.3.1 INTRODUCTION

The use of shapes is employed to again eliminate any sequentiality which may exist with numbers. Shapes, like colours, are not normally presented in any specific order, having no concept of ascendency which appears to be crucial in the last series of experiments. As such shapes should have no "natural" sequential component. It is hypothesised that, as with colours, there will be no difference in row and sequential recall performance. The suggestion was made in the last experiment that following the work of Metcalfe et al. (1981), the presentation modality may also be of some importance. The results, however, illustrated that the presentation format does not differentially effect form of recall. The apparent difference between these results and those of Metcalfe et al. (1981) and others (e.g.,Murdock,1969) was explained by reference to the fact that in the experiments presented here, subjects were encouraged, in each of the conditions to image the matrix and the stimuli and as such one would not expect to find qualitative differences unless different image systems/processes were involved. In order to substantiate this point it was decided to incorporate this variable again, hypothesising that the results of Experiment 9 would be confirmed.

9.3.2 METHOD

DESIGN

As with Experiment 9 this experiment is a two-factor design with repeated measures on the first variable. The first variable, the Recall variable is the same as that used in the previous study. The second variable, the between-subjects variable was termed the Presentation variable and it contained the same three conditions as before. Condition 1, the Verbal condition, presented the sentence sets auditorily as had been the case in the previous studies. The Verbal/Visual condition, condition 2, involved presenting the shape and its location verbally and visually. In the third condition, termed the Visual condition, the memory material was presented visually, i.e., the matrix on the computer screen would flash up shapes in the appropriate box.

SUBJECTS

24 undergraduate students acted as subjects in this experiment and each was tested individually.

MATERIALS

Taking each condition in turn:

VERBAL- A sheet with twelve sets of seven sentences depicting the spatial location and the shape to be remembered was read out by the experimenter, who had a stop watch to time the presentation of the sentences. Extensive pilot work involving 12 subjects had indicated that 7 sentences provided the optimal difficulty level. Each subject had a 3x3 matrix taped to the table and a series of cards, with the shapes individually drawn on them, with which to record their responses. The seven shapes employed were a : Triangle, square, kite, star, octagon, parallelogram and cross. It was not the case that each of the shapes always appeared in each set of sentences, some sets included repeated shapes. Presentation was randomised which meant that subjects could not be sure what the last shape would be as would have been the case if the seven shapes were each only presented once. Of course, this randomised shape repetition would have no differential effect over form of presentation or recall. The subjects sat 1m in front of the computer which had a 3x3 matrix permanently displayed on it, each cell of which measured 4cm by 4cm.

VERBAL/VISUAL - The materials here were the same as above. Although the shapes and their location were also presented visually on the computer screen.

VISUAL - The appropriate shapes and their spatial locations were presented in the boxes of a 3x3 matrix by computer. A response matrix and cards were as above.

The matrix on the computer screen was present in all conditions in order to avoid matrix presence becoming a differentially important variable.

PROCEDURE

Again taking each condition in turn:

VERBAL - In this condition the subjects were told they were going to hear 12 sets of seven sentences of the sort "In the top left put a triangle, in the bottom centre put a kite...etc"

VERBAL/VISUAL - Here the subjects were told they would hear sentences as above and at the same time the said shape would appear in the said square on the computer screen.

VISUAL - Here the subjects were told that they would see seven shapes individually flashed up onto the screen at 4sec intervals in different boxes of the already visible matrix as was the case with the Verbal/Visual condition.

The subjects were instructed to attempt to build up a visual image of the shapes in their appropriate locations so that they could recall them in the required formation (either row or sequential) which was always specified before each set of the messages were presented. In order to get the subjects used to the shapes on the screen and their respective reconstruction cards a familiarisation period was allowed.

Each subject received four practice trials before the start of the experiment, two of row and two of sequential. The shapes were allocated random squares and presented successively with a display time of 4 sec and and ISI of 4 sec with no time limit on recall. The subjects would respond by entering the appropriate shape cards in the appropriate boxes of the table matrix in the required recall format. The verbal presentation rate involved each message being given over a 4 sec period with an ISI of 4 secs.

9.3.3 RESULTS

The method of scoring used in the previous experiment was adopted here. That is, one point was given for each shape card presented in the appropriate relative postion. The data from the experiment was analysed using a 3x2 mixed anova. There was a main effect of : Presentation (F)2,21)=4.5045,p=0.0236) with a Newman-Keuls indicating that both Verbal/Visual and Visual presentation (26.2 and 27.9 vs 21.2 and SDs of 5.0 and 5.18 vs 3.61) provide superior performance over Verbal (p<0.5). There was no main effect of Recall and no interaction.

9.3.4 DISCUSSION

Taking the Presentation variable first. It is clear from the results that the hypothesis put forward in the Introduction has been supported, in that the presentation format does not differentially effect form of recall. The reason that these results and those of Experiment 9 differ from those of Metcalfe et al (1981) among others is that in each of the conditions presented here subjects are encouraged to image the matrix and the stimuli. As such, one would not expect to find qualitative differences unless different image systems/processes were involved. In explaining why Verbal/Visual and Visual resulted in superior performance levels to Verbal one can assume, as in Experiment 9, that there is a translatory process involved. Visually presented material gains direct access to the VSSP but auditory material requires translation. This translation process results in the auditory material being represented visuo-spatially, but the representation is somewhat weaker than that of the material which received direct access.

The Results section indicates that there was no main effect of Recall. That is, there was an equality of performance for Row and Sequential recall. This result supports the hypothesis put forward in the Introduction. It had been suggested that employing shapes, which have no concept of ascendency and no normal ordering sequence, would lead to an equality of performance over the two recall conditions, as was the case with colours. This, in fact, is what happened and this result supports the finding of Anderson (1976) who used "pictorial forms" and found this gave rise to a temporal and spatial retention equality. The two experiments reported in this chapter, combined with the work of Anderson, do support the idea that there are conditions where subjects employ recall order that is different from presentation order with no apparent deficit in performance.

9.4 CONCLUSION

Experiments 5, 6, 7 and 8 showed that sequential coding is not a necessary part of this system as previous researchers (e.g., Healy, 1975b) had led us to believe (Murdock, 1969). There was support for the idea that numbers have an inherent sequential component which leads to sequential coding under certain conditions, while other stimuli which do not may not be dependent on sequential coding. This chapter presented two experiments which were designed to explore this further. Stimuli were employed, namely colours and shapes, which do not have any notion of ascendency or any inherent sequential component which the previous experiments had shown were crucial. These experiments have also shown that sequential coding is not necessarily a fundamental part of the system, at least not under the present experimental conditions.

This chapter began by asking whether there are two systems that are independent both of which are dependent on particular situations, or whether one is derivative of the other. The experiments reported here suggest that under certain conditions sequential coding does appear to be important, but they also suggest that when these conditions are not met then subjects are able to recall the required information in an order different from the presentation order. Combining the experiments here with the work of Frick (1985), Anderson (1976) and Battacchi, Franza and Pani (1984) among others (Metcalfe et al.,1981) provides support for the view that the coding of information in visual STM is very much dependent on a number of factors. These factors include memory materials, presentation formats and subject groupings.

CHAPTER 10 : CONCLUSION

10.1 INTRODUCTION

It was stated in the Preface to this thesis that each of the literature review chapters would take an essentially historical perspective. This was to illustrate how we as cognitive psychologists have developed our ideas : how we view the work being carried out as part of a continually evolving outlook. Bearing this in mind this chapter will indicate how our conceptions of the VSSP may develop as a result of the research presented here. To begin with then, a description of its form prior to this investigation will be briefly outlined. This will be followed by a presentation of the relation between this original concept and the results of the study carried out here. Following this issues raised which require further study will be put forward.

10.2 ORIGINAL FORMULATION

The Working Memory framework as described in Chapter 2 is presently thought to have three components, a central processing system known as the Central Executive, a system dealing with verbal information, called an Articulatory Loop and a system responsible for visuo-spatial information termed the VSSP. It has been accepted that of these three components the Central Executive is the most important and unfortunately the most difficult to explore. In approaching this problem theorists working within this area decided the best way forward would be to explore the so called slave systems and by separating off and clarifying these components we will eventually be left with those responsibilities necessarily attributable to the CE. Exploration of the Articulatory Loop advanced quickly. This was due to the presence of techniques of investigation such as Articulatory Suppression (Murray 1968). The AL has thus far evolved into a system which is believed to comprise a phonological store and an articulatory rehearsal process. This system, it has been suggested, has a role to play in learning to read, arithmetic and other verbal information processing tasks.

Investigation into the visuo-spatial component of the Working Memory framework was less dramatic. It was essentially neglected. The central reason for this can be said to be the lack of techniques of investigation (Logie, 1986). In fact since the Working Memory framework was originally postulated in 1974 there have been few papers published relating to the VSSP. Most of these studies have attempted to shed some light on the nature of the code. That is, whether it is spatial and/or visual. Together they combine with other research to provide us with a picture of the VSSP as a system which has a large spatial component and that either incorporates a visual component or that encompasses a parallel system for visual information.

10.3 DEVELOPMENTS

The first issue addressed in this thesis related to whether or not movement has a role to play in the VSSP. There had in the past been several studies examining the possible part movement may have in imagery, ranging from introspective reports (Paivio, 1971) to more general work in the imagery field (Janssen, 1976). However, with the exception of one unpublished study by Idzikowski et al (1983) there were no studies directly relating movement to the VSSP. If movement did have a role, a further question would require exploration, namely what type of movement is involved? It was not clear from the previous work whether the movement involved was eye movement as postulated by Hebb (1968) or a more abstract "move" process as suggested by Lea (1975). Another problem was the possibility that previous results indicating the presence of movement may have been confounded by the involvement of attentional factors. Two questions were asked : When the material to be encoded is spatially distinct within the visual field is movement at the base of the code? Is the type and form of movement important? The first series of experiments in this thesis set out with two aims. First, it was designed to examine whether the movement involved in spatial encoding is limited to eye movement or whether arm movements are relevant. Second, it was designed to produce a plausible separation of movement and attention. These experiments supported the idea that movement has a role to play in spatial coding and further specifically demonstrated that arm movements which are not compatible with the presentation of spatial material can cause disruption. In addition it was shown that when movement identical to that involved in presentation is encouraged at recall subjects show marked improvement in performance. Together these results very strongly suggest that movement should be given prominent reference in the definition of spatial coding and in the description of the properties of the VSSP.

Another development in our understanding of the VSSP that has come out of this thesis relates to a problem mentioned throughout this field. This is the problem of a lack of investigative techniques. This has always been a problem for researchers in the area of visual-spatial STM. Unlike those working in the AL field, visuo-spatial STM workers have struggled to develop techniques for exploration. It is hoped that the recent increase in suggestions, such as Logie's (1986) unattended patterns and Morris' (1987) stimulus arrays will help. The fact that it has been shown here that movement is important suggests that techniques employed to investigate kinaesthetic memory may provide appropriate techniques in the investigation of spatial coding.

This methodological change will have other important implications. The recent experiments exploring the VSSP often have as an important feature of their rationale and method, work performed in the visual imagery field, where a close cognitive relationship with the visual system has been established for some time (Paivio, 1971, see also Chapter 3). A seemingly unavoidable consequence of this has been the problem of avoiding interpretations heavily influenced by visual metaphors, with consequent difficulty for a possible separation of visual and spatial components of the VSSP. Interestingly, however, the theoretical development of kinaesthetic memory has neither relied on the research involved in the imagery sphere, nor have the techniques employed been ones taken from that sphere. One can legitimately hypothesise that a greater knowledge and awareness of the techniques and theories employed in research into kinaesthetic memory could combine with those involved in visual imagery to elucidate the distinction between visual and spatial components of the VSSP.

The second issue in this thesis explored the nature of the internal code further. Research into the nature of coding in visual-spatial STM has often argued for the presence of a sequential component. From the review in Chapter 7 it was clear that a number of different approaches have been employed to explore the influence of temporal and spatial elements on coding. These approaches ranged from the examination of the modality effects (Murdock, 1969); materials and format (Anderson, 1976); simultaneous vs. sequential presentation (Frick, 1985) and different subject groupings (O'Connor and Hermelin, 1973). These studies had indicated that there is still a great deal of debate within this area. Experiments 1-4 in this thesis had shown that movement had an important role to play in coding. The fact that movement by its very nature would appear to be sequential suggested that there was a strong sequential element in coding within the VSSP. However concern was expressed that the materials and presentation format employed (e.g., Anderson, 1976) may lead to sequential coding. Experiments 5-8 explored this. They supported the view that the material and presentation format used had led to sequential coding. This view was further explored by Experiments 9 and 10 which employed different stimuli. They once again illustrated that while it may be important under certain conditions, sequentiality is not always a dominant element in coding within the VSSP. Subjects are able to recall the required information in an order different from presentation, without this leading to a decrement in performance.

A view not dissimilar to the materials and format hypothesis was expressed by Quinn (1976) when he said that the mediation of particular codes is not an all or none matter. One may wish to say that a particular representation can be generated by different presentation modalities. There is no evidence to suggest that an underlying representation is necessarily defined by the modality of the presentation. As Hampson and Duffy (1984) suggest, a visual or spatial representation could be generated from a verbal description, from haptic input, or retrieved from semantic memory. Reducing this even further one could argue that particular aspects of an individual task could set up the code. Thus, it may be that there is a sequential component in movement but there may be other components which are just as important or even more so in their influence on the nature of the code. For example, one can divide movement up into three elements. It exists in space, time, and is sequential. It may be that it is the spatialness of movement that is influential in coding and that sequentiality and temporality are not as important and are only influential under certain conditions. This being the case we may say that to expect sequential recall to be generally superior to other forms was based partly on an erroneous interpretation of the dominant element within the movement task.

One could also argue that in movement, sequentiality may be of major importance but in tasks which do not involve overt movement, as in Experiments 5-10 then sequentiality will not predominate. In such experiments it is not surprising therefore that sequentiality is not an issue, or only under favourable circumstances such as the presence of Ascendency.

Another important issue that requires elucidation is the demands of the tasks employed in this thesis. This becomes clearer if we refer back to the discussion in Chapter 7 of the work of Alice Healy. She talks of an asymmetry present in the temporal and spatial tasks used in many early studies (e.g., Mandler and Anderson, 1971). Do the tests in this study contain an asymmetry? If one takes the movement experiments first : Here the subjects are asked to recall the spatial positions of the digits (i.e., the position of the digits in space). Is this the same in Experiments 5-8? What these experiments illustrated was that sequentiality was important providing Ascendency was present. What we need to ask is, are there any other differences present which may explain the superiority of Ascendency other than the inherent sequentiality of numbers posited earlier in this thesis. To explore this further one must look at what is required of subjects in both Sequential and Spatial recall under Ascendency and Non-Ascendency conditions. If we take Non-Ascendency first : With Sequential recall subjects have to recall both the Spatial position of the digits, i.e., where they are in space, and the order of the digits, i.e., whether they were presented (e.g., 3,1,5,7,6,2, or 3,1,7,5,2,6, or...n). With Spatial recall subjects have to recall both the spatial position of the digits, as in sequential recall, and the order of the digits, not their presentation order but the right to left order in the 3x3 matrix (e.g., 3,1,5; 7,6,2;...). If we take Ascendency presentation now we will see a difference. With sequential recall subjects still have to recall the spatial position of the digits, as above, but they do not have to recall the order of the digits. This is because the same order is used all the time, i.e.,1,2,3,4... . Spatial recall however is the same in Ascendency as in Non-Ascendency conditions. The conclusion one may wish to draw from this is that sequential recall is greater than spatial recall, not because of some inherent sequentiality within numbers but because an asymmetry has been set up which means that more processing capacity is required to cope with spatial recall than sequential recall. This increased processing requirement is not because the code is sequential but because one task requires more processing than another, perhaps at a simple attentional level.

With Experiments 9 and 10, where colours and shapes were used, no set order was used and sequential recall here was more similar to the Non-Ascendency conditions. That is, subjects had to recall both the spatial position, and order of colours and shapes. It may be important in the future to carry out an experiment incorporating a condition where Non-Ascending numerical order was employed, but the same order all the time, e.g., 2,5,3,...and/or an experiment where colours and shapes were presented but again in a consistent order all the time.

A final interpretation of the presentation of Ascending and Non-Ascending stimuli and, Sequential and Spatial recall involves hypothesising about the role of the Working Memory system as a whole during Experiments 5-8. Following from what was said above it may be that while the spatial position for digits is coded in the VSSP, the order of digits is coded in the AL. If as Morris (1987) states the CE is involved in coding and/or retrieval of information in these slave systems, then it may be that the difference in the recall conditions present in these experiments is a result of the limitations within the CE. If the CE is employed in coding then in Non-Ascending presentation and sequential condition, it is required to send the spatial position to the VSSP and at the same time the order of digits to the AL. This is the same for spatial recall when Non-Ascending presentation is employed. With Ascendency conditions for sequential recall only the spatial position has to be dealt with by the CE.

However, with spatial recall the CE has had to process the spatial position to the VSSP and order of digits to the AL. If the CE is involved in coding it may be that in conditions where information has to be distributed to both slave systems then there is a capacity overload and therefore information is not sent so efficiently and the subsequent representation is less well coded. It is also possible that if the CE is involved in retrieval then the same problem may arise, with information from both slave systems incoming and requiring output, one may again see overload. Whereas if information comes simply from the VSSP, as in sequential recall with Ascending numerical order, then the CE can cope quite easily and so output is easy and produces superior recall.

10.4 FUTURE

It is clear then that from its humble beginnings in 1974 and subsequent neglect, the VSSP has recently become of increasing interest to memory theorists. Its original postulation was understandably vague but over the years more studies have surfaced exploring this component of the Working Memory framework. This thesis has shown progress on two of the three central issues discussed at the beginning of Chapter 4. The first issue was not explored experimentally but is worth mentioning. It relates to the fact that while there is evidence for a spatial component in this system there is also support for a visual non-spatial component. Future research may explore whether there are two components within the VSSP. Two components which are relatively independent, or whether one is derivative of the other. What is obvious from the studies carried out thus far (e.g., Baddeley and Lieberman, 1980) is that more care must be taken to ensure that the tasks we employ are what we say they are (e.g., spatial rather than tactile) and that when using dual-task procedures our secondary tasks are at the very least formally equivalent.

The first issue explored experimentally in this thesis has stated the importance of movement. The type of movement involved in the VSSP requires further delineation. For example, does imaginal movement unaccompanied by any overt movement play a role in spatial coding? Is there a separate movement code which has close links with the VSSP? How does the work on whole body movements, such as those employed by Thomson (1980) relate to the VSSP?

The second issue in this thesis has specifically shown that sequential coding is not necessarily at the base of the VSSP. More generally it can be seen that from section 10.3 a greater analysis of the elements within tasks employed is required if we are to conclude anything from experiments involving them. This is not a new issue. It was discussed at some length in Chapter 4. It has been emphasised here by the previous section. Such asymmetries as may have occurred here clearly need to be minimised. We can also see that exploration of the role of the CE within the Working Memory framework may be further enhanced by adopting various manipulations of tasks involving verbal and spatial material such as that used in Experiments 5-10.

10.5 CONCLUSION

This thesis has attempted to explore two issues presently interesting theorists working in the VSSP. It is clear that it has furthered our knowledge of the workings of this particular slave system and added to the techniques for exploring it. What is also clear is that like all scientific endeavour it has raised more questions than it has provided answers. It is therfore appropriate perhaps to leave the last word to Andre Gide.

> I present this thesis for what it is worth - a fruit filled with bitter ashes, like those colocynths of the desert that grow in a parched and burning soil. All that it can offer to your thirst for a solution is a still more cruel fierceness-yet lying on the golden sand it is not without a beauty of its own.

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