USING IRRELEVANT PICTURES TO INVESTIGATE VISUAL WORKING MEMORY

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Using Irrelevant Pictures to Investigate Visual Working Memory

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Dedication

For Mum, Paddy, Gran and Grandad.

Abstract

Experiments 3 to 12 show that certain kinds of visuospatial material will differentially disrupt a visual memory strategy, even though subjects are instructed that the material is irrelevant. This irrelevant pictures effect is shown with a wide range of visual material including dynamic visual noise (Experiments 3 to 7 and 9 to 12), line drawings of common objects (Experiments 3 and 8), three by three matrices with the cells randomly black or white (Experiment 7) and a single dot that consecutively appears in five different positions in space (Experiment 12). The irrelevant pictures effect can also be demonstrated with two visual memory strategies that are qualitatively different from each other, the pegword mnemonic strategy and the method of loci strategy (Experiment 11).

This robust irrelevant pictures effect is used as a tool for investigating visual working memory and the results of Experiments 1 to 12 are presented as being broadly consistent with Logie's 1995 two-component model of visual working memory comprising a visual cache and an inner scribe.

The irrelevant pictures effect is evidence for the existence of the visual cache into which visual material is thought to have obligatory access. Experiment 9 demonstrates that static noise causes no interference with visual memory. Serially presented static noise in Experiment 10 does, however, selectively disrupt the visual strategy. It is hypothesised that the difference between the effect of the static pattern and the re-presented static pattern reflects the decay function of the visual cache. There is also support for the inner scribe part of the model. The star dots in

Experiment 11 are thought to disrupt the pegword mnemonic strategy because both draw on common resources within the inner scribe. Moreover, Experiment 11 shows that the two components of Logie's 1995 model of visuospatial working memory can be empirically distinguished within one experiment. It shows that a visual task which requires access to the rehearsal component is disrupted by a concurrent, irrelevant spatial task as well as a concurrent, irrelevant visual task. In contrast, a visual task that requires little access to the rehearsal mechanism is not disrupted by a concurrent spatial task but is disrupted by a concurrent visual task.

There are, however, also circumstances when the irrelevant visuospatial material disrupts visual and verbal memory strategies in a more general way, making attentional demands on the central executive part of working memory that are additional to those required to carry out the memory strategies. Three experiments look at this general effect of irrelevant pictures. Results suggest that the factors responsible for the placing of general demands on the central executive's attentional resources involve a focused, sufficiently unexpected change (Experiment 7) at the encoding stage of information processing (Experiment 8).

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Chapter One - Introduction

1.1 Cognition

Cognitive psychology, the area of psychology in which this thesis is based, is concerned with studying the principles underlying human mental behaviour. It seeks to explain patterns of intact behaviour in terms of the relationships among the behaviour's different components in a model of normal cognitive functioning. For this to be possible it is assumed that the various internal strategies for dealing with information are finite.

Cognition takes an information processing approach and is concerned with how information such as visual patterns or pictures is internally represented, related and manipulated. Cognition aims to develop broad models that preserve the complexity of events while also revealing new and testable relationships. To this end the components of a cognitive model must be clearly enough defined to be testable but broad enough to encompass the behaviour that is being modelled.

The cognitive approach assumes that mental processes can be broken down into modules which have a specific function and a specific input and output. This modularity only has to hold true at a functional level of analysis. Modularity may hold true at other levels as well but that is irrelevant to this work. For the cognitive approach to be valid it is not necessary to assume modularity at other levels so that, for example, a part of the working memory model discussed later, the articulatory loop, could be modular at a cognitive level but still be physically distributed throughout the brain.

Thus although cognition can be related to biological processes, it is not primarily concerned with mapping models to gross biology or brain structures, only with constructing models to reflect observed behaviours. Cognition looks at the functional architecture rather than neurological implementation. Although, ultimately, it will be important to discover which functions are carried out by specific parts of the brain, without the construction of accurate cognitive models it is difficult to begin to make sense of human behaviour.

1.2 Memory

Memory is a crucial part of the cognitive view of the human organism as an active information processor and all of our higher cognitive functions depend on it. Without a means to select, process and store relevant information about the world it would not be possible to build mental representations. Higher cognitive skills such as reading, mental arithmetic and reasoning all depend on a memory system that operates across a wide range of tasks and input modalities.

Although memory experiments in the laboratory tend to concentrate on simple tasks such as immediate recall of unrelated lists of words or numerals, in our daily lives memory is much more than a means to learn telephone numbers. Eventually any model of memory has to be relevant to the complex tasks that depend on memory processes. Given this complexity, a major issue in research into memory in the 1950's and 1960's was whether one system can cope with all our requirements of memory or whether there exist various independent processors operating with different processing representations.

Some memory tasks themselves seem to have two different components. For example, in free recall tasks where subjects are presented with more items than they can repeat back, they typically are poor at remembering items in the middle of the list when compared to items at the start or at the end of the list. This results in a distinctive serial position curve. The tendency for subjects' performance to be better for the last few items is called the recency effect while the improved performance at the start of the list is termed the primacy effect. These two effects are not confined to free recall tasks but can be found in other memory tasks such as serial recall. An important point about the recency and primacy effects is that a filled delay causes the recency but not the primacy effect to disappear. From this it seems likely that recency and primacy effects represent different components in memory. This is consistent with a dichotomous view of memory that assumes that the last few items presented to the subject in a free recall task are held in some form of limited capacity short-term store whose performance is diminished if there is a filled delay. In contrast, the primacy effect remains because it is thought to reflect a more stable long-term memory component, presuming that earlier items in the list have already been transferred to the long-term store.

Other evidence against a unitary view of memory is based on the idea of there being more than one coding involved in memory tasks. This argument is supported by the phonological/ semantic coding distinction. Using a span task which involved either phonologically similar or phonologically dissimilar letters, Conrad (1964) had found that phonologically similar letters tend to be more confused in both auditory and visually presented span tasks than phonologically dissimilar letters. This indicates that the processing involved in an immediate recall span task is phonologically based. In contrast, Baddeley (1966) presented subjects with the same list several times with the assumption that repetition would result in the words entering long term memory. When he also prevented subjects from using rehearsal, he found that the phonological similarity effect gradually disappears as the same list is re-presented to the subject and instead words with similar meanings become more confusable than words with different meanings. This is evidence that long term memory depends on semantic not phonological coding.

In addition, neurological evidence exists which implies the existence of at least two separate memory stores. Most of the relevant neuropsychological evidence comes from reports of patients with very specific brain damage and often involves selective disorders of either long or short-term memory. Milner's (1970) patient HM had been treated for epilepsy with bilateral lesions of the hippocampus and areas of the temporal lobes which resulted in his having problems remembering new memory traces. Patients with bilateral damage to the hippocampus were also described by Drachman and Arbit (1966). When such patients were compared to normal subjects it was found that their performances on immediate memory sub-span and span tasks were comparable to the normal subjects. Their performances on supraspan tasks, however, were much worse than the control subjects, even when they were presented with several repetitions of the lists. They appeared to have problems with encoding new information into long-term memory. Similarly, Baddeley and Warrington (1970) compared normal control subjects with patients suffering from Korsakoff's syndrome, a disorder brought about through alcohol abuse coupled with a poor diet. It was found that the patients' memory disorder was limited to the first part of the serial position curve and they were found to have impaired primacy effects but intact recency effects. In other words, they also had problems encoding new information into long-term memory.

Shallice and Warrington (1970), however, described a patient, KF, with damage to the left parietal lobe who had an impaired digit span. The patient's digit span was barely two items and the recency part of the serial position curve was impaired. In contrast, the initial and middle parts of the curve which are generally assumed to reflect long-term memory performance were intact. Unlike Baddeley and Warrington's (1970) patients, KF showed unimpaired long-term learning. Shallice and Warrington (1970) point out that this is incompatible with a view of memory that assumes that long-term memory and short-term memory use the same cognitive resources, only in different ways. They argue that at the very least it suggests a model in which verbal short-term memory and long-term memory have parallel inputs.

Eventually, results such as these were interpreted as evidence for the existence of two different memory mechanisms, a stable long-term representation based on semantic coding and a less stable short-term, phonologically based representation.

1.3 Short-term Memory

Although evidence accumulated against the view of memory as a unitary system, there was disagreement about the nature of the short-term store and there were several models in existence. These models had some common elements, however, and Atkinson and Shiffrin (1968) were able to combine common features of them to form a modal model which summarised thinking at that time.

The modal model had three stages. It consisted of sensory buffer stores which accepted information from the different modalities of the senses. These were thought to be low-level, passive, automatic stores in which the entry of information was obligatory, though some selection could take place from links with the long-term store (Atkinson and Shiffrin, 1968). The traces were initially very detailed but were thought to decay rapidly if the selected traces were not quickly fed into the next part of the model, a limited capacity short-term store. The short-term store was where conscious mental activities took place. It was thought that people could consciously choose to maintain material via a range of different strategies such as sub vocal rehearsal. The material was then fed into a much larger capacity long-term store. The longer that information remained in the short-term store the greater chance it had of entering the long-term store. Information in the long-term store did not decay as with the sensory stores and the short-term store but was stored permanently.

In essence, therefore, the modal model was relatively detailed and made a number of testable predictions. The three stores in the model were postulated as being distinct in the way that information was stored and preserved. Although there were some links between all the stores so that, for example, long-term information could be used for the selection processes in the sensory register, the passage of the information through the model was always the same, from the sensory register to the short-term store and then to the long-term store. The other predictions of the model included the correlation between learning and the amount of time an item is maintained in the short-term store.

Problems soon developed with this view of memory, however. Craik and Watkins (1973) tested whether it was true that the time an item spent in the short-term store determined recall performance. The data did not support such a relationship. The neurological evidence was also inconsistent with the modal model. In the three stage model, one stage followed another in a clear sequence with the short-term store being regarded as essential to long-term learning. In a model in which information had to pass through the short-term store before it reached the long-term store it should not be possible to find patients with deficits in short-term memory but with intact long-term memory performance. Unfortunately for the model, patients with this deficit did exist (Warrington and Weiskrantz, 1968). A further problem was demonstrated by Shallice and Warrington (1970). If KF had an impaired short-term store how could he still show intact comprehension and learning?

It was difficult for the modal model to account for the fact that it is possible to find a patient who has an impaired recency effect but an intact primacy effect (Shallice and Warrington 1970). This implies that the patient has a problem with short-term memory but not long-term memory. However, the modal model has long-term performance dependent on the amount of short-term processing. A deficit in short-term memory should lead to impairment in long-term memory but this does not always occur.

Another problem for the modal model was that the previous views of the recency effect and the coding in short and long-term memory were being modified. Recency effects were found in the organisation of material in long-term memory (Baddeley and Hitch 1977). In addition, Schulman (1974) found that experiments could be designed which demonstrated that semantic codes could be held in the short-term store as well as in the long-term store.

In the context of these problems, Baddeley and Hitch (1974) looked again at the role of the short-term store. Although it was thought to be crucial for tasks such as reasoning, problem solving and long-term learning, there was not very much evidence for this. For example Coltheart (1972) tried to show that the short-term store played a part in tasks of concept formation but could only provide evidence for the involvement of long-term memory in concept-formation. This was difficult to explain if short-term memory had a crucial part to play in carrying out these tasks. Baddeley and Hitch (1974) looked further at what short-term memory might be for.

1.4 The Working Memory Model

Baddeley and Hitch (1974) investigated whether short-term memory did have a role in tasks involving reasoning, language comprehension and learning. Moreover, if it could indeed be shown that short-term memory had a part to play in carrying out tasks such as reasoning and learning, they wanted to see if there was any evidence that such tasks shared a common working memory system.

Baddeley and Hitch (1974) used three different tasks. The first was a task of reasoning where subjects were presented with a sentence such as 'B is not preceded by A" followed by an answer "AB". Subjects were required to judge whether the answer was consistent with the sentence and respond accordingly, either true or false. In this case the correct response would be "false". The second task was a reading comprehension task where subjects listened to spoken prose passages, each of approximately 170 words and consisting of descriptions, narratives or arguments. Subjects were then given a typed script of the passage with every fifth word deleted. They were allowed three minutes to fill in the blanks. The third type of memory task adopted involved the retention and free recall of lists of 16 unrelated words. Baddeley and Hitch (1974) required subjects to carry out one of the three main tasks at the same time as they carried out various other information processing tasks. They reasoned that if performance on either or both tasks was disrupted, then this would be evidence that the tasks shared the same cognitive resources from a single, fixed capacity source.

The first manipulation that was carried out was to present subjects with an additional memory pre-load. Subjects were required to carry out one of the three above tasks while also holding three or six digits in memory. A second manipulation involved subjects having to concurrently perform an articulatory suppression task such as repeating "the", counting continually from one to six or repeating six randomly presented digits. This manipulation was not used in the comprehension task but was used for the reasoning and free recall tasks. The last manipulation of the three tasks was that of susceptibility to phonemic similarity. This was shown by the degree to which performance was decreased when sequences were phonemically similar.

Over all of the three tasks a consistent pattern of additional memory load effects was shown, with the size of the decrement being a function of the size of the preload. It was found that whilst a memory load of six items disrupted performance on all three tasks, a memory load of three items had little or no effect. Articulatory suppression resulted in a decrement in performance in both the reasoning and free recall tasks. All three tasks also showed evidence of phonemic coding. Baddeley and Hitch argued that this consistent pattern of effects was evidence for the operation of a single working memory system. This system was also thought to have something in common with the mechanism responsible for the digit span. Not only is it susceptible to disruption by a concurrent digit span task, like the digit span it also shows signs of being based at least in part upon phonemic coding. This resemblance to digit span was not thought to be a perfect fit, however, because the effects of phonemic coding and articulatory suppression were not very strong. This suggested that although there was overlap between digit span and working memory, there was a significant portion of working memory remaining which was not taken up by the digit span task.

From this Baddeley and Hitch (1974) argued that there was indeed a common working memory system, the core of which consisted of a limited capacity store responsible for both control processing demands and storage. In addition they also proposed a phonemic response buffer which is able to store a limited amount of speechlike material in the appropriate serial order.

Although it is argued that the central part of working memory can be used for storage, Baddeley and Hitch (1974) suggest that it is mostly responsible for control processes such as setting up the appropriate phonemic "rehearsal" routines. In other words, the central executive loads up the phonemic buffer and retrieves information from the buffer when necessary. Only when the capacity of the phonemic buffer is exceeded does the central part of working memory have to use some of its capacity for storage, thus leaving less resources for executive functions. This flexible "work space" later became known as the Central Executive while the phonemic buffer component developed into the Articulatory Loop.

Although their model so far had mainly dealt with the processing of verbal material, Baddeley and Hitch (1974) suggested that it seemed probable that a comparable system existed for visual memory. They reported an unpublished study by R. Lee which required subjects to look at different pictures of scenes and say whether further pictures were views they had already seen or were new views. It was found that subjects performance on this task was worse if they were required to carry out a concurrent mental arithmetic task. From this Baddeley and Hitch concluded that this separate visual system uses the same "core" of working memory as does the system for processing verbal material.

Instead of the idea of a single short-term store, Baddeley and Hitch therefore developed the idea of a multi-component working memory with a limited-capacity Central Executive responsible for attentional processes and with temporary storage occurring in a number of different subsidiary systems. These subsidiary systems were referred to as slave-systems.

1.5 The Development of the Working Memory Model

The development of working memory has been the story of the continuing fractionation of its concept of memory.

The working memory model was not different from that of the modal model in assuming that the short-term store acts as a temporary working memory for holding and manipulating information, enabling us to perform a wide range of cognitive tasks. What was different was the idea of a multi-component model of short-term memory where the interconnected parts of the model had different sub-systems that in turn could have independent resources. This model was useful in that it did not have the same problems that the unitary models of short-term memory were encountering.

For example, the description of K.F. by Shallice and Warrington (1970) can be better understood with a multi-component working memory model. K.F was shown to have an impaired digit span but no long-term learning problems. This presents problems for the view of a single short-term memory store but is quite compatible with the idea of a multi-component working memory system as proposed by Baddeley and Hitch (1974). The working memory model would assume that it is possible for one part of the model to be impaired leaving other parts intact. In the case of K.F. it was suggested that the phonemic buffer component of working memory was impaired while the central executive component remained intact. However, the working memory model as originally proposed in 1974 was still quite sketchy.

In their initial paper, Baddeley and Hitch (1974) had suggested that word-length could be used to look closer at the phonemic buffer component. They reported an unpublished experiment by Baddeley and Thomson which showed that performance on a span task decreases as word-length increases. If the crucial units in verbal working memory are words then manipulating word-length should not alter performance. The fact that performance is affected by word-length therefore suggested that words are not the fundamental factor in verbal working memory. This still left the possibility, however, that its capacity could be measured in syllables or phonemes.

Baddeley, Thomson and Buchanan (1975) studied the influence of word-length on memory span. They carried out two experiments comparing span performance with long and short words and found that memory span was sensitive to word-length over a range of verbal materials. They then carried out three further experiments to investigate the importance of the number of syllables and the temporal duration on memory span. It was found that when the number of syllables and phonemes were kept constant, memory span was better with words of short temporal duration than with words of long temporal duration. Memory span was found to be roughly equivalent to the number of words that could be read in about one and a half to two seconds.

This was a very important finding because the word-length effect was evidence that the capacity of verbal working memory is not based on the number of syllables. Instead capacity appears to be based on time needed to articulate. The initial investigations of the word-length effect seemed to be evidence that verbal working memory consists of a simple limited capacity articulatory loop system akin to a closed loop on a tape recorder, with capacity being not item-based but time-based. This would assume that the word-length effect occurs because long duration words take longer to rehearse so less long words can be remembered than short words. However, further experiments by Baddeley, Thomson and Buchanan (1975) showed that the articulatory loop alone was not sufficient to model verbal working memory.

An important secondary interference task used in research in verbal working memory is the technique of articulatory suppression. This is a task that involves the continual repetition of an irrelevant word such as "the" or a short sequence of numbers. It is thought that articulatory suppression interferes with and may prevent rehearsal. If carried out at the same time as other tasks, concurrent articulatory suppression should show how these tasks are affected by rehearsal being disrupted. Certainly, if a subject carries out articulatory suppression it results in a substantially reduced digit span which suggests that memory span relies at least partly on the ability of the subject to rehearse.

Baddeley, Thomson and Buchanan (1975) used articulatory suppression in order to prevent their subjects from rehearsing and found that the word-length effect disappears with articulatory suppression and visual presentation but remains intact when presentation is auditory. This was a problem for the interpretation that the word-length effect is the result of the limited capacity of the rehearsal loop because if suppression prevents rehearsal and the articulatory loop is unable to function then the word-length effect should disappear with suppression and auditory presentation, not just with visual presentation. This anomaly was resolved by Baddeley and Lewis (1981) who found that articulatory suppression has different effects depending on whether the articulatory suppression occurs during presentation or presentation and recall. They found that if articulatory suppression occurs only during presentation subjects are still able to use rehearsal during the recall period to maintain items if the presentation is moderately rapid. When articulatory suppression is present at both presentation and recall then subjects are prevented from rehearsing and the word-length effect is abolished, even with verbal presentation.

Additional evidence for the organisation of the verbal part of working memory came from Colle and Welsh (1976). They reported that the verbal span performance of subjects declined when they were presented with irrelevant sounds in a foreign language that they were not familiar with. In their experiments, German was used. Even though the subjects knew that the sounds they were being presented with were irrelevant and even though they didn't understand their meaning, their performance on recalling sequences of letters declined. This finding that verbally presented speech-like sounds interfere with span tasks, even when subjects are instructed to ignore the irrelevant sounds became known as the irrelevant speech effect.

Salame and Baddeley (1982) looked further at the irrelevant speech effect and found that the magnitude of the effect is still the same regardless of whether subjects are presented with meaningful words or with nonsense words. The effect is not shown, however, when the subjects are presented with white noise which suggests that only speech-like material elicits the interference. Their experiments were not simply designed to focus on irrelevant speech itself, however. They also wanted to focus on the contribution of articulatory suppression and semantic and phonemic factors in the irrelevant speech effect to look further at the organisation of verbal working memory. Salame and Baddeley (1982) found that the irrelevant speech effect disappears with articulatory suppression and visual presentation of the material to be remembered. Moreover, when they looked at the phonological characteristics of the irrelevant material they found that like the phonological similarity effect, greater disruption was found when the irrelevant material was phonologically similar to the span items than when the irrelevant material was phonologically dissimilar.

Salame and Baddeley (1982) suggested that instead of a single system, verbal working memory should be thought of as comprising of two components, a passive, phonologically based store that is maintained by control processes within a separate active sub-vocal rehearsal store. In this model of verbal working memory, verbal memory span is taken to be a function of both the durability of a trace within the phonological store and the rate at which rehearsal can refresh the trace. It seems that a phonological trace will fade within one to two seconds unless rehearsed to reactivate the trace. As well as maintaining memory traces in the phonological store which would otherwise fade, the articulatory rehearsal process is also thought to be the way that visual material is transformed into a phonological code. The irrelevant speech effect suggests that speech-like material has obligatory access into the passive phonological store. Once in the phonological store the irrelevant speech is thought to interfere with phonologically similar material that is also present in the store. If the material is presented visually, however, then access to the phonological store is only possible via active subvocal rehearsal mechanisms.

Baddeley, Lewis and Vallar (1984) looked further at the expanded version of the working memory model. Over a series of experiments they confirmed the finding that the phonological similarity effect is not diminished under conditions of articulatory suppression and verbal presentation. They explained this by suggesting that the phonological similarity effect was a feature of the passive phonological store, not the articulatory loop and that the phonological similarity effect reflects the nature of the coding in the phonological store. The phonological store is presented as being responsible for the phonological similarity effect on the assumption that phonologically similar items lay down similar and hence confusable traces in the store. The persistence of the phonological similarity effect with auditory presentation, despite articulatory suppression during both input and recall, is consistent with the assumption that auditory, speech-like material gets obligatory access to the phonological store. With visual presentation, registration in the phonological store occurs only if the subject is able to vocalise the items using the active rehearsal process. If this is prevented by articulatory suppression, then the material is not registered in the phonological store, recall is based on other sources of stored information, and no phonological similarity effect occurs. The word-length effect is assumed to be a characteristic not of the phonological store but of the articulatory rehearsal process. Long duration words take longer to rehearse so less long words can be remembered than short words. With articulatory suppression the subject is prevented from rehearsing and the effect of word-length disappears with both visual and verbal presentation.

The working memory model continues to be developed. The model suggests that articulatory suppression prevents visually presented items from being phonologically encoded. This is at odds with the finding that subjects are still capable of making rhyme judgements on visually presented words while suppressing articulation (Baddeley and Lewis, 1981). Baddeley and Lewis make a distinction between an "inner voice" located in the articulatory loop system and an "inner ear" which is assumed to be independent of articulation. It is suggested that this could be mediated by "some form of acoustic image", by the assumption that different codes are used in the phonological store setting up "traces of different strength or durability" or by accessing phonological representations in long-term memory (Baddeley, 1986, p86). This is an area of the model that is still evolving.

Even more fundamental to the development of verbal working memory is recent work which focuses on identifying the characteristics of verbal material that will elicit the irrelevant speech effect. Morris and Jones (1990) presented subjects with lists of different lengths and asked subjects to recall the last four items that were presented. The subjects were not able to predict the length of each word list and so had to keep updating the four words that were being maintained. Morris and Jones found that irrelevant speech impaired performance on the subjects serial recall but found that the magnitude of the disruption did not increase with the longer lists. They concluded that the effect of the irrelevant speech operated on the part of verbal memory responsible for maintaining the serial order of the words, not the part of verbal working memory responsible for updating the target set of words the subject was maintaining. This is consistent with Salame and Baddeley (1982) who found that it is only tasks requiring serial recall which are disrupted by irrelevant speech. Morris and Jones (1990) concluded that a requirement for serial recall is necessary in a memory task if irrelevant speech is to have a disruptive effect on that memory task. More fundamentally, it is suggested that it is the presence of changing state cues which account for the irrelevant speech effect. It is argued that disruption in memory occurs due to confusion between the cues to serial order present in both the serial recall task and the irrelevant speech. This contrasts with Salame and Baddeley (1982) who argued that only speech-like sounds would elicit the irrelevant speech effect and that it was the phonological coding in the irrelevant material which was the decisive factor.

Jones, Madden and Miles (1992) investigated the hypothesis that it is the changing state within verbal material which elicits the disruption caused by irrelevant speech. This hypothesis predicts that the disruption caused by irrelevant speech should be in proportion to "the variation in the auditory stream" (p653). The first two experiments presented evidence that not every speechlike sound will disrupt serial recall. Subjects in the first experiment were presented with two forms of speech-like irrelevant material, either a continuous "ah" sound or and intermittent "ah" sound. Experiment two involved varying the spectral properties of the sound in a predictable or in an unpredictable way. No disruption on a serial recall task was found in either experiment. Experiment three contrasted the effect of repeating a single syllable with repetition of a set of syllables to assess the importance of changing phonology on the irrelevant speech effect. The repeated presentation of the same syllable did not disrupt serial recall but the repetition of a set of syllables did disrupt serial recall. This set of syllables were presented in a random order. Experiment four contrasted this random order of syllables with more predictable sequences. Making the sequences more predictable did not reduce the disruption caused by the sequences of irrelevant syllables. This supports the prediction that it is the changing state of the irrelevant material that is the crucial factor in irrelevant speech. Moreover, it confirmed that it is changes between single discrete syllables that elicits the disruption, not some higher-order feature that operates between groups of syllables.

These results did not dismiss the argument of Salame and Baddeley (1982) that the irrelevant speech effect is associated with the phonological similarity between the relevant and irrelevant material; the results do not rule out phonetic composition being an important factor. A more convincing demonstration of the changing-state hypothesis was demonstrated when Jones and Macken (1993) found that a stream of changing tones will disrupt serial recall just as much as the repeated four syllables used in Jones, Madden and Miles (1992). This is a promising area of investigation as it is starting to focus on much broader features of the irrelevant speech than just phonology. As the definition of "changing state" is developed further this will give a more detailed model of the representations within the phonological store.

1.6 Implications of the Working Memory Model

The combination of using techniques such as articulatory suppression and irrelevant speech on word-length and phonological similarity have clearly resulted in a more detailed understanding of the two different components of verbal working memory, the active sub-vocal rehearsal process and the passive, phonologically based store. The detailed nature of the extended model of working memory has made it ideal for investigating verbal deficits. Vallar and Baddeley (1984) used the technique of articulatory suppression combined with tests of word-length and phonological similarity to see how the extended version of the articulatory loop model could explain the locus of the deficit of P.V.

P.V. was a thirty year old Italian woman who had suffered a stroke with a transient loss of consciousness. She had suffered a right hemiparesis which had cleared in one month. P.V. is described by Vallar and Baddeley as having a "classic deficit of short-term memory" (p153). Her auditory span was extremely poor, while her performance on visual tasks was better than average. Her performance did not improve when tested on a recognition-by-pointing technique which ruled out the possibility that covert deficits of speech production were impairing her performance. In addition, she had no general cognitive deficits. P.V. had a problem with repeating sentences, being unable to repeat phrases longer than eight syllables. In addition, she was unable to process sequences of digits, words or actions if presented auditorily. She did not have a problem, however, when the same sequences of words were presented visually. When computerised tomography was used to look further at her deficit, P.V. was found to have an ischemic lesion that covered the whole language area in the left hemisphere.

Vallar and Baddeley (1984) used the extended version of the working memory model to pinpoint the nature of P.V.'s deficit. They carried out three experiments to assess her performance on tests of phonological similarity, word-length and articulation rate. With verbal presentation P.V. did show a phonological similarity effect which indicated that she did have use of the phonological store. The fact that this phonological similarity effect was weak, however, indicated that the capacity of her phonological store was low. In contrast with normal controls P.V. did not show a phonological similarity effect with visual presentation, suggesting that she was unable or unwilling to subvocalise the items to be remembered. This interpretation was confirmed by the fact that P.V. did not show a word-length effect with either visual or verbal presentation. P.V.'s articulation, however, was found to be normal which confirmed that she did not have a basic articulatory problem. Baddeley and Vallar suggest that her failure to use subvocal rehearsal is caused by the rehearsal processes being dependent on the phonological store for its effectiveness. If the store is not functioning adequately, then subvocal rehearsal might be expected to offer no advantage and so there is no point in P.V. using subvocal rehearsal. This suggests that her failure to use subvocal rehearsal reflects a strategy choice due to the fact that the phonological store is damaged.

Baddeley, Papagno and Vallar (1988) demonstrated that although P.V. was able to associate pairs of meaningful words, she was not able to learn associations between words and non-words. P.V. was unable to learn associations involving non-words because the non-words did not already exist in long-term memory and she was required to rely totally on her phonological store. As this store was damaged she was not able to learn new associations involving non-words. This implies that the phonological store may have a role in long-term learning, especially in learning the vocabulary of a new language. It also suggests that tests of non-word repetition that present subjects with novel nonwords are sensitive indicators of the effectiveness of the phonological store.

Gathercole and Baddeley (1989a) investigated the role that the phonological store has in the acquisition of vocabulary by young children. Instead of comparing the phonological skills of normal children and language-disordered children as previous studies had done (e.g. Gathercole and Baddeley, 1989b), they looked for an association between phonological memory and vocabulary within a normal group of children. For this reason they looked at the vocabulary, nonverbal intelligence, reading and phonological memory skills of 150 children who had no known language problems. The children were first tested between the ages of four and five and then again a year later. A test of phonological memory involving associations between words and non-words such as was used with P.V. would have been too demanding for such young children. The test selected for measuring phonological memory was therefore a nonword repetition test that had been previously shown to be effective in distinguishing language-disordered children from their verbal controls (Gathercole and Baddeley, 1989b).

At the first stage of testing it was found that the children's score on the test of phonological memory was correlated with that of vocabulary. The association between phonological memory and vocabulary was found to be a stable association which could not be attributed to factors of intelligence or chronological age. This confirmed that individual differences in vocabulary are associated with phonological memory skills in normal pre-school children. It was found that this relationship was preserved at the second stage of testing one year later when the children were starting to acquire reading skills. Repetition performance at age four was also found to be a significant predictor of vocabulary skills one year later, even when the contribution of vocabulary knowledge at age four was partialed out. This means that phonological memory skills at school entry do predict the degree of vocabulary development during the first year of school. Although the relationships are correlational in nature, the data are consistent with phonological skills having a causal role in vocabulary development. Unfortunately the mechanism by which phonological memory contributes to vocabulary learning is less clear. The authors conclude that as we presently lack a detailed quantitative model of the phonological short-term store, the articulatory loop, or the learning system as a whole then any conclusions reached on this issue are necessarily speculative.

Research in the working memory field has concentrated not only on expanding the model but has also been carried out to focus on the implications of the model for various information processing tasks such as reasoning, comprehension and learning (e.g. Toms, Morris and Foley, 1994). Gathercole and Baddeley (1989a) focused on the role of working memory in only one aspect of learning, in this case the role of the phonological store in learning vocabulary. Other studies have been carried out focusing on the contribution of working memory to other types of learning. For example, ambitious research has taken place into the contribution of working memory in the acquisition of complex skills. Logie, Baddeley, Mane, Donochin and Sheptak (1988) used the working memory model to analyse the performance of subjects on a complex computer game and assess difference that occurred following extensive practise.

1.7 The Working Memory Approach

Although the working memory model has proved detailed enough to be used in the investigation of many different aspects of cognition, the techniques that have been adopted have common elements and a distinctive working memory approach has emerged. One of the key concerns in the working memory approach is to take account of the attentional processes within the central executive. The central executive was proposed as the supervisory controlling part of working memory carrying out complex processing and co-ordinating the slave systems. As such it was assumed to have a limited amount of processing capacity yet, ideally, to function as a pure attentional system, off loading most of the storage demands on to the subsidiary slave systems. When the model was proposed, Baddeley and Hitch (1974) admitted that the central executive represented the most important but the least understood part of the model and to a large extent this is still the case (Baddeley, 1992).

Experiments in working memory often take a dual-task approach, comparing the effect of secondary interfering tasks on different main tasks. While the work is usually aimed at investigating the kinds of processing in the sub-systems, any work done in the working memory field has to take account of the existence of the central executive by trying to equalise the attentional demands of the main memory tasks that the subjects are required to carry out. In the multi-component model of short-term memory the interconnected parts of the model have different sub-systems that in turn have independent resources. A particular memory task or secondary task can call upon these resources to differing extents and so the nature and organisation of the multi-component working memory can potentially be teased apart by observing the degree of disruption caused by various secondary tasks. This explains the popularity of the dual-task approach in working memory and experiments often involve investigating the extent to which a secondary task will selectively disrupt performance on a particular main task, while leaving performance on other tasks intact.

An appropriate secondary task is one that can be performed at the same time as the main task with the experimenter having control over the difficulty level of the secondary task. This is not always easy to achieve as trade-offs of attention can occur between two tasks, with subjects using strategies to reduce the cognitive load such as varying the speed or accuracy of their responses. Subjects could also try switching their attention from one task to the other. The dual-task design only works if the subject is carrying out both tasks simultaneously, and giving the tasks a constant amount of attentional resources.

One of the tasks is typically fairly simple. It should be able to be performed relatively automatically and often the subject is trained in the task in advance. For example in a pursuit rotor task the subject might be asked to keep a photo cell on target as much as possible using only auditory feedback. The nature of the task means that the subject has to be paying attention the whole time and there is only one measurement (being on or off target). The speed of the target and hence the initial difficulty of the task can be adjusted until performance is at a certain level.

A good example of the working memory approach is provided by Baddeley, Grant, Wight and Thomson (1975). They used pursuit tracking as a main task and adjusted performance to around the 80-90% level. They adopted two different secondary tasks, a visualisation task and a verbal categorisation task and subjects were required to maintain their practice levels of performance while carrying out the secondary tasks. Brooks (1968) had found the visualisation task and the verbal categorisation task to be of roughly comparable difficulty so they should cause equivalent disruption. It was found that the amount of disruption that the secondary task elicited varied depending on the nature of the tasks. The verbal task did not significantly disrupt performance on the pursuit rotor task while the visualisation task did result in a significantly reduced level of performance. Moreover, the fact that the subjects were able to carry out the verbal task without disrupting the pursuit rotor task implies that the verbal categorisation task was using different resources to those required by the main task. In contrast, the visualisation task did significantly disrupt performance on the pursuit rotor task, implying that to some extent these two tasks rely on common resources.

Varying the nature or the task demands of the secondary material can give clues as to the nature of the underlying memory representation in the specific sub-systems and dissociations occur when a particular secondary task disrupts one task but not another. Dissociations are important because they can be used to support or present difficulties for a theory of normal function. Double dissociations, however, are much more robust. Baddeley, Grant, Wight and Thomson (1975) assumed that the visualisation task and the verbal categorisation tasks were of roughly comparable difficulty because of Brooks (1968). There was, however, a significant difference between the time that it took to complete the two tasks (table 2, p210). The results of the experiment would have been more convincing if another main task had been introduced which was disrupted by the verbal categorisation task but not the visualisation task. This on its own would not rule out the possibility that the visualisation task and the verbal categorisation task have different attentional demands. It would, however, have shown that the two secondary tasks are not using a single pool of resources.

Converging evidence from other sources can also be used to test cognitive theories and in the working memory literature, evidence from neuropsychology has increasingly become important (e.g. Hanley et al, 1991; Farah, 1988). Much of the work still follows the simple dual-task approach that is empirically driven. Double dissociations rule out effects of task difficulty and so are more robust than single dissociations. Often, however, methodological constraints can make double dissociations very difficult to achieve and single dissociations are the only data available. Single dissociations are not sufficient on their own to form a theory but a variety of different results can contribute evidence to form a theory. In his paper asking "Is Working Memory working?", Alan Baddeley describes his approach to researching working memory as being "phenomenon-driven, relying on a pattern of results from a number of relatively simple experiments" (Baddeley 1992, p3) and this gradually cumulative approach has led to the development and refinement of the working memory model over the last twenty years.

Baddeley and Hitch (1974) expected that eventually a number of subsidiary slave-systems would emerge as the sub components of the executive were separated to become tractable problems for study. It was hoped that this would leave a much more manageable central executive, one that was simply an attentional system. However, only two slave-systems have been proposed and systematically investigated, the articulatory loop which maintains verbal material by sub vocal rehearsal, and the visuospatial sketchpad (VSSP) which performs a similar function for visuospatial material. Much less is known about the organisation of visual working memory than verbal working memory and in the original formulation of the working memory model by Baddeley and Hitch (1974), a non-verbal slave-system responsible for the temporary storage of visuospatial material is discussed only briefly and in no detail. The working memory model, especially the verbal component, has, however, been very successful. Work in the verbal memory sub-system of working memory has not only provided clues as to the cognitive architecture of the sub-system, isolating the separate articulatory loop and passive phonological store components of the verbal sub-systems, but also has provided clues as to the nature of the representation of the verbal material.

Chapter Two - The Visuo-spatial Sketchpad

2.1 Evidence For A Functionally Separate VSSP.

Since 1974, many studies have been carried out specifically to uncover more of the details of the non-verbal parts of working memory (e.g. Baddeley, Grant, Wight and Thomson 1975, Baddeley and Lieberman 1980). In contrast to our relatively detailed knowledge of the verbal part of working memory, these studies have not yet resulted in a clear idea of the underlying organisation of the VSSP but progress has been made.

Even before 1974, there was evidence emerging for the existence of a functionally separate visual store. Brooks (1968) required subjects to categorise verbal or visual material. The Brooks verbal task involved categorising words in a recently presented sentence as nouns or non-nouns. In the example given, a subject would be presented with a sentence "a bird in the hand is not in the bush". In this case the answer would be "no, yes, no, no, yes, no, no, no, no, yes" (p350). As well as having subjects respond vocally, Brooks required some of the subjects to tap with one hand or the other or to point to the words "yes" or "no" which were printed in an irregular sequence on a sheet of paper. The corresponding visual task to this involved categorising each corner of a recently presented line drawing, indicating whether each corner was a point on the extreme top or bottom of the figure, or was a point in between. In the example given the subject was presented with a large capital F figure with an asterisk at the bottom left for the starting point and an arrow pointing upwards for the direction the subject proceeds in. The answer to this would be "yes, yes, yes, no, no, no, no, no, no, yes" (p351) if the subjects was required to respond verbally. As before, subjects could instead be asked to tap the answer or point to the sequence. Using both the categorising main tasks and the three different response conditions, Brooks found that the verbal form of report interfered most with the verbal main task while the pointing task interfered most with the visual main task. Experiment 2 increased the task demands by making the subjects' verbal responses more complex. He still found that the verbal response interfered more with the verbal main task. From this Brooks concluded that visuospatial information and verbal information are recalled and processed in a modality-specific way.

A less direct source of evidence for a specialised visuospatial component in short-term memory separate from the verbal component comes from developmental research which suggests that visual and verbal stores develop in quite different ways. Hitch, Halliday and Schaafstal (1988) suggest that the pattern of development is initially that of the child relying on a more visual form of memory. Young children do not rehearse because they show no word-length effect and no primacy effect. The late emergence of the word-length effect indicates that the use of the verbal store develops after use of the visual store. Hitch, Halliday, Schaafstal and Schraagen (1988) suggest that the pattern of development "is one of an increase in the number of codes available in working memory rather than the substitution of one type of coding for another" (p130). In the youngest children, access to the phonological storage component is still developing so they only lay down the visual code in memory. When older children have to remember nameable pictures they lay down both visual and verbal codes. This is supported by developmental work on reading (Holligan & Johnston 1988) where when tasks demands are high, both good and poor children abandon verbal rehearsal as a mnemonic strategy, thus showing less phonological similarity effects. It seems that poorer readers normally find task demands higher than average readers and they habitually use a different form of coding, probably visual.

Additional evidence for a separate specialised visuospatial component in short-term memory comes from neurological data. It has been argued by Salthouse (1974) that there is an anatomical difference in verbal and visuospatial processing since the right hemisphere is typically specialised for processing spatial information, while the left is specialised for verbal information. De Renzi and Nichelli (1975) described a group of patients with damage to the right hemisphere who typically showed low scores on the Corsi block span task but who had normal scores for digit span and long-term visuospatial memory. This was in contrast with a group of patients with damage to the left hemisphere who showed the opposite pattern of results. Warrington and Shallice (1972) reported that a patient K.F., who had damage to the left parieto-occipital region. K.F. was shown to make a greater number of visual errors when material was presented visually than should occur by chance. When presentation was verbal the patient made a significantly greater number of acoustic errors. They used this data to argue for the existence of separate visual and verbal short-term stores.

Shallice and Warrington (1970) reported that unlike normal subjects, patients with damage to their short-term memories tended to have better spans for visually presented material than for material that was verbally presented. They suggested that this implied that the patients had problems with the verbal part of their working memory and so were having to rely on the visual side of working memory. Vallar and Baddeley (1984) also argued that patients with short-term memory deficits such as P.V. who have a consistently higher performance on memory span tasks with visual presentation, provide evidence for the existence of a separate visual short-term memory system. P.V. had a better memory span with visually presented digits than with verbally presented digits. She had a grossly deficient auditory span but performed well within the normal range on tasks of visuospatial short-term memory such as the Block Tapping Test and a visual maze (De Renzi, Fagliori and Previdi, 1977). P.V. was unable to process sequences of digits, words or actions if presented auditorily but she had no problem when the same sequences were presented visually. Vallar and Baddeley (1984) argued that P.V. chose not to use articulatory rehearsal processes because her phonological store was damaged and that she instead appeared to rely on a more visual form of storage.

There have, however, been arguments against the existence of a functionally separate visual store. In looking at evidence within the working memory literature for visual and verbal tasks having separate forms of representation, Phillips and Christie (1977) agreed that the evidence for the existence of the articulatory loop with its specific verbal processing is plausible, but argued that visualisation-type tasks may only require general purpose resources. Earlier experimenters such as Brooks (1968) assumed that their results indicated the existence of a functionally separate visuospatial system. Phillips and Christie rejected this view when they looked at the effect of a variety of secondary tasks and found that most tasks, no matter what their modality, resulted in a drop in performance of a visual task, suggesting that the tasks were eliciting general disruption, not specific disruption. Phillips and Christie (1977) argued that "it is just as plausible to assume that a central executive of some kind performs the visualisation as to assume that it does not." (p649). This means that the existence of a functionally separate VSSP is not necessary. Baddeley and Lieberman (1980) found this argument convincing initially and suggested that visuospatial working memory is dependent on "a central processor of limited capacity" (p538). This would mean that visualisation uses general cognitive resources. Farmer, Berman and Fletcher (1986), however, felt that this argument could be countered if they could demonstrate the existence of a task that places heavy demands on the VSSP but minimal demands on the central executive. They found that articulatory suppression in the form of the continuous repetition of the digits one to four disrupted a verbal but not a spatial reasoning task. In contrast, spatial suppression in the form of continuous sequential tapping disrupted the spatial but not the verbal reasoning task. Neither the articulatory or the spatial suppression placed significant demands on the central executive. This, together with the crossover interaction, led Farmer, Berman and Fletcher (1986) to conclude that there was evidence for a separate specialised visuospatial short-term storage mechanism in working memory.

Phillips (1983) argued there is still evidence that the VSSP relies on general purpose resources since an arithmetic task can be shown to interfere with the retention of matrix patterns. Since arithmetic is a non-visual task it is not consistent with the idea of a specialised VSSP slave-system that arithmetic can disrupt the matrix patterns unless the central executive plays a significant role in the retention of the matrix patterns. Logie, Zucco and Baddeley (1990), however, countered this by arguing that the amount of general disruption that the visual secondary task causes "is far outweighed by the differential disruption produced by a secondary task with a strong visual processing component" (p67). Like Phillips (1983), they found that arithmetic did disrupt visual retention but this was significantly less than the disruption caused by the secondary task. They accept that the impairment in performance in short-term visual memory from secondary arithmetic reflects a small general processing load but maintain that the selective interference due to the mode of processing is by far the stronger effect. In this way, Phillips (1983) argument is weakened by crossover results which can not be explained if processing is carried out by a general resource pool. Crossover results of visual and verbal tasks where one secondary interference task disrupts the visual but not the verbal task, while another source of interference disrupts the verbal but not the visual task provide evidence for a separate specialised visuospatial component in short-term memory.

In conclusion, the evidence for the existence of the VSSP in working memory does seem more consistent with the data than the idea of general short-term memory resources. What is less clear, however, is the kinds of tasks and processing that researchers assume the VSSP is capable of mediating. This is important because one reason why less progress has so far been achieved in uncovering the details of the VSSP than the articulatory loop may be that it is more complex than was originally thought, possibly comprising several different stores.

2.2 Definitions of Visuospatial Tasks and Visuospatial Processing

There appears to be some confusion amongst researchers in their ideas of what a visuospatial task entails. An example of this is the question of the role that imagery plays. Imagery is not strictly a non-verbal issue because instructing subjects to use visual images when they are memorising lists of words results in an enhanced performance on verbal memory tasks. As well as the use of imagery to aid memory, it was found that words can be rated for their concreteness and imageability; words with a high imageability rating are retained better than words of a lower imageability rating (Paivio, 1971). Although imagery has a role to play in memory, however, the mechanism that underlies effects of imagery remains unclear. Examples of work into imagery include the finding that when subjects are required to make size judgements, the relative size of the objects makes a difference, with judgements between objects taking more time than when there is less of a size difference (Kosslyn, 1975). This does not happen for printed words. While such work is interesting, however, Baddeley wonders "whether such results in fact tell us how the system works ..... [or] tells us very much about the underlying processes" (Baddeley 1986, p134). This is relevant because many tasks in VSSP research involve the use of imagery. For example, Baddeley, Grant, Wight and Thomson (1975) used Brooks letter visualisation and noun/verb classification tasks with or without a concurrent tracking condition to see what effect this secondary task would have. It was found that the tracking interfered with the letter visualisation but not the verbal task. Experiment 2 repeated this procedure using the Brooks matrix and nonsense sentences and got a similar result. Baddeley et al were able to show that imagery instructions impaired performance on the tracking task and that the tracking task in turn impaired performance on an imagery task. This implied that imagery and tracking were drawing on the same resources within the VSSP.

Several different tasks are used in research into the VSSP. In addition to imagery tasks, researchers also use tasks such as tracking or movement to positions in space. At first it was generally assumed that these different tasks all involve visuospatial processing. In the face of the different tasks that are used, definitions are necessary so that we can be clear about the assumptions that the researcher is making about what constitutes visuospatial processing. This is rarely attempted. When Baddeley and Lieberman (1980) chose a task that was "spatial but nonvisual" (p523) they had subjects try to keep a light-sensitive torch on a photo-sensitive cell on a pendulum while blindfolded. From this it would seem that Baddeley and Lieberman appear to see "spatial" processing as involving a representation in space, perhaps connections to do with movements in a mental space. They do not, however, make this very clear. When they chose a task that involved "visual but nonspatial processing" (p523) they had subjects discriminate between light and dark squares. This implies that they see visual processing as having more to do with the location of a single item in space but this is not stated.

One of the clearest definitions of visual and spatial processing is given by Farah, Hammond, Levine and Calvanio (1988) where "visual representations are taken to be modality-specific representations that encode the literal appearance of objects, including perspective properties, colour information, and aspects of form not available through touch or other modalities. Spatial representations are taken to be relatively abstract, amodal, or multimodal representations of the layout of objects in space with respect to the viewer and each other" (p442). This makes it much clearer what kind of codes in working memory they are aiming to investigate.

Clearly, research carried out on the VSSP should ideally focus on the kinds of visuospatial processing that are understood to be involved in the particular tasks chosen for experiments, and, more important, the kinds of assumptions that are being made. One researcher's use of "visuospatial processing" in terms of the actual tasks used in the experiment may bear very little resemblance to the "visuospatial" tasks of another experimenter yet they both discuss the implications of such tasks for the nature and organisation of the VSSP. Tasks may have different components to them and to carry out such tasks, subjects may be using different processing resources. This was made particularly clear in the research which was carried out to look at whether the processing in the VSSP is primarily visual or spatial (e.g. Baddeley and Lieberman, 1980). More emphasis was initially placed on investigating spatial processing within working memory than on investigating visual processing, largely due to the types of tasks that researchers selected as being representative of visuospatial processing. In this way the selection of tracking as a secondary tasks initially biased the researchers into assuming that the spatial side of working memory was more important than the visual side.

2.3 Spatial Coding Within the VSSP

There is evidence from neuropsychology that visuospatial processing is not a unitary phenomenon and can be further subdivided into at least two parts, visual and spatial. Using PET scans, Jonides, Smith, Koeppe, Awh, Minoshima and Mintun (1993) reported data which suggest that the storage of images occurs in the occipital lobe while the record of its position in space takes place in the parietal lobe. This is anatomical evidence for separate visual and spatial stores in the visual sub-systems in working memory. Farah, Hammond, Levine and Calvanio (1988) also argued that "there exists evidence that in animals and in humans the representation of the visual appearance of stimuli and the spatial location of stimuli are subserved by distinct, independent systems" (p445). Furthermore, they suggest that this visual and spatial distinction is also maintained in mental imagery and that visual and spatial imagery consists of separate and independent representations. In this sense, it is argued that it is not a question of whether imagery is visual or spatial but whether a particular task depends more on one kind of representation than another. They describe a patient, L.H., who shows a clear dissociation in performance on visual and spatial imagery tasks. L.H.'s performance on visual imagery tasks (involving colour, size comparisons and classification of shapes and animal tails) was very poor compared with controls. His performance on spatial imagery tasks (involving various image transformations and memory for spatial locations), however was within the normal range. L.H. had damage to the right temporal lobe, as well as damage to temporo-occipital regions in both hemispheres.

In the neuropsychology literature, the case of L.H. is often contrasted with that of E.L.D who is argued to show intact visual imagery but to have a deficit in spatial processing (Hanley, Young and Pearson, 1991). E.L.D. performed well on the same visual tasks used by Farah et al (1988) but had a poor performance on the Corsi blocks test and the Brooks matrix task Hanley et al (1991), however, interpreted E.L.D's pattern of performance as suggesting that she has a deficit in the part of the visuospatial system that processes incoming visuospatial information but that the part of the visuospatial system involved in the retrieval of visuospatial information from long-term memory is untouched. They argue that this is consistent with Logie (1989) who proposed that short-term memory comprises of an active rehearsal process and a functionally separate store. By this reasoning, E.L.D.'s passive store would be intact and able to receive information directly from long-term memory, but the active part of the store which manipulates and maintains information could be damaged. The contribution of long-term storage means that the case of E.L.D. is not a perfect double dissociation with the case of L.H. Moreover, although E.L.D. is shown to have damage to the right hemisphere, the damage is widespread and extends into the right frontal lobe.

Piggott and Milner (1993) argue that loss of spatial memory is often associated with hippocampal damage (though this does not seem to be the case with L.H.), while visual memory appears to rely on the right temporal lobe. They report a group of patients with right anterior temporal damage who show impairments in the recognition and recall of faces, complex visual scenes and geometric designs. Therefore, although there is some disagreement in the literature over neuroanatomy, there is clear evidence from neuropsychology that there are functionally distinct visual and spatial stores in the VSSP.

Baddeley and Lieberman (1980) investigated whether the system involved in the control processes of imagery employs visual or spatial coding. They used Brooks' matrix task (Brooks, 1967). The secondary suppression tasks involved subjects either having to discriminate between light and dark squares (a visual task) or having to keep a torch beam on a photo-sensitive cell on a pendulum while blindfolded (a spatial task). Baddeley and Lieberman found that remembering the nonsense sentences was disrupted more by the visual task than the pendulum while the Brooks spatial task was disrupted more by the task with the pendulum. Both a peg-word and a method of loci mnemonic were disrupted by concurrent tracking, whereas a rote rehearsal strategy was unaffected. On the assumption that the concurrent tracking task was predominantly a spatial task that was relatively free from visual input, Baddeley and Lieberman (1980) concluded that the VSSP in working memory relies on spatial rather than visual coding. They proposed a simple analogy in which the VSSP was a screen on which spatial information may be represented. Although the paper focuses more on spatial processing than visual processing, however, they do not rule out the existence of visual processing within working memory. Although they argued that the VSSP relies more on spatial processing they maintained that this "does not ... preclude the occurrence of a parallel system or component concerned with pictorial or nonspatial visual representation" (p537). Indeed, they suggested that the demonstration of "blindsight" by Weiskrantz, Warrington, Sanders and Marshall (1974) would support the notion of two separate visual systems, one dealing with where an object was seen, the other dealing with identification of what was seen.

2.4 Movement

The initial research which focused on spatial coding within the VSSP appeared to have potential for uncovering the organisation of the VSSP. Although it did not define what was being meant by spatial, the use of tasks such as tracking and tapping suggested that spatial should be defined in terms of movement, actual or imaged, between positions in space. This seemed useful because movements to positions in space have the potential to be tested in a very precise way. Manipulations such as the distance between positions in space, the time taken to move between positions immediately come to mind as features which can be investigated. In addition, just as order is important in verbal working memory, the order in which the positions in space are coded can also be manipulated. One reason, especially, for focusing on movement is that if tasks involving movement were found to interfere with spatial but not visual coding then the use of movement might be a means of separating the visual and spatial elements of a task.

Idzikowski, Baddeley, Dimbleby and Park (1983) investigated whether spatial memory was related to kinaesthetic memory. They induced post-rotational nystagmus to see if this interfered with the Brooks test but found that the introduction of involuntary eye movements did not selectively disrupt performance on the spatial imagery memory task. This was taken to imply that it is not the eye-movements themselves that are important in the process of imagery. In the Experiment 2 they looked at whether controlled eye movement (having to follow a sinusoidal wave) would disrupt the Brooks task. They found that selective disruption did occur when subjects had to make voluntary movements of the eyes, though simply holding the eyes stationary or having a moving visual field did not disrupt performance. This indicates that it is having to concentrate on moving the eyes that disrupts the Brooks test, not eye movements per se. Experiment 3 demonstrated that this selective disruption occurs for eye-movements during both presentation and retrieval. The fact that Idzikowski et al showed that voluntary eye movements caused a decrement in the recall of Brook's matrices implies that control of movement (in this case, eye movement) plays a part in the organisation of the spatial code. It would seems from the work by Byrne (1974) and Baddeley et al (1975) that arm movements may also have a similar effect.

Quinn and Ralston (1986) looked more closely at the kind of movement which would interfere with spatial processing. In order to separate the effects of movement and attention, their paper looked at the interference effects of two different kinds of hand movement on the generation of a spatial code. Subjects were required to carry out compatible movement where they traced out the pattern designated by the set of sentences in the spatial task and incompatible movement in a predetermined sequence. The pre-determined sequence the subjects were required to follow was very simple and was thought to require a minimal amount of attention. In each condition the movement occurred within a box which did not allow subjects to see their hand movements. Experiment 1 involved the Brooks matrix sentences and four interference conditions. As well as the compatible and incompatible movement conditions, there was also a no interference condition and a condition of tapping movement where subjects tapped once per sentence presentation. It was found that the incompatible movement did interfere. This could either be because "the incompatible movement establishes an internal representation that interferes with the code established by the sentences under the imagery instructions; or attention has to be shared between the two tasks to a degree not present in the other movement conditions" (p169).

Experiment 2 gave the subjects more practice trials on the grounds that increased practise should ensure a more automatic performance, thus reducing the effects of attention. The tapping conditions was also dropped. Only the main effect of movement was significant, showing that the practice trials failed to cause any significant difference to the movement results. Experiment 3 further reduced the effects of attention by using passive movement as a factor. Four conditions were used, compatible and incompatible movement both actively and passively. Again, there was only a main effect of movement, showing that incompatible movement, whether active or passive, leads to a fall in performance. In this way the experiments showed that it was the effect of movement rather than attention to movement that caused the interference. This contrasts with Idzikowski, Baddeley, Dimbleby and Park (1983) because they found that the spatial code was only disrupted when movement of the eyes was under voluntary control. They used post-rotational nystagmus to generate involuntary movement, however, and it seems likely that passive eye-movements caused by post-rotational mystagnus may not be analogous to passive arm movements caused by a deliberate external force (the experimenter). What does seem likely from this is that movement per se does have a role in spatial coding.

Although the use of movement appears to have potential to tell us more about the VSSP the role of movement in working memory is not quite so straightforward as it first appears. Smyth, Pearson and Pendleton (1988) presented five experiments which together imply that memory for patterns of limb movement differs from memory for movement to spatial targets. Although task demands differ, the double dissociation found between the two sorts of movement makes this argument very plausible. This paper is important because it argues that movement per se is not important for the VSSP as movements that are specific to particular body parts do not appear to interfere with movements to spatial targets. This suggests that it is the goal to which movement is directed that affects processing. While both tasks involve spatial processing of a visual input it seems likely that movement to particular targets in space has different processing requirements than the task of copying patterns of limb position. This interpretation is consistent with that of Quinn (1994).

Hock, Smith, Escoffery, Bates and Field (1989) looked at performance on a visual memory task. Items were displayed at various points on the screen and subjects were instructed to remember the identity of the items. Instead of simply looking at memory for the pattern identity, Hock et al also focused on the subject's memory for the patterns positions in space. Subjects were not informed that this was part of the task. Despite this it was found that the subjects did unintentionally retain information concerning the position of the pattern relative to a frame. It was found that this could be used to aid memory of the picture and this in turn suggested that even in mainly visual tasks of pattern recognition, position information was also being automatically retained. It is clear that although there are more issues to be dealt with when using tasks involving movement to positions in space than initially appeared to be the case, movement retains an important role in research directed towards the VSSP and that the processing of movement will have to play a part in any future model of the VSSP.

2.5 The Locus of Disruption

Another issue in the literature is whether secondary tasks that result in the selective interference of visuospatial processing within the VSSP have most effect at encoding or maintenance. Morris (1987) looked at the effects of interference on a spatial memory task that required subjects to recall the locations of five filled circles randomly presented within a blank square. The circles were shown serially and subjects were required to record their responses by placing five crosses in a blank square on a recall sheet. For half of the trials subjects were required to repeat a sequence of numbers from 300 to 305. For the other trials, subjects were required to carry out a Moar (1978) tracking task that involved pressing a series of 5 by 5 keys in a particular sequence. These keys were hidden from sight. Morris showed that when retention of the circles was coupled with concurrent arm movements performed by the subject in carrying out the Moar task, there was mutual disruption of performance. No disruption was shown with concurrent articulation. No disruption was shown when subjects were only required to carry out the task during the maintenance of the circles. Morris argued that the disruption caused by the Moar task occurred during the presentation (encoding) of the pattern of circles. On the assumption that the VSSP requires central executive resources during encoding (and probably also retrieval), Experiment 4 looked at the effects of verbal pre-loads, post-loads and concurrent loads on visuospatial memory encoding. The reasoning behind this was that this verbal loading should reduce the capacity of the central executive, following Baddeley and Hitch (1974) who found that a near-span load slows verbal reasoning. Morris expected that a verbal load presented after the visuospatial material would not disrupt the circles task because the executive is not involved in maintenance of visuospatial material. The verbal pre-load and a concurrent load would be expected to interfere, however. This was indeed found, reinforcing the view that central executive resources are required for encoding and retrieving but that minimal central capacity is required for maintenance rehearsal. It should be noted that the magnitude of this disruption was quite small when compared to the effect of tracking. Morris used this to imply that tracking differentially disrupts the VSSP but it could equally occur because the verbal loading task is not providing as much of a general load as the tracking task.

One of the main points of Morris's paper was to compare the encoding and retention stages in the processing of visuospatial material. Quinn (1988) reported a similar series of experiments. Using the Brooks procedure as the main task, it was found that a spatial interference task involving movement was more disruptive than a visual interference task involving the monitoring of brightness. The locus of this effect was found to occur at the encoding stage, with interference having little effect on the maintenance of information. This would imply that the cognitive resources involved in encoding, maintenance and recall, may not be the same. Like the previous papers which argue that movement has more of a role to play in spatial than visual coding, Quinn argued that spatial interfering tasks have a greater disrupting effect on the VSSP than visual interfering tasks, though it seems likely that the nature of the main task (visual versus spatial elements) and the differing demands of the interfering tasks may also play a part in this. In other words, the spatial task may be interfering more simply because the matrix sentences are more spatial in nature than visual.

Quinn (1991) looked again at whether the VSSP is especially susceptible to interference at encoding rather than at maintenance. One problem is that the other papers all involved interfering tasks which themselves lowered performance and involved effort, clearly involving the central executive. This experiment therefore used passive movement in an effort to minimise central executive involvement. The Brooks-type procedure was again used as the main task. The interference conditions involved no movement, delayed movement (passive movements of the hand in the delay following sentence presentation) and concurrent movement in time with the sentence presentation. It was found that the movement condition and the interaction between movement and sentence type were significant. While there was a marginal decrease in performance in both sentence conditions under concurrent movement compared to no movement, the decrease was significant only with the spatial sentences. This meant that the VSSP is susceptible to interference by concurrent movements. It was found that the delayed movement did not disrupt processing in the VSSP. In this way the interference was found to be limited to the encoding stage and no interference was found with movement at maintenance.

Quinn (1991) discussed why there was less interference once the directions had been encoded. It could be that a different coding is used at maintenance than encoding or it could be that "once formed the directions are remembered as an overall pattern rather than a sequence of discrete relative directions and are therefore not susceptible to interference by discrete movement" (p103). He argued that this could be looked at using an interference task targeted at this complex pattern.

Smyth and Pendleton (1990) and Morris (1987) suggested that whatever cognitive systems are involved in encoding are also involved in the control of active movement. They also suggested that the system responsible for retaining the encoded information is probably not associated with movement control. This indicates that the mechanisms involved in encoding and retention may be different.

2.6 Visual Coding Within the VSSP

The paper that was most responsible for reclaiming the visual side of working memory was Logie (1986). Logie's aim was to develop a form of visual suppression similar to the articulatory suppression used in the study of verbal working memory. Articulatory suppression is a very useful technique and has helped to uncover the organisation of verbal working memory. Logie aimed to develop a visual suppression task that, like articulatory suppression, has as minimal an attentional component as possible. He investigated the possibility of a visual part to the VSSP by presenting subjects with unattended pictures in the form of matrices, coloured squares or line-drawings. In initial experiments subjects made simple judgements about whether the currently presented pattern was identical to the pattern presented immediately before. In later experiments in the 1986 paper, however, Logie simplified this by removing the decision element of the task. Subjects were instructed to look at the screen but were told that the material was irrelevant to their task. Logie wanted to see whether this material had the same effect on visuospatial processing as unattended speech has on verbal material.

Instead of using the Brooks-type tasks that the earlier experiments in visual working memory had often relied on, Logie adopted the peg-words visual mnemonic task for the visual task and rote-rehearsal for a comparable verbal task. Logie reported that unattended visual material disrupted the use of a visual image-based mnemonic, while it had very little effect on rote rehearsal. Differing task difficulties made the findings of this paper less robust than they might have been. In addition, the details of the four experiments all differed from each other, presumably because Logie was still refining the techniques. Nevertheless the paper has been very influential.

It was an appealing idea that an unattended picture effect existed in visual working memory that corresponded to the unattended speech effect in verbal working memory. This seemed to give a neat symmetry to the visual and verbal sub-systems. In addition, Logie's paper made it clear that there was more than just spatial coding in the VSSP. The fact that a task such as viewing irrelevant pictures, a task that does not emphasise spatial content, appeared to interfere with the pegword mnemonic drew researchers attention towards the probability that visual coding also had a part to play in the organisation of the VSSP, whether as part of a single system or, as Baddeley and Lieberman suggested, as a parallel store to the spatial sub-system. The paper was also very important in showing that the arguments for the VSSP being more spatial than visual were probably due to the nature of the secondary and main task used and that the coding in the store may be either visual or spatial.

While most researchers such as Quinn (1991) and Morris (1987) were focusing on the locus of disruption of spatial tasks, Logie and Marchetti (1991) investigated the locus of disruption within visual working memory. Quinn (1991) and Morris (1987) had suggested that the mechanisms involved in encoding and retention may be different and had found little effect of visuospatial interference during maintenance of a spatial task. Interference was only found if the secondary visuospatial task was present during encoding. Like Quinn (1991), Logie and Marchetti argued that this may have come about because of the nature of the tasks that had been selected to reflect spatial processing. They suggested that only the initial encoding of the material had to be spatial and that once encoding was complete, the subject was probably only required to remember a static pattern of numbers in the matrix, not a spatial sequence. Logie and Marchetti predicted that the result might not be the same if the subject was genuinely required to retain a sequence of movements rather than a static pattern, as well as to recall a strictly visual sequence. Thus, in their experimental design the subject was required to retain information about either the sequential order in which a series of squares was presented at different locations on the screen or to remember colour hues. The retention interval was filled either by a concurrent movement task or irrelevant pictures. It was hypothesised that if separate systems are involved in retaining spatial and visual material then the movement task should disrupt memory only for the presentation sequence while the irrelevant pictures should only disrupt retention of the colour hues. This is what was found.

It should be noted that this finding does not say anything about whether or not the central executive is implicated in encoding. It does point to VSSP involvement in retention, however, and moreover provides evidence for separate cognitive systems being involved in the spatial and visual tasks. This is consistent with Logie (1989) who holds that the passive visual store would be responsible for retention of the colour hues and interference occurred because irrelevant visual input is thought to have obligatory access to such a store. The rehearsal mechanism would be responsible for spatial recognition. As the control of movements is also involved with the rehearsal mechanism, the irrelevant movements disrupts the rehearsal mechanism.

2.7 The Organisation of the VSSP

Progress has been made in researching the VSSP; it is likely that what was originally treated as a unitary store has several further subdivisions such as visual and spatial components (e.g. Farah, Hammond, Levine and Calvanio, 1988, Piggott and Milner, 1993). Moreover the role of movement in the spatial side of working memory is beginning to become clearer and differences are being found for the processing of active or passive movements and movements to positions in space compared to movements of body parts (Smyth, Pearson and Pendleton, 1988). The research which focuses on the locus of disruption within the VSSP is one of the most complex issues that has so far been tackled. There is some disagreement in that researchers such as Morris (1987) and Smyth and Pendleton (1990) argue that the VSSP is more susceptible to interference at encoding rather than at maintenance. In contrast, Logie and Marchetti (1991) argue that this is because of the task requirements that were used and if subjects are required to retain a sequence of movements then a distracting effect will also be found at maintenance. This is one of the more profitable areas in VSSP research in that researchers are beginning to focus on visuospatial processing in much more detail and speculate on the role of the central executive in encoding.

However, although progress is being made, it is difficult to see how all these different elements should be combined to form a model of the VSSP.

Although it does not currently explain how all the elements fit together, the clearest model of the VSSP so far is that of Logie (1995). This model claims that the VSSP is split into two separate cognitive functions, the visual cache and the inner scribe. Logie describes the visual cache as a passive system that stores static visual patterns. Information in the visual cache is argued to fade unless rehearsed by the scribe and is also subject to interference from new visual data entering the cache. The passive visual cache is thought behave in a similar way to the passive phonological store in that visual data has obligatory access to the cache and irrelevant pictures cause disruption to items in the cache. In contrast the inner scribe is a more active system which deals with movement as well as being responsible for rehearsal of the cache. In the model it is therefore the scribe that manipulates the information in the cache, "redrawing the contents" of the cache (Logie 1995, p3) in order to perform transformation functions upon the image as well as refreshing the passive store. The scribe is also seen as being responsible for movement to positions in space. Information is thought to enter the cache by way of long-term memory processes. These processes make sense of the data and input it either into the visual cache or the inner scribe depending on the nature of the material.

Although promising, Logie's (1995) model does not explain all of the findings within the VSSP literature, especially the spatial literature. The model does not make a distinction between movements to particular targets in space and the movements required for copying patterns of limb position, for example. These have been shown to have different processing requirements (Smyth, Pearson and Pendleton, 1988). Eventually the model will have to be expanded to become more wide-ranging such as that of Kosslyn (1991). This model includes mental operations such as pattern activation and pre-processing and more specific long-term elements such as "categorical property look-up". The most relevant part of Kosslyn's model to that of Logie (1995) is the visual buffer. This has a similar function to the VSSP except that it is proposed as a more unitary system. In Kosslyn's model, spatial elements such as spatiotopic mapping, body-head-eye position and motion relations are dealt with separately from the visual buffer. These are all features that are currently assumed to be incorporated in the inner scribe part of Logie's model but which will eventually have to become more differentiated. The visual buffer in Kosslyn's model can not be treated as being essentially equivalent to Logie's passive visual store either as the visual buffer contains an attention window. In the working memory model attentional processes are assumed to be handled by the central executive. Kosslyn's model splits attentional processes and there are attentional features elsewhere in the model such as "attention-shifting". There are clear differences between the two models that can be tested experimentally. Kosslyn's model does, however, demonstrate the complexity which a model of the VSSP will eventually be required to incorporate.

2.8 Conclusion

We have good evidence that there is a functionally separate cognitive system that deals with visuospatial information rather than some more general system (Logie, Zucco and Baddeley, 1990). Less clear is the relationship of the VSSP to the rest of working memory, especially the relationship of the VSSP and the control processes in the central executive. The nature of the central executive in working memory is that it is a flexible system that enables us to use our cognitive resources efficiently, choosing among various strategies to minimise cognitive load. This flexible nature to the central executive may well be one of the reasons why it has been so hard to construct a model of its function. Research focusing on whether visuospatial interference has more effect on encoding or maintenance is, however, beginning to suggest an increased role for the central executive at encoding (e.g. Morris, 1987) and hopefully, once we know more about the nature of the VSSP, its relationship with the central executive will become clearer.

Other promising areas that should help shed more light on visuospatial processing include how visuospatial processing develops and the patterns of dysfunction that emerges when visuospatial processing is impaired. As the thesis is only concerned with normal, adult performance these are less directly relevant questions but can nonetheless provide evidence relevant to the previous questions.

There is clear evidence which suggests that the VSSP is not a unitary system but consists of at least separate visual and spatial components (e.g. Piggott and Milner, 1993; Logie, 1989) This makes issues such as capacity or the relative role of the

VSSP in the different stages of information processing difficult to tackle unless they focus on specific kinds of visuospatial processing rather than the VSSP as a whole. To do this we need to develop definitions of the different kinds of visuospatial processing. As there are likely to be very different kinds of processing in the VSSP, the details of any task that is used to investigate the VSSP will be very important. Although tasks have different components it would be desirable to choose a task that concentrates on a particular type of processing within the VSSP.

One way to investigate the VSSP might be to put the emphasis as much on the nature of the task used in the experiment as the issue that the experiment is looking at. For example, rather than focusing on an area of interest such as the locus of disruption caused by a visuospatial task and looking at this issue with different tasks, it may be better to select a particular task or technique and use this task to investigate a number of different questions (e.g. the nature and organisation of the VSSP and its relationship with the central executive, as well as the locus of disruption).

In addition to these key concerns there are other lesser issues that need to be addressed. One important consideration when looking at the literature concerning the non-verbal part of working memory is how we should go about defining the coding that is involved in visuospatial processing. Few papers come up with clearly stated definitions of the codes that may be being used in their experiments. Definitions are important because they make clear what kind of assumptions are being made about the codes experimenters expect to be involved in a particular task.

Another important issue is the identification of techniques or approaches in the literature that have the most potential to uncover more about the nature of visual short-term memory. Such techniques will be necessary if the key areas that have been identified are to be investigated. In a recent paper asking 'Is Working Memory working?", Baddeley (1992) identified a key aim in working memory research as "the search for techniques and methods that will increase our ability to choose among available theories" (p3).

Although still speculative we have been given a model of the VSSP by Logie (1995) that fits some of the available evidence (e.g. the irrelevant picture effect reported by Logie, 1986). The model does make predictions that are testable and so makes a good framework and a starting point for research into the VSSP. It is appealing as a model because it suggests a neat symmetry between the structure of the VSSP and of verbal working memory. This should mean that comparable advances should be possible for our knowledge of the nature and organisation of visual working memory as have been achieved in verbal working memory. Just as the irrelevant speech effect was used successfully in verbal working memory (Salame and Baddeley, 1989), the irrelevant pictures effect is a potential tool for investigating the VSSP. The irrelevant picture effect reported by Logie (1986) plays a key role in his model of the VSSP.

This irrelevant pictures effect is not as straightforward as it first appears, however. There is a potential problem in that all of the visuospatial material that Logie used in his experiment involved regular change in its presentation. For example, the display time for the red/green squares in Experiment 1 was 300 msecs with an ISI of 1700 msecs (Logie, 1986). This meant that the visuospatial material was changing regularly every two seconds. Although the nature of this irrelevant material was visuospatial, the regular, predictable change involved in the presentation of the irrelevant material was another common feature between the different kinds of unattended material. This regular change may itself have been attention-demanding of the central executive. A further potential problem was that task demands differed throughout Logie's experiments. If the regular change is in itself attention-demanding then it should be found that when task demands are equal that both the rote rehearsal and the visual mnemonic will be disrupted by the unattended visuospatial material due to the regularity of the change involved in its presentation. By this reasoning, only when the regular change in the visuospatial material is taken away can we see whether visuospatial material is gaining obligatory access to the VSSP. Failure to find a robust irrelevant pictures effect would hinder development of Logie's (1995) model. For this reason the irrelevant pictures effect is the place where the investigation of the model begins.

Chapter Three - Looking for the Irrelevant Pictures Effect

3.1 Experiment One

Introduction

The irrelevant speech effect has helped uncover much about the organisation of the articulatory loop (Salame and Baddeley, 1989) and is still being used successfully (Jones, Madden and Miles, 1992). The theoretical development of the VSSP has been slower than that of the articulatory loop, partly because investigators do not have enough robust techniques to draw on. The irrelevant pictures effect (Logie, 1986) is important because it is a potential tool for investigating the characteristics of the VSSP. The irrelevant pictures effect appears to parallel the irrelevant speech effect in the verbal side of working memory, suggesting that similar conceptual advances could be made in the VSSP as have been achieved in our understanding of the articulatory loop. The irrelevant picture effect also plays a key role in Logie's (1995) model of the VSSP. There is evidence, however, that the irrelevant pictures effect is not very robust and researchers have reported difficulties in replicating the effect (Quinn, personal communication). Before using the irrelevant pictures effect to investigate the VSSP it will be necessary to establish its robustness. An additional problem is that in the original report of the irrelevant pictures effect by Logie (1986), all the irrelevant stimuli that were presented to the subjects involved a regular change. Task demands between the visual and verbal memory strategies were not equalised in the experiments. It is possible that the regular change in the presentation of the irrelevant pictures could be engaging attentional mechanisms within the central executive. As task demands were not equalised, the irrelevant pictures effect as shown by Logie (1986) could actually be eliciting general interference of both visual and verbal strategies, not selectively interfering with the visual strategy.

Experiment 1 is designed to address all these problems. It will ensure that task demands are equalised between the two memory strategies and then it will compare the effect of presenting subjects with regularly changing irrelevant visuospatial material and irrelevant visuospatial material that does not involve a regular change. It is hypothesised that the regularly changing irrelevant material will interfere with both a rote rehearsal and a visual mnemonic memory strategy when task demands have been equalised because the regular change will engage attentional processes within the central executive. The irrelevant visuospatial material that does not involve a regular change, however, is expected to differentially disrupt the visual mnemonic strategy, indicating that visuospatial material does indeed have obligatory access to the VSSP when the effect of attention has been controlled by eliminating the regular change in the irrelevant material.

A major consideration in testing this hypothesis is the selection of the two different forms of irrelevant visuospatial material that are to be used. The different materials have to be of a similar level of visual complexity, differing only in that one involves patterned change while the other does not. Single squares that were randomly green or red were selected for the visuospatial material with a regular change as it is relatively simple in terms of visual complexity. For the visuospatial material that does not involve a regular change, a static visual noise pattern was adopted as, like the squares, it is visuospatial in nature but not visually complex or particularly meaningful.

The hypothesis of Experiment 1 is therefore that a regularly changing visual display in the form of red and green squares will interfere significantly with performance on both the visual mnemonic and the rote recall memory strategies. In contrast, a visual display that does not involve a regular change, a static visual noise pattern, is expected to differentially disrupt the performance of the visual mnemonic strategy. This will be evidence of the existence of the irrelevant pictures effect.

Method

Subjects

Subjects were thirty-six volunteers from the Psychology Department subject panel, eighteen in each of the two memory conditions. All were aged between 17 and 21.

Materials

Two sets of sixteen lists of words were constructed, each consisting of ten high-frequency, high-imageability, single-syllable concrete words chosen from Gilhooly and Logie (1980). The criterion used in selecting these was that each dimension of frequency, imageability and concreteness had a score of at least four and a half on the scale given in the paper. All scales were from one to seven with one indicating a low rating on the scale. These two sets of lists were used in both memory conditions.

For the regularly changing visuospatial material condition, a program was written to present a square eight centimetres long in the centre of a standard VDU monitor of a BBC computer.. The colour of the square was randomly changed using the colours red and green. This change occurred every two seconds. The rest of the screen was blank and there was a very slight discernible pause between the colour change so that a change from red to red or green to green was perceptible. A second program on the same computer consisted of the same area of the monitor having a static random visual noise pattern.

Pilot Trials

A second experimenter assisted in the running of the pilot and experimental trials in this experiment. The objective of the pilot trials was to make sure that performance on the rote recall and visual mnemonic tasks was equivalent. The same task instructions were adopted as had been used by Logie (1986). Each subject did both the verbal and the visual conditions with no secondary interference tasks. The verbal condition was carried out first followed by the visual strategy. Although this was unbalanced, this would be corrected in the experiment itself. Two series of pilot trials were carried out. Each series used six subjects who consisted partly of volunteers from the subject panel and partly of friends of the experimenters. None of the subjects in the second series took part in the first series and none of the subjects in either series took part in the main experiment. The first series of trials consisted of seven items in the rote condition and ten in the visual mnemonic, as Logie has used in Experiment 4. A three second interval between each word to be recalled was adopted instead of the four second interval that Logie had used, to help equalise performance. A seventeen percent advantage for the visual mnemonic was still found, however. The second series of trials adopted six items on the verbal task and the same three second interval between each word to be recalled and it was found that performance was equalised at about 71%

Task Instructions

The task instructions were a crucial part of the experiment and great care was taken to make sure that the subjects were carrying out the task in the correct manner. Subjects were reminded throughout the experiment of the way that they were to memorise the word lists and they were asked to persevere with the strategy even if they found it difficult or awkward and not to use any other strategy. Instructions for the verbal condition consisted of telling the subject to commit the words to memory by adding each word to the one heard previously and to repeat them sub vocally in the order in which they had been presented. Explicit examples of this were given so that the subject clearly understood. The instructions for the visual condition consisted of telling the subjects to learn a list of ten peg-words (one is a bun, two is a shoe etc.) to a criterion of two perfect recalls, then construct a clear image for each item. Subjects were then instructed to create a visual image of each word from the list as it was presented, integrating it with the image of the pegword. This integrated image was then used to recall each item on the list. Again, explicit examples were given so that the subjects understood exactly what they had to do. Throughout the experiment the experimenter checked with the subject that they were carrying out the appropriate strategies. In the control condition with no interference, subjects were told to keep their eyes on the centre of the blank monitor. Eyes were to be kept open throughout the presentation of the word lists.

Design

One difference between the design of this first experiment and that of Logie (1986) is that the 1986 paper had had each of the subjects take part in both the pegword mnemonic and rote rehearsal conditions, with the rote rehearsal condition being carried out first. This meant that performance in the visual mnemonic could have been affected by the fact that each subject had experience of carrying out the rote condition. To eliminate this possibility, it was decided that half the subjects should take part in a rote memory condition while the other half should participate in the visual pegword mnemonic condition.

The design was a two (memory strategy) by three (interference) mixed design with different subjects used for each memory strategies but with all three interference conditions counterbalanced over all the subjects. In each of the memory strategy conditions (rote rehearsal or the visual mnemonic), subjects were to fixate on a monitor while being presented with three interference conditions. One condition consisted of a blank screen control. Another condition consisted of a square in the centre of the screen that was randomly changed between red and green every two seconds. The other condition consisted of a static visual noise pattern. As the experiment was carried out by two people, the use of the word lists and experimenter were also counterbalanced across the two main memory tasks and conditions.

Procedure

Subjects were tested individually and alternately assigned to each mediation strategy. Subjects were given the instructions about the memory strategy they were to use throughout the experiment (either rote rehearsal or the visual mnemonic) and were given a practice trial to make sure they had understood the instructions. If necessary subjects were given additional practice trials from the alternative list but this did not occur often. In the visual pegword mnemonic condition subjects were required to learn lists of ten words following the specific memory instructions that had been given. The same lists were used for the rote rehearsal condition, except that only the first six items in each list were presented. The items to be remembered were preceded by their number in the list (for example, one...wood two...arm). The number and the word took a second each to present and there were three seconds between each number and word pair. This meant that the words were being presented to the subject every five seconds (as opposed to six seconds in Logie's (1986) design). At the end of each list (item six in the verbal condition, ten in the visual condition) there was a ten second interval before the subject was instructed to "recall". The subject was then cued by each number in the order they had been presented so that they only had to name the item. It was understood that there would be a four second interval between each of the number cues regardless of how quickly the answer came and as soon as the next number had been presented the subject was told to go onto the next item even if they had just recalled the previous one. Subjects were told about the procedure that would be followed and the experimenter made sure that they knew what to expect. There were five trials in each of the three interference conditions and the first one was always a practice trial. With the practice trial at the start this made sixteen trials in all. The presentation of the irrelevant visuospatial material continued throughout all the stages of the presentation, the interval and recall of the words in the list.

Results

The number of words that were correctly recalled by the subjects was expressed as a percentages and entered into a two by three (two memory instruction conditions and three interference conditions), mixed design analysis of variance.

While there was no significant effect of memory condition [$F(1,34)=2.43$, $p>0.12$] which showed that the experiment succeeded in its goal of equating performance on the two tasks, there was also no significant effect of interference [$F(2,68)=0.31$, $p>0.73$] or an interaction [$F(2,68)=0.55$, $p>0.57$]. No significant experimenter effect was found [$F(1,32)=2.39$, $p>0.13$]. The results are shown in Table 1.

Table 1

Subjects' percent performance under the conditions of Experiment 1. Performance figures are given for the control (no interference), static visual noise and the squares that are randomly red or green, along with their standard deviations.

Experiment 1	Control	s.d	Static Visual Noise	s.d	Red/Green Squares	s.d
Rote main task	71.3	16.4	73.8	15.9	73.4	16.7
Visual Mnemonic	67.3	13.8	67.5	10.6	64.6	13.3

The fact that the main interference task, the red and green squares, failed to have an effect on the two main memory strategies, differential or otherwise, was disappointing. It would seem that although Logie had found differential interference with them, the interference has not been robust enough to show up here.

Discussion

This was a surprising result in that many of the subjects had reported finding the red and green square condition very distracting. However, no decrement in performance resulted in either of the memory conditions. From the level of performance of the subjects it would be very difficult to ascribe this to either floor or ceiling effects. The fact that the distracter that was chosen for the experiment, the red and green squares, had no effect on the performance of the pegword mnemonic means that it is difficult to begin to come to any real conclusions about whether visuospatial material will have obligatory access to the visual short-term store.

3.2 Experiment Two

Introduction

Experiment 1 failed to show any effects of interference, let alone selective interference of the visual strategy by irrelevant material without a regular change in its presentation. The primary aim of Experiment 2 was therefore to find visuospatial material that would interfere with the main memory strategies. Neither the red/green squares nor the static visual noise pattern had been effective in disrupting performance on the visual and verbal strategies. It is clear that different kinds of irrelevant visuospatial material need to be chosen. Logie (1986) had found his strongest results by presenting subjects with irrelevant line-drawings. For this reason the red and green squares used as the main interference condition in Experiment 1 were replaced by a series of a hundred line drawings chosen from Snodgrass & Vanderwart (1980), the same line-drawings used by Logie (1986). The static visual noise condition was replaced by a dynamic visual noise pattern on the grounds that it would be a more valid comparison with the line-drawings. Like the line-drawings, the dynamic visual noise involves change in its presentation but as the random changes of the visual noise are continuous and not focused in a particular place and time, they should have a minimal focused attentional factor. If the hypothesis is supported by the results of Experiment 2 then it can be interpreted that interference with both the rote and visual strategies occurs because of the regularity of the change in the line-drawings, not the change itself.

By the same reasoning adopted in Experiment 1, the hypothesis of this experiment is that both the memory conditions will be disrupted by the line-drawings but the dynamic visual noise will disrupt only the visual strategy.

Method

Subjects

Subjects consisted of a mix of first and second year students, volunteers from the Psychology Department subject panel and paid volunteers who had signed up on a sheet in the Psychology building. Twenty-four subjects took part in the experiment. None had taken part in the Experiment 1.

Materials

The changes to the material from that of Experiment 1 consisted of the static visual noise distracter being replaced by a dynamic visual noise distracter and the red/green squares being replaced by the line-drawings. The same word lists were used in Experiment 2 as had been used in Experiment 1.

The line-drawings were to be presented to the subject by a computer, each one being shown once in a random order for six seconds. One hundred line drawings of common objects (for example, a tap or an apple) were chosen from Snodgrass &

Vanderwart (1980) and used as a guide for constructing the line-drawings. These line-drawings were different from the words used in the memory trials and were presented on an 1040 STE with 4 Mb of memory. The monitor used was a 12 inch Sm124 model and it was run in high resolution mode (60 Hz refresh rate). The area of screen that could be worked on was approximately 22 by 12.5 cm (600 by 400 pixels).

A second program on the same computer consisted of a dynamic random visual noise display. For the dynamic visual noise, each dot actually comprised of 4 by 4 pixels - a megapixel. In the experiment both the dynamic visual noise and each of the line drawings were displayed in a rectangular area 10.5 by 6.5 cm (320 by 200 pixels or 80 by 50 megapixels). The dynamic visual noise program was written in HiSoft Basic to run as fast as the STE was able to manage. The rate of change of the visual noise was measured by simply running the program for 50 seconds and having the computer measure the number of changes. The rate of change was 291.694 changes per second. Each change consisted of a dot changing state from white to black or from black to white within the display. Irrelevant material was to be present throughout presentation, the interval and during recall. Figure 1 represents a moment taken from the dynamic visual noise display that has been frozen in time.

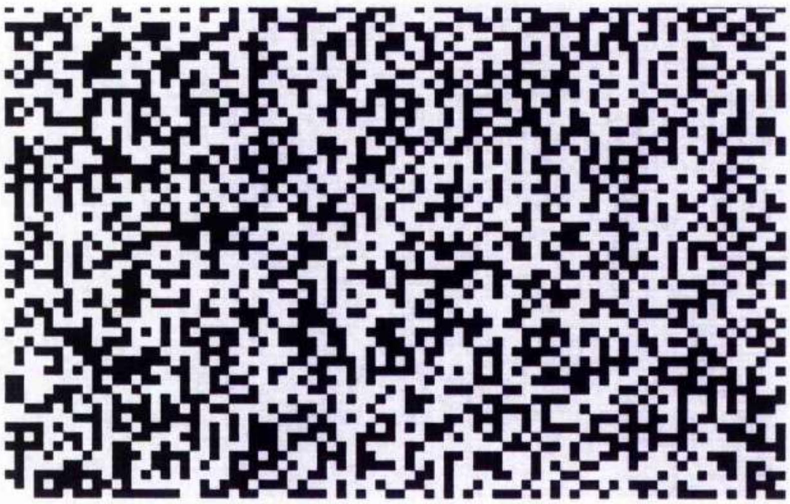


Figure 1. A static representation of the dynamic dot display. The display measured 10.5 cm by 6.5 cm (320 by 200 pixels with each dot consisting of 4 by 4 pixels) on the computer monitor and was subject to a continuous on/off rate of change of a random 291 dots per second.

Design and Procedure

One experimenter ran the pilot and experimental trials. The static noise distracter was replaced by a dynamic visual noise distracter and the red/green squares were replaced by the line-drawings. Apart from this, the design and procedure for Experiment 2 was the same as for Experiment 1. The dynamic visual noise was present throughout the condition. Whereas the red or green squares in Experiment 1 had been presented every two seconds, the line-drawings in this experiment were presented once in a random order every six seconds, the same timing that Logie (1986) had used with each sort of distracter in Experiments 3 and 4. Each line-drawing was present on the monitor for six seconds then was replaced by the next line-drawing with no interval of blank screen between them. The third interference condition, the control, remained a blank screen and the instructions for the two main memory conditions remained the same.

Results

The number of words which were correctly recalled by the subjects was expressed as a percentage and entered into a two by three (two memory instruction conditions and three interference conditions), mixed design analysis of variance. A significant main effect of memory condition [$F(1,22)=5.49$, $p<0.03$] was found but there was no significant main effect of interference [$F(2,44)=2.12$, $p>0.13$] or an interaction [$F(2,44)=0.56$, $p>0.57$]. The results are shown in Table 2.

Table 2

The mean percentage of items correct on each of the three interference conditions, no interference, line-drawings and visual noise patterns, for the visual and verbal memory strategies in Experiment 2.

Experiment 2	Control	s.d	Dynamic Visual Noise	s.d	Line-drawings	s.d
Rote main task	76.4	14.6	79.9	10.2	73.3	13.8
Visual Mnemonic	60.2	18.1	60.4	18.4	56.7	19.8

The significant main effect of memory strategy means that the task demands had not been equalised this time. Consequently the experiment had differing task difficulties and this has to be taken into account when analysing the other results. The data does not provide any support for the hypothesis of the experiment.

Discussion

The failure to equate the task demands was a surprise since it seemed that this problem had been solved in Experiment 1. It is difficult to explain: the blank screen control conditions for each of the memory strategies, the procedures and materials were the same for all intents and purposes, unless looking at the blank screen of an ST monitor is much different from looking at the blank screen of a BBC monitor. The timing of the memory trials was the same for Experiment 1 and 2 and the fact that each list is presented with such precise timing would seem to make a systematic effect unlikely. Apart from the fact that half of the subjects were paid in Experiment 2, the subject pool should have been much the same in the two experiments. Perhaps the subjects in Experiment 1 were more enthusiastic since they replied straight away to the letter asking them to take part. Or it could be that Experiment 2 was carried out at the end of term and the subjects, who were mainly undergraduates, were generally tired after exams. This would account for the drop in performance on the visual conditions but why the corresponding rise in performance on the verbal condition?

Whatever the explanation, it was clear that subjects in Experiment 2 were much worse on the visual task and much better on the verbal task than the subjects in Experiment 1. Instead of only a four percent difference between the control conditions on the rote and the mnemonic main tasks as in Experiment 1, there was now about a fifteen percent difference. Performance was fairly consistently about five percent poorer on the visual task in Experiment 2 than it was in Experiment 1 but at the same time the performance on the verbal task was about five percent better. The failure to equate task demands means that little more can be said about the results.

3.3 Experiment Three

Introduction

Clearly, there were problems with the task demands in Experiment 2 and one obvious solution is to carry out new pilot-trials and then re-run the experiment. Problems with task demands apart, however, the results of Experiment 2 do not give any support to the existence of an irrelevant pictures effect. It is always possible that the irrelevant material or its presentation can be improved and this possibility was investigated before Experiment 2 was repeated.

One of the factors that had been changed in the initial set of pilot trials prior to Experiment 1 to equate performance between the rote rehearsal and the visual mnemonic memory conditions was that the interval between presentation of the target words had been reduced by one second. This means that when the irrelevant line-drawings were presented once every six seconds in Experiment 2, it resulted in the line-drawings being out of step with the words that were presented to the subjects to learn. If it is the predictability of the regular change between the irrelevant line-drawings that attracts attention then presenting the irrelevant material· every five seconds so that it is in step with the material to be remembered should be more helpful in testing the hypothesis. This change will be helpful not only because it will keep the irrelevant material in step with the relevant material but because it should be more distracting to present the irrelevant material while the relevant material is being encoded. Logie and Marchetti (1991), using visual material, found support for the "interpretation of the data reported by Quinn (1991) and by Morris (1987). That is, the central executive is involved in encoding the Brooks matrix material in some form of mental image, but is less important for maintenance of information in that image, or the image itself." (p112-113). This suggests that it would be more in keeping with the hypothesis of a confounding of attention to present the unattended material while the subject is engaged in encoding. This will most likely be at word presentation.

A difference between the presentation of the line-drawings in Experiment 2 and the procedure used by Logie (1986) was the use of a computer to present subjects with the line-drawings instead of a slide-projector. The slide-projector is also not only noisier than using a computer, there is also some blank screen while the slide changes. This in itself may attract the subject's attention and so it is potentially an important factor in the irrelevant picture effect. For this reason it was decided to introduce one second of blank-screen between the presentation of each line-drawing. To simulate this difference in presentation of the line-drawings (and keep the material in step with the trials), line-drawings are to be presented for four seconds just as the word is being presented, there will be one second of blank screen, another line-drawing for four seconds, one second of blank screen and so on.

To equate task performances again it was necessary to carry out more pilot trials. New pilot trials were not carried out prior to Experiment 2 to make sure that performance levels between the visual and verbal memory strategies were equalised because the timing had not changed and it was assumed that performance levels would be similar to those found in Experiment 1. Although there appeared to be no reason why a difference should be found in equating task demands between Experiments 1 and 2, it is clear that in future it will not be advisable to make this assumption. For this reason it would seem to be necessary to run a new series of pilot trials for each experiment.

Apart from the small changes in the presentation of the line-drawings, Experiment 3 was essentially a re-run of Experiment 2 with new pilot trials. As such, Experiment 3 had the same hypothesis as Experiment 2, namely that the line-drawings would disrupt both the visual mnemonic and the rote rehearsal memory strategies while the dynamic visual noise would disrupt only the visual mnemonic.

Method

Pilot Trials

Each series of pilot trials consisted of six subjects who carried out both memory instructions, rote then visual, with no secondary interference. Each memory condition consisted of one practice trial followed by five trials. A seventy percent level of performance was considered desirable to rule out floor or ceiling effects. The first series of pilot trials used the same procedure as had been used in the previous experiments, namely six items in the rote rehearsal condition and ten in the visual mnemonic condition. There was a three second interval between the presentation of each number and word pair, a ten second interval between the end of presentation and the beginning of recall and a four second interval between the numbers which cued recall. As before, recall was the same order as the words had been presented. This resulted in a mean performance of 67.6% on the verbal condition and an 85% mean performance on the visual condition. Experience from previous experiments indicated that in the actual experiment the average score on the verbal condition would increase. This is because subjects tend to get better at the rote rehearsal strategy as they have more experience with it. A mean visual mnemonic performance of 85%, however was too high, a very odd result as the mean performance in the visual condition in Experiment 2 was only 60.2%. Although the tendency in previous experiments was that performance would drop slightly with three times as many trials, as subjects tended to tire as the experiment proceeded, a 15% drop would seem unlikely. For this reason, in the second series of pilot trials the timing of the cued recall was reduced by one second so that there was an interval of three seconds instead of four between the number cues. This resulted in a mean performance level of 84.7% in the rote rehearsal condition and a 76% mean performance in the visual mnemonic condition. The one second difference in the cued recall resulted in far too high a performance in the rote condition so for this condition the four second timing used in the first series of pilot trials was retained. The 76% performance level for the visual mnemonic in this series of trials is likely to equate task demands so this timing is retained. Although there is still an 8.4% difference between the timing of the rote rehearsal condition used in the first series of pilot trial and the timing used for the visual mnemonic strategy in the second series of pilot trials it is hypothesised that this difference will be substantially reduced in the actual experiment due to fatigue in the mnemonic strategy and improvement in the rote condition.

Subjects

Subjects consisted of thirty-eight volunteers from the Psychology Subject Panel. Thirty-six took part in the experiment, the other two being rejected for failing to carry out the visual mnemonic strategy as instructed. Eighteen subjects took part in the visual mnemonic condition, eighteen in the rote rehearsal condition. None of the subjects in the experiment had taken part in the previous experiments or any pilot trials.

Procedure

The procedure of Experiment 3 differed from that of the Experiment 2 in only having three seconds between the number recall cue in the visual mnemonic condition, a change adopted to equate task demands, and in the presentation rate of the irrelevant material. The line-drawings were presented to coincide with the presentation of the word. They were present on screen for four seconds, followed by one second of blank screen between each line-drawing. The presentation of the number of the word in the list was timed to coincide with the one second of blank screen and the presentation of the word itself coincided with the display of the irrelevant line-drawing on the screen..

Results

The number of words that were correctly recalled by the subjects were again expressed as percentages and entered into a two by three (two memory strategies and three interference conditions), mixed design analysis of variance. There was no significant effect of memory condition [$F(1,34)=2.40$, $p>0.13$] which meant that the pilot trials had succeeded in equalising task demands. There was a main effect of interference condition [$F(2,68)=23.31$, $p<0.01$] and also an interaction effect [$F(2,68)=3.37$, $p<0.04$]. The mean results are shown in Table 3.

Table 3

The mean percentage of items correct on each of the three interference conditions, no interference, line-drawings and dynamic visual noise patterns, for the visual and verbal memory strategies in Experiment 3.

Experiment 3	Control	s.d	Dynamic Visual Noise	s.d	Line-drawings	s.d
Rote main task	72.9	15.5	69.2	16.5	61.6	16.4
Visual main task	72.4	13.2	57.4	13.3	54.4	12.8

Performing a Newman-Keuls test on the interference effect showed that performance with no interference (the control condition) was significantly better than both the visual noise and the line-drawing interference conditions at the 0.01 significance level but that performance on the visual noise and line-drawing interference conditions did not significantly differ from each other.

Performing a Newman-Keuls test on the interaction effect showed that performance on both memory strategies was disrupted by the interference conditions but in different ways. The "unattended" line-drawings interference disrupted performance with both the visual mnemonic and rote rehearsal strategies as compared to the control condition while the visual noise interference only disrupted performance on the visual mnemonic condition as compared to the no interference condition. The rote rehearsal strategy comparison of line-drawing interference and visual noise interference was significant at the 0.05 significance level. All other significant comparisons were at the 0.01 significance level.

Discussion

The hypothesis of Experiment 3 predicted that the line-drawings would disrupt both the visual mnemonic and the rote rehearsal memory strategies while the dynamic visual noise would only disrupt the visual mnemonic, and this hypothesis was supported by the results.

The "unattended" line-drawings and the dynamic visual noise pattern are both visuospatial in nature and both interfere with the performance of a visual memory strategy. However, the line-drawings also interfere with performance of a verbal strategy because the "regularity" of the change of the visuospatial material in the line-drawings condition attracts general attentional resources which are necessary to perform the memory strategies. The dynamic visual noise interference does not involve regular focused change and so lacks this attentional component. For this reason the dynamic visual noise does not act as a general distracter on the performance of the verbal strategy.

The non-attention grabbing dynamic visual noise material interferes with the visual task, even though subjects have been told that the material is irrelevant to the task they have to perform. This confirms that Logie's (1986) hypothesis was indeed correct and visuospatial material does have obligatory access to the VSSP.

General Discussion

Although the differential disruption caused by the dynamic visual noise is evidence for the existence of an irrelevant picture effect, the fact that the irrelevant line-drawings in Experiment 3 interfere with both the visual and the verbal strategy suggests that the results Logie used to justify his hypothesis were confounded by an attentional component. All of the visuospatial materials that Logie (1986) presented to his subjects (the matrices, the squares and the line-drawings) involved "regular change" that was attention-demanding. Logie probably found that line-drawings differentially disrupted the visual memory strategy because it is more demanding than the verbal strategy. Even though the imagery instructions result in an improvement in performance, this improvement probably occurs because subjects have to put more effort into carrying out the task instructions. Any general interference will therefore have more of an effect on the visual strategy and will appear to be causing differential interference even though it is a general effect. If Logie's task demands had been equalised then it is likely that the line-drawings he presented to his subjects via a slide projector would have also interfered with performance on the verbal memory condition. Only when this attentional component has been removed can the irrelevant picture effect be shown properly.

Performance on the irrelevant visual noise and line-drawing interference conditions, with the mnemonic memory strategy, does not differ, suggesting that the disrupting effect of attention and the disrupting effect of the obligatory access of the visuospatial material to the VSSP are not independent of each other. This is an interesting result as it could imply that the effects of an attentional drain and specific visuospatial drain on VSSP resources are not additive. Certainly in future the term 'irrelevant pictures' has to be used very carefully. If they are used to differentially disrupt visuospatial processing, the presentation of the line-drawings has to be such that it does not elicit a general attentional effect. No disruption of the verbal strategy was found with the irrelevant line-drawings in Experiment 2, suggesting that the line-drawings do not have an attentional effect when there is no ISI but this would be more convincing in an experiment that did not show task demand differences.

A potential problem with Experiment 3 is the possibility that the irrelevant line-drawings are disrupting the verbal memory strategy, not because of the regularity of the line-drawings but because of the fact that they are nameable. It could be that subjects are unable to prevent themselves from processing the line-drawings verbally as they are presented, even though they have been instructed to ignore the line-drawings. It could be this additional verbal processing that naming the line-drawings requires that is causing the disruption in performance, not general attentional processes elicited by the "regularity" of the change in the line-drawings. Until the results of Experiment 3 have been replicated using non-nameable, "regular" visuospatial material it is impossible to rule this out completely. However, the results from the previous experiments make this unlikely. The irrelevant line-drawings in the Experiment 2 did not have any significant disrupting effect on the rote rehearsal mnemonic and it was not the semantic content of the line-drawings that was changed between Experiments 2 and 3 but the addition of one second of blank screen between the line-drawings and the change in timing to ensure that they were in step with the words to be remembered. Task demands were not equalised in Experiment 2 which makes the results suspect. Also, it is possible that the subjects in the visual mnemonic condition may not have been carrying out the visual strategy as they had been instructed to do at all times during the experiment. This doesn't affect the results of the rote rehearsal condition, however, and there is no reason to believe that the subjects were not carrying out the correct strategy. Performance levels of 76.392% in the control condition are similar enough to the 72.922% found in the control condition in Experiment 3 to make the two conditions comparable.

Thus it is the change in the timing of presentation of the irrelevant line-drawings that is most likely to be the reason that the line-drawings disrupted performance in Experiment 3, not the fact that their meaningfulness elicited verbal processing. Exactly the same line-drawings were presented so that the line-drawings in Experiment 3 were not more nameable. It is possible that it was the combination of the nameability of the words together with the effect of changing the timing that elicited the effect but assuming that it was the timing alone is more parsimonious.

In addition, the timing explanation helps explain why Logie (1986) found that the red and green squares interfered with the visual strategy but that Experiment 1 did not, even when task demands are equalised. In both experiments a square was presented which was randomly coloured red or green every two seconds. Logie, however, used an ISI of 1700 msecs and a display time of 300 msecs while Experiment 1 had virtually no ISI. This difference in timing of presentation of the irrelevant regularly-changing material may have been responsible for the difference in results as nothing else had been changed.

The introduction of one second of blank screen between each of the irrelevant line-drawings was one difference between the presentation of the line-drawings in Experiments 2 and 3. It is possible that Experiment 1 would have shown similar effects to Experiment 3 if the red/green squares in Experiment 1 had had a longer blank-screen ISI between each change. The comparatively long ISI that Logie (1986) used could have been attention-demanding and interfered with both visual and verbal processing because of the ISI. In Experiment 1 it was assumed that it was the discernible change occurring in the square every two seconds that was the important factor and so it was not considered that the display time or ISI would be important to the disruption caused. Experiment 1 focused on the fact that the change was predictable and occurred every two seconds, even though the colour change itself was unpredictable. However, the fact that the line-drawings showed a general disruptive effect in Experiment 3 but did not seem to do so in Experiment 2 (despite the problem in task demands) would seem to suggest that the ISI is a factor.

It is always possible that the squares in Experiment 1 were having a general disruptive effect due to the regular change involved in presentation and that this simply was not enough of a disruption to show up in the results. It seems clear, however, that the long ISI in Experiment 3 could add to the disruptive effect, if not causing it entirely. Further experiments will be necessary to clarify the point as to what exactly it is in the "regular change" that is causing the general attentional effect. The present results would indicate that the ISI between the regular change is an important factor.

The other important question still remaining is whether or not the material such as the static visual noise in Experiment 1 is having obligatory access to the VSSP. Even though there was no support for this from the results it could be that any disruption occurring was not strong enough to show up in the results. Logie's (1991) model predicts that all visuospatial material should have obligatory access to the VSSP so the red/green square and the static visual noise pattern should have disrupted the visual strategy. The fact that no disruption of the visual memory strategy was found for the red/green square or the static visual noise would seem at first to be evidence that the irrelevant pictures effect is not a general one but it could also be that the material was not sufficiently visually complex enough to interfere with visuospatial processing. The model suggests that the irrelevant pictures effect should prove to be a general effect. Although the only material to support this is the dynamic visual noise, other irrelevant material will eventually be adopted to investigate the generality of the irrelevant picture effect. Further experiments must be carried out in order to discern whether the effect is limited to the dynamic visual noise in Experiment 3, whether all visuospatial material enters the VSSP and has an equally disruptive effect, whether visual complexity will play a part in either obligatory access or the amount of disruption caused and also whether there is a visual equivalent of the speech-like sounds/non speech-like sounds distinction in the loop.

In conclusion, however, the presence of an irrelevant picture effect in visual working memory does support Logie's (1991) model of a passive visual store in visual working memory equivalent to the passive verbal store in verbal working memory. Investigating this effect further to determine which properties of the visuospatial material cause differential disruption of the visual memory strategy can hopefully say more about the nature of that store. In addition to this, investigating the reason why the line-drawings in Experiment 3 are disrupting both visual and verbal strategies has the potential to shed more light on the central executive.

3.4 Methodological Changes

A Change to the Visual Strategy Task Requirements

There is a problem with the visual and verbal strategies in that these tasks are supposed to be at least superficially similar kinds of task of comparable difficulty, the difference being that one uses verbal processes in the articulatory loop while the other relies on non-verbal processes in the VSSP. However, it is clear that these tasks are not comparable in nature because the verbal task requires subjects to remember the order of the words in order to carry out the task whereas the visual task has the pegwords as cues to order to aid the subject in the task. Moreover the task instructions for the verbal task are very simple, while the instructions for the visual task are much more complex, requiring the subject to recall the pegwords as well as the target words. There is no good theoretical reason why the subject should be required to memorise the pegwords, in effect making an additional memory drain on the subject. It is the imagery part of the task that is more important.

For these reasons the presentation of the visual strategy were altered in the next series of experiments. The problem with the visual task was that subjects were required to recall the ten pegword rhymes in order to encode and recall the target images. This need to recall the pegwords can be eliminated by having the experimenter present the subject with the pegword and the target word instead of the number of the item in the list and the target word. For example, the subject might hear "bun" followed by "stool" instead of the number "one" followed by "stool" or "shoe" followed by "room" instead of "two" followed by "room". When it is time to recall the target words the subject will be cued with each of the pegwords in turn instead of the numbers. This simplifies the task requirements for the visual strategy so that the subject is required to carry out one less step, a step that is not actually necessary. The two tasks are still not perfect but this change is thought to help redress the balance between the task requirements of the two strategies.

New Pilot Trials to Use as a Guide to Tailor the Presentation of Trials for Individual Subjects

The other procedural change that was initiated at this point concerns the variability of subjects performance of the visual and verbal memory strategies. Apart from the fact that it is time-consuming to carry out pilot trials prior to each experiment there is also a problem with the subjects performance in Experiments 1, 2 and 3 in that there was too much variance in the data. In Experiment 3 the standard deviation in the no interference conditions was 15.47 for the verbal memory strategy and 13.16 for the visual memory strategy. This is explained by the fact that the data for the verbal strategy ranges between 41.7% and 100% and between 42.5% and 95% for the visual memory strategy. Although the means of the two strategies are close to the 70% level, the individual data points vary. The 70% level was chosen to avoid floor or ceiling effects but this is precisely what was happening for each subject. For this reason it was decided to set the performance levels for each individual subject, changing the difficulty of the memory strategy depending on the subjects initial performance and varying the presentation of the memory trials to ensure a performance level on the control condition as close to 70% for each subject. To act as a guide for setting both the initial presentation rate and for selecting the appropriate change in presentation rate to bring about the correct change in performance, pilot trials were planned to see what an average performance would be at a particular presentation rate and the difference between performance at that and other presentation rates.

The pilot trials therefore compared performance levels with different timings of presentation. In the experiment itself the subject had two sets of three test trials with no interference and the timing was altered, using the pilot trial averages as a guide, to try to elicit a performance close to seventy percent.

Procedure For The Pilot Trials

The first series of pilot trials consisted of three subjects who carried out four conditions each of which consisted of a practice trial and five actual trials. Each subject carried out the conditions in the same order. The words were always presented and recalled in the same order. Before each condition the subjects were told how to memorise the words following the correct strategy and were given explicit examples of the strategy. They were also informed of the timing of the trials. They were told to look at the blank monitor rather than anywhere else but knew that nothing would appear on the monitor.

The first condition involved the subjects learning lists of seven words using a rote rehearsal strategy. The subject was presented with the number of the word in the list, the target word, a three second interval, the next number, the next target word and so on such that the words were presented to the subjects every five seconds. After the seventh number and word pair there was a ten second interval and then the subject was presented with the appropriate number every five seconds which they knew was their cue to recall the target word. The second condition differed from this procedure only in that the words were presented and recalled every four seconds. The third condition involved the subjects learning lists of ten words using a visual mnemonic strategy. The subject was presented with the first pegword, the target word, a three second interval, the next pegword, the next target word and so on such that the target words were presented to the subjects every five seconds. After the tenth word pair there was a ten second interval and then the subject was presented with the appropriate pegword every five seconds which they knew was their cue to recall the target word. The fourth condition differed from this procedure only in that the words were effectively presented and recalled every four seconds.

The second series of pilot trials also consisted of three subjects who carried out four conditions each of which consisted of a practice trial and five actual trials as before. These were presentation conditions five to eight. The presentation of the fifth condition differed from the first condition only in that six items were presented and recalled, not seven. Similarly the presentation of the sixth condition differed from the second condition only in that six items were presented and recalled, not seven. The presentation of the seventh and eighth conditions differed from conditions three and four only in that the target words in condition seven were effectively presented every five seconds and recalled every four seconds and the target words in condition eight were effectively presented every four seconds and recalled every five seconds. These comparisons of performance levels on these eight conditions led to the following mean performance scores being constructed:

Table 4

The eight practice conditions used to determine the presentation and recall parameters during the experimental phase are listed. Mean performance gives the performance measured over all subjects in that practice condition. With a performance level of around 70% throughout the experiment considered desirable, conditions 2 and 7 were the default conditions used. However, any given subject could be given a different pair of conditions from the list to bring the performance levels more closely together.

Condition	Strategy	Items	Presentation	Recall	Mean Performance
1	Verbal	7	5 secs	5 secs	65.7%
2	Verbal	7	4 secs	4 secs	72.4%
3	Visual	10	5 secs	5 secs	78.9%
4	Visual	10	4 secs	4 secs	56.7%
5	Verbal	6	5 secs	5 secs	77.8%
6	Verbal	6	4 secs	4 secs	87.8%
7	Visual	10	5 secs	4 secs	74.0%
8	Visual	10	4 secs	5 secs	72.0%

Condition two was selected as the default presentation time for the verbal strategy and condition seven was selected as the default presentation time for the visual strategy. If the subjects performance deviated from a seventy percent performance level after the first three practice trials the condition was changed to compensate, using the eight conditions as a guide. In addition to this it was decided that further difficulty levels could be extrapolated from this if required. Although it was thought that it would probably be more practical to keep the timing between the trials to either three or four seconds, it would be feasible, for example, to reduce or increase the number of words in each trial. Further details of the number of trials and the presentation and recall rates for each subject are given in the appendix.

3.5 Experiment Four

Introduction

Experiment 4 is a control experiment, using the technique of double dissociation. Previous experiments argue for the operation of separate visual and verbal slave-systems. However, a seventy percent level of performance on the visual task in terms of numbers of words recalled in the correct order may not necessarily reflect a similar cognitive load to the verbal task. A particular problem would be if one memory strategy required more of a central executive input than the other memory strategy, as any interference which also required a central executive input could then appear to disrupt one strategy more than another, not because of the nature of the interference but simply because of this central executive input. Using such data to uncover anything about the nature of the slave-systems in working memory would then be invalid. A double dissociation result would indicate that any attentional difference was less of a factor than the specific disruption caused by the nature of the irrelevant material.

This kind of crossover result is difficult to design because the irrelevant speech interferes with rote presentation of the memory trials and irrelevant line-drawings interfere with visual presentation of the memory trials. Subjects only have one pair of eyes and one pair of ears. The solution adopted follows the procedure in Logie's (1986) experiment whereby he presented the trials visually with the irrelevant speech (and a no interference control) while in the condition with or without irrelevant line-drawings the memory trials were presented verbally. The hypothesis of Experiment 4 is that irrelevant visuospatial material in the form of dynamic visual noise will disrupt a visual memory strategy but not a rote rehearsal strategy while at the same time, irrelevant verbal material in the form of a foreign language that the subject does not understand, will disrupt a rote rehearsal strategy but not a visual memory strategy. This crossover result would support the existence of two separate visual and verbal stores and greatly reduce the possibility that differing task difficulty between the visual and rote memory strategies were responsible for the results of Experiment 3.

Method

Pilot Trials

Even though there was a change in procedure in that half of the memory tasks were to be presented visually this was not expected to make that much of a difference and the pilot trials for each subject were used as a guide to determine the appropriate timing for each subject in six initial practice trials to achieve a performance near to 70% in the control condition. Further details of this are given in the appendix.

Subjects

Thirty-two first year undergraduate subjects from the Psychology Subject Panel took part in the experiment. They were paid and none had taken part in previous experiments or pilots.

Materials

The same words were used for the memory trials as in previous experiments. The dynamic visual noise used in Experiment 3 was again used as the irrelevant visuospatial material for the visual secondary interference. An obscure foreign language presented on a tape recorder through earphones was used as the irrelevant speech. Readings from Genesis in Hebrew were selected. None of the subjects were familiar with any Hebrew.

Design and Procedure

Due to the procedural change described in the last section, the subjects in this experiment were not required to remember the pegwords. The only other difference to the procedure for the experiment from the previous experiments was that in this case, half the memory trials where to be presented visually on the computer monitor, not presented verbally by the experimenter. As before, half the subjects were alternately assigned to the visual condition and given visual strategy instructions, while half took part in the verbal condition and were given the rote rehearsal memory instructions. Subjects began by carrying out three sets of two practice trials where the timing of presentation of the memory trials was varied to find the most appropriate presentation rate that would elicit a performance level of around seventy percent. If the first two experimental conditions were memory trials that were to be presented visually on the monitor the pilot trials were also presented visually. If the memory trials in the first two conditions were to be verbally presented then the pilot trials were verbally presented.

In the first experimental condition the memory trials were presented visually and subjects heard irrelevant speech through headphones. In the second condition the memory trials were also presented visually on the monitor but this time, though the subject still wore earphones, there was no irrelevant speech presented. In the third condition the memory trials were presented verbally and subject watched irrelevant visual material in the form of a continuous dynamic visual noise pattern on the monitor. In the fourth condition the memory trials were verbally presented and the subject was told to watch the monitor but this time the monitor was blank.

The presentation rate of each of the memory trials varied depending on the pilot trials for each subject but typically the trials consisted of the cue being presented on the monitor for one second or spoken at a rate of one second (a number in the verbal memory condition, the relevant pegword in the visual memory condition) followed by the word to be recalled, also presented on the monitor for one second or spoken at a rate of one second. After an interval of two or three seconds, the subject was presented with the next cue, the next relevant word and another two or three second interval and so on. After the appropriate amount of items (determined by the pilot trials but typically ten in the visual condition and six or seven in the verbal condition) the word "recall" was flashed up on the screen or spoken and the subject was given the first cue. They knew that they were to respond verbally and that they had to wait for the next cue before they could give their next response.

Where irrelevant visual or verbal material was presented to the subject it was present through the four trials, during presentation. maintenance and recall. As before recall was in the same order as presentation and each set of trials consisted of a practice trial followed by three actual trials. The trials weren't completely counterbalanced because it was thought best for the subjects only to have to get used to one change in presentation of the memory trials. It also meant that the number of changes in presentation of the memory trials was kept constant for each subject. For this reason the two conditions where the memory trials were presented visually were kept together, as were the two conditions were the memory trials were presented verbally. Apart from this, however, the trials were counterbalanced.

Results

The number of words that were recalled correctly and in the right order by the subject was expressed as a percentage and entered into two by four (two memory strategies and four interference conditions) mixed analysis of variance. The mean results are shown in Table 5.

Table 5

Performance levels are presented separately for trials presented visually and those presented verbally in Experiment 4. Figures are the percent performance levels and the corresponding standard deviations.

Trials Presented Visually	Irrelevant Speech	s.d.	No Interference	s.d.
Rote Main Task	55.2	9.7	70.5	3.9
Visual Main Task	70.6	3.7	71.0	3.4

Trials Presented Verbally	Dynamic Visual Noise	s.d.	No Interference	s.d
Rote Main Task	68.4	5.2	70.5	4.1
Visual Main Task	53.8	10.5	71.2	4.5

No significant main effect of memory strategy was found [$F(1,30)=0.18$, $p>0.67$] which meant that overall performance on the visual memory strategy was no different from overall performance on the verbal memory strategy. This meant that task demands between the visual and verbal strategies were equal overall in the experiment. A significant interference effect was found, however, [$F(3,90)=24.08$, $p<0.01$] as well as a significant interaction effect [$F(3,90)=34.06$, $p<0.01$].

Performing a Newman-Keuls test on the interference effect showed that performance with either kind of interference (irrelevant dynamic noise or irrelevant speech) was significantly worse than both the visually and verbally presented control conditions at the 0.01 significance level. Performance overall between the two control conditions did not differ from each other. There was also no overall difference between the disruptive effect of irrelevant dynamic noise and irrelevant speech. A Newman-Keuls test on the interaction effect showed that for the visual memory strategy, performance on the condition with irrelevant dynamic noise was significantly poorer than the irrelevant speech condition, the visually presented control condition and the verbally presented control condition. For the verbal memory strategy the irrelevant speech resulted in a significantly poorer performance than with irrelevant dynamic noise or either of the control conditions (all $p<0.01$).

Discussion

The results supported the hypothesis that irrelevant visuospatial material disrupts a visual memory strategy but not a verbal memory strategy while at the same time, irrelevant verbal material disrupts a verbal memory strategy but not a visual memory strategy. This crossover result supports the existence of two separate visual and verbal stores and rules out the possibility that differing task demands between the visual and verbal memory strategies were responsible for the results of the previous experiments.

This replicates the results of Experiment 3 where irrelevant visuospatial material that did not involve regular change differentially disrupted a visual memory strategy. Moreover, it shows that this did not occur simply because the visual memory strategy made a significantly greater demand on the central executive in order to reach the 70% level of performance than was required by the verbal memory strategy. If the two memory strategies had made significantly different demands on the resources of the central executive then the irrelevant speech would not have been found to differentially disrupt the verbal memory strategy at the same time as the irrelevant line-drawings differentially disrupted the visual memory strategy. In this way the crossover result supports the existence of two separate visual and verbal stores in working memory.

In Experiment 4, the standard deviations for the no interference controls for the visual memory strategy were 3.374 for the visually presented trials and 4.544 for the verbally presented trials. Together the individual subjects performances ranged from 63.3% to 76.6%. The standard deviations for the no interference controls for the verbal memory strategy were 3.903 for the visually presented trials and 5.224 for the verbally presented trials. Together the individual subjects performances ranged from 61.9% to 77.4%. This shows that the individual pilot trials for each subject succeeded in their goal of reducing the variance for the individual performances of each of the memory strategies. They also cut out floor and ceiling effects for each subject.

3.6 Experiment Five

Introduction

One of the first puzzles posed by the results of Experiment 3 was why the line-drawings in Experiment 3 had a general disruptive effect on both the visual and verbal memory strategies while the dynamic visual noise only disrupted the visual strategy. In other words, what quality did the line-drawings have that the dynamic visual noise lacked?. The hypothesis of Experiment 3 was that the line-drawings would have a disruptive effect on both strategies because of the "regular change" involved in its presentation. The term "regular change" is, however, a little vague. Finding out more about what this "regular change" might actually involve should tell us more about both visual working memory and the central executive.

There is, however, the possibility already mentioned that the irrelevant line-drawings disrupted the verbal memory strategy, not because of the regularity of the line-drawings but because of the fact that the line-drawings were nameable. It could be that subjects were unable to prevent themselves from processing the line-drawings verbally as they were presented, even though they had been instructed to ignore the line-drawings. It could be that it was the additional verbal processing that naming the line-drawings required that caused the disruption in performance, not general attentional processes elicited by the "regularity" of the change in the line-drawings.

Although the results from the previous experiments would make this explanation unlikely on its own, until the results of Experiment 3 have been replicated using non-nameable, "regular" visuospatial stimuli it is impossible to rule this out completely. To test this possibility that it was the nameability of the line-drawings that made them disrupt both the visual and verbal strategies, non-nameable line-drawings or doodles were constructed and pilot trials constructed to test the nameability of both the doodles and the more meaningful line-drawings.

Pilot Trials to Compare the Nameability of the Doodles and the Line-drawings

The aim of these pilots was to test whether the doodles generated for Experiment 5 are significantly less nameable than the line-drawings that had been used in Experiment 3. These two different types of visuospatial material had been generated by hand so an objective test is required. Subjects were shown a mixture of the doodles interspersed with the line-drawings. If the image made them think of a word, they were to name that word. If not, they were to keep silent. It was expected that they would be able to consistently name most of the line-drawings but not the doodles.

Method

Subjects

Eighteen subjects took part in these pilots, mostly first-year Psychology students from the Departmental Subject Panel. They were paid for taking part.

Materials

The Visuospatial material consisted of 80 line-drawings of common objects generated for Experiment 3 and 100 abstract doodles generated for Experiment 5. The material was combined and randomised and the order saved into a file. The material was then presented in the same order for each subject simply to make marking easier.

Design and Procedure

Subjects were presented with the following instructions. "You will be presented with a series of line-drawings presented one every four seconds. If the image has a name which clearly comes to mind, say that name out loud. It the image does not have a name that clearly comes to mind then keep silent." Each of the images was presented on the monitor for three seconds, interspersed with one second of blank screen. Subjects responses were noted. The procedure was then repeated to see if subjects were being consistent.

Results

The percentages of line-drawings recalled and doodles not recalled were so high that the subject was marked as having named a doodle or not named a line-drawing even if they had only done so once. The mean number of line-drawings named was 96.6%, ranging from 93% to 99%. The mean number of doodles named was 2.4%, ranging from 0% to 6%. Not surprisingly when the naming of line-drawings and doodles were compared in an analysis of variance a significant difference was found [$F(1,17)=47567.2$, $p<0.01$].

Conclusion

The results showed overwhelmingly that most of the line-drawings were nameable and most of the doodles were non-nameable.

Experiment Five

Substituting the doodles for the line-drawings in Experiment 5 will test whether the line-drawings in Experiment 3 really did have a general disruptive effect because of the "regular change" involved in their presentation, and not just because they were nameable. It is hypothesised that the doodles will disrupt both the visual and verbal strategies just as the line-drawings in Experiment 3 did because they have a "regular change" involved in their presentation whereas the dynamic visual noise condition should only disrupt visual processing because it does not involve regular change.

Method

Other Pilot Trials

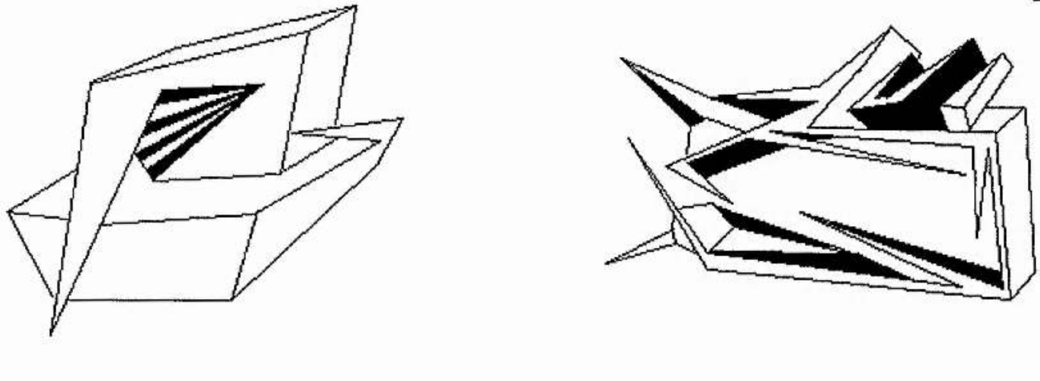
As in Experiment 4, no pilot trials were carried out specifically for the experiment and the data in the pilot trials carried out prior to Experiment 4 was used as a guide. The aim as before was to manipulate the timing of the memory trials so that the subjects would achieve as near to a seventy percent performance level as possible, by choosing between the different possible timings of presentation of the memory trials. Each subject undertook several practice trials (typically six) until a reasonable performance level was reached.

Subjects

The twenty-four subjects in the experiment consisted mainly of non-psychology post-graduate students recruited during the summer term. The remainder of subjects were first-year psychology students from the Psychology Subject Panel. All subjects were paid for their participation. Half were alternately assigned to the visual condition, the other half took part in the verbal condition. None had taken part in previous experiments.

Materials

Non-nameable line-drawings or doodles were drawn by hand on an Atari STE computer. Each line-drawing filled the centre of the monitor (approximately ten centimetres by seven centimetres just as the line-drawings did. As in previous experiments the second program on the computer consisted of a dynamic random visual noise display. Examples of the doodles are given in Figure 2.



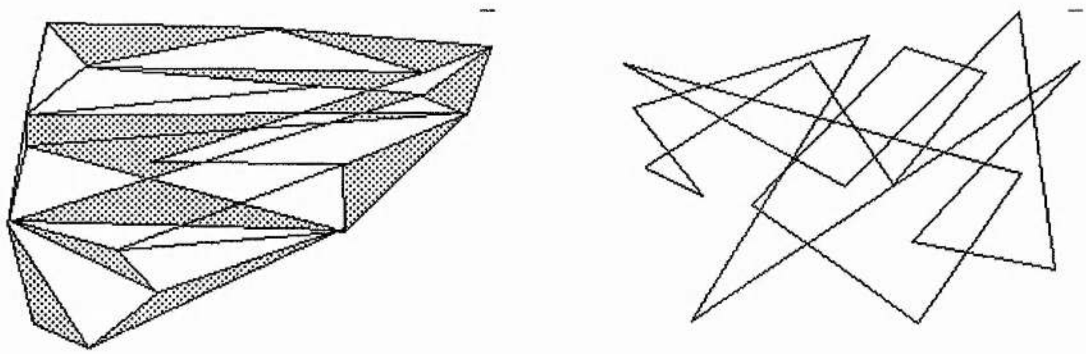


Figure 2. Four doodles out of the one hundred used in Experiment 5.

Design and Procedure

Each subject was given either the visual or the verbal memory strategy instructions. Subjects began by carrying out three set of two practice trials to elicit a performance level of around seventy percent. Experiment 5 consisted of three counterbalanced sets of trials, one where there was no interference on the monitor, one with unpredictable doodles and the third condition with continuous dynamic noise. Each set of trials consisted of a practice trial followed by three actual trials. As in Experiment 4, subjects were not required to remember the ten pegwords in the visual strategy in order to carry out that strategy and were instead presented and cued with the appropriate pegword rather than the number of the word in the list. This, and the fact that individual pilot trials were used, were the only changes between Experiment 5 and Experiment 3.

Results

The number of words which were correctly recalled by the subjects were expressed as percentages and entered into a two by three (two memory instruction conditions and three interference conditions), mixed design analysis of variance. The mean percentages are shown in Table 6, along with the standard deviations.

Table 6

Subjects' percent performance under the conditions of Experiment 5. Performance figures are given for the control (no interference condition), dynamic visual noise, and the doodles conditions, along with their standard deviations.

Experiment 5	Control	s.d.	Dynamic Visual Noise	s.d.	Doodles	s.d.
Rote Main Task	70.9	4.9	69.2	8.4	57.6	5.3
Visual Main Task	70.8	3.9	55.0	8.9	51.0	13.1

A significant main effect of memory condition was found [$F(1,22)=11.34$, $p<0.01$]. This was a potential problem in that it could mean that task demands are not equalised. Mean performance overall on the visual condition was 59.0% while performance on the verbal condition was 65.9%. The interaction results show, however, that this was because performance on the visual strategy was disrupted by both the noise and the doodles whereas performance on the verbal strategy was only disrupted by the doodles. The manipulations of timing during the pilot trials for each subject actually resulted in the control performances with no interference being very close for the visual and verbal strategies (70.917% and 70.833% respectively). When an analysis of variance was carried out only on the verbal and visual control conditions the analysis was not significant [$F(1,22)=0.002$, $p>0.96$].

There was a main effect of interference [$F(2,44)=28.39$, $p<0.01$] and an interaction effect [$F(2,44)=5.19$, $p<0.01$]. Performing a Newman-Keuls test on the interference effect showed that performance with no interference (the control condition), with dynamic noise and with the non-nameable doodles all differed significantly from each other at the $p<0.01$ level. A Newman-Keuls test was also performed on the interaction effect. It was found that performance on the verbal strategy with no interference was significantly better than performance with the doodles interference but not the dynamic noise. Performance with the dynamic visual noise interference was also significantly better than with the doodles. For the visual strategy, however, the no interference condition was significantly better than both the dynamic noise and the doodles, with performance on the doodles and the noise interference conditions not resulting in a significantly different performance.

Discussion

These results support the hypothesis that the irrelevant doodles have a general attentional effect because they represent a "regular change" that demands the subjects attention. Like the meaningful line-drawings in Experiment 3, the dynamic visual noise interference disrupted performance on the visual but not the verbal memory strategies, showing a specific disruption of visuospatial performance. The doodles, presented to coincide with each word to be remembered like the line-drawings in Experiment 3, had a more general disruptive effect, lowering performance on both the visual and the verbal strategies. This is more convincing than the line-drawings in Experiment 3 because the doodles were much less nameable and so could had little chance of engaging verbal processing because of an effect of nameability.

General Discussion

Taken together, Experiments 3, 4 and 5 all confirm the existence of an irrelevant pictures effect in visual working memory. In all these experiments the irrelevant pictures were shown not only to be consistent but also to be quite a strong and robust effect. Experiments 4 and 5 did more than simply replicate the effects of Experiment 3, however. Experiment 4 was an important control to make sure that the irrelevant line-drawings weren't differentially disrupting the visual strategy simply because the task requirements of the visual strategy were greater than those of the verbal strategy.

Experiment 5 made sure that the line-drawings in Experiment 3 had not disrupted the verbal strategy as well as the visual strategy simply because the line-drawings were nameable. Instead some factor in the presentation of the material, the "regular change", would seem to be responsible for eliciting a general disruptive effect.

The initial aim of the thesis has been achieved in that a general technique of using irrelevant pictures has been developed which has the potential to show us something about the nature of visual working memory. The irrelevant pictures task is very simple task that should have a minimal attentional component. Manipulating the visuospatial material used for the irrelevant pictures will help us investigate which material has a specific or general disruptive effect. The specific effects can tell us more about the nature of the VSSP while the general effects can tell us something about the relationship of the VSSP with the central executive. Now that a robust irrelevant pictures effect has been developed it is time to use it as a tool to investigate the VSSP.

Chapter Four - Using Irrelevant Pictures to Investigate General Disruption in Visual Working Memory

4.1 Experiment Six

Introduction

The aim of this series of experiments is to find a more precise description of what has only been presented so far as a "regular change". What is it about the nature of this "regular change" that makes demands of central processing resources by drawing our attention towards something we have been told is irrelevant? It is not change itself that demands our attention otherwise the dynamic visual noise would also have a general attentional effect. Nor is it focused change. Both the visuospatial stimuli used in Experiment 1 and the line-drawings in Experiment 2 involved a regular focused change but neither form of visuospatial stimuli disrupted the visual or the verbal memory strategies.

In Experiment 2 and Experiment 3, subjects were presented with the same line-drawings, the only difference being in the way that the line-drawings were presented. The overall results of Experiment 2 were flawed in that the task demands of the two memory strategies were unequal. The fact that no disruption of the visual strategy was found with the dynamic visual noise suggests that the visual strategy was not being carried out correctly, especially since the same irrelevant visual noise material presented in Experiments 3, 4 and 5 did disrupt performance on the visual condition. There was no reason, however, to doubt that the verbal strategy was being carried out correctly and the performance of 76.392% on the verbal strategy without interference in Experiment 2 was close enough to the 72.922% performance on the same memory strategy in Experiment 3 to make performance on the two verbal conditions comparable. Performance on the verbal strategy with irrelevant line-drawings in Experiment 3 dropped to 61.572% and the line-drawings were shown to disrupt performance of the verbal strategy. Performance on the verbal strategy with the same irrelevant line-drawings in Experiment 2, however, stayed at 73.267% and the line-drawings did not disrupt verbal performance.

One of the differences in the way that the material was presented was that a one second blank screen inter-stimulus interval (ISI) was present in the line-drawings in Experiment 3 but not Experiment 1. As well as a serial change of identity in the line-drawings in Experiment 3 there was also an extended on/off period as the drawings were serially presented. In Experiment 2 this on/off period was minimal because onset of each line-drawings occurred immediately after the offset of the preceding line-drawing. In Experiment 3 the focused change in the on/off period between the line-drawings was extended by the insertion of one second of blank screen. It is possible that the inclusion of this ISI, combined with the focused change in the serial identity of the line-drawings, was sufficient in Experiment 3 to engage attentional mechanisms and disrupt both visual and verbal strategies.

There is additional evidence from Experiment 1 that the presence or absence of an ISI in the presentation of visuospatial material can make a difference as to whether irrelevant material will disrupt performance on a memory task. One reason why the red and green squares in Experiment 1 failed to disrupt performance may have been because they had virtually no ISI and thus a minimal on/off period between the squares. In contrast, similar squares in Logie (1986) had an ISI of 1700 msecs, a timing which extended the on/off period. The squares with the extended on/off period between them did differentially disrupt the visual strategy. The ISI in Logie's timing was the only difference in the presentation of the squares between the two kinds of material. It is possible that the presence or absence of an ISI could play a part in eliciting general disruption as well as specific disruption.

The aim of Experiment 6 is to investigate whether the introduction of an ISI in the presentation of irrelevant visuospatial material is sufficient to elicit general disruption. To this end, performance on the visual and verbal memory strategies is compared when irrelevant visuospatial material is present that either does or does not contain an ISI. The continuous dynamic visual noise pattern was selected for the irrelevant material with no ISI. This material had no focused on/off period at all in its presentation. The continuous dynamic noise is compared with the same irrelevant material which has an ISI of one second introduced into its presentation as the target word was presented. This artificially inserts an extended on/off period into the presentation of the dynamic noise, thus introducing a focused change that was not present before the ISI was introduced.

To determine whether the focused change introduced by the ISI is a crucial factor in eliciting a general disruptive effect, the hypothesis of Experiment 6 is that constant dynamic visual noise will have a differential effect on the visual memory condition while the dynamic visual noise with a blank screen ISI will disrupt both visual and verbal memory strategies. This would demonstrate that specific disruption with irrelevant line-drawings can only be elicited with material that does not have a ISI in its presentation that introduces a focused change into the presentation of the material.

Method

Subjects

Subjects were twenty-four volunteers from the Psychology Subject Panel. Half were assigned to the visual condition, the other half took part in the verbal condition. None had taken part in previous experiments.

Design and Procedure

The task instructions for the two memory strategies were the same as for Experiments 4 and 5 in that subjects in the visual condition were presented and cued with the appropriate peg-word rather than the number of the word in the list. Subjects began by carrying out two sets of three practice trials to select the most appropriate timing to elicit a performance level of around seventy percent. Experiment 6 consisted of three counterbalanced sets of trials, one where there was no interference on the monitor, one with a continuous visual noise pattern identical to that used in Experiment 5, and one with one second of blank screen inserted to coincide with the presentation of the target word. Each set of trials consisted of a practice trial followed by four experimental trials.

Results

The number of words that were correctly recalled by the subjects was expressed as a percentage and entered into a two by three (two memory strategies and three interference conditions), mixed design analysis of variance. The results are shown in Table 7.

Table 7

Subjects' percent performance under the conditions of Experiment 6. Performance figures are given for the control (no interference), continuous dynamic visual noise and dynamic visual noise with a one second ISI in its presentation every two seconds. The standard deviations for the subjects performance are also given.

Experiment 6	Control	s.d	Dynamic Visual Noise	s.d	Visual Noise + ISI	s.d
Rote main task	61.7	9.1	60.1	9.5	60.1	9.7
Visual main task	72.7	5.5	53.5	7.6	57.5	8.9

No significant effect of memory condition was found [$F(1,22)=0.05$, $p>0.82$] which meant that task demands had been equalised. There was, however, a significant effect of interference condition [$F(2,44)=14.94$, $p<0.01$] and a significant interaction effect [$F(2,44)=10.46$, $p<0.01$]. Performing a Newman-Keuls test on the interference effect showed that performance with no interference (the control condition) was significantly better than both the visual noise and visual noise with ISI conditions at the 0.01 significance level but that performance on the visual noise and visual noise with ISI interference conditions did not significantly differ from each other. A Newman-Keuls test was also carried out on the interaction effect. It was found performance on the control condition on the rote strategy did not significantly differ from either of the interference conditions, neither of which differed from each other. On the visual strategy, however, both the interfering conditions were different from the control but not each other (all $p<0.01$).

Discussion

The results do not support the hypothesis that an ISI of one second of blank screen is sufficient to elicit a general attentional effect. The constant focused change at a given time, as indicated by the on/off period caused by the ISI, was not sufficient to engage attentional process. As the verbal condition was unaffected by any irrelevant material on the monitor, other factors must be considered in arriving at an explanation of why the line-drawings elicited a general attentional effect in Experiment 3 but not Experiment 2. The results did, however, show once more that some forms of visuospatial material have obligatory access to the VSSP.

4.2 Experiment Seven

Introduction

The results of Experiment 6 indicated that the introduction of a focused change by including an ISI into irrelevant visuospatial material is not sufficient to elicit the general attentional effect shown by the line-drawings in Experiment 3. This seemed to be the obvious target for investigation because the same line drawings in Experiment 2 but presented without this ISI did not cause general disruption. The only factor remaining to account for the changes between Experiments 2 and 3 is the fact that the line-drawings were presented in step with the target words in Experiment 3 but were out of step in Experiment 2.

In Experiment 2 the line-drawings were presented every six seconds. The memory trials occurred every five seconds. This meant that the line-drawings were out of step with the memory trials. In Experiment 2, the onset of most of the line-drawings only coincided with the onset of the relevant words in the memory trials for one trial out of every six. This means that for most trials in Experiment 2 the presentation of the line-drawings did not coincide with the encoding stage of information processing of the words in the memory trials. In Experiment 3, however, the line-drawings were presented in step with the memory trials. The onset of each line-drawing was presented at the same time as each word in the memory trial was presented, coinciding with the encoding of that word. The subjects were told the line-drawings were irrelevant but they were told to look at the screen and it seems likely that they processed the line-drawings at some level. The presentation of the line-drawings in Experiment 3 did disrupt performance with the verbal memory strategy which means that the irrelevant line-drawings were being processed in a way that demands the attention of the subject. This suggests that presenting the line-drawings in step with the memory trials so that their presentation coincides with onset of each word in the memory trials results in the subject having to process each of the irrelevant line-drawings at the same time as they encode the words in the memory trials and that this attracts attentional processes.

This implies that whatever circumstances attracted attentional resources and impaired performance on the verbal strategy in Experiment 3 either only occurred or had its strongest effect at the encoding stage. The visual noise in Experiment 6 presented after the one second of blank screen did, however, coincide with the target words so another explanation must be found to account for the fact that this material did not elicit the general disruptive effect on verbal performance shown by the line-drawings. One difference between the continuous visual noise pattern and the line-drawings of Experiment 3 is that the small changes in the visual noise pattern did not form an overall pattern that was radically different and so the presentation of the visual noise pattern after the ISI was not unexpected for the subject. When the line-drawings changed, however, the drawings were different every time so that the subject could not predict what they were about to see. The same was true for the doodles. It could be the unpredictability of the line-drawings that draws the subjects attention towards something they have been told is irrelevant.

Previous results can be reinterpreted by substituting the idea that it is an "unexpected" change presented at the encoding stage that elicits a general disruptive effect rather than simply a "regular" change. Although the subjects in Experiment 1 could not predict whether the square would be changing to red or green every two seconds the fact that they knew it would be either red or green could have been a small enough set of possibilities to make either colour change expected. The changes in the line-drawings in Experiment 2 were unexpected in that the subject could not predict what line-drawing would be presented next but presentation was not in step with the memory trials and so the unexpected change did not cause enough disruption at the encoding stage to be significant. This was rectified in Experiment 3 which did present unexpected material at the encoding stage and so a general disruptive effect was elicited. The same is true for Experiment 5. The changes in the visual noise in Experiment 6 were presented at the encoding stage but were not unexpected enough to demand attentional resources. To say more about what material is predictable and what material is not predictable, it is necessary to look at the notion of predictability in more detail.

Definitions of predictability are difficult, however, as the criteria are unclear as to what makes a change predictable or unpredictable. It seems clear that the dynamic visual noise does not involve predictable change as it involves constant internal changes that are not spatially, temporally or semantically focused. These criteria are clearly important as even when the dynamic noise was given temporal focus external to the pattern in Experiment 6 by inserting a blank ISI between noise presentations, the selectivity of the interference was maintained. In contrast to the dynamic noise, the line-drawings in Experiment 3 and the doodles in Experiment 5 were recognisably different and unpredictable to the subjects and elicited general rather than specific interference. Using these results as a guide, a visual display was constructed to test the importance of unpredictable changes for the nature of the interference. Three by three matrices with their cells randomly black or white were selected as being suitable for these purposes. Matrices are good candidates to test the notion of unpredictability because they contain both predictable and unpredictable elements. They are unpredictable because the internal structure of each matrix is different. They are predictable because the matrices do not change their outline from instance to instance. Moreover, the internal structure of each matrix conforms to the same criteria, namely that there will be three by three cells and each cell will be either black or white. In this way, the internal features of each matrix can be controlled and the differences manipulated systematically.

Whether the subjects treat the matrices as predictable or unpredictable will depend on the level of analysis at which the irrelevant matrices are being processed; whether the subjects focus on the matrix as a whole or on the changes in the internal structure of the matrices. When Logie (1986, Experiment 2) ran a similar experiment he found some evidence for a selective effect of three by three matrices, at least when his experimental group was subdivided into good and poor rote learners. This would indicate that three by three matrices are sufficiently predictable to subjects that they elicit selective interference. It suggests that the internal changes between each matrix are within limits that are circumscribed enough as to be predictable. It is hypothesised that matrices, like the dynamic visual noise, will be sufficiently predictable that they will selectively disrupt the visual strategy.

Method

Pilot Trials

The data in the pilot trials carried out prior to Experiment 4 was again used as a guide to achieving a mean 70% performance level with no interference present on screen.

Subjects

Subjects consisted of 24 paid volunteers who had signed up on a notice board in the Psychology building. Half were assigned to the visual condition, the other half took part in the verbal condition. None had taken part in previous experiments.

Materials

The matrices occupied a ten centimetre square area of the centre of the monitor and consisted of three by three matrices whose cells were randomly white or black. The dynamic visual noise was the same as that used in Experiment 6.

Design and Procedure

The task instructions for the two memory strategies and procedure for Experiment 7 was the same as in Experiment 6 in that the subjects began by carrying out two sets of three practice trials to select the most appropriate timing to elicit a performance level of around seventy percent. Experiment 7 consisted of three counterbalanced sets of trials, one where there was no interference on the monitor, one with the matrix patterns and the third condition with continuous dynamic visual noise. Each set of trials consisted of a practice trial followed by four experimental trials. As Experiment 7 is designed to test whether the matrices have the same general attentional effect as the line-drawings in Experiment 3, the same timing was adopted as in Experiment 3. The matrices were presented in step with the memory trials either every four or five seconds (depending on the pilot trials), with a blank-screen ISI of one second presented one second before the presentation of the word.

Results

The number of words that were correctly recalled by the subjects was expressed as a percentage and entered into a two by three (two memory strategies and three interference conditions), mixed design analysis of variance. The mean scores are shown in Table 8.

Table 8

Subjects' percent performance under the conditions of Experiment 7. Performance figures are given for the control (no interference), dynamic visual noise and the three by three matrices with the cells randomly black or white. The standard deviations for the subjects performance are also given..

Experiment 7	Control	s.d.	Visual Noise	s.d.	Matrices	s.d.
Rote main task	72.0	4.0	68.9	11.5	68.8	11.4
Visual main task	71.3	4.3	54.6	12.5	58.1	12.5

A significant effect of memory condition was found [$F(1,22)=9.90$, $p<0.01$]. This was a potential problem in that this could mean that task demands are not equalised. Mean performance overall on the visual condition was 61.319% while performance on the verbal condition was 69.883%. This, however, probably occurred because performance on the visual strategy was disrupted by the visual noise and matrix interference whereas no disruption occurred with the interference on verbal strategy. When an analysis of variance was carried out only on the verbal and visual control conditions the analysis was not significant [$F(1,22)=0.19$, $p<0.66$]. For this reason, task demands were equalised in Experiment 7.

There was also a significant effect of interference condition [$F(2,44)=7.86$, $p<0.01$] and a significant interaction effect [$F(2,44)=3.46$, $p<0.05$]. Performing a Newman-Keuls test on the interference effect showed that performance with no interference (the control condition) was significantly better than both the visual noise and matrix while performance on the visual noise and matrix interference conditions did not significantly differ from each other. Performing a Newman-Keuls test on the interaction effect, for the rote strategy the control did not differ from either of the interference conditions, which also did not differ from each other. For the visual strategy, performance on the control condition differed from both interference conditions, neither of which differed from each other (all $p<0.01$).

Discussion

Both the continuous visual noise and the matrices selectively disrupted the visual strategy even though subjects had been instructed that they were not relevant to the memory task. This supports the findings of the previous experiments in that the matrices are shown to have obligatory access to the VSSP. Moreover, the results support the hypothesis that the matrices were predictable enough for the subject so that the matrices did not draw on attentional resources. Although the subjects could not predict the internal structure of each matrix, the overall fact that the next pattern would be a three by three matrix with the cells either black or white was enough of a certainty to let subjects "ignore" the new image. Experiment 7 shows that subjects processed each matrix as a whole and that this level of processing is more important to the irrelevant pictures effect than differences in the internal structure of each individual matrix.

The line-drawings in Experiment 3 were all different and subjects did not have any parameters to predict anything about the next line-drawing except perhaps the broad size and position on the screen. The doodles in Experiment 5 also had shapes that were not predictable to the subject. Like the line-drawings, the doodles had a general disruptive effect. This result is consistent with the argument that the general interfering effect of the line-drawings or doodles is caused by their being sufficiently and unpredictably different from one another to engage attentional processes even under instructions that they are irrelevant to the main recall task.

4.3 Experiment Eight

Introduction

This aim of this series of experiments has been to explore why the line-drawings in Experiment 2 did not disrupt performance on the verbal strategy whereas the same the line-drawings in Experiment 3 did disrupt the verbal memory strategy. The difference between Experiments 2 and Experiment 3 was in the timing of the presentation of the line-drawings. Experiment 6 was designed to test whether the introduction of a focused change plus ISI was sufficient to disrupt verbal processing and elicit a general disruptive effect. No evidence was found for this interpretation. From this it seemed likely that the critical manipulation between Experiments 2 and 3 was the change from presenting the visuospatial material out of step with the memory trials to being in step with the memory trials. This resulted in the presentation of the line-drawings in Experiment 3 coinciding with the encoding of the memory trials. In Experiment 2 the line-drawings only coincided with the encoding of the line-drawings in one trial out of six. This indicated that a change at encoding was a critical factor in eliciting general disruption.

A change at encoding was not sufficient to explain the results of Experiment 6, however, as the introduction of a focused change resulted in the dynamic noise being presented to coincide with the encoding of the words but this did not elicit general resources. It was hypothesised that as well as being presented at encoding, the irrelevant visuospatial material had to involve an unpredictable change. Experiment 7 was designed to look at the notion of predictability. It was found that presenting a subject with three by three matrices with cells that were randomly black or white did not involve a sufficiently unpredictable change at encoding to engage general resources. Although the internal structure of each matrix was unpredictable, these differences were within limits that were circumscribed enough as to be predictable to the subject.

The matrices in Experiment 7 were presented to coincide with the encoding of the words to be remembered as it was assumed that this was a critical factor. The evidence for this is the fact that the line-drawings in Experiment 3 which coincided with encoding elicited a general effect whereas the same line-drawings in Experiment 2 that did not coincide with encoding did not disrupt the verbal strategy. There are other theoretical reasons for believing encoding to be an important factor, however.

There is evidence in the literature which suggests that interference is restricted to the encoding phase of spatial tasks (Morris, 1987; Quinn, 1991) and that once encoded, spatial positions can be represented as a percept that is no longer susceptible from concurrent movement tasks. Logie and Marchetti (1991) argued that the encoding of visuospatial tasks is effortful and requires resources from the central executive. Once encoded as a percept, it is argued that the spatial tasks require few resources and are no longer susceptible to spatial interference. The one-bun visual mnemonic is an effortful task involving subjects being required to image the referent of the presented word and integrate the referent with the mnemonic image. The encoding of items under these instructions is therefore likely to require resources from the central executive. Encoding words with rote rehearsal is also expected to draw on resources from the central executive. It is argued that a sequence of changing line-drawings also attracts the resources of the central executive. The central executive has limited resources and if the presentation of the line-drawings coincides with the encoding of the visual or verbal memory strategies competition for resources will occur and will elicit general interference. However, once the words have been encoded, fewer attentional resources are required. The visually encoded words can be represented in the passive visual store with reduced executive resources while rote rehearsal can be performed without a continuing analysis of semantic identity. Any interference at this point will be caused by the visual nature of the irrelevant material and so will cause selective interference with the visually maintained words.

Experiment 8 aims to test this hypothesis by directly comparing the effect of presenting the same line-drawings at the encoding, maintenance and recall stage of information-processing as compared to only maintenance and recall. The hypothesis of Experiment 8 is that line-drawings which are presented so that their onset coincides with the encoding of the memory trials will disrupt both the visual and verbal memory strategies. In contrast, the same line-drawings presented only at maintenance and recall are not expected to engage attentional processes and instead will differentially disrupt the visual strategy.

Method

Pilot Trials

Again, the pilot trials prior to Experiment 4 were used to determine the appropriate timing for each subject to achieve a performance as near to 70% in the control condition.

Subjects

Twenty-four first year undergraduate subjects from the Psychology Subject Panel took part in Experiment 8. They were paid and none had taken part in previous experiments.

Design and Procedure

Experiment 8 consisted of 3 counterbalanced sets of trials, one where there was no interference on the monitor, one where the presentation of irrelevant meaningful line-drawings coincided with the encoding of the relevant words in the memory trials and the third condition where the same line-drawings coincided with the maintenance of the words.

Subjects were tested individually. Half the subjects were given visual strategy instructions and half were given the rote rehearsal memory instructions. Subjects began by carrying out three sets of two practice trials where the timing of presentation of the memory trials was varied to elicit a performance level of seventy percent. Each of the three interference conditions consisted of a practice trial followed by three experimental trials. The line-drawings used in Experiment 3 were used, presented in step with the memory trials. The line-drawings remained on the screen for either three or four seconds (depending on the results of the pilot trials) followed by one second of blank-screen ISI before the next picture was presented. In one interference condition the onset of each line-drawing coincided with the word the subject was required to memorise. In the second interference condition the onset of the line-drawing occurred two seconds after the presentation of the word that the subject was required to memorise.

Results

The number of words that were recalled correctly and in the right order by the subject was expressed as a percentage and entered into a two by three (two memory strategies and three interference conditions) mixed analysis of variance. The mean scores are shown in Table 9.

Table 9

Subjects' percent performance under the conditions of Experiment 8. Performance figures are given for the control (no interference), line-drawings presented to coincide with maintenance and line-drawings presented to coincide with encoding. The standard deviations for the subjects performance are also given.

Experiment 8	Control	s.d.	Maintenance	s.d.	Encoding	s.d.
Rote Strategy	71.6	5.1	68.8	8.9	53.6	12.9
Visual Strategy	71.2	3.7	57.0	12.6	53.6	10.8

No main effect of memory strategy was found [$F(1,22)=2.27$, $p>0.14$] which meant that task demands had been equalised. A significant main effect of interference was found, however, [$F(2,44)=25.87$, $p<0.01$] and an interaction effect [$F(2,44)=3.70$, $p<0.05$]. A Newman-Keuls test on the interference effect showed that the three interference conditions all differed significantly. A Newman-Keuls test on the interaction effect showed that performance on the visual strategy with no interference was significantly better than both the line-drawings at encoding and the line-drawings at maintenance conditions, neither of which was significantly different from each other. For performance with the rote strategy, the no interference control condition was greater than the line-drawings presented at encoding but was not significantly different from the line-drawings presented at maintenance. The performance of subjects on the rote strategy with irrelevant line-drawings presented only at maintenance and recall was also significantly better than with the same irrelevant line-drawings presented at encoding, maintenance and recall (all $p<0.01$).

Discussion

Experiment 8 directly compared the effect of presenting the same line-drawings at the encoding, maintenance and recall stage of information-processing as compared to only maintenance and recall. The line-drawings presented at maintenance engaged visuospatial processing even though subjects had been told that the line-drawings were irrelevant. This visuospatial processing interfered with the visual memory strategy, because they shared the same memory resources but did not disrupt the verbal strategy which did not involve visuospatial memory resources. The line-drawings presented to coincide with encoding, however, disrupted both visual and verbal processing and so engaged general attentional resources.

It is interesting that there was no significant difference in performance on the visual strategy between the conditions where line-drawings are presented at maintenance and encoding. This either means that the effects of the attentional interference of the line-drawings at encoding and the specific interference caused by the visuospatial nature of the line-drawings are not additive. However it is also possible that the design of Experiment 8 was not sensitive enough to pick up any differential effects of interference.

Another interesting factor about the results of Experiment 8 concerns the possibility that the general disruptive effect of the line-drawings in Experiment 3 may have come about because of the fact that the line-drawings were nameable. The fact that the non-nameable doodles in Experiment 6 also had the same disruptive effect helped rule out this possibility. Experiment 8, though, offers the best argument against this nameability factor as the same line-drawings presented at maintenance did not produce a general effect even though they were presumably just as nameable as the line-drawings presented at encoding.

These results support the hypothesis that the line-drawings in Experiment 3 and the doodles in Experiment 5 disrupted the verbal strategy because their presentation coincided with the encoding of the memory trials. The same line-drawings presented at maintenance did not engage these attentional processes and instead differentially disrupted the visual strategy because of the visuospatial nature of the line-drawings. Obviously this is not a complete explanation because the matrices in Experiment 7 were presented at encoding and did not disrupt the verbal strategy. Although some measure of unexpectedness that has not yet been defined is probably also involved, results so far suggest that it is sufficiently unexpected visuospatial material presented at encoding that elicits the general attentional effects found in Experiment 8 and Experiments 3 and 5.

Chapter Five - Using Irrelevant Pictures to Investigate Specific Disruption in Visual Working Memory

5.1 Experiment Nine

The aim of this series of experiments is to investigate which factors in the irrelevant visuospatial material are necessary to elicit differential disruption to the visual strategy. Previous experiments provide some clues as to which factors might be focused on. Experiment 1 found that a static visual noise pattern did not disrupt a visual memory strategy. In contrast, Experiment three found that a dynamic visual noise pattern did differentially disrupt the visual memory strategy. This is one point where investigations can begin to determine the critical elements in the irrelevant visuospatial material necessary to elicit the irrelevant pictures effect.. Some changes in procedure have occurred since Experiment 1 was run, however (for example the adoption of individual pilot trial for subjects or the use of the pegwords as cues in the visual memory strategy instead of the numbers). In addition, the experimenters in Experiment 1 were not as experienced as in later experiments. For that reason, in what was the first test of a new procedure, the results of Experiments 1 and 2 may not be as reliable as later experiments. Experiment 9 was run to determine whether the previous results were justified, which indicated that a static visual noise pattern would not disrupt the visual memory strategy. It is hypothesised that Experiment 9 will replicate the results of Experiment 1 and Experiment 3 in a single experiment. A dynamic visual noise is expected to differentially disrupt the visual memory strategy while the static visual noise disrupts neither the visual or verbal memory strategies.

Method

Pilot Trials

As before, the pilot trials prior to Experiment 4 were used to determine the appropriate timing for each subject in six initial practice trials to achieve a performance as near to 70% as possible in the no interference condition.

Subjects

Twenty-four first year undergraduate subjects from the Psychology Subject Panel took part in Experiment 9. They were paid and none had taken part in previous experiments.

Materials

The continuous dynamic visual noise used in Experiment 7 was used. The static visual noise pattern was derived from a dynamic pattern frozen at a point in time. As such, it occupied the same area of the screen as the dynamic visual noise.

Design and Procedure

Experiment 9 consisted of three counterbalanced sets of trials, one where there was no interference on the monitor, one where the subject saw a static visual noise pattern, and a dynamic visual noise condition. Subjects were instructed to keep their eyes on the centre of the monitor. Subjects were tested individually. Half were assigned to the visual condition and given the visual strategy instructions, half took part in the verbal condition and were given the rote rehearsal memory instructions. Subjects began, as before, by carrying out six sets of practice trials where the timing of presentation of the memory trials was varied to find the most appropriate presentation rate that would elicit a performance level of around seventy percent. For each of the three interference conditions, subjects carried out one pilot trial and four experimental trials.

Results

The number of words that were recalled correctly and in the right order by the subject was expressed as a percentage and entered into two by three (two memory strategies and three interference conditions) mixed analysis of variance. The mean scores are shown in Table 10.

Table 10

Subjects' percent performance under the conditions of Experiment 9. Performance figures are given for the control (no interference), static visual noise and continuous dynamic visual noise, along with their standard deviations.

Experiment 9	Control	s.d.	Static Visual Noise	s.d.	Dynamic Visual Noise	s.d.
Rote Main Task	70.6	4.2	68.9	4.5	70.1	4.5
Visual Main Task	70.9	4.5	72.1	4.8	49.3	12.5

A significant main effect of memory strategy was found [$F(1,22)=9.43$, $p<0.01$]. The fact that there was a significant effect of memory condition was a potential problem in that this could mean that task demands were not equalised. When an analysis of variance was carried out only on the verbal and visual control conditions, the analysis was not significant [$F(1,22)=0.02$, $p>0.88$]. For this reason, task demands were equalised during Experiment 9.

A significant interference effect [$F(2,44)=29.69$, $p<0.01$] and a significant interaction effect [$F(2,44)=32.12$, $p<0.01$] were also found. Performing a Newman-Keuls test on the interference effect showed that performance with the dynamic visual noise condition was poorer than the static visual noise or the control ($p<0.01$). Performance on the static and control conditions did not significantly differ from each other. A Newman-Keuls test on the interaction effect showed that the dynamic visual noise significantly interfered with the visual strategy ($p<0.01$). No other significant interactions were found.

Discussion

These results supported the hypothesis and confirmed that a static visual noise pattern does not disrupt the visual memory strategy while dynamic visual noise pattern does have a differential disruptive effect on the visual strategy.

5.2 Experiment Ten

Introduction

The aim of Experiment 10 is to look closer at which factors in the visuospatial material are necessary to elicit specific disruption. Experiment 9 showed that a static visual noise pattern does not disrupt a visual memory strategy whereas a dynamic visual noise pattern does have a differential disruptive effect on the visual strategy. One possibility is that the static visual noise pattern did enter the passive visual store but that the pattern faded because it was not refreshed. The dynamic visual noise pattern is continually refreshed and so does disrupt the visual strategy. One way to test this possibility would be to see whether the same alternating single static visual noise pattern and a blank screen ISI will disrupt the visual strategy. This will contain the same sort of visuospatial information. though only for only half the time as the static pattern in Experiment 9 but the fact that its presentation is continually interrupted by a second of blank screen means that it should be re-entering the passive visual store, not simply fading. For the hypothesis to be properly tested it is desirable that the subject should be looking at the same area of the screen each time the pattern is re-presented and they were asked to do this. Subjects did know, however, that it was the same pattern being presented each time.

The hypothesis of Experiment 10 is that both the flashing static visual noise and the continuous dynamic visual noise will differentially disrupt the visual memory strategy.

Method

Pilot Trials

As before, the pilot trials prior to Experiment 4 were used to determine the appropriate timing for each subject.

Subjects

Twenty-four first year undergraduate subjects from the Psychology Subject Panel took part in Experiment 10. They were paid and none had taken part in previous experiments.

Materials

The dynamic visual noise used in Experiment 9 was used. The static visual noise pattern was derived from the dynamic pattern frozen at a point in time. It was flashed on the screen, lasting for one second, then there was one second of blank-screen and so on. The static pattern occupied the same area of the screen as the dynamic visual noise. The same static visual noise pattern was presented each time.

Design and Procedure

Experiment 10 consisted of three counterbalanced sets of trials, one where there was no interference on the monitor, one where the subject saw a static visual noise pattern for one second alternating with one second of blank screen, and one where subjects were presented with continuous dynamic visual noise. Subjects were instructed to keep their eyes on the centre of the monitor.

Subjects were tested individually. Half were assigned to the visual condition and given the visual strategy instructions, half took part in the verbal condition and were given the rote rehearsal memory instructions. Subjects began, as before, by carrying out three sets of two practice trials where the timing of presentation of the memory trials was varied to find the most appropriate presentation rate that would elicit a performance level of around seventy percent. For each of the three interference conditions, subjects carried out one pilot trial and four experimental trials.

Results

The number of words that was recalled correctly and in the right order by the subject was expressed as a percentage and entered into two by three (two memory strategies and three interference conditions) mixed analysis of variance. The mean scores are shown in Table 11.

Table 11

Subjects' percent performance under the conditions of Experiment 10. Performance figures are given for the control (no interference), static visual noise with ISI and dynamic visual noise, along with their standard deviations.

Experiment 10	Control	s.d.	Static Visual Noise + ISI	s.d.	Dynamic Visual Noise	s.d.
Rote Strategy	71.5	3.5	70.0	8.4	73.8	9.6
Visual Strategy	70.9	5.2	51.9	9.3	50.0	10.5

A significant main effect of memory strategy was found [$F(1,22)=31.16$, $p<0.01$]. This was a potential problem in that it could mean that task demands were not equalised. Mean performance overall on the visual condition was 57.6%, while performance on the verbal condition overall was 71.8%. This was because the static and the dynamic visual noise interfered with the visual but not the verbal strategy. When an analysis of variance was carried out only on the verbal and visual control conditions, the analysis was not significant [$F(1,22)=0.12$, $p>0.73$]. For this reason, task demands were equalised during Experiment 9.

A significant interference effect [$F(2,44)=18.17$, $p<0.01$] and a significant interaction effect [$F(2,44)=20.99$, $p<0.01$] were also found. Performing a Newman-Keuls test on the interference effect showed that performance with no interference was significantly better than both the static and dynamic visual noise conditions at the 0.01 significance level while performance on the static and dynamic visual noise interference conditions did not significantly differ from each other. A Newman-Keuls test on the interaction effect showed that in the visual condition, performance on the dynamic and the static visual noise conditions were both significantly worse than with the control but did not differ from each other. In the verbal condition, however, performance on the control, the dynamic visual noise and the static visual noise did not differ significantly from each other.

Discussion

The results supported the hypothesis of Experiment 10 that a static visual noise interference pattern that was interrupted by regular bursts of blank screen will differentially disrupt a visual strategy in the same way as dynamic visual noise. This gives support to the possibility that the static visual noise pattern in Experiment 9 did enter the passive visual store but that the pattern faded because it was not refreshed. The static visual noise pattern in Experiment 10 presumably contained the same sort of visuospatial information (though on the screen for only half the time) as the pattern in Experiment 9 but the simple fact that its presentation was continually interrupted by a second of blank screen meant that it re-entered the passive visual store. Once in the store it requires similar resources to those required for the visual memory strategy and so disrupts the visual strategy.

If it is the simple manipulation of adding one second of blank screen that elicits the disruption in the visual store this is quite different from the way that the general attentional effect appears to work. This effect takes accounts of such things as predictability and is relatively sophisticated so that the black and white matrices in Experiment 7 did not elicit the effect while the less predictable doodles and meaningful line-drawings did. It would seem that the more specific, irrelevant pictures effect is a more simple, more automatic effect of irrelevant visuospatial material entering a passive store and disrupting a visual strategy providing it is refreshed and doesn't simply fade.

Chapter Six - Using Irrelevant Pictures to Look for Functional Distinctions Between the Components of Visual Working Memory

6.1 Experiment Eleven

Introduction

Experiments 1 to 10 looked at visuospatial processing within the VSSP by focusing on a single visual memory task, the pegword mnemonic. Therefore, the evidence for the existence of the irrelevant pictures effect exists solely on one visual memory task. Within the confines of that task the irrelevant pictures effect has proved to be a robust effect that can be shown with several different forms of irrelevant material. It would be unfortunate, however, if the irrelevant pictures effect turned out to depend on something unique to the mnemonic task. The aim of the thesis is to investigate the nature of the VSSP and any findings would be much stronger if the effects of irrelevant pictures could be demonstrated with another visuospatial memory strategy. Thus there is a need to develop a second visuospatial task that is qualitatively different from the pegword mnemonic strategy. It should be possible, given Logie's (1995) model of the VSSP, to design a visual task which relies on different resources within the VSSP to the pegword mnemonic visual strategy. Logie (1995) has suggested that there are two functionally distinct subcomponents within the VSSP, a passive visual component and an active rehearsal mechanism. Although no attempt was made in experiments 1 to 10 to subdivide the VSSP into active or passive components, feedback from subjects would suggest that the pegword mnemonic task is an effortful one that requires rehearsal. Integrating images of presented words with the ten pegwords to ensure that the pegwords can be used as retrieval cues is clearly a difficult task for subjects to carry out, a task that accesses the rehearsal mechanism within the VSSP, as well as the passive store. If an additional visual task could be constructed which would reduce the subjects requirement for access to the visual rehearsal mechanism, then a comparison of the two visual tasks would have the potential to empirically distinguish between the two subcomponents of the VSSP within the same experiment.

The additional visual task selected is the "method of loci" used by the ancient Greeks. According to Cicero, this task was devised by the Greek poet Simonides around 500 BC (Baddeley, 1992). The task exploits a subjects existing knowledge of ordered spatial relations of locations such as a building or a route in a town. The subject imagines placing items to be memorised in particular spatial locations and at recall will mentally revisit these locations to retrieve the items to be recalled. It is a similar task to the pegword mnemonic in that both require the construction of images. However, in the pegword mnemonic the subject is not familiar with the pegwords before the experiment. Moreover, the pegwords are selected only because they rhyme with the numbers one to ten. Apart from this the words are not related to each other. In contrast, the spatial locations have clear relationships with each other and so should be much clearer cues for the subject, cues that have some relationship to the real world. Consequently, the subject can be expected to form much richer images with the target words and location because the location exists as a particular place, not just as an arbitrary word such as "bun". The fact also that the locations have stronger associations between each other than do the pegwords means that it should be less effortful for the subject to remember the sequences of images. Not only should the method of loci task be less demanding because the subject should form richer images, there should be less need to rehearse the sequences of integrated images. The reduction in the memory load brought about by the requirement that the loci are well known before the experiment should also reduce the requirement for access to the visual rehearsal mechanism.

If these two visual tasks are using different resources within the VSSP then it should be possible to differentially disrupt the tasks using different interfering stimuli within the same experiment. This would then show that the two subcomponents within the VSSP can be empirically distinguished. A dynamic visual noise display has been shown to reliably interfere with lists of words learned using the pegword mnemonic strategy (Experiments 3 to 7 and Experiments 9 and 10). It is thought that this material has obligatory access into the passive visual component of the VSSP. What is required is irrelevant visuospatial material which will interfere more with the active rehearsal component of the VSSP.

Logie (1995) argues that the inner scribe part of his model is not only responsible for rehearsing the contents of the visual store, it is also a system used to plan movement. Findings such as Baddeley and Lieberman (1980), Quinn (1994), and Logie and Marchetti (1991) suggest that "the link between spatial representation and motor control is quite close" (Logie, 1995, p117). The second interfering task that is designed to disrupt the rehearsal component of the VSSP therefore should involve movement. In addition it should have minimal visual form (Baddeley and Lieberman, 1980) and the movement should not be random (Quinn, 1994). The task which meets these criteria consists of a single dot that consecutively appears in five different positions in space, predictably following the points of a five-pointed star. This star dot task should clearly involve rehearsal component of the VSSP. In contrast, the dynamic visual noise should gain direct access to the passive visual store with less involvement of the rehearsal mechanism.

The method of loci is a strategy that mainly relies on the passive visual store. Lists learned under the method of loci should be disrupted by the dynamic visual noise because the dynamic noise has direct access into the passive visual store. The star dots rely more on the active rehearsal mechanism and so lists learned under the method of loci should not by disrupted by the star dots. In contrast the same lists learned under pegword mnemonic instructions should be disrupted by both the dynamic visual noise and the star dots because the pegword mnemonic is a strategy that relies on both the passive visual store and the visual rehearsal mechanism within the VSSP. The lists learned under rote rehearsal instructions should not be disrupted by either the dynamic visual noise or the star dots because rote rehearsal does not involve the VSSP. The hypothesis of Experiment 11 is therefore that the pegword mnemonic should be disrupted by both the dynamic visual noise and the star dots, the method of loci should be disrupted by the dynamic visual noise but not the star dots and rote rehearsal should be disrupted by neither the dynamic visual noise or the star dots.

Method

Subjects

Thirty-six first-year undergraduate subjects from the Psychology Subject Panel took part in Experiment 11. They were paid and none had taken part in previous experiments.

Pilot trials

For the rote and pegword mnemonic conditions, the information generated prior to Experiment 4 was again used as a guide to modifying performance to reach a seventy percent performance level. The same information was used as a guide in the method of loci conditions. Pilot trials were run to see which of the timings was most appropriate and also to make sure that the subject understood the procedure. It was found that the subjects performance was closest to the seventy percent level with a performance time of three seconds between the presentation of each of the direction and word pair and with four seconds between each of the direction cues at recall. It was anticipated that if subjects performance was too high the time between the recall cues could be reduced and if the subject had difficulty with the task the number of items to be recalled could be reduced (giving them more time to recall the words would have made Experiment 11 longer than one hour which might have resulted in subjects in this memory strategy being more tired overall).

Materials

The dynamic visual noise was presented as in the previous experiments for the visual secondary interfering task. For the new spatial secondary interfering task another programme was written and presented on the Atari STE computer. In this program an invisible circle was drawn with a diameter of 6 cm (taking up roughly the same area of screen as the dynamic visual noise except that the visual noise covers a square area) with five equal points around it. The program was written so that a single dot would appear in each of the five different positions around the invisible circle in turn following the points of a five pointed star shape. The point appeared momentarily once per second. The dots followed a predictable pattern. If the five points were labelled clockwise around the circle in order from one to five the dot would appear at 1, then 3, then 5, then 2, then 4, then 1, then 3 and so on.

Design

A mixed design was used with the three memory instructions (lists to be learned under the method of loci, the pegword mnemonic or rote instructions) as a between subject factor and the three means of concurrent interference (none, spatial or visual) as a within subject factor.

Task Instructions and Procedure

The same words were used for the memory trials as in Experiment 10. Subjects were tested individually and were randomly assigned to one of the three list encoding instructions. Each subject was given six pilot trials to approximate a performance level of 70%. After the pilot trials, each subject was given one practice trial and three experimental trials under each of the three interference conditions. Each experimental trial was followed by a ten second delay before recall was required. The procedure and the task instructions for the rote task and the pegword mnemonic were the same as for Experiment 10.

Task instructions for the method of loci involved presenting subjects with a grid representing twelve locations around St. Andrews that the students were familiar with. These locations roughly formed a three by four matrix. The three streets in the centre of St. Andrews run roughly parallel to each other and have a length of approximately one kilometre. Each row in the matrix represents one of the streets. In each of the three parallel streets, four well-known landmarks were chosen, covering a street length of approximately five hundred metres. These were then regularised into a four by three matrix and presented as a stylised map of twelve locations to undergraduates who had to learn their relative locations. The grid is shown in Table 12.

Table 12

Locations around St. Andrews.

MacIntosh Hall	Cinema	Library	St Leonard's Quad
The Union	Woolworth's	Fountain	PMs (a chip shop)
The West Port	Greyfriars Monument	John Menzies	Psychology Foyer

The students learnt the stylised map of the twelve locations, the map was taken away and they were then tested on their memory of the map. This took the form of starting at different locations and asking what location was left, right, up or down etc. All subjects had become consistently good with the map after ten minutes of this.

Subjects were presented with a random starting point on the grid. They were then presented with a direction (left, right, up or down) and they were required to mentally walk to this new location. Then they were presented with an item that they had to imagine at this location. Subjects were then presented with another direction and another item. This went on until ten items in total had been presented. After an interval of ten seconds subjects were reminded of the starting location and cued with each of the direction words in turn. They were required to think of the appropriate location and say which item they had imagined at that location.

Results

The number of words that were recalled correctly and in the right order by the subject was expressed as a percentage and entered into a three by three mixed analysis of variance (three main tasks based on differing memory strategies and three secondary interference conditions). The mean results are shown in Table 13 below.

Table 13.

Percent performance along with standard deviations under the major conditions of Experiment 11.

Experiment 11	Control	s.d.	Dynamic Visual Noise	s.d.	Star Dots	s.d.
Rote Main Task	72.5	3.5	71.6	8.0	72.6	7.9
Pegword Mnemonic	72.0	5.0	55.6	9.5	54.7	10.6
Method of Loci	72.7	4.7	50.2	10.4	64.9	11.5

A main effect of memory strategy was found [$F(2,33)=15.14$, $p<0.01$]. However, when an analysis of variance was carried out only on the no interference control conditions for the three memory strategies, the analysis was not significant [$F(2,33)=0.08$, $P>0.91$]. An interference effect [$F(2,66)=27.28$, $p<0.01$] and an interaction effect [$F(4,66)=9.17$, $p<0.01$] were also found. A Newman-Keuls on the secondary interference task effect found that all three conditions differed significantly from each other. A Newman-Keuls was also performed on the interaction effect. This found that in the rote memory strategy condition, performance with no interference, dynamic visual noise and the star dots did not differ significantly. Performance on the visual memory strategy condition with no interference, however, was significantly better than performance on both the dynamic visual noise and the star dots interference conditions, with no difference found between performance on the dynamic visual noise and the star dots. In contrast, in the method of loci strategy condition with no interference, performance did not differ significantly from the star dots, but performance on both the no interference and the star dots interference conditions was significantly better than with the dynamic visual noise (all $p>0.01$).

Discussion

These results are clearly consistent with the hypothesis of Experiment 11. Using the two component VSSP as the theoretical background, it was hypothesised that a visual task that required minimal access to the visual rehearsal mechanism would not be disrupted by an interference task that has the rehearsal mechanism as its principal focus of action. This is what was found. The method of loci task used cues that were already familiar to the subjects and that also existed in the real world. Image encoding in this task was thought to be both easier and less dependent on the visual rehearsal mechanism of the VSSP than the pegword mnemonic task. Consequently, the method of loci task was disrupted only by the dynamic visual noise. The star dots did not disrupt the method of loci task because the focus of action of this task is the visual rehearsal mechanism and the method of loci requires little access to this mechanism. In contrast, the pegword mnemonic requires to be more actively rehearsed and therefore requires access to the rehearsal mechanism. This ensures that this mnemonic is susceptible to interference which acts through the rehearsal mechanism and is additionally susceptible to interference acting directly through the passive visual store. Thus the pegword mnemonic was disrupted by both the star dots and the dynamic visual noise.

Neither the dynamic visual noise nor the star dots had any disruptive effect on rote rehearsal. This confirms that the interfering tasks operated through specific visual processes rather than general processes within the central executive.

6.2 Experiment Twelve

Introduction

Experiment 12 was run as a control for Experiment 11 to test the possibility that the method of loci is such a different task that it will be disrupted by any secondary interference. Although individual pilot trials were to be adopted as in the previous experiments, it is still possible that subjects may have to work harder to ensure a seventy percent performance on one task than on another task. For this reason Experiment 12 was a control designed to rule out the potential problem of the two tasks having differing task demands. It tests whether irrelevant speech will interfere with the method of loci task.

The hypothesis of Experiment 12 is that visuospatial interference in the form of dynamic visual noise will selectively disrupt the method of loci strategy while verbal interference in the form of irrelevant speech will selectively disrupt the rote memory strategy.

Method

Pilot trials

The same criteria were used as had been adopted in Experiment 12.

Subjects

Sixteen first-year undergraduate subjects from the Psychology Subject Panel took part in Experiment 11. They were paid and none had taken part in previous experiments.

Materials

The dynamic visual noise was presented as in Experiment 11 for the visual secondary interfering task. Irrelevant speech in the form of Hebrew (as in Experiment 4) was adopted to form the verbal secondary interfering task.

Design and Procedure

Half the subjects were assigned to the visual condition and given instructions for the method of loci strategy, while half took part in the rote condition and were given the rote rehearsal memory instructions. Task instructions were the same as for Experiment 11. Half the memory trials for each subject were presented visually on the computer monitor while the other half were presented verbally by the experimenter. Subjects began by carrying out six practice trials. The timing of presentation of the memory trials was varied to find the most appropriate presentation rate that would elicit a performance level of around seventy percent. If the first two experimental conditions were memory trials that were to be presented visually on the monitor the pilot trials were also presented visually. If the memory trials in the first two conditions were to be verbally presented then the pilot trials were verbally presented.

Experiment 12 consisted of four sets of four memory trials, one practice trial and three experimental trials for each of the four conditions. In the first condition the memory trials were presented visually and subjects heard irrelevant speech through headphones. In the second condition the memory trials were also presented visually on the monitor but this time, though the subject still wore earphones there was no irrelevant speech presented. In the third condition the memory trials were presented verbally and subject watched irrelevant visual material in the form of a continuous dynamic visual noise pattern on the monitor. In the fourth condition the memory trials were verbally presented and the subject was told to watch the monitor but this time the monitor was blank.

The trials were not completely counterbalanced because it was thought best for the subjects only to have one change in presentation of the memory trials. It also meant that the number of changes in presentation of the memory trials was kept constant for each subject. For this reason the two conditions where the memory trials were presented visually were kept together, as were the two conditions were the memory trials were presented verbally. Apart from this, however, the trials were counterbalanced.

The presentation rate of each of the memory trials varied depending on the pilot trials for each subject but typically the trials consisted of the cue being presented on the monitor for one second or spoken at a rate of one second (a number in the rote memory condition, the direction cue in the visual memory condition) followed by the word to be recalled, also presented on the monitor for one second or spoken at a rate of one second. After an interval of either two or three seconds depending on the pilot trials, the subject was presented with the next cue, the next relevant word and another two or three second interval and so on.

After the appropriate amount of items (determined by the pilot trials but typically ten in the visual condition and six or seven in the rote condition) the word "recall" was flashed up on the screen or spoken and the subject was given the first cue. They knew that they were to respond verbally and that they had to wait for the next cue before they could give their next response. Where irrelevant visual or verbal material was presented to the subject it was present through the four trials, during presentation. maintenance and recall. As before recall was in the same order as presentation and each set of trials consisted of a practice trial followed by three experimental trials.

Results

The number of words that were recalled correctly and in the right order by the subject was expressed as a percentage and entered into two by four (two memory strategies and four interference conditions) mixed analysis of variance. The mean results are shown in Table 14.

Table 14

Performance levels are presented separately for trials presented visually and those presented verbally in Experiment 12. Figures are the percent performance levels and the corresponding standard deviations.

Trials Presented Visually	Irrelevant Speech	s.d.	No Interference	s.d.
Rote Strategy	52.6	12.4	70.3	5.4
Method of Loci Strategy	71.7	6.3	70.3	2.7

Trials Presented Verbally	Dynamic Visual Noise	s.d.	No Interference	s.d
Rote Strategy	70.6	4.2	71.7	3.0
Method of Loci Strategy	53.2	12.1	72.4	4.8

No significant main effect of memory strategy was found [$F(1,14)=0.095$, $p>0.76$] which meant that overall performance on the method of loci memory strategy was no different from overall performance on the rote memory strategy. This meant that task demands between the method of loci and rote strategies were equal overall in Experiment 12. A significant interference effect was found, however, [$F(3,42)=8.687$, $p<0.01$] as well as a significant interaction effect [$F(3,42)=17.071$, $p<0.01$].

Performing a Newman-Keuls test on the interference effect showed that performance with either kind of interference (irrelevant pictures or irrelevant speech) was significantly worse than both the visually and verbally presented control conditions (all $p<0.01$). Performance overall between the two control conditions did not differ from each other. There was also no overall difference between the disruptive effect of irrelevant pictures and irrelevant speech.

A Newman-Keuls test on the interaction effect showed that the irrelevant pictures interfered significantly with the method of loci strategy but not the rote strategy or the control conditions. In contrast, the irrelevant speech interfered significantly with the rote memory strategy but not the method of loci strategy or the control conditions.

Discussion

The results support the hypothesis that visuospatial interference in the form of dynamic visual noise selectively disrupts the method of loci strategy while verbal interference in the form of irrelevant speech selectively disrupts the rote memory strategy. This crossover result confirms that the results of Experiment 11 did not come about simply because the method of loci task is so sensitive that it will be disrupted by any interference.

Chapter Seven - Conclusion

7.1 Logie's (1995) model.

The results of Experiments 1 to 12 are broadly consistent with Logie's 1995 model. None of the results conflict with the predictions made by the model and there is considerable support. Logie's (1995) model of the VSSP is concerned with two separate cognitive structures, the visual cache and the inner scribe.

Logie describes the visual cache as a passive system that stores information about static visual patterns. It is thought to be closely linked to, but to be distinct from, perception. It is described as having a function similar to that of the passive phonological store, "to lay information to one side and return to it a few seconds later after processing segments of the information that are in the conscious image" (Logie 1995, p131). The sole function of the visual cache is therefore as a temporary storage system for static visual patterns while the processing and manipulation of conscious visual images is carried out by processes elsewhere, either within the inner scribe or within the central executive. As shall be shown shortly, the model is unclear at this point. However, the central executive is presumably where the "conscious" image resides as the central executive is thought to be responsible for such "conscious" activities as strategy selection. A distinction is clearly made between the visual representation within the general workspace in the central executive and the representation in the visual cache and it is argued that "the visual cache contains more visual information than does the conscious image" (Logie, 1995, p129). It is suggested that 'temporary visual storage is a back-up store on which the conscious visual image (the contents of Kosslyn's visual buffer) relies" (Logie, 1995, p131).

Information in the visual cache is argued to fade unless rehearsed by the inner scribe and is also subject to interference from new visual information entering the visual cache. The passive visual cache is thus thought behave in a similar way to the passive phonological store. Visual information is thought to have obligatory access to the visual cache in a similar way to verbal information having obligatory access to the passive visual store. Irrelevant pictures are thought to cause disruption to items in the visual cache in a similar way to verbal information causing disruption within the passive verbal store.

The visual cache part of Logie's 1995 model receives considerable support from the results of Experiments 3 to 12 and the existence of a robust irrelevant pictures effect also supports the notion of visual material having obligatory access into the passive visual store. Experiment 9 demonstrated that static noise causes no interference with visual memory. The serially presented static noise in Experiment 10 did, however, selectively disrupt the visual strategy. The contrast between the results of Experiment 9 and Experiment 10 was interpreted as being consistent with visual material entering the passive visual store but fading once in the store.

In contrast to the visual cache, the inner scribe is more a complex mechanism. It is described as an active system which is responsible for holding information about a visual scene and the spatial locations of potential targets within that scene. It is also thought, however, to retain dynamic information about movement and movement sequences and is linked with the control of physical actions. Although the inner scribe is linked with movement control, however, it is not thought to mediate this function. Logie suggests that the system involved with movement planning and the system involved in representing locations within a visual scene are separate "but that when movement to a target is required, the movement planning system and the object representation system act in concert" (Logie, 1995, p118).

In addition to being responsible for spatial representation and having a link with movement control, the inner scribe is also conceived of as providing "a means of "redrawing" the contents of the visual cache, offering a service of visual and spatial rehearsal, manipulation, and transformation" (Logie, 1995, p3). This suggests that it is the scribe that manipulates the information in the visual cache, performing transformation functions upon the image as well as refreshing the passive store. However, elsewhere the implication is that it is the central executive which performs this function. Certainly, Logie argues that there is a "key role for a general-purpose central executive resource in imagery manipulation tasks" (Logie, 1995, p126). Another example of this lack of clarity is where Logie suggests that there are similarities between his model and Pavio's (1971) dual coding model of imagery. The dual coding model states that when information can be coded both visually and verbally then the retention of the information will be better than if it had only been coded within one modality. In a similar way, Logie argues that if information is able to enter both the phonological loop and visuospatial working memory, retention should be better than if it had just entered one store because it should then be less vulnerable to interference or decay. Logie argues that the main difference between Pavio's dual coding model and his model is that the phonological loop and the visual and spatial components of working memory are seen as stores and not processors.

Yet he clearly suggests elsewhere that the inner scribe has a role in the manipulation and transformation of images. This results in the details of the inner scribe part of the model being unclear.

The model is, however, described as tentative and it is likely that the description of the inner scribe is not as clear as the visual cache part of the model because it fulfils several different functions. Once further research has made these functions clearer, as well as the relationship among these functions, the definition of the inner scribe should become less unclear.

Despite the complexity of the inner scribe and the current confusion of some of its functions, Experiment 11 was able to show that the two components of the Logie's 1995 model of visuospatial working memory can be empirically distinguished within one experimental methodology. It showed that a visual task which requires access to the rehearsal component is disrupted by a concurrent, irrelevant spatial task as well as a concurrent irrelevant visual task. In contrast, a visual task that requires little access to the rehearsal mechanism is not disrupted by a concurrent spatial task but is disrupted by a concurrent visual task. This is consistent with Logie (1995) as instead of two separate visual and spatial stores, he envisages visual and spatial elements as closely related parts of the same visuospatial mechanism, originally conceived of as the VSSP. Experiment 11 provides some support for this because the star dots, a form of spatial interference involving movement and having minimal visual form, disrupted the pegword mnemonic, a task that is considered to be visual, not spatial. This occurs because although the pegword mnemonic is not a spatial task, it does require resources from the inner scribe. The same resources within the inner scribe are thought to be responsible for analysing movement to positions in space. The fact that a visual task requiring rehearsal is disrupted by spatial interference involving movement to positions in space is confirmation of the dual function of the inner scribe. The inner scribe is currently implicated in the analysis of movement sequences and spatial relationships. It is also possibly implicated in manipulating visual images. The fact that visual, spatial and movement elements are so closely related to one another within the VSSP may explain why progress on researching the VSSP has been slower than research on the articulatory loop.

The results of Experiments 3 to 12 are, however, broadly consistent with Logie's (1995) model of the VSSP. The irrelevant pictures effect is evidence for the existence of the visual cache into which visual material has obligatory access and the star dots in Experiment 11 are thought to disrupt the pegword mnemonic because both draw on common resources within the inner scribe.

Even with the problems in the definition of the inner scribe, there are similarities between the functions of the inner scribe and the articulatory loop in verbal working memory. The articulatory loop is primarily responsible for maintaining items within the passive verbal store via its rehearsal processes. Similar functions are thought to be carried out on visual material by the inner scribe. In other ways, however, the inner scribe is quite different from the articulatory loop. As well as refreshing the contents of the visual cache, however, the inner scribe is thought to be responsible for representing spatial information about locations and movements in time and space. It is also possibly responsible for manipulating images within the visual cache, although the model is a little unclear on this point.

The star dots in Experiment 11 have implications for our understanding of the inner scribe. When subjects were informed that the star dots were not relevant to their task in Experiment 11, the star dots still disrupted the pegword mnemonic strategy. This was clearly not because the star dots were having access to the visual cache because the method of loci task was not disrupted. Instead it would seem that material involving movement to different positions in space may have obligatory access to the inner scribe. This is because subjects appeared to be unable to block this material from entering the inner scribe, just as subjects were unable to prevent irrelevant pictures from entering the visual cache. If this inability of subjects to block irrelevant pictures from the visual cache is interpreted as indicating that the irrelevant pictures have obligatory access to the visual cache, then in a similar way the inability of subjects to block the star dots from entering the inner scribe can be interpreted as indicating that the irrelevant star dots have obligatory access to the inner scribe. This suggests that the inner scribe may contain passive elements as well as more active elements.

The final part of Logie's 1995 model is that visual information is thought to enter the VSSP by way of long-term memory processes. These processes make sense of the data and input it either into the visual cache or the inner scribe depending on the nature of the material. Apart from the line-drawings of common objects, the material in Experiments 1 to 12 consisted of visual patterns that were not semantically meaningful. There seems no reason why the dynamic dots, for example, should require long-term memory processes to gain access to the visual cache. Moreover, Logie (1986) argued that the visual material was having obligatory access into the visual cache even though the material was known to be irrelevant to the task in hand.

This process does not seem consistent with information needing to pass through screening procedures in long-term memory. If such procedures existed it would make more sense for irrelevant material to be screened out before entering the visual cache. Instead, material such as the dynamic dots appeared to enter the visual cache relatively automatically. In conclusion, Experiments 1 to 12 do not provide any support for the assumption that visual information enters the VSSP by way of long-term memory processes. Although the contribution of long-term processes in the short-term memory tasks remains untested, the results of Experiment 1 to 12 appear to be inconsistent with this assumption made by the model.

7.2 The Irrelevant Pictures Effect and the Passive Visual Store.

The previous experiments clearly demonstrate the existence of a robust irrelevant pictures effect which confirms Logie's (1986) hypothesis that visual material has obligatory access to the VSSP. Experiments 3 to 7 and 9 to 12 showed that a constantly changing random noise pattern will disrupt a subject's performance on a visual pegword task but will not disrupt a rote rehearsal strategy. This effect occurs despite subjects being told that the material is not relevant to the memory task.

The effect is not limited to the dynamic noise interference, however. Different forms of the noise pattern can also show the irrelevant pictures effect. A static version of the dots will not disrupt the visual mnemonic strategy but if this static dot pattern is continually re-presented to the subject by introducing a blank ISI into its presentation, selective disruption of the visual mnemonic strategy is elicited.

At first it was hypothesised that the irrelevant pictures effect was only elicited by a pattern which had no objective focus semantically, in time or in place. It has been shown, however, that the effect is not as limited as this and can also be demonstrated with a regular or focused change of display. The irrelevant pictures effect can be shown when temporal focus has been added to the dynamic noise by introducing a blank ISI into its presentation (Experiment 6). The pegword strategy is also selectively disrupted by regular presentations of three by three matrices with the cells randomly black or white (Experiment 7), line-drawings of common objects whose presentation does not coincide with the encoding of the words in the memory trials (Experiment 8) and a single dot that consecutively appears in five different positions in space, predictably following the points of a five pointed star (Experiment 11). The fact that so many forms of visual interference will elicit the irrelevant pictures effect shows how robust it is.

The effect is not limited to the pegword mnemonic strategy. Experiment 11 demonstrated that the method of loci is a qualitatively different visual strategy than the pegword mnemonic, one that relies on different resources within the VSSP. Nevertheless, this qualitatively different visual strategy showed selective disruption by dynamic noise but not irrelevant speech (Experiment 12).

Using irrelevant pictures as a secondary interfering task is particularly useful because it is assumed that the instructions to the subjects to look at the pictures but keep their attention on the memory tasks, results in the pictures having a minimal attentional component, reducing the central executive involvement. The robust irrelevant speech effect continues to be used successfully to characterise the properties of the passive phonological store and to generate profitable debate on the nature of verbal working memory (Jones, Madden and Miles, 1992; Jones and Macken, 1993). A robust irrelevant pictures effect provides a technique for examining the characteristics of the VSSP in a similar way. It is especially profitable for determining the nature of the passive visual store.

The various kinds of irrelevant pictures that have been shown to selectively disrupt a visual strategy form a pool of examples that can be used to determine the circumstances under which selective interference occurs and this give clues as to the nature of the passive visual store. Experiment 9 demonstrated that static noise causes no interference with visual memory. The serially presented static noise in Experiment 10 does, however, selectively disrupt the visual strategy. One possibility is that the static dot pattern in Experiment 9 did enter the passive visual store but the static pattern faded because it was not refreshed. Only when the pattern is re-presented will it remain in the store long enough to disrupt visual memory. It may be hypothesised that the difference between the effect of the static pattern and the re-presented static pattern could reflect the decay function of visual memory. A serially re-presented display where the re-presentation rate is outside the decay interval may fail to show this interference. Following this reasoning, it should be possible to determine the decay interval of the passive visual store by systematically varying the inter-presentation interval of the static noise.

Additionally, the failure of the static noise to disrupt the visual strategy can be compared with the success of the dynamic visual noise in eliciting the irrelevant pictures effect. The dynamic dot pattern is continually refreshed and so does disrupt the visual strategy. It should be possible to systematically vary the parameters of the dynamic noise to investigate those features crucial for selective interference. Decreasing the rate-of-change intervals of the individual dots is the most obvious parameter to manipulate but there are others. For example, the randomness of the changes of the dots can be reduced to explore further the role of expectancy in the irrelevant pictures effect.

The irrelevant pictures effect has the potential to show more than just the characteristics of the VSSP. The matrices in Experiment 7 were used to test the importance of predictability in the irrelevant pictures. The matrices were chosen to begin to test the notion of predictability because the internal features of each matrix can be controlled and the differences manipulated systematically so that the matrices contain both predictable and unpredictable elements. The internal structure of each matrix is different. However, the matrices do not change their outline from instance to instance and the internal structure of each matrix conforms to the same criteria, namely that there will be three by three cells and each cell will be either black or white. If the subject had focused on the fact that each matrix had an internal structure that was unpredictable, it would be hypothesised that the matrices would have disrupted both visual and rote memory strategies. The finding that the matrices elicit selective disruption of the visual strategy could indicate that the subjects view each irrelevant picture at the level of the whole pattern and that the internal features of the pattern are not as important as the external features of the pattern as a whole. This may indicate the level of analysis at which the irrelevant pictures effect is operating within the visual cache.

7.3 General Interference in Visual Working Memory

In addition to irrelevant visual material showing selective effects, from the start of the thesis it was hypothesised that certain kinds of irrelevant material would have a general disruptive effect, interfering with both visual and verbal strategies. It was thought that any visual stimulus which incorporated a regular or focused change of display in its presentation would lead to a decrement in performance as a function of the effect of the focused changes themselves on attentional mechanisms. This hypothesis appeared to be confirmed by the general disruption caused by the line-drawings of common objects in Experiment 3 and the doodles in Experiment 5. This contrasts with the specific disruption caused by the dynamic visual noise pattern which unlike the line-drawings or the doodles, involved constant change that was not focused in time or space. However, the inclusion of focused change in the presentation of visual material was not found to be an adequate explanation for the general effect. The selectivity of the dynamic noise was maintained in Experiment 6 when it was given temporal focus by inserting a blank ISI between the noise presentations. Another explanation had to be found to explain which dimensions in the irrelevant pictures are crucial for determining selective and general interference in visual working memory.

The general effect of the line-drawings in Experiment 3 contrasted with the same line-drawings in Experiment 2 which did not disrupt the rote strategy. The only difference between the line-drawings in the two experiments was in the way that they were presented. One of the differences in the way that the material was presented was that a one second blank screen inter-stimulus interval (ISI) was present in the line-drawings in Experiment 3 but not Experiment 2. Experiment 6, however, showed that this in itself was not sufficient to explain the general effect elicited by the line-drawings in Experiment 3. Another difference, however, between Experiments 2 and 3 was the fact that the line-drawings were presented in step with the target words in Experiment 3 but were out of step in Experiment 2. In Experiment 2 the presentation of the line-drawings coincided with the onset of the relevant words in the memory trials for only one trial out of every six. In Experiment 3, however, the line-drawings were presented in step with the memory trials and the onset of every line-drawing was presented at the same time as the words in the memory trials so that each drawing coincided with the encoding of a word. This suggests that presenting the line-drawings in step with the memory trials so that their presentation coincides with onset of each word in the memory trials should result in the subject processing each of the irrelevant line-drawings at the same time as they encode the words in the memory trials. The central executive is thought to have a finite amount of resources and competition for these resources would occur. In contrast, the same line-drawings presented only at maintenance and recall were not required to share resources within the central executive and instead were expected to differentially disrupt the visual strategy. This is what was found in Experiment 8.

This implies that whatever circumstances attracted attentional resources and impaired performance on the verbal strategy in Experiment 3 either only occurred or had its strongest effect at the encoding stage. The visual noise in Experiment 6 presented after the one second of blank screen did, however, coincide with the target words so another explanation must be found to account for the fact that this material did not elicit the general disruptive effect on verbal performance shown by the line-drawings.

One difference between the continuous visual noise pattern and the line-drawings of Experiment 3 is that the small changes in the visual noise pattern did not form an overall pattern that was radically different and so the presentation of the visual noise pattern after the ISI was not unexpected for the subject. When the line-drawings changed, however, the drawings were different every time so that the subject could not predict what they were about to see. The same was true for the doodles. It was hypothesised that it us the unpredictability of the line-drawings that draws the subjects attention towards something they have been told is irrelevant.

In order to look at the notion of predictability in more detail, matrices which contained both predictable and unpredictable elements were adopted. In Experiment 7 it was found that the subjects focused on the matrix as a whole, not on the changes in the internal structure of the matrices. The external features of the matrices were be sufficiently predictable to subjects that they elicited selective not general interference. It was concluded that the general interfering effect of the line-drawings or doodles was caused in part by their being sufficiently and unpredictably different from one another to engage attentional processes even under instructions that they are irrelevant to the main recall task, and in part by the fact that the unexpected changes between each succeeding image coincided with encoding.

The matrices showed that the degree of predictability of the irrelevant visual displays can be manipulated. In future it should be possible for matrices or geometric patterns to be changed incrementally to further manipulate the predictability of the displays. For example, the outside contours of the matrices could be varied to determine whether changing the predictability of overall shape elicits general disruption and whether such manipulations have a different disruptive effect than varying the predictability of the internal components. The results of Experiment 7 suggest that general interference would be more likely to occur if succeeding shapes or matrices differed in external contour rather than in aspects of their internal components, but this, however, is tentative and remains to be demonstrated. It is clear that irrelevant pictures not only have the potential to allow the investigation of the VSSP, they also have the potential to tell us something of the nature of the relationship between the VSSP and the central executive.

7.4 Final Thoughts.

It may be useful to comment on why the effects of specific and general disruption do not seem to be additive. In Experiment 3 there was no difference between the amount of disruption of the pegword mnemonic caused by the line-drawings which were thought to elicit both specific and general interference and the amount of disruption caused by the dynamic noise which should only have been eliciting specific disruption. Similarly, the specific and general interference in Experiments 5 and 8 failed to be significantly different from specific disruption alone. This could be an important theoretical point which has so far not been explained. However, it is also possible that tasks such as the pegword mnemonic are presently too crude to show these smaller differences. A more precise strategy may be required in the future to ask more precise questions, perhaps relying on reaction times rather than whether an answer is correct or not. This would have the advantage that task demands need not be particularly high in order to show the effects of interference. At present, the main tasks have to be very difficult for the subjects so that effects of irrelevant pictures can be shown at all. It is likely that irrelevant pictures can interfere with visual strategies that are less demanding but the current design of experiments is not sensitive enough to pick this up.

Using data from Experiments 1 to 12, it should be possible to determine the level at which interference is operating. It appears that each pattern which enters the visual cache is treated as a whole rather than simply a sum of its parts. Certainly it seems that the external features of the pattern are more important than the internal features. General interference effects, however, which operate at the level of the central executive appear to be a more complex phenomenon, involving combinations of factors such as expectancy and changes occurring at encoding. As further research is carried out to find the critical features in the irrelevant pictures which gives them access to passive stores or the central executive and we begin to refine the notion of thresholds for entry into the different parts of the VSSP, it should be possible to measure whether the threshold is the same for all subjects. If there are individual differences, does this have implications for people's ability to learn and therefore their basic intelligence? In the case of general disruption particularly, will this threshold remain the same over time or will subjects be able to learn to ignore particular forms of material?

Appendix

Experiment 4

Visual Condition

In the visual condition all 16 subjects were presented with 10 items. For 14 subjects the trials were presented every 5 seconds. For the remaining 2 subjects, the trials were presented every 4 seconds. For 9 subjects the recall cues were given every 5 seconds. For the remaining 7 subjects the recall cues were given every 4 seconds.

Verbal Condition

In the verbal condition 2 subjects were presented with 6 items to recall, 7 subjects were presented with 7 items to recall and 7 subjects were presented with 8 items to recall. For 2 subjects the trials were presented every 5 seconds. For the remaining 14 subjects, the trials were presented every 4 seconds. For 3 subjects the recall cues were given every 5 seconds. For the remaining 13 subjects the recall cues were given every 4 seconds. In this experiment both types of interfering material (the dynamic noise and the irrelevant speech) were presented continuously during presentation, the 10 second gap and recall. These details are summarised in Table 15.

Table 15

A summary of the task details of Experiment 4.

Visual Strategy	Number of Subjects	Items or Timing
Items	16	10 items
Presentation	14	every 5 secs
	2	every 4 secs
Recall	9	every 5 secs
	7	every 4 secs

Verbal Strategy	Number of Subjects	Items or Timing
Items	2	6 items
	7	7 items
	7	8 items
Presentation	2	every 5 secs
	14	every 4 secs
Recall	3	every 5 secs
	13	every 4 secs

Experiment 5

<u>Visual Condition</u>

In the visual condition all 12 subjects were presented with 10 items. For 9 subjects the trials were presented every 5 seconds. For the remaining 3 subjects, the trials were presented every 4 seconds. For 9 subjects the recall cues were given every 5 seconds. For the remaining 3 subjects the recall cues were given every 4 seconds.

<u>Verbal Condition</u>

In the verbal condition 1 subject was presented with 5 items to recall, 5 subjects were presented with 6 items to recall, 5 subjects were presented with 7 items to recall and 1 subjects was presented with 8 items to recall. For 5 subjects the trials were presented every 5 seconds. For the remaining 7 subjects, the trials were presented every 4 seconds. For 6 subjects the recall cues were given every 5 seconds. For the remaining 6 subjects the recall cues were given every 4 seconds.

In this experiment the dynamic noise was presented continuously during presentation, the 10 second gap and recall. Where the presentation rate was every 5 seconds, the doodles were present on the screen for 4 seconds with one second of blank screen which coincided with the pegword in the visual condition or the number of the word in the list in the verbal condition. Where the presentation rate was every 4 seconds, the doodles were present on the screen for 3 seconds with one second of blank screen which coincided with the pegword in the visual condition or the number of the word in the list in the verbal condition. For 6 subjects out of the 24 subjects in the experiment the timing of recall was out of step with the timing of presentation and so was also out of step with the timing of the doodles. These details are summarised in Table 16.

Table 16

A summary of the task details of Experiment 5.

Visual Strategy	Number of Subjects	Items or Timing
Items	12	10 items
Presentation	9	every 5 secs
	3	every 4 secs
Recall	9	every 5 secs
	3	every 4 secs

Verbal Strategy	Number of Subjects	Items or Timing
Items	1	5 items
	5	6 items
	5	7 items
	1	8 items
Presentation	5	every 5 secs
	7	every 4 secs
Recall	6	every 5 secs
	6	every 4 secs

Experiment 6

Visual Condition

In the visual condition all 12 subjects were presented with 10 items. For 7 subjects the trials were presented every 5 seconds. For the remaining 5 subjects, the trials were presented every 4 seconds. For 6 subjects the recall cues were given every 5 seconds. For the remaining 6 subjects the recall cues were given every 4 seconds.

Verbal Condition

In the verbal condition 4 subjects were presented with 6 items to recall and 8 subjects were presented with 7 items to recall. For 5 subjects the trials were presented every 5 seconds. For the remaining 7 subjects, the trials were presented every 4 seconds. For 5 subjects the recall cues were given every 5 seconds. For the remaining 7 subjects the recall cues were given every 4 seconds.

In the experiment the dynamic noise was presented continuously during presentation, the 10 second gap and recall. For the dynamic noise and ISI, where the presentation rate was every 5 seconds, the dynamic noise was present on the screen for 4 seconds with one second of blank screen which coincided with the pegword in the visual condition or the number of the word in the list in the verbal condition. Where the presentation rate was every 4 seconds, the dynamic noise was present on the screen for 3 seconds with one second of blank screen which coincided with the pegword in the visual condition or the number of the word in the list in the verbal condition. For 9 subjects out of the 24 subjects in the experiment the timing of recall was out of step with the timing of presentation and so was also out of step with the timing of the dynamic noise and ISI. These details are summarised in Table 17.

Table 17

A summary of the task details of Experiment 6.

Visual Strategy	Number of Subjects	Items or Timing
Items	12	10 items
Presentation	7	every 5 secs
	5	every 4 secs
Recall	6	every 5 secs
	6	every 4 secs

Verbal Strategy	Number of Subjects	Items or Timing
Items	4	6 items
	8	7 items
Presentation	5	every 5 secs
	7	every 4 secs
Recall	5	every 5 secs
	7	every 4 secs

Experiment 7

Visual condition

In the visual condition all 12 subjects were presented with 10 items. For 2 subjects the trials were presented every 6 seconds. For 5 subjects the trials were presented every 5 seconds. For the remaining 5 subjects, the trials were presented every 4 seconds. For 10 subjects the recall cues were given every 5 seconds. For the remaining 2 subjects the recall cues were given every 4 seconds.

Verbal Condition

In the verbal condition 2 subjects were presented with 6 items to recall, 8 subjects were presented with 7 items to recall and 2 subjects were presented with 8 items to recall. For 6 subjects the trials were presented every 5 seconds. For the remaining 6 subjects, the trials were presented every 4 seconds. For 6 subjects the recall cues were given every 5 seconds. For the remaining 6 subjects the recall cues were given every 4 seconds.

In this experiment the dynamic noise was presented continuously during presentation, the 10 second gap and recall. Where the presentation rate was every 6 seconds, the matrices were present on the screen for 5 seconds with one second of blank screen which coincided with the pegword in the visual condition or the number of the word in the list in the verbal condition. Where the presentation rate was every 5 seconds, the matrices were present on the screen for 4 seconds with one second of blank screen which coincided with the pegword in the visual condition or the number of the word in the list in the verbal condition. Where the presentation rate was every 4 seconds, the matrices were present on the screen for 3 seconds with one second of blank screen which coincided with the pegword in the visual condition or the number of the word in the list in the verbal condition. For 5 subjects out of the 24 subjects in the experiment the timing of recall was out of step with the timing of presentation and so was also out of step with the timing of the matrices. These details are summarised in Table 18.

Table 18

A summary of the task details of Experiment 7.

Visual Strategy	Number of Subjects	Items or Timing
Items	12	10 items
Presentation	2	every 6 secs
	5	every 5 secs
	5	every 4 secs
Recall	10	every 5 secs
	2	every 4 secs

Verbal Strategy	Number of Subjects	Items or Timing
Items	2	6 items
	8	7 items
	2	8 items
Presentation	6	every 5 secs
	6	every 4 secs
Recall	6	every 5 secs
	6	every 4 secs

Experiment 8

Visual Condition

In the visual condition all 12 subjects were presented with 10 items. For 11 subjects the trials were presented every 5 seconds. For the remaining 1 subject, the trials were presented every 4 seconds. For 11 subjects the recall cues were given every 5 seconds. For the remaining 1 subject the recall cues were given every 4 seconds.

Verbal Condition

In the verbal condition 5 subjects were presented with 6 items to recall, 5 subjects were presented with 7 items to recall, 1 subject was presented with 8 items to recall and 1 subject was presented with 10 items to recall. For 9 subjects the trials were presented every 5 seconds. For the remaining 3 subjects, the trials were presented every 4 seconds. For 9 subjects the recall cues were given every 5 seconds. For the remaining 3 subjects the recall cues were given every 4 seconds.

Sufficient details of the timing of the two line-drawing interference conditions are given with the experiment. For all subjects, the recall rates were the same as the presentation rate. Details of Experiment 8 are summarised in Table 19.

Table 19

A summary of the task details of Experiment 8.

Visual Strategy	Number of Subjects	Items or Timing
Items	12	10 items
Presentation	11	every 5 secs
	1	every 4 secs
Recall	11	every 5 secs
	1	every 4 secs

Verbal Strategy	Number of Subjects	Items or Timing
Items	5	6 items
	5	7 items
	1	8 items
	1	10 items
Presentation	9	every 5 secs
	3	every 4 secs
Recall	9	every 5 secs
	3	every 4 secs

Experiment 9

Visual Condition

In the visual condition 1 subject was presented with 7 items to recall, 2 subjects were presented with 8 items to recall and 9 subjects were presented with 10 items to recall. For 11 subjects the trials were presented every 5 seconds. For the remaining 1 subject, the trials were presented every 4 seconds. For 11 subjects the recall cues were given every 5 seconds. For the remaining 1 subject, the recall cues were given every 4 seconds.

Verbal Condition

In the verbal condition 2 subjects were presented with 6 items to recall, 6 subjects were presented with 7 items to recall and 4 subjects were presented with 8 items to recall. For 7 subjects the trials were presented every 5 seconds. For the remaining 5 subjects, the trials were presented every 4 seconds. For 8 subjects the recall cues were given every 5 seconds. For the remaining 4 subjects the recall cues were given every 4 seconds. In this experiment both types of interfering material (the dynamic noise and the static dots) were presented continuously during presentation, the 10 second gap and recall. These details are summarised in Table 20.

Table 20

A summary of the task details of Experiment 9.

Visual Strategy	Number of Subjects	Items or Timing
Items	1	7 items
	2	8 items
	9	10 items
Presentation	11	every 5 secs
	1	every 4 secs
Recall	11	every 5 secs
	1	every 4 secs

Verbal Strategy	Number of Subjects	Items or Timing
Items	2	6 items
	6	7 items
	4	8 items
Presentation	7	every 5 secs
	5	every 4 secs
Recall	8	every 5 secs
	4	every 4 secs

Experiment 10

Visual condition

In the visual condition all 12 subjects were presented with 10 items to recall. For 11 subjects the trials were presented every 5 seconds. For the remaining 1 subject, the trials were presented every 4 seconds. For 7 subjects the recall cues were given every 5 seconds. For the remaining 5 subjects, the recall cues were given every 4 seconds.

Verbal Condition

In the verbal condition 5 subjects were presented with 6 items to recall, 5 subjects were presented with 7 items to recall and 2 subjects were presented with 8 items to recall. For 6 subjects the trials were presented every 5 seconds. For the remaining 6 subjects, the trials were presented every 4 seconds. For 4 subjects the recall cues were given every 5 seconds. For the remaining 8 subjects the recall cues were given every 4 seconds.

In this experiment, the dynamic noise was presented continuously during presentation, the 10 second gap and recall. The repeated static dots were on screen for one second, there was one second of blank screen, one second of static dots, one second of blank screen and so on. For 4 subjects out of the 24 subjects in the experiment the timing of recall was different than the timing of the presentation trials. These details are summarised in Table 21.

Table 21

A summary of the task details of Experiment 10.

Visual Strategy	Number of Subjects	Items or Timing
Items	12	10 items
Presentation	11	every 5 secs
	1	every 4 secs
Recall	7	every 5 secs
	5	every 4 secs

Verbal Strategy	Number of Subjects	Items or Timing
Items	5	6 items
	5	7 items
	2	8 items
Presentation	6	every 5 secs
	6	every 4 secs
Recall	4	every 5 secs
	8	every 4 secs

Experiment 11

Method of Loci

In the method of loci, 1 subjects was presented with 6 items to recall and 11 subjects were presented with 10 items to recall. For 9 subjects the trials were presented every 5 seconds. For 2 subjects the trials were presented every 4 seconds. For the remaining 1 subject, the trials were presented every 3 seconds. For 10 subjects the recall cues were given every 5 seconds. For 1 subject the recall cues were given every 4 seconds. For the remaining 1 subject, the recall cues were given every 3 seconds.

Pegword Mnemonic

In the pegword mnemonic condition all 12 subjects were presented with 10 items. For 9 subjects the trials were presented every 5 seconds. For 1 subject the trials were presented every 4 seconds. For the remaining 2 subjects, the trials were presented every 3 seconds. For 6 subjects the recall cues were given every 5 seconds. For 5 subjects the recall cues were given every 4 seconds. For the remaining 1 subject, the recall cues were given every 3 seconds.

Verbal Condition

In the verbal condition 8 subjects were presented with 6 items to recall, 3 subjects were presented with 7 items to recall and 1 subjects was presented with 10 items to recall. For 5 subjects the trials were presented every 5 seconds. For the remaining 7 subjects, the trials were presented every 4 seconds. For 5 subjects the recall cues were given every 5 seconds. For the remaining 7 subjects the recall cues were given every 4 seconds.

In this experiment both types of interfering material (the dynamic noise and the single dot following a predictable star pattern once every second) were presented continuously during presentation, the 10 second gap and recall. These details are summarised in Table 22.

Table 22

A summary of the task details of Experiment 11.

Method of Loci	Number of Subjects	Items or Timing
Items	1	6 items
	11	10 items
Presentation	9	every 5 secs
	2	every 4 secs
	1	every 3 secs
Recall	10	every 5 secs
	1	every 4 secs
	1	every 3 secs

Pegword Mnemonic	Number of Subjects	Items or Timing
Items	12	10 items
Presentation	9	every 5 secs
	1	every 4 secs
	2	every 3 secs
Recall	6	every 5 secs
	5	every 4 secs
	1	every 3 secs

Verbal Strategy	Number of Subjects	Items or Timing
Items	8	6 items
	3	7 items
	1	10 items
Presentation	5	every 5 secs
	7	every 4 secs
Recall	5	every 5 secs
	7	every 4 secs

Experiment 12

Method of Loci

In the method of loci condition 2 subjects were presented with 7 items, 4 subjects were presented with 8 items and 2 subjects were presented with 10 items. All 8 subjects were presented word lists every 5 seconds and were given recall cues every 5 seconds.

Verbal Condition

In the verbal condition 3 subjects were presented with 6 items to recall, 2 subjects were presented with 7 items to recall and 3 subjects were presented with 8 items to recall. For 7 subjects the trials were presented every 5 seconds. For the remaining 1 subject, the trials were presented every 4 seconds. For 7 subjects the recall cues were every 5 seconds. For the remaining subject, the recall cues were given every 4 seconds.

In this experiment both types of interfering material (the star dots and the irrelevant speech) were presented continuously during presentation, the 10 second gap and recall. These details are summarised in Table 23

Table 23

A summary of the task details of Experiment 12

Method of Loci	Number of Subjects	Items or Timing
Items	2	7 items
	4	8 items
	2	10 items
Presentation	8	every 5 secs
Recall	8	every 5 secs

Verbal Strategy	Number of Subjects	Items or Timing
Items	3	6 items
	2	7 items
	3	8 items
Presentation	7	every 5 secs
	1	every 4 secs
Recall	7	every 5 secs
	1	every 4 secs

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