ON THE NATURE OF THE MENTAL IMAGE

WIEL JANSSEN

1976

Institute for Perception TNO

Soesterberg – the Netherlands

'ON THE NATURE OF THE MENTAL IMAGE'

CONTENTS

CHAPTER 1

INTRODUCTION

Summary

This chapter describes the primary aim of the work to be reported, which is to establish to what degree there is a structural correspondence between visual images and visual percepts.

1.1. THE ISSUE

In his dealings with the outer world man makes use of internal representational structures. These have the function of permitting him to evaluate the outcome of an intended act without actually having to perform it. To understand behavior, therefore, it is important to know what the nature of internal representation is.

The present work tests certain ideas about the nature of the internal representation commonly designated as the visual image. Specifically it is aimed to establish to what degree there is a correspondence, particularly in structure, between visual images (c.q. imagery) and visual percepts (c.q. perception).

If we were to put ourselves on the standpoint of a devoted behaviorist this issue would appear an entirely mythological one. The behaviorist would argue that percepts - and certainly images - should not be spoken of at all since they are private experiences that could not possibly function in a scientific theory. According to this point of view only verbal responses, being observable to anyone, might claim scientific attention. One should realize, however, that this objection has lost its former power in almost all of psychology, including the field of cognition. In a simple and yet convincing way this is demonstrated by Paivio (1969) who, commenting upon the (neo-) behaviorist attempt to smuggle implicit verbal responses back into the organism, rightfully remarks that "implicit verbal responses are no less inferential than images" (p. 212), and thus can claim no special theoretical status at all.

Despite the behaviorist revolution the study of mental imagery never stopped completely, but was continued by a fair number of dissidents throughout the twenties and thirties (most notable among them Bartlett, 1932). In the sixties the study of imagery became respectable again, mainly as a consequence of the renewed interest for the function of internal representational structures evoked by the work of Newell, Shaw and Simon (1958) and Miller, Galanter and Pribram (1960). Today there exists a vast body of literature demonstrating the important role of both perception and imagery in human cognitive functioning (see Paivio, 1971, for an extensive review). In particular the role of images as carriers of information in human learning and memory has been stressed and contrasted with the more traditional role of verbal responses. It is most remarkable, however, that in this entire line of research there has been a relative disconcern with the *nature* of the (visual) image itself as compared to, say, its function as a mnemonic. That is, attention has been directed to the question of how it works rather than what it is. This is unfortunate because, in the present author's opinion, our understanding of what goes on during certain cognitive activities will remain limited until it is sufficiently clear what the nature of the image is and how it should be separated theoretically from other kinds of internal representation. This opinion provided the motivation for the present investigation.

The main idea to be developed is that there is a fundamental structural correspondence between visual percepts and visual images in that the features of an image are direct derivatives of perceptual features. However, we intend to show that it is absolutely necessary to qualify this hypothesis by distinguishing between two types of features, namely spatial features indicating basically *where* things are, and nonspatial (sensory) features containing information about *what* things are.

1.2. RESTRICTIONS

There are at least two major restrictions in the present work of which the reader should be aware. First, there will be exclusive concern with the so-called visual image. This implies no denial of the importance of auditory, olfactory, gustatory, cutaneous or kinesthetic imagery. Visual imagery is focused upon because it has attracted most attention in the literature, the consequence being that the basic empirical facts are best established for the visual modality. Second, there will be no treatment of differential-psychological or clinical issues. There exists a body of literature dealing with these aspects (e.g., Barber, 1971), but to link that with the experimental literature falls beyond the scope of the present investigation. Nevertheless we *will* sometimes be concerned with individual imagery ability as an experimental variable. In that case, however, what matters is the light that data of individuals differing in that ability can throw on the fundamental process of imagery.

1.3. OUTLINE

Is visual imagery really worth bothering about? Chapter 2 tries to answer this question by presenting the core empirical results from the literature on the role of imagery in learning and memory. Also our concern for the neglect of the structure of the visual image will be explained in more detail there. A theoretical structure for the visual image will be developed in Chapter 3. Chapter 4 presents an overview of the literature which in fact has dealt with the nature of the image. The literature is reviewed with the aim of selecting the experimental paradigms which potentially seem most fit to provide a test of the theoretical ideas developed in Chapter 3. From Chapter 5 on new empirical work making use of the selected paradigms is reported.

CHAPTER 2

THE FUNCTIONAL SIGNIFICANCE OF MENTAL IMAGERY

Summary

This chapter contains a brief review of the core empirical results on the two issues of most importance in imagery research. The first one is what the effects of stimulus imageability (I) are and how these compare with the effects of other stimulus attributes. Results from recognition, free recall, serial memorization and paired-associate memorization studies indicate that I is a variable which is more potent than such long-established variables like m and frequency-familiarity.

The second issue is what the effects of an imagery mnemonic are and how these compare with the effects of other mnemonic strategies. It is concluded that imagery is a strong mnemonic, at least for concrete material.

2.1. IMAGERY AS A MNEMONIC DEVICE

Visual imagery as a memorization technique has its roots in antiquity. For example, a popular way of memorizing a list of items was to put images of objects representing the items at certain positions along a familiar walking trajectory in one's town of residence. When the time for recall came the items could be retrieved from their respective locations in the course of an imaginary walk along the trajectory.

Very complex elaborations upon this and similar basic schemes came into existence later. Mnemonic devices were developed in which an elaborate system of tags was learned first to which images were then hooked during memorization (see Paivio, 1971, Chapter 6, and the references cited there for a description). These mnemonic techniques went largely unnoticed by modern experimental psychology until Miller, Galanter and Pribram (1960) launched their magic rhyme (p. 135)

" One is a bun,
Two is a shoe,
Three is a tree,"
etc.

which was to function as a system of tags. That is, one first has to learn the number-word rhyme so that, when given a list of items to memorize, one numbers the items in sequence and forms an image involving the first object and a bun, the second one and a zoo animal, or a shoe, etc.

The experimental efforts started after the rediscovery of imagery have mainly concentrated on the following two issues:

1. What are the effects of stimulus imageability (henceforth abbreviated as *I*), on memory performance, and how do these compare with the effects of other stimulus attributes?
2. What are the effects of an imagery mnemonic, or a strategy for image formation, on memory performance and how do they compare with the effects of other strategies?

A brief review of the most relevant outcomes of research dealing with these two questions will now be given. The review covers four classical experimental situations in which memory performance has been studied, namely recognition memory, free recall, the memorization of a series (serial learning) and the memorization of paired-associates.

2.2. STIMULUS ATTRIBUTES IN LEARNING AND MEMORY

There are two classes of variables which determine if, and in what way, an item is stored in memory. One class comprises the dimensions on which stimuli can be distinguished, i.e., the set of stimulus attributes. In the second class of variables are the various processes, techniques and strategies by means of which *S*s are able to produce and store a memory representation of a given item.

Although these types of variables can theoretically be distinguished there are interactions in that a certain mediational strategy may be better suited to handle one kind of stimulus than an other. For example, a feature of imagery attributed much weight by most theorists is that it seems eminently suited to deal with *concrete* stimuli, that is, stimuli referring directly to particular objects and events that exist in the external world. However, imagery seems not so suited to deal with *abstract* stimuli lacking a direct external referent. What this example shows is that the presence of interactions implies, formally spoken, that statements about the effects of a certain stimulus attribute should always be accompanied by a specification of the mediational strategy known to have been used by the *S*s.

What exactly are the variables in these two classes?

That there are two main types of mediational strategy (disregarding rote memorization, in which mediators function at best minimally) appears firmly established by now in the literature. These are mediation by means of imagery and by verbal mediation. Whereas images are memory representations corresponding to concrete things, the verbal code refers to stored representations corresponding most directly to linguistic units. Verbal mediation is an older subject of study than imagery (at least in experimental psychology). Section 2.3, therefore, concentrates on imagery in order to set the balance straight, and compares it to what is known about verbal mediation. The present section (2.2) will deal with the relevant stimulus attributes.

The list of stimulus attributes identified as contributing to memory performance is of an amazing length. Familiarity, frequency, associative meaningfulness (*m*), linguistic specificity, emotionality, and the three semantic differential factors are some of the best established ones. One of the prominent results of the research effort in the field of mental imagery is the rediscovery of abstractness-concreteness as a very potent factor in learning and memory. The effects of this dimension have actually been found to be so overall powerful as to be to some extent independent of the mediational strategy applied. That is, concrete material has been found to be consistently superior to abstract material in almost all memory paradigms (see below), though the extent of the superiority appears to be a function of certain other variables.

The general hypothesis implicit in the literature that is reviewed is that the more concrete a stimulus is the stronger the representation it acquires in memory. Memory performance consequently should decrease from concrete objects actually observed to pictorial material to concrete words to abstract words. Let us consider the empirical evidence.

2.2.1. Recognition memory for pictures and words

In a by now classical experiment Shepard (1967) showed the superiority of pictures over words and sentences in recognition memory. *S*s looked through an inspection series of about 600 stimuli selected from a larger population at a self-paced rate. No particular mediation technique was specified. The medians of the percent correct on an immediate two-alternative recognition test were 98.5, 90.0 and 88.2 for pictures, words, and sentences, respectively.

Picture memory was also tested for different subsets of stimuli after varying intervals of up to 120 days. Even after one week memory for the pictures was equivalent to that found at the immediate test for verbal material (92.0 percent).

Nickerson (1965) reported a similar experiment in which there was an overall 95% correct discrimination between new and old pictures as measured by a yes-no procedure. Nickerson used a Shepard and Teghtsoonian (1961) technnique in which the test trials are interspersed within the inspection series itself rather than assembled in a block at the end. He did not collect similar data for verbal material.

Standing, Conezio and Haber (1970) gave their *S*s a single presentation of a sequence of 2,560 photographs, for 1 or 10 sec per picture. The *S*s subsequently scored approximately 90% correct with pairs of photographs (one previously seen, one new), even when up to 3 days elapsed between learning and testing. *S*s were not instructed to use any particular memorization technique.

The final word as far as human capacity for remembering pictures is concerned seems to have been said by Standing (1973). By testing recognition memory for as many as 10,000 pictures or 1,000 words presented for 5 sec each (no memory technique specified) after a delay of two days evidence was obtained (1) that the capacity of recognition memory for pictures is almost unlimited and (2) that pictorial material has an overall superiority over verbal material.

Effects of stimulus concreteness have also been demonstrated within verbal material alone. Gorman (1961) presented a series of abstract and concrete nouns at a 1-sec presentation rate and found superior recognition for concrete nouns, even though *S*s were told to read each word silently for meaning rather than try to memorize them. Olver (1965) also found that concreteness had a highly significant positive effect on recall.

2.2.2. Free recall and stimulus concreteness

In the earliest research reported on this issue Kirkpatrick (1894) tested recall for names of objects and for the actual objects and found it to be higher for actual objects. Calkins (1898) replicated Kirkpatrick's finding using pictures of objects rather than the actual objects. Moore (1917) found immediate recall to be better for objects than for pictures than for words.

The results of these early experiments have remained unchallenged in the modern literature (e.g., Kaplan, Kaplan and Sampson, 1968; Paivio, Rogers and Smythe, 1968). Within words the superiority of concrete over abstract words in free recall has also been shown repeatedly (Stoke, 1929; Olver, 1965; Paivio, 1968; Paivio, Yuille and Rogers, 1969; Morris and Stevens, 1974).

Paivio and Csapo (1973) tried to explain exactly *why* items presented as pictures lead to higher free recall than when they are presented as printed (concrete) words. They found strong support for the hypothesis that image and verbal memory codes are independent and additive in their effect on recall. Moreover, the contribution of imagery appeared to be substantially higher than that of the verbal code. Paivio and Csapo concluded that the usual superiority of pictures in free recall is best explained by dual encoding, or possibly a combination of image superiority and dual encoding, both of which are ordinarily favored when items are presented as pictures. The reason that concrete words are superior to abstract words presumably is that while the verbal code is directly available in the case of both concrete and abstract words, the former are more likely to evoke images. More about this interaction between imageability and mediational set will be said in section 2.3.

2.2.3. Serial learning and stimulus concreteness

In contrast to free recall learning the *S* in a serial learning experiment is not free to report items in any order. He should adhere to the order in which the stimuli were originally presented. Is stimulus concreteness an effective variable in this paradigm once thought to be the prototype of S-R chain formation?

Positive effects of concreteness have been reported by Herman, Broussard and Todd (1951), who showed that pictures were learned better than words, and by Paivio et al. (1969), who found a superiority of concrete over abstract nouns. In both experiments no specific mediation instructions were given. Paivio and Csapo (1969), comparing pictures, concrete nouns and abstract nouns, found that pictures and concrete nouns did not differ and that abstract nouns were only inferior to the other two stimulus types at the slower of two relatively fast rates of presentation (2 items/sec versus 5.3 items/sec; no mediation technique specified). Presumably *S*s were unable to label the pictures even implicitly at the faster rate, but were able to do so at the slower rate. Similarly, the faster rate did not allow enough time for the arousal of images to concrete words whereas the slower rate did. Again this can be interpreted as evidence for Paivio's dual coding theory mentioned in section 2.2.2.

We conclude that stimulus concreteness is a relevant variable in serial recall, provided presentation rate is not so fast as to prevent it from becoming manifest. This latter condition is not specific for serial learning, of course, since it is common to all learning paradigms: it only happens to be the case that the rate variable has been studied in serial learning.

2.2.4. Paired-associate learning and stimulus concreteness

Extensive research on paired-associate learning has identified a virtual myriad of variables to exert influences, especially at the response side of pairs (Goss and Nodine, 1965). The effects of concreteness, however, have only recently been demonstrated by Paivio and his collaborators, especially at the stimulus side of pairs. Their reasoning is that the stimulus member of a pair serves as a 'conceptual peg' to which the associate is hooked during learning trials and through which the response member can be retrieved on recall trials (when the stimulus member is presented alone). Moreover it is assumed that compound images incorporating both terms serve as the mediator in learning and that an image occurs more easily when the terms are concrete than when they are abstract. The resulting prediction that learning would become more difficult in the order concrete-concrete, concrete-abstract, abstract-concrete and abstract-abstract has been confirmed in several experiments (e.g., Paivio, 1965; Paivio, Smythe and Yuille, 1968). That learning picture pairs is superior over word pairs has also been demonstrated (Epstein, Rock and Zuckerman, 1960; Iscoe and Semler, 1967).

2.2.5. A comparison of abstractness-concreteness with other relevant stimulus attributes

Before imageability was explored as a dimension in memory tasks many other variables had already demonstrated their influences in these tasks. For this reason an evaluation of the potency of imageability relative to these long-established variables is appropriate.

The main variables that must be considered in this respect are frequency (*F*), familiarity and verbal-associative meaningfulness (*m*). Word frequency is determined by counts carried out on written language (e.g., the Thorndike-Lorge (1944) counts for American and the Van Berckel et al. (1965) counts for Dutch newspaper language). Familiarity is defined by subjective rating. The measurement of *m* (Noble, 1953) involves the determination of the average number of continuous written associations given to an item in a standard time period of 1 minute by a group of *S*s. Let us add that *I* (Imageability) is also defined by subjective rating (Paivio, Yuille and Madigan, 1968; the Appendix to the present work describes the collection of *I* for a number of Dutch nouns).

The issue which variable is the most potent in learning and memory tasks is a complex one because some of the variables are intercorrelated to a certain, often quite high, degree.

The correlation is probably very low between *I* and either rated familiarity or frequency. Paivio (1968), in a factor-analytic study in which 96 nouns were scaled for various semantic and associative characteristics, found no loading of either rated familiarity or Thorndike-Lorge frequency on a concreteness factor. Paivio et al. (1968) obtained a significant but small correlation (r=.23) between *I* and *F* for their sample of 925 nouns.

A strong positive correlation has been reported between *I* and *m*. For the nouns in the Paivio et al. (1968) sample it was .72. Also, Paivio (1968) found a substantial loading of *m* on a concreteness factor.

The correlations between *m* and familiarity and frequency are generally found to be moderately positive. For example, in the Paivio et al. (1968) sample there was a correlation of .33 between *m* and *F* and of .23 between *m* and rated familiarity.

It appears that the existence of a certain degree of correlation should be recognized, especially between *I* and *m*. On the other hand, the mere fact that none of these correlations is perfect makes it feasible to compare the effects of separate variables by independent factorial variation. A major point to take care of in planning these comparisons is that each variable, when possible, should be varied over an equivalent range in order for comparisons across variables to be fair. This can in principle be accomplished by equalization of ranges in terms of standard scores.

No comparison across the relevant variables seems to have been made within a single experiment employing a recognition paradigm. The evidence that is available does permit the conclusion that frequency is negatively related to recognition performance. Shepard (1967), in the study referred to earlier, found that words were better recognized when they were rare than when they were frequent. A similar result was obtained by Gorman (1961) who found the result to hold for abstract and concrete nouns as well.

The effect of *m* on recognition memory is not known at present. However, one may hypothesize that *m* will have no effect or possibly a negative one because of the increasing possibility of associative interference with increasing *m*.

More attention has been paid to a comparison across the relevant variables in free and serial verbal recall. Paivio et al. (1969) took great care to ensure that their comparison of *I* and *m* was free of unequal range effects. Stimuli were selected on the basis of comparisons between *I* and *m* in terms of their respective standard scores obtained for Paivio et al.'s (1968) 925 nouns.

One variable was always held constant while the other was varied at high and low levels. It turned out that the overall effect of *I* was stronger than that of *m* and that this was more clearly so in free than in serial recall learning.

Unclear findings have been obtained when the effects of *I*, *m* and *F* or familiarity in free and serial verbal recall have been compared. In both learning paradigms the relation between frequency or familiarity and recall has been found to be inconsistent, i.e. to vary from positive (Deese, 1960; Murdock, 1960) to zero (Peters, 1963) to negative (Frincke, 1968). Effects of *I* have been found to be positive (e.g., Paivio and Madigan, 1970).

By far the most extensive attempts to compare *I*, *m* and *F* have been undertaken in the area of paired-associate learning. Several studies (e.g., Paivio and Olver, 1964; Paivio, 1967) have shown that partialing out *m* had little effect on the positive correlation between learning scores and *I*, but with *I* similarly controlled any effect of *m* completely vanished. It has also been demonstrated in PA-learning, as in free and serial recall learning, that *I* is more effective than *m* when the two variables are independently varied over an equivalent range (Paivio and Yuille, 1967; Smythe and Paivio, 1968). In these paired-associate studies frequency and familiarity were controlled for. Frequency and *I* were factorially varied among stimulus and response members by Paivio and Madigan (1970). While *I* had a strong overall effect only a small effect of *F* was found when varied on the response side.

An issue that has recently attracted attention is whether rated imageability is exactly equivalent to rated concreteness. In Paivio et al.'s (1968) sample there was a correlation of .83 between *I* and *C* (concreteness). That this degree of correlation is not sufficient to conclude that variables are close to identical is demonstrated by the diverging effects of *I* and *m*, although these variables were correlated .72. Richardson (1975a, b) recently has indicated under what circumstances rated *I* and rated *C* are separable and indeed give a distinctly different pattern of results. Richardson was able to conclude that, in the absence of explicit instructions, *S*s only use imagery for the small number of items which are imageable but of low concreteness ('fantasy' is an example Richardson gives). However, when *S*s are given imagery instructions the distinction breaks down and rated imageability becomes the dominant determinant of ease of learning. Since the latter will always be the case in our own experiments we need not go into detail here as to the issue of what distinguishes *I* and *C*.

Another variable which has recently been indicated as confounding the effects of imageability is linguistic complexity (Kintsch, 1972a, b). Kintsch points out that many words commonly referred to as abstract may also be regarded as linguistically complex, whereas concrete items may be regarded as relatively simple. The dimension of complexity with which Kintsch is concerned is that between simple nouns and derived nouns (such as *distinction* and *refusal*) which may be regarded as resulting from the application of nominalizing transformations to the underlying stems. From his own data Kintsch (1972a) concluded that both imageability and lexical complexity affect recall, though they have usually been confounded in previous research. Yet he also had to admit that imageability effects remain even when lexical complexity is controlled. Matters are further complicated by Richardson's (1975a) finding that when imageability and concreteness are both controlled there is no effect of lexical complexity, from which he concluded that lexical complexity does not seem to be a factor influencing human memory. If we take this latter conclusion as reflecting our state of knowledge at the present moment there seems to be no reason to be very worried about the lexical complexity variable.

2.2.6. Conclusion

The general conclusion from this overview of empirical results dealing with the effects of stimulus attributes on learning and memory is that *I* is in almost all conditions a more potent variable than either *m* or frequency and familiarity. In some conditions there may be confounding effects of still other variables, but it seems beyond doubt that these variables are not going to account for the larger part of the effects attributed to imageability. It is certainly justified to concentrate on the *I*-dimension, at the relative expense of other dimensions, as a means of studying visual imagery.

2.3. MEMORY STRATEGIES: APPLYING IMAGERY AS A MEDIATOR

Is memory performance affected when we tell *S*s to use imagery as a strategy? How does an imagery mediation strategy compare with a verbal mediation strategy? This section is directed to answering these questions. Reference will again be made to empirical findings obtained by means of the traditional memory paradigms. In the first part of the review we have only included studies dealing with the effect of imagery instructions as compared to standard (control), i.e., rote learning instructions. Subsequent to that we will consider the relationship between imagery and verbal coding.

2.3.1. Imagery instructions and recognition

Curiously enough the effects of imagery instructions on recognition performance have received attention only recently. Morris and Reid (1974) had their *S*s learn lists of High *I* and Low *I* nouns and tested for recognition upon a list containing the old words mixed with an equal number of new High *I* and Low *I* nouns. Half the *S*s received instructions to form images, the other half received standard (control) instructions. Analysis of total errors (i.e., the sum of old words reported as new and new words reported as old) showed that instructions to form images improved the recognition of High *I* nouns relative to the control instructions. Instructions to form images improved the recognition of old High *I* nouns, but did not reduce the number of false positives. Instructions had no differential effects on the recognition of Low *I* nouns. What this finding suggests is that applying imagery may only work for High *I* nouns. Morris and Reid recognized that a rate parameter could play a role here, and therefore they compared the effects of instructions (and of *I*) for a 3-sec and a 6-sec presentation rate. However, the result of this variation was negligible. It seems, therefore, that imagery is not readily applicable when it comes to the memorization of Low *I* items. Of course this is entirely in line with theoretical ideas about a direct relationship between an item's position on the abstractness-concreteness dimension and the probability that an image is produced.

2.3.2. Imagery and free recall

In an other part of the study by Kirkpatrick (1894) referred to earlier 10-item lists of concrete nouns were compared for recall by *S*s with or without instructions to form a mental picture of the objects named. Immediate recall was superior under imagery conditions and superiority had even increased during a recall test three days later. However, Rogers (1967) found better recall for abstract nouns under instructions to form images relative to a control condition, but not for concrete nouns. Exactly the reverse was reported by Gupton and Frincke (1970), who asked for noun recall after the presentation of a list of noun-verb pairs. Another relevant finding is that of Mueller and Jablonski (1970) who demonstrated that instructions to *combine* items in free recall learning by means of imagery resulted in higher recall than standard instructions. In some experiments (Shaugness, Zimmerman and Underwood, 1972; Sheehan, 1971) recall did not improve at all when *S*s were instructed to use imagery.

Morris and Stevens (1974) ran the first free recall experiment in which systematic factorial variation of instructions and *I* was applied. Their results suggested that imagery only facilitates recall when the images which are formed link together. Morris and Stevens concluded that this finding resolves the apparent discrepancies in the literature in which this factor was consistently being overlooked (with the exception of the Mueller and Jablonski (1970) study).

2.3.3. Imagery and serial recall

Delin (1969) had two groups of *S*s learn a list of English nouns (familiar object names) to a criterion of one error-free anticipation. One group was instructed to try to connect each item to the preceding one by making a vivid and active mental image containing the two items. (Observe the similarity with the Mueller and Jablonski (1970) and Morris and Stevens (1974) instructions in the recall studies cited in the previous paragraph). Moreover the *S*s were told that their images should be as bizarre or fantastic as possible. It appeared that this second group was highly superior to the control group both in terms of number of trials and errors before criterion.

Delin's study appears to be the only one dealing with the effects of imagery instructions on serial recall. It must be regarded as somewhat unfortunate, therefore, that Delin had his *S*s generate bizarre and fantastic instead of 'conventional' images. The inclusion of a group of *S*s creating the latter kind of images would have brought the study somewhat more in line with the mainstream of imagery research.

2.3.4 Imagery and paired-associate memorization

Imagery instructions have also been investigated in paired-associate settings and have been compared with standard rote instructions. Schnorr and Atkinson (1969) used a within-*S*s design, in which half of the items in 32-pair lists of concrete nouns were studied by rote repetition and the other half by imagery. An immediate recall test showed much higher recall for the pairs learned by means of imagery (±80 versus ± 30%). Long-term retention, tested one week later, was also better for noun pairs studied by imagery.

Although the experimental design did not include comparisons with control conditions, a study by Wallace, Turner and Perkins (1957) is interesting because it demonstrated an extraordinary efficiency in the formation of associations with the use of imagery. At a self-paced presentation rate *S*s recalled up to 500 noun-noun pairs perfectly and, even with 700 pairs, correct recall was of the order of 95 percent. Similar results were obtained by Seibel, Lockhart and Taschman (1967).

2.3.5. The relative effectiveness of memory strategies

In order to make a realistic evaluation of the contribution of an imagery strategy to memory performance its effects should be compared with those of other possible strategies, in particular those by which verbal mediating devices are generated.

Verbal mediators have been assumed by neo-behaviorists to explain a variety of overt behavior (e.g., the discussion of reversal and non-reversal shifts in concept learning: Goss, 1961; Kendler and Kendler, 1968). The theoretical properties of imaginal mediation, and its distinction from verbal mediation, have been profoundly discussed and sharpened only recently by Paivio (1971). In Paivio's two-process view of meaning and mediation images and verbal processes are viewed as alternative coding systems, or modes of symbolic representation. Images are seen as representations corresponding to concrete things whereas the verbal code refers to representations corresponding to linguistic units. A most important theoretical extension of this view is that the availability of imaginal, but not verbal, mediators is related directly to stimulus concreteness. By virtue of their capacity to handle concrete material images are assumed to be most readily available in the case of object- or picture-stimuli, somewhat less available with concrete words and least available with abstract words. The availability of verbal mediators, on the other hand, should not be affected so much by item concreteness per se, since words derive their meaning mainly in an intra-verbal context. Thus, two-process theory predicts an interaction between mediational strategy and *I*. This interaction should occur at the level of the *availability* of mediators: to predict the interaction to emerge at subsequent recall requires additional assumptions about the relative *effectiveness* ('strength') of imaginal and verbal mediators.

What research on mediational strategies *has* unequivocally demonstrated is the overall inferiority of rote memorization, the old behavioristic work horse to establish associative connections by repetition. Paivio and Yuille (1967) and Elliott (1973) are two of the numerous studies which have led to this conclusion.

2.4. IMAGERY AS AN EXPLANATORY CONSTRUCT

The literature reviewed in the previous section clearly demonstrates the potency of instructions to use imagery in several learning and memory tasks, in particular when it comes to the handling of concrete material.

It thus appears that the question posed in section 1.3 must be answered in the affirmative: visual imagery is really worth bothering about, as manifested both in the importance of the *I*-dimension and of imagery strategies in learning and memory performance.

Two questions now follow logically when a theoretical structure is to be devised that should account for these effects.

First, is it necessary to introduce a separate hypothetical *entity* 'image' and a separate hypothetical *function* 'imagery', next to already existing theoretical structures, in order to account for empirical results like those discussed in the previous sections? That is, do experimental operationalizations such as asking *S*s to form images really give access to underlying mechanisms which are theoretically distinguishable from other mechanisms? And, second, if it appears necessary to introduce those constructs, what functional and structural properties should be ascribed to them? It is to those two questions that we will address ourselves in Chapter 3.

CHAPTER 3

A FORMAT FOR THE VISUAL IMAGE

Summary

Pylyshyn (1973) has expressed doubts on the appropriateness of the imagery concept to account theoretically for findings such as those reviewed in Chapter 2. This chapter deals with his critique and introduces a new format for the visual image. The most important distinction to be made when talking about the structure of the visual image, according to the format, is between its spatial and nonspatial (sensory) features. This is analogous to the fundamental distinction in perception between where an organism sees something and what it sees. The memory representation in which these two types of features are interwoven is indicated as the feature network.

3.1 A CRITIQUE OF MENTAL IMAGERY

The questions posed in the preceding section might be answered in a relatively straightforward manner. First, it might be argued that imagery should be introduced as a theoretical construct simply *because* of the kind of empirical evidence available. Second, both private experience and the finding that imagery is particularly suited to deal with concrete material seem to suggest that the visual image should be thought of as a picture stored in memory.

Against both these propositions and their implications Pylyshyn (1973) has directed a thoughtful critique, which can serve here to introduce some of the problems associated with attempts to define visual imagery. The critique is all the more important in view of the fact that the criticized propositions, in particular the second, do underly most current-day imagery literature, as Pylyshyn quite convincingly demonstrates.

What do Pylyshyn's criticisms amount to? For a start he leaves no doubt that ' ..... the existence of the experience of images cannot be questioned ...' (p. 2) nor does he challenge ' ..... the status of imagery either as object of study (i.e., as dependent variable) or as scientific evidence .. ' (p. 2).

Having established this Pylyshyn raises two questions corresponding to those we have asked at the beginning of this section, namely: Can the concept of imagery function as a primitive explanatory construct (i.e., one not requiring further reduction) in psychological theories of cognition? And does the common sense understanding of the term 'imagery' as a picture before the mind's eye contain misleading implications which carry over undetected into psychological theories?

The first question Pylyshyn answers in the negative. The crux of his argument is: 'As long as we recognize that people can go from mental pictures to mental words or vice versa, we are forced to conclude that there must be a representation which encompasses both. There must, in other words, be some common format or interlingua' (p. 5). Pylyshyn concludes that imagery cannot be a primitive explanatory construct and then goes on to propose and discuss several symbolic modes of representation which, he feels, should replace images in theorizing; these being propositional representations, datastructure representations and procedural representations.

Pylyshyn is right in his reasoning that a common format must underly both mental pictures and mental words, since we can go from one to the other. Yet it is difficult to see for what logical reasons it should follow from this argument that the concept of imagery (or of verbal mediation, for that matter) should be abandoned or replaced by a symbolic mode of representation. The issue really is the old one of levels of analysis. Suppose that images were actually isomorphic to some type of underlying symbolic representation. It could then, nevertheless, still be worthwhile to treat imagery at a separate theoretical level. This is because the format a representation takes may become critically important under some circumstances. For example, if a representation at some level would involve a motor component as part of its structure it might suffer from concurrent motor activity when at that level.

The isomorphism between a map and the geographical environment it pictures may illustrate the point. While there is isomorphism between them there are still things one can do with the one but not with the other, such as setting fire to the map or tearing it into pieces. Thus, to the extent that images can be shown to have properties of their own, so to say, it is theoretically required to distinguish a level at which representation is by means of images. And, of course, the issue of whether images *have* such distinctive properties can only be solved by a suitable combination of theorizing and empirical research.

The argument that is given here for imagery also applies, as a matter of fact, to the symbolic representational formats that Pylyshyn favors. Surely no one will dispute that it is useful to distinguish levels of analysis below the level of symbolic representation, such as the physiological or neurological levels. However, this does not in the least diminish the relevance of analysis at the symbolic representational level as long as it can provide insights which cannot, or not yet, be obtained at other levels.

Now for Pylyshyn's second point, the common sense understanding of the term 'image' as a picture before the mind's eye. Pylyshyn makes it quite clear that this 'picture metaphor' permeates the whole of the imagery literature, though it is fraught with logical difficulties. He says: ' ..... one misleading simplification in using the imagery vocabulary is that what we retrieve from memory when we image, like what we receive from our sensory systems is some sort of undifferentiated (or at least not fully interpreted) signal or pattern a major part of which (although perhaps not all) is simultaneously available. This pattern is subsequently scanned *perceptually* in order to obtain meaningful information regarding the presence of objects, attributes, relations, etc.' (p. 8). In Pylyshyn's view this 'image retrieval before perception' idea runs into insurmountable difficulties when it comes to the question as to what it is that could possibly serve as the input to the perceptual process.

Again we agree with Pylyshyn's reasoning, but fail to see why it would follow that there is no room for a concept of imagery. There is no reason to conclude that, because one current popular view of imagery is wrong, the concept as a whole should be abandoned. What *does* follow is, fairly trivially, that we should look for better ideas to conceptualize the nature of the visual image.

3.2. SPATIAL AND NONSPATIAL FEATURES IN IMAGERY AND PERCEPTION: A HYPOTHETICAL FORMAT

A somewhat more sophisticated way to conceptualize the visual image is to think of it not as a *picture* but as a *percept*. Thus, an image is assumed to be no more than a picture than a percept is one. Several authors have described the image in this fashion. For instance, Richardson (1969) defines it as follows: 'Mental imagery refers to (1) all those quasi-sensory or quasi-perceptual experiences of which (2) we are self-consciously aware, and which (3) exist for us in the absence of those stimulus conditions that are known to produce their genuine sensory or perceptual counterparts, and which (4) may be expected to have different consequences from their sensory or perceptual counterparts' (p. 2). Short's (1953) definition may serve as a second example: 'An image is a sense-experience in one or other of the sense modalities which can only be distinguished from a percept, hallucination, or illusion according to (a) the context in which it occurs, and (b) the attitude of the experiencer, including his ability to construct it' (p. 38). This general idea of a high degree of equivalence between imagery and perception is already sufficiently sharp to permit some experimental test, such as whether perceptual illusions occur in visual imagery (Segal, 1971). Yet there is an essential incompleteness in this class of definitions in that it contains no statements about the internal structure that percepts and images must be assumed to have. There is neither a conception of the nature of a percept nor of that of an image, except that they must be similar to a certain degree: the description is at the functional level only. Consequently tests of the assumed equivalence of percepts and images based on this class of definitions will of necessity be restricted and vague. The best way to develop the general assumption therefore seems, first of all, to have a close look at what is involved in a perceptual act.

A fundamental distinction in perception is between *where* an organism sees something and *what* it sees. When an object is present there is, on the one hand, information with respect to its orientation and position in space and its localization relative to other objects or a frame of reference.

There is also information concerning the spatial lay-out of parts and features within the object itself. For briefness we will in the sequel refer to these aspects as the *spatial* component of visual perception.

On the other hand an object contains *features* which identify it and which are the factual constituents of the object itself. We will refer to this aspect as the nonspatial or literal component of visual perception.

A word is in order about what exactly is meant by spatial and nonspatial features in a stimulus pattern. If we take a fixed frame of reference laid over a three-dimensional space the spatial relationships between objects placed in the space can be described by assigning coordinates to each object with respect to the frame of reference and noting which previously defined relations ('above', 'behind', 'to the left of', etc.) apply between sets (3-tuples) of coordinates. The noteworthy property of a description of spatial relationships now is that it is *not* invariant under all rigid spatial transformations. It can not stand *all* rotations, translations and mirror transformations that can be applied in the coordinate space. For example, when a pattern is turned upside down relations between parts like 'above' or 'to the left of' obviously have changed. Those features of the pattern, however, which *are* invariant under rigid spatial transformations imposed on the pattern as a whole are what is meant by nonspatial or content features. For example, a picture of a cow still represents a cow even if it is turned upside down: its set of features (primitives) has remained the same.

Thus, a complete description of a stimulus pattern is provided by an enumeration of a set of primitive features and a set of spatial relationships applying between them. This idea in itself is not new. It is the basis of the 'picture grammars' developed by people working in the area of automatic pattern recognition (e.g., Kirsch, 1964; Narasimhan, 1964; Shaw, 1969).

That there similarly are these two aspects in pattern perception, and that they rely on underlying mechanisms which are largely independent, has been demonstrated both at the functional and neurological levels by experimentation on vertebrates such as goldfish (Ingle, 1967), frogs (Ingle, 1973), golden hamsters (Schneider, 1967, 1969) and apes (Trevarthen, 1967). It appears that an answer to the question "Where is it?", when put to the visual system of mammals, requires the superior colliculi of the optic tectum. By contrast, an answer to the question "What is it?" requires forebrain mechanisms (the visual cortical areas in mammals) (Schneider, 1969). Thus, in the golden hamster (Schneider, 1967, 1969) lesions of the striate cortex produce pattern discrimination deficits, while tectal ablations abolish visually elicited turning of the head toward interesting objects such as food.

No such direct neurological evidence on the distinction between localization and identification mechanisms is available for man. However, van Galen (1974) has succeeded in obtaining behavioral evidence relating the distinction to certain aspects of single-channelness in human information-processing. Van Galen uses the terms 'ambient' and 'focal' for what we have called 'spatial' and 'nonspatial'. He concludes that, if persons are confronted with focal patterns, they react in accordance with a converging channel and by a successive mode of processing. In contrast, the presentation of ambient tasks, he suggests, gives rise to assimilation processes which, though they affect one another, are of a parallel type.

In most everyday situations the underlying distinction does not manifest itself very clearly since situations most often involve both the spatial and nonspatial mechanisms simultaneously. It must, therefore, be realized that perceptual tasks vary in the degree to which they appeal to each mechanism. For example, the inspection of an array of objects laid out in three-dimensional space seems more of a spatial task than the inspection of the same objects presented one by one at the same spot.

If the visual image is conceived as the memory counterpart of the visual percept we need a description of how the two types of information are extracted during perception and how they are subsequently laid down in memory. It is customary to regard making eye movements as the means by which spatial information is obtained, at least if the stimulus pattern is large enough. In case of a small pattern, or a pattern presented for a period too short to allow eye movements, the information on its spatial organization must be provided by rapid shifts of attention over the pattern which go unaccompanied by a peripheral motor component. Thus, Grindley and Townsend (1970) have presented evidence which indicates that visual search, i.e., looking for a particular object in a field of other objects, can be fairly successful even when the exposure is so short as to eliminate scanning of the field by eye. Engel (1971) similarly concluded from his attention area experiments that a difference may exist between the spot our eyes are fixated on, the fixation point, and the location where our attention is directed to, the attention point.

On the other hand, however, there is now evidence that eye movements may sometimes play a role in perception even under tachistoscopic presentation conditions. Some of Sperling's *S*s (1960) displayed scanning eye movements in processing iconic images, and Hall (1974a) has reported similar postperceptual eye movements to occur.

Pending further evidence it is thus not clear at the moment under what conditions of tachistoscopic presentation a role is played by eye movements. Under 'natural' presentation conditions however, i.e., reasonably-sized patterns displayed for a not too short time, it is probably safe to assume that coding spatial information depends largely on eye movements.

There exists an interesting link here with the physiological literature mentioned before in that it has been shown that information carried by optic tract fibres to the superior colliculi can be used in controlling the movements of the eyes. Thus Adamük (1870) showed that eye movements could be produced by stimulating the superior colliculi electrically. Also Apter (1946) found that after strychnine had been applied to a point on one superior colliculus in a lightly anaesthesized cat, diffuse illumination of either eye caused conjugate deviation of the eyes towards the part of the visual field that projects to the strychninized point on the colliculus.

Both eye movements and attention shifts over the stimulus pattern result in a coding of where things are in space. The second, nonspatial, feature-extracting component of perception is formed by the intake episodes which alternate with the saccades or shifts. The formal description of a complete perceptual act thus is that it is a sequence of spatial (in most cases: motor) episodes alternating with stationary intake episodes. The resulting percept is to be described as the set of spatial and nonspatial features obtained from the perceptual act.

The basic proposal we now will elaborate upon is (1) that the visual memory image likewise can be described as a structure of spatial and sensory features (the feature network), and (2) that the imagery *function* consists in traversing the feature network.

The first part of this proposal is what the experiments to be reported later in the study will be concerned with. For the second part of the proposal, which may be indicated as a sequential scan hypothesis, there is already some evidence in the literature which may serve as initial evidence as to its usefulness. This is Noton and Stark's (1971) work on how a pattern is matched during recognition with an internal representation derived from previous inspection of the pattern. Noton and Stark started from a similar format as described above (except that they did not use the words 'image' or 'imagery'), but entrusted it with an additional property bearing on the organization of the sequential process.

This property is that the sequence has a cyclic character, i.e., that it is always traversed in a fixed order. A sequence of features having this property Noton and Stark named a *feature ring* (see Fig. 1). The concept of the feature ring Noton and Stark derived from their basic hypothesis that for each pattern with which he is familiar each person has a fixed and characteristic

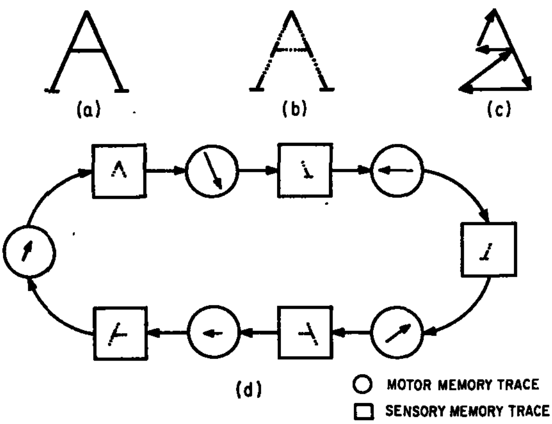

Fig. 1. Internal representation of a pattern according to the feature ring hypothesis: (a) pattern, (b) features, (c) scanpath, (d) feature ring. (From Noton and Stark, 1971).

path of eye fixations (the 'scanpath') from sensory feature to feature. The scanpath would occur both during the initial viewing of a pattern (learning phase) and when the pattern is subsequently presented for recognition. For this reason Noton and Stark suggested that it is the feature ring, the internal representation of the pattern, that is matched with the pattern presented during recognition. Matching takes place by executing the eye movements recorded in the motor memory traces and verifying the features recorded in the successive sensory memory traces, leading to recognition of the pattern.

Scanpaths were not always present in Noton and Stark's experiments, contrary to their initial hypothesis. Only 25-35 percent of the total viewing time during the learning phase was, on the average, occupied by occurrences of the scanpath. During the recognition phase the appropriate scanpath appeared in the eye movements in 65 percent of the cases. Because of these results Noton and Stark elaborated and modified the basic model of the feature *ring* into a feature *network*. The defining property of the feature network is that it permits alternative paths to be followed. Fig. 2 illustrates the principle. However, a habitually preferred scanpath may often be expected to develop during the learning of a pattern, as Noton and Stark's data show.

If the feature network is accepted as a tentative hypothesis of the structure of the visual image a variety of details needs to be filled in. To a certain extent these details are already implicit in vaguer conceptions of the visual image. For example, a strength measure over the set of images must be defined such that an image's strength is related to its probability of being retrieved at recall. Another fairly trivial assumption is that feature networks can interact or become interconnected, so as to account for the fact that associative learning by means of imagery is altogether possible. Yet another as-

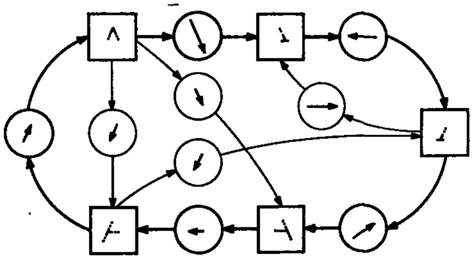

Fig. 2. Feature network, with habitual path emphasized. (From Noton and Stark, 1971).

sumption is that it is possible to go from images to verbal representations and on to overt verbal responses. A well-documented discussion of these general assumptions is contained in Paivio (1971).

Further theoretical properties specifically to be ascribed to the image as a feature network are the following. First, by virtue of the sequential ordering of its memory traces it is capable of being rehearsed. That is, when the network is activated the sequence may be traversed a number of times, thereby temporarily increasing its strength. This traversing may be identified with the imagery process.

Second, since there exist alternative paths of traversing the feature network there is not *one* possible image of an object, but a multitude of them. Through habit one of these may become the preferred one, as indicated in the occurrence of typical scanpaths, but others might be evoked if required. Thus the image need not be specific in the sense that it must be a single, invariant structure.

Third, only part of the network may be activated, or the path may be short-circuited, if for some reason (e.g., time pressure) no complete cycle through the network can be made. Thus it is meaningful to speak of part-images.

3.3. CONSEQUENCES

In order to make the above speculations somewhat less gratuitous we must consider what empirically testable consequences follow from them. Two types of consequences may be distinguished. The first is based on the specific assumptions about the *internal* structure of images as presented in the previous section. For example, a consequence of this type would be that preventing *S*s to make eye movements may cause them difficulties in forming visual images of a spatially organized group of objects, since eye movements are assumed to be part of this image.

The second set of testable consequences stems from the assumption that the features which are in a visual image are a direct derivation of corresponding features in visual perception. Thus, they deal not so much with what features there are as with whether they can be said to be 'visual' in both cases. The prime examples of this type of test are the analysis of eidetic imagery and the analysis of sensory after-images and illusions in imagery.

A prediction which encompasses both types of test is that of selective interference between an imagery and a perception task, provided that they are either both spatial or nonspatial. Testing this interactive pattern will be one of our main concerns in the experimental parts of this thesis.

Chapter 4 now will somewhat more formally examine research bearing on the possible functional or structural relationships between and within images and percepts. Apart from reviewing the results as they stand the primary aim is to select the potentially most powerful experimental paradigms to be applied in our own experiments on the visual image as a feature network.

CHAPTER 4

METHODS TO INVESTIGATE A POSSIBLE CORRESPONDENCE BETWEEN IMAGES AND PERCEPTS

Summary

This chapter examines the experimental methods by means of which properties of the feature network might most appropriately be tested. It is concluded that introspection, protocol analysis, the analysis of eidetic imagery, and the analysis of the occurrence of sensory after-images and illusions in visual imagery are suboptimal to this purpose.

Methods that appear to bear more promises in them are the analysis of interference between images and percepts (selective interference paradigms) and the analysis of the role of eye movements in visual imagery.

4.1. INTROSPECTION AND PROTOCOL ANALYSIS

Introspection, the systematic description of one's mental contents, is the oldest method used in the study of imagery (Galton, 1883). It fell in disuse when it was realized that what is accessible to conscious experience may not be what plays the important causal role in psychological processes (see Pylyshyn, 1973).

In recent years introspection has reappeared in a more modest form as part of the method of protocol analysis. This method has mainly been developed in the context of studies of human problem solving (e.g., de Groot, 1965; Newell and Simon, 1972). It has not found its way into imagery research, probably because most of that research has dealt with memory and not so much with the possible use of imagery in problem solving. Protocol analysis thus seems better suited to investigate the properties of a problem space (e.g., an internal decision network which has as its vertices all possible positions of a game and the possible transitions between them) than to investigate the structure of an internal model of the external world (e.g., the internal representation of an actual game position); cf Michon, 1968. For this reason the method of protocol analysis is not a plausible one to be applied in the present context.

4.2. THE ANALYSIS OF EIDETIC IMAGERY

If any kind of imagery ever deserves to be called truly perceptual it ought to be eidetic imagery. It is characterized by the length of persistence of the perception of a stimulus long after it has disappeared and by its clarity, independent of the intensity of the original presentation. The eidetic subject ('Eidetiker') can during minutes read off all sorts of detail from the stimulus.

The incidence with which Eidetikers have been found in the population appears to be an inverse function of the strictness of the criteria applied to characterize performance as eidetic. However, it appears that, even by the strictest criteria, there are indeed some individuals who may have an unusually persistent sensory memory as indicated, for example, by their ability to fuse images of two successive picture presentations (Stromeyer and Psotka, 1968). Because these individuals are the exception rather than the rule, however, there is no reason to assume that the strong correspondence between image and percept observed in them holds also for people with everyday imagery ability. Also, the fact that Eidetikers are so rare would make it difficult to investigate their capacities by means of large-scale experimentation. For these reasons the analysis of eidetic imagery is not considered to be a recommendable approach for our purposes.

4.3. SENSORY AFTERIMAGES AND ILLUSIONS

Slightly less exciting is the issue of whether imagery can give rise to aftereffects and illusions. Do we experience a green afterimage after just having imagined a red spot? And does, say, the Mueller-Lyer illusion occur when we imagine an appropriate configuration of elements?

These questions pose delicate experimental problems. How, for example, could we instruct a subject to imagine the Mueller-Lyer illusion, given the fact that measuring purely perceptual illusions already gives rise to fairly complicated measurement problems (Robinson, 1973)? And how are we going to describe what the subject must try to imagine in more complex stimulus configurations known to give rise to perceptual illusions? We may show our subject a horizontal line all right and ask him to imagine a vertical line of equal length perpendicular to it, but more complex configurations are not that easily described - they must be seen to be understood. It may be for methodological reasons of this kind that the literature on afterimages and illusions in visual imagery provides no consistent picture. The occurrence of afterimages to imagined colors has been reported by some investigators (Binet and Féré, 1891; Downey, 1901; Stromeyer, 1970) but not by others (Miller, Lundy and Galbraith, 1969, discussed in Segal, 1971). The same pattern emerges in the literature on attempts to induce visual illusions by means of imagery. While some have reported positive results (Underwood, 1960; Pressey and Wilson, 1974), others (Singer and Sheehan, 1965) have pointed to methodological (demand) factors which could have invalidated these results.

While the attempt to evoke afterimages and illusions in visual imagery seems legitimate, the experimental enterprise is bound to be slippery. For that reason it is worthwhile to investigate whether still other, less esoteric methods exist to establish the alleged correspondence between images and percepts.

4.4. SELECTIVE INTERFERENCE PARADIGMS

What should be expected to occur when an imagery and a perceptual task are performed simultaneously, given that they have to share the same processing channel? This will depend, first of all, on the similarity in structure between the image and the percept. In case one succeeds in making the image congruent with the percept facilitation should occur. This is what happened in the famous Perky (1919) experiment and it has also been observed to occur in at least one modern study (Peterson and Graham, 1974).

We will restrict ourselves here to the case of interference between images and percepts, i.e., when there is no structural resemblance to be expected between them. The prediction that will be examined is that percepts and images interfere more when they are in the same modality than when they are in different modalities. This is the prediction of *selective* or *modality-specific interference*. On the face of it the prediction does not seem to be concerned with the internal structure of images or percepts. We will soon see, however, that the empirical evidence *does* in fact make such assumption necessary.

Two experimental paradigms have been used to test the prediction of selective interference. They differ with respect to which is defined to constitute the *S*'s primary task, that is, the task from which measurements of the dependent variable are derived. In the paradigm explored mainly by Segal and her associates (Segal and Nathan, 1964; Segal and Glicksman, 1967; Segal and Gordon, 1969) *S* is given a primary perceptual task - most often an auditory or visual detection task - while he must simultaneously produce (auditory or visual) images to material presented by the experimenter. The question is whether performance on the perceptual task depends on the modality in which imagery is required. Studies employing the Segal paradigm have generally shown positive evidence for the phenomenon of selective interference (see Segal, 1971, for a review). That is, visual imagery has been found to interfere especially with the detection of visual signals and auditory imagery with the detection of auditory signals.

Positive evidence has not unequivocally been obtained with the complementary paradigm, in which imagery is the primary and perception the secondary task.

First to be considered here is one out of a series of experiments reported in 1967 by Brooks. A conflict was demonstrated between reading verbal messages and imagining the spatial relations described by the messages, but not between listening to the same messages and visualization. In one of these experiments messages were of the form: "In the starting square put a 1. In the next square to the *right* put a 2. In the next square *up* put a 3", and so on. Some of the messages were spoken to the *S*, others were spoken at the same rate but were accompanied by the simultaneous exposure of a type-writer copy of the message. The *S*s were asked after each message to report it verbatim.

As a control, nonsense messages were presented which had the same sentence form and length as the spatial messages but in which the words *quick*, *slow*, *good* and *bad* were substituted for the words *right*, *left*, *up* and *down*. The main result of the experiment was that the *S*s made more errors after reading (+ listening to) the spatial messages than after listening to them. This might simply mean, of course, that listening + reading is for some reason more difficult in itself than listening only. However, that this is not a correct interpretation appeared from the results for the nonsense messages: here listening was more difficult than listening + reading. Thus, it was the spatial character of the messages which must have caused the decrement in performance when the messages were read. This conclusion was confirmed in three other experiments of Brooks (1967) and in a later study (Brooks, 1968).

What do Brooks' results mean if we interpret them in terms of the spatial and nonspatial features visual images presumably possess? We tentatively suggest that the reason Brooks found selective interference is that there was a conflict between the *spatial* features of the visual image and the *spatial* features of the perceptual task (i.e., the eye movements required in reading). Presumably the nonspatial components of each task were minimal compared to the spatial components, so that the interference most likely was *not* between the nonspatial components. Before discussing this further, however, it seems useful to consider a second study.

Atwood (1971) used a, somewhat unconventional, paired-associate task in which the noun pairs to be learned were embedded within linguistic phrases. Some *S*s were (auditorily) presented phrases designating visual scenes which they were instructed to visualize, such as 'nudist devouring a bird' and 'pistol hanging on a chain'. One group of *S*s was presented with the visual stimulus '1' or '2' one second after each phrase. Those presented with '1' were required to give the vocal response '2', and vice versa. A second group received the *auditory* stimulus '1' or '2' and responded as the first group. Another group received no interfering signals during the interphrase intervals. Immediately following presentation of the phrases all *S*s were supplied with the first word of each phrase (e.g., 'nudist') and were asked to recall the last word ('bird'). Other groups of *S*s had the same three interference conditions, but the learning task consisted of phrases designating abstract but meaningful relations, such as 'the intellect of Einstein was a miracle' and 'the theory of Freud is nonsense'. Prior to the task *S*s were told to contemplate the meaning of each phrase as a whole during the interval that followed (presumably this instruction was intended to stimulate verbal mediation). The *S*s were then tested for associative recall in the same way as the imagery group. In agreement with the hypothesis of selective interference it appeared that *S*s presented with visual interference had lower recall scores in the imagery mediation condition than those presented with auditory interference, while the reverse was found for the *S*s in the contemplation condition.

In connection with this study there is a number of aspects which deserve consideration. First of all, how does the result itself, apart from possible methodological drawbacks, fit in the theoretical framework of the image as a mixture of spatial and nonspatial features? Our suggestion is that Atwood created a conflict which was the opposite of Brooks', namely between images *lacking* spatial organization and similar percepts (apart from the very few eye movements required to identify the '1' or '2'-stimulus in the perceptual interfering task, which were always presented in a fixed position). This is only a very tentative conclusion, however, since a number of methodological objections might be raised against Atwood's study. First, from the sample of phrases given in Atwood's paper one obtains the impression that the phrases presented to the imagery group of *S*s were somewhat bizarre ('nudist devouring a bird'). This is important because it could be that the case that the interference effect is less for more conventional images. It need only be assumed that the formation of conventional images strains the visual system less than when bizarre images are requested. Nappe and Wollen (1973), for example, present evidence that bizarre images take considerably longer to be generated than 'common' images.

Second, embedding the critical noun pairs within *phrases* confuses the issue by introducing a host of linguistic and semantic factors irrelevant to the question under study.

Third, the interfering task always required a *vocal* response by the *S*. Thus, even the visual interpolated task involved a verbal component. A comparison between uncontaminated visual and auditory interfering tasks would certainly have been more appropriate.

Fourth, there obviously was a confounding of instructional set and abstractness-concreteness of the stimulus material in the experimental design. By not running the experiment according to a complete factorial design Atwood deprived himself of the possibility to show that the interaction defining selective interference does *not* occur, or has a different pattern, in circumstances under which it should not occur (or should have a different pattern). Thus, it would be interesting to see what would happen if *S*s were also instructed to verbalize to concrete material or to generate images to abstract material under different types of interference. The possibility to check this three-factor interaction was, however, precluded by Atwood's incomplete experimental design.

Finally, Atwood used a learning procedure which may be described as mildly incidental, since *S*s were not told that they were to be tested for recall afterwards. It remains to be seen whether his results did depend in some way on this choice of conditions.

Given these objections it may not look too surprising that Atwood's result has not stood up under attempts to replication by other investigators (Brooks, cited by Paivio, 1971, p. 374; Bower et al., cited by Anderson and Bower, 1973, p. 459; Baddeley et al., 1975). Let us have a look at the Baddeley et al. (1975) study.

In Experiment 3 of that study it was shown that there was no interaction between a visual tracking task and the abstractness-concreteness (*I*) of noun-adjective pairs to be memorized. Yet the visual tracking task had been shown (in their Experiments 1 and 2) to cause considerable interference with some of the spatial visualization tasks used by Brooks (1967, 1968). The explanation Baddeley et al. give for this apparent failure to replicate Atwood's result was that the crucial factor in the memorization of verbal material is the (imagery) instruction rather than the material. Therefore, imagery mnemonics would be disrupted by concurrent visual activity regardless of the abstractness-concreteness of the material. Atwood, Baddeley et al. imply, would have noted this had he used a complete factorial experimental design. However, since their *S*s were not instructed to use any particular mnemonics Baddeley et al. were unable to check this prediction on the basis of their own data. (In fact, our own findings will show it to be false; see Ch. 5).

There may be another explanation for Baddeley et al.'s failure to find selective interference. This is that they in fact were trying to create a conflict between a relatively *nonspatial* imagery task (the noun-adjective pairs not explicitly describing spatial relations) and a clearly *spatial* perceptual-motor task (visual tracking). In so far as spatial and nonspatial features are independent of each other this may explain the failure. Let there be no misunderstanding: the explanation put forward here does not assume that the tasks were *exclusively* spatial or nonspatial. It is only suggested that one component strongly dominated the other in each task, and that it is these strong components which enter into phenomena of selective and nonselective interference.

There is some more evidence available in the literature on this issue. Byrne (1974) undertook to separate the relative contributions of item concreteness and interitem spatial organization to recall processes. He attempted to induce modality-specific interference between recall and certain categorization responses by using an adaptation of the technique devised by Brooks. *S*s first learned a list of items to a criterion of three successive errorless recall trials, following which they categorized the items from memory into classes (e.g., *animal* and *man-made*). They signalized categorization either vocally, by saying 'Yes' or 'No' for each item, or via a visually guided response, namely pointing to a column of Y(esses) and N(o's) printed on a card before them. This latter response thus had a spatial component, which the former had not. Some ways of presenting lists for learning that are traditionally regarded as increasing reliance on mediating imagery were effective in generating conflict between recall and the visually guided pointing response. This effectiveness was limited to presentation conditions and list types that introduced spatial organization into the stimulus material. The concreteness of individual items was not useful in predicting visual conflict. Thus, when *S*s were shown a list of pictures drawn on separate cards and presented one at a time (Experiment III) no conflict was found between recall and the concurrent pointing task, while a conflict was apparent (Experiments I and II) when the same pictures were combined into an overall, spatially organized scene. On the other hand, when *S*s learned and subsequently categorized a list of abstract words presented as a spatial matrix (Experiment VI) the pointing response interfered with recall. Thus it appeared that visual conflict occurred whenever the items were arranged spatially and that it was relatively independent of item concreteness.

Byrne obviously succeeded in making a distinction between spatial organization and the more static, pictorial or structural aspects as factors in memory storage in a visual format. In so far his data provide support for our position. One prominent feature of his experiments to be noted, however, is that the critical interfering task (pointing to an array of responses) was always of a spatial character. Byrne did not use a task which could be considered to be predominantly nonspatial. This may explain why the pointing task did not interfere with the retrieval of concrete, but nonspatial items, but that it did so with the retrieval of abstract, but spatially organized items.

There is still more evidence in the literature which points to the spatial-nonspatial distinction as a crucial one. An unsuccessful replication of Atwood's experiment by Quinn (cited by Baddeley et al., 1975) involved the learning of abstract and concrete phrases, which went undisrupted by a spatial interfering task of pressing a left or right hand key according to arrows pointing either to the left or to the right. The failure possibly could be attributed to the attempt to induce a conflict between relatively *nonspatial* imagery and *spatial* perception. An experiment by Elliott (1973) is also relevant. Learning abstract and concrete noun triads was *not* interfered with by a spatial task which consisted in copying Bender Gestalt-like geometric figures. In another experiment, by Den Heyer and Barrett (1971), the interfering task was also a spatial one, but it was combined with a spatial primary task. Den Heyer and Barrett presented letters in a matrix and required *S*s to recall both the letters (identity information) and their position (spatial information). They found that position information was interfered with more by a visual than a verbal interpolated task, and that the reverse was true of identity information. The verbal task was a number addition task. The visual task consisted in presenting a card containing three 2 x 4 matrices, each matrix containing three randomly positioned dots. Two of the 2 x 4 matrices had dots in identical positions, with the third matrix being different, and it was the *S*'s task to detect the deviating position.

The results reviewed so far seem encouraging for the idea that the spatial and nonspatial aspects of visual images are quite distinct. A conclusion one moreover seems forced to draw on the basis of the results of Elliott (1973), Baddeley et al. (1975) and Quinn (1975) is that in the conventional imagery tasks, i.e., memorization of single nouns or noun pairs, there is only a weak spatial component. This seems the only explanation that can account for the outcomes of these studies. Yet none of the studies reviewed settles the issue. One of the most important things that remains to be done is to carry out the crucial experiment in which the spatial or nonspatial character of the visual imagery task is factorially combined with the spatial or nonspatial character of the visual interfering task. If the distinction between independent spatial and nonspatial factors is valid an interaction should emerge between these two factors when varied factorially at the imagery and the perception side.

As may have become clear the selective interference paradigm has already yielded stimulating results, proving its fruitfulness in the present context. It might also provide the opportunity to obtain at least some insight in what the feature network is worth as a model of the visual image. For these reasons the selective interference paradigm will be used extensively in our experimental program.

4.5. EYE MOVEMENTS AND VISUAL IMAGERY

The viewpoint that eye movements play a role in visual imagery was expressed long ago by Stricker (1882) and Ladd (1892) and has been rephrased recently by, among others, Rey (1958), Hebb (1968) and Haslerud (1972). In the feature network model that assumption is qualified by the explicit proposal that eye movements provide information on the spatial organization of a stimulus pattern.

As stated earlier there are differences between tasks with respect to the relative weights of their spatial and nonspatial components. Thus we would expect that eye movements play a much larger role during imagery of a set of objects positioned at several locations in space, or during movement imagery, than in the relatively nonspatial type of imagery that is most common in conventional learning tasks.

What is the empirical evidence on the role of eye movements in visual imagery?

Two general methods of attack on the relation between eye movements and visual imagery have been followed in the experimental literature. In most studies eye movements have functioned as the *dependent* variable. In these studies *S*s have typically been instructed to form images to a set of prespecified stimuli while eye movements were registered as *S*s carried out the imagery task. In most of these studies (Brown, 1968; Deckert, 1964; Goldthwait, 1933; Perky, 1910; Schifferli, 1953; Totten, 1935) though not in all (Antrobus, Antrobus and Singer, 1969; Marks, 1973) positive correlations between imagery and either the mere occurrence, the amount or the type of eye movements have been observed.

The most recent example of this approach is a study by Marks (1973), which led to a negative conclusion regarding the relationship between imagery and perception.

Marks gave a picture memory task to groups of vivid and poor visualizers. The pictures were ten colored photographs reproduced as transparancies. Five of these were photographs of sets of 15 unrelated objects in a random arrangement and five displayed pictures of complete scenes. Each trial consisted of four stages: stimulus presentation (20 sec), a delay (40 sec), a 5-point vividness rating (10 sec) and questioning (75 sec). During the first 30 sec of the delay between stimulus presentation *S*s performed a serial subtraction task to prevent verbalizing while they tried to keep in mind a picture of the displayed slide. In the questioning stage five multiple-choice questions were asked. Some of the questions explicitly referred to a position in the picture and others provided no explicit positional cue. Eye movement records were obtained throughout the trial. Eye movement rate (EMR) was computed as the average change in the amplitude in the horizontal component during 1-sec intervals.

The main outcome of this experiment was that EMR was significantly *lower* during imagery than during perception. One explanation for this result would be, of course, that imagery does not rely on eye movements and is thus not in this way related to perception. It is doubtful, however, whether this is a fair conclusion from Marks' experiment. First, as indicated the perception stage in the experiment took 20 sec, while the imagery stage took 40. The negative result could be explained by the plausible assumption that eye movement activity becomes less the longer the period a picture is inspected or imaged. Lengthening the imagery interval relative to the perception interval would then depress the average EMR for the imagery interval. Second, only the imagery stage in Marks' experiment contained the serial subtraction task but not the perception stage. While it is not immediately clear in what way this task would influence the EMR it seems not unreasonable to wonder why the subtraction task was not given in the perception stage too. This would also have provided some degree of control over the *S*'s coding of the picture. Coding now may have been (partially) verbal, which brings us to the third and most fundamental point of critique of Marks' study. This is that there is no guarantee that what the *S* was imaging was identical to what he had perceived previously. It seems improbable that a *S*, after having been presented with a picture containing 15 unrelated objects in a random arrangement for no more than 20 sec, is capable of imaging *all* he saw. Rather he will have to restrict himself to imaging some subset of the set of objects depicted, with a consequent reduction in EMR because this subset encompasses a smaller set of spatial relationships between objects than the original picture.

This last point of criticism, as a matter of fact, applies to all experiments employing a paradigm that involves a direct comparison of indices obtained during perceptual inspection of some stimulus pattern and during imagery of the same pattern. The *S* may be imaging all right, but there is simply no way to assure that what the *S* is imaging is in all respects the same that he saw.

Eye movements have been manipulated as the *independent* variable in imagery studies only recently. Hale and Simpson (1971) instructed *S*s to generate interactive images linking two given nouns, and to press a button when such an image had emerged, under instructions which required *S*s to: a) make eye movements during the imagery task; b) not make eye movements during the imagery task (by fixating on a target), but to think about or imagine making eye movements; c) not make eye movements nor think about making eye movements during the imagery task. Response latencies indicated no differences in the case of generating images among these treatments. Also, no relationships were found among treatment conditions and vividness ratings of the images as given by the *S*s. These findings were obtained both when treatments were varied within and between *S*s.

What do these results mean with respect to the relationship between eye movements and visual imagery? It may be questioned, first of all, whether there was really a prominent spatial component in the imagery task which could be influenced by the opportunity to make eye movements. In fact the task was of a type we have already concluded to be of a predominantly nonspatial nature. Second, in so far as there was anything spatial in the task the instructions given by Hale and Simpson may have interfered with it. *S*s were simply told 'to move their eyes freely', and this wording may have led some *S*s to make more or less random eye movements which acted to inhibit rather than enhance the formation of an image.

Hall (1974b) has examined the relationship between eye fixation and imagery in a task in which spatial organization was a salient visual dimension. Eye fixations were manipulated to produce external patterns appropriate or inappropriate to an internal scanning pattern involved in the spatially organized recall of a visual stimulus. Geometric shapes were presented one at a time at one of a number of different locations on a screen. *S*s were instructed either to fixate a central light during stimulus presentation or to look around as they wished. Subsequently *S*s were asked to recall the shapes by name, according to which had appeared at each spatially consecutive location. If *S* had fixated the central light during stimulus presentation he had to fixate the light during recall, and if *S* had looked around previously he could do so during recall.

There was a significant effect of conditions (fixation vs scanning) on the number of items recalled and on the latency of recall, the scanning condition leading to better performance on both variables. This indicated that eye fixation has an important role in spatially organized imagery, in accordance with the expectations one would have on the basis of the theoretical distinction between spatial and nonspatial features in visual imagery.

A final result to be mentioned in this context has been reported by Kahneman (1973), who found that *S*s recalling information from a spatial array tended to fixate areas of a blank screen where the information had appeared.

Besides eye movements there is a number of other physiological variables which, at one time or another, has been assumed to be correlated with visual imagery. These include the alpha rhythm, cortical evoked potentials, pupillary size and latency, the GSR, and respiratory movements. From the reviews presented by Paivio (1971) and Bower (1972) one gets the impression that these attempts have not yielded very encouraging results, with the possible exception of cortical evoked potential measurements studied in this context by John and his associates (e.g., John, 1967; Herrington and Schneidau, 1968). Presumably these variables are related to so many psychological phenomena that it is extremely difficult to sieve out the specific contribution of imagery, if there is any.

To sum up the discussion of the relation between eye movements and visual images: we have assumed that the spatial component in visual images is in many cases a derivative of eye movement patterns made during the inspection of the actual stimulus. We cannot escape the conclusion that we must test this part of the feature network model by relating parameters of eye movement patterns to relevant task variables, e.g., whether the imagery task is predominantly spatial or predominantly nonspatial.

4.6. CONCLUSION

It seems that any initial exploration of the feature network model could best be undertaken with the help of (a) selective interference methods and (b) the use of methods employing eye movements as a variable. Other methods seem less promising because they are either methodologically doubtful or do not provide the possibility to give insight in the internal structure of the visual image.

CHAPTER 5

THE SENSORY COMPONENT OF THE VISUAL IMAGE

Summary

This chapter contains the description of five experiments which have made use of a selective interference paradigm. In all of them an opportunity was created for a conflict between a relatively nonspatial imagery task and a nonspatial perceptual interfering task.

Selective interference was obtained in the acquisition stage of two paired-associate experiments as well as in a free recall experiment (Experiments I, II and III). In a subsequent Experiment (IV) selective interference occurred at the retrieval stage of memorization. Experiment V, finally, showed that a spatial interfering task had no selective degrading effect on memory performance for the nonspatial imagery task, indicating the independence of spatial and nonspatial features as specified by the feature network format.

5.1. EXPERIMENT I. SELECTIVE INTERFERENCE IN ONE-TRIAL PA-MEMORIZATION[1]

Starting from Atwood's (1971) experiment and the criticisms directed against it in section 4.4 the first three experiments to be reported here tried to answer the question of whether selective interference reliably occurs in situations where it should and does not occur in situations where it should not.

In order to perform these experiments it was necessary to have norms available for the *I*-value of a large number of Dutch nouns. The Appendix contains the description of the way in which these ratings were collected and the complete set of ratings for 327 nouns.

Apart from the procedural and methodological criticisms raised in connection with Atwood's study there remains the question of whether the factors that could play a role in the selective interference phenomenon were exhaustively included in his experimental design. A factor which seems worth studying, and which was uncontrolled in Atwood's experiment, is the differential ability of people to use different mnemonics. It is a well-established fact by now that people differ considerably in their capacity to generate images (e.g., Sheehan and Neisser, 1969). A promising way to test the hypothesis that imagery is basically a perceptual phenomenon therefore seems to be to study the interaction between imagery ability and the modality of the interfering task. This was one of the aims of the first experiment. Another aim was to try to check Atwood's results in a somewhat less untidy experimental design.

5.1.1. General design

The experiment made use of a one-trial mixed-list PA-learning task with noun pairs as material and with the same interfering stimuli as used by Atwood. Variables investigated for their effect on retention were: (a) instructional set (imagery mediation, verbal mediation and standard rote learning instructions), which was a between-*S*s variable; b) imagery ability (High versus Low imagers); c) type of interference (none, auditory and visual), a within-*S*s variable; d) *I*-value of noun pairs (both nouns High *I* or both Low *I*), also a within-*S*s variable; e) type of response to the interfering stimuli (explicit vocalization, as in Atwood's experiment, versus silent inspection), again a within-*S*s variable.

5.1.2. Subjects

Forty-eight students from Utrecht State University were hired and paid Hfl 6,-- per hour. *S*s were run individually.

5.1.3. Material

Experimental lists consisted of 16 noun pairs each, 8 of these having a High *I* value ($I>6.0$) and 8 having a Low *I* value ($I<3.0$) according to the norms assembled previously (see Appendix). To reduce serial position effects four noun pairs of Medium *I* value ($4.0<I<5.0$) were added to each list, two at the beginning and two at the end. Recall performance for these pairs was not considered in the data analysis. Lists were recorded on tape and presented through headphones. Presentation rate was one pair per 8 sec. The sequence of events during a presentation cycle is indicated in Fig. 3.

Interference consisted in either auditory or visual presentation of either the digit '1' or '2' for approximately 0.5 sec. Interference modality was fixed during the presentation of a list. Immediate oral recall was tested by auditorily presenting the stimulus members of the pairs from tape at a rate of one per 5 sec.

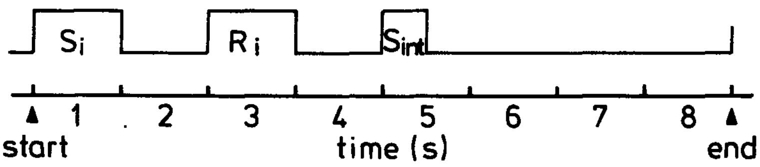

Fig. 3. Temporal sequence within an 8 sec presentation cycle. S_i and R_i are the stimulus and noun members, respectively. S_{int} is the interfering stimulus.

5.1.4. Procedure and design

Instructional set was varied between three groups of 16 *S*s each. Imagery mediation instructions stressed the need to form an interactive visual image linking a pair of nouns so that later retrieval of the response member through the image would be possible. Verbal mediation instructions required the *S* to (silently) produce a phrase or sentence incorporating both members of the pair in order to be able to retrieve the response member during later recall. Standard rote learning instructions, serving as a control condition, required the *S*s to (silently) repeat the pair as often as possible before the presentation of the next pair.

Within each group of *S*s there were 8 High imagers and 8 Low imagers. Imagery ability was defined in terms of a *S*'s score on Sheehan's (1967) abbreviated version of Bett's Questionnaire Upon Mental Imagery (translated into Dutch). The score obtainable on this 35-item Questionnaire ranges from 35 (high imagery ability) to 245 (low imagery ability). Average scores and standard deviations for the High imagers working under imagery, verbal and rote instructions were 72.5 (12.3), 75.9 (11.5) and 75.5 (11.4), respectively; for the corresponding group of Low imagers they were 107.4 (12.5), 103.5 (11.9) and 103.8 (13.2). There was no overlap in the ranges of individual scores between any two subgroups of High and Low imagers.

In case an explicit response was required to the interfering stimuli it consisted in immediately calling out the alternative of the presented digit ("2" when "1" was presented and vice versa). In case no respose was required *S* merely listened to or watched the interfering stimulus. The required response mode to interfering stimuli was fixed within lists and within experimental sessions.

*S*s worked through a total of six lists, each of these preceded by a number of practice pairs. Learning took place in two experimental sessions separated by a 2-hr break.

5.1.5. Results and discussion

A 3x2x3x2x2 ANOVA was carried out on the percentages of response terms *S*s were able to reproduce during the immediate recall test.

Instructional set had a highly significant effect on recall performance (F=23.2, df=2/42, p<0.0001). The effect was due to the rote learning condition, which proved to be inferior to both sets employing mediating devices. Recall percentages were 61.5 for imagery instructions, 53.7 for verbal mediating instructions - which was not significantly different from the percentage for imagery instructions - and 31.2 for rote learning. This confirms the usual pattern reported in the literature (e.g., Elliott, 1973).

Imagery value, I, also had its usual massive effect (F=331, df=1/42, p<0.001), average recall being 67.5% for High I and 30.1% for Low I pairs. Instructional set and I interacted in the way depicted in Fig. 4 (F=12.6, df=2/42, p<0.001). This interaction was due to the deviating pattern obtained under rote learning instructions.

Of theoretical importance was the absence of significant differences between imagery and verbal instructional set as a function of I. This is in disagreement with the prediction from Paivio's dual-mode theory discussed earlier, which says that verbal mediation should be superior to imagery for Low I material, while the reverse should be the case for High I material.

This failure to obtain the predicted pattern could not in some way be explained by underlying higher-order interactions cancelling out at the level of the two-factor interaction, since none of these reached significance. It should also be noted that the history of attempts to demonstrate the predicted pattern at the level of mnemonic *effectiveness* (as contrasted to *availability*; see section 2.3) shows a long sequence of failures (Paivio, 1971, pp. 361-372), except for one experiment in which *S*s were literally forced to produce mediators by having them draw their images and write down their mediating sentences (Paivio and Foth, 1970). However, since this procedure in any case confounds memory for the *image* with memory for the *drawing* it is not clear what interpretation to attach to this result. Moreover, later attempts to replication by Yuille (1973) and by the present author (in preparation) have not been successful.

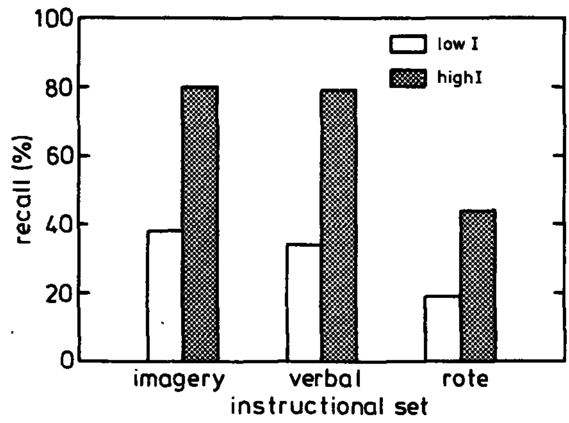

Fig. 4. The instructional set x *I* interaction in Experiment I; it is due to the deviating pattern for the rote instructional set.

The effects of type of interference on recall performance are more directly relevant to the subject of the present investigation. There was a main effect of interference (F=5.58, df=2/84, p<0.01) which showed that interfering stimuli did indeed degrade performance relative to the condition without interference. The amount of interference was the same for auditory and visual stimuli. Average recall was 52.3% for the no-interference condition, 46.2% under auditory interference and 47.8% under visual interference. More important still was the significant interaction between type of interference and *I* (F=3.13, df=2/84, p<0.05), which is shown in Fig. 5. *Auditory* interference affected the recall of Low *I* material in particular, whereas *visual* interference did so for High *I* material. For Low *I* pairs performance under auditory interference was only about 75% of that under visual interference. For High *I* pairs visual interference led to recall performance which was about 90% of that obtained under auditory interference. This differential effect of auditory and visual interference on Low *I* and High *I* stimuli is evidence for the phenomenon of selective interference. The interaction was not further qualified by higher-order effects.

The ANOVA also demonstrated a main effect, in the absence of interactions, of the factor 'explicit vocal response required vs silent inspection' (F=9.03, df=1/42, p<0.01). Average recall was 46.2% with vocalization required and 51.3% under silent inspection. The absence of interactions with this variable makes it probable that Atwood's result cannot be attributed to the requirement

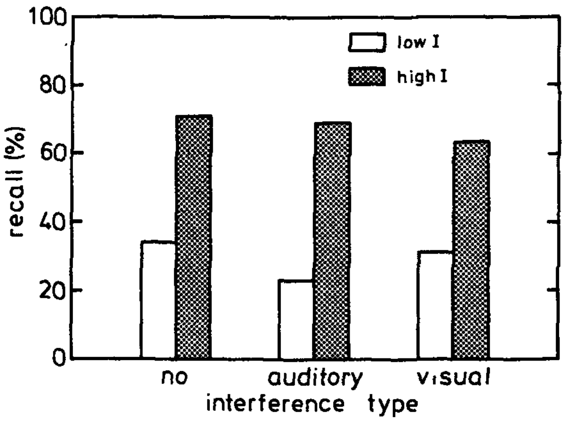

Fig. 5. The interference type x *I* interaction in Experiment I.

that his *S* vocalized a response.

The ANOVA revealed no significant main or interactive effects of imagery ability. One reason for this failure to obtain reliable effects could be that the instructions prompted intentional learning - since *S*s were aware that they would be tested for recall -, whereas empirical results show a tendency that individual differences in imagery ability are of importance mainly under incidental learning conditions (Paivio, 1971, pp. 511-513). Therefore a further exploration of the role of imagery ability during incidental learning was carried out in Experiment II. Another possibility, suggested by Neisser (1970), is that verbal reports of image vividness, as required by the Betts test, are simply of little predictive value for recall.

The main result of Experiment I is the significant interference modality x *I* interaction. This effect should be contrasted with the total absence of any significant second- (or higher-) order interactions involving instructional set or imagery ability together with *I* or interference modality. The appropriate conclusion from this is, in the first place, that it is the position of verbal material on the abstractness-concreteness (*I*) dimension which determines the format in which information is transmitted to and stored away in memory. Mediational strategies, whether specified by instructions or by individual ability, appear not to interact with this format but only serve as carrier or control processes (Atkinson and Shiffrin, 1968). This conclusion is in sharp contrast with the prediction of Baddeley et al. (1975) discussed in section 4.4, and already rejected there for theoretical reasons.

In the second place, the present results suggest that some of the features of concrete material that are transmitted to memory are visual, though non-spatial, in nature. Interestingly, on the other hand, at least part of the features retained of abstract material must be considered to be auditory-verbal in nature.

These conclusions shed some new light on Atwood's finding. We suspect Atwood would have found exactly the same interaction he reported had he reversed instructions, that is, if the group learning abstract phrases had been given imagery instructions and the group learning visual phrases had been given contemplation instructions. This follows because the nature of the material appears to be the crucial factor and not the mediational strategy employed.

5.2. EXPERIMENT II. SELECTIVE INTERFERENCE IN INTENTIONAL VERSUS INCIDENTAL LEARNING(1)

This experiment served the twofold purpose of replicating Experiment I and of introducing the intentional versus incidental learning distinction. The reasons to include incidental learning were, first, to allow the individual imagery ability variable to manifest itself under a possibly more appropriate condition and, second, to maximize the probability of *S*s sticking to a prescribed instructional set by minimizing the pressure towards high recall performance inherent in intentional learning.

5.2.1. General design

There were a few departures from the procedure and the design of Experiment I which will become apparent from the description of the experimental set-up. The variables included in the experimental design were: (a) task orientation (incidental versus intentional), a between-*S*s variable; (b) instructional set (imagery versus verbal mediation), also a between-*S*s variable; rote instructions were not included because they already had sufficiently served their control function in Experiment I; (c) imagery ability (High versus Low); (d) modality of the interfering task (auditory versus visual), a within-*S*s variable; no condition without interference was included because this would have made the single experimental list to be learned unwieldily long; (e) *I* (both nouns High *I* versus both Low *I*), also a within-*S*s variable.

5.2.2. Subjects

Seventy-two students from Utrecht State University, none of whom had taken part in Experiment I, served as *S*s. They were paid Hfl 6,-- per hour and they were run in groups of 9 under a fixed combination of task orientation and instructional set.

5.2.3. Material

The inclusion of a group of *S*s learning incidentally dictated that all within-*S*s variables had to be varied within a single list. The list consisted of 16 High *I* (>6.0) and 16 Low *I* (<3.0) noun pairs. Two Medium *I* pairs each ($4.0<I<5.0$) were added to the beginning and the end of the list.

Within each group of 16 pairs 8 were followed by an auditory and 8 by a visual interfering stimulus in the way described in the Method section under Experiment I. The list was divided in 4 blocks of 8 pairs in such a way that within a block there were always 2 Low *I* pairs + auditory interference, 2 Low *I* pairs + visual interference, 2 High *I* pairs + auditory interference and 2 High *I* pairs + visual interference. Pair order within blocks was random with the restriction that no combination of *I* and interference modality occurred two times in sequence. The purpose of composing the list in this way was to make it balanced with respect to the positions taken by pairs of different *I* and followed by different types of interference. *S*s reacted to the interfering stimuli by mouthing the digit that was *not* presented.

The list was recorded on tape and presented through loudspeakers. Presentation rate was one pair per 10 sec. Compared to Experiment I the interval between interference and presentation of the next pair was extended by 2 sec to give *S*s sufficient opportunity to perform the orienting task. This task consisted in pressing a button when *S* felt he had completed developing an interactive image or phrase (sentence). *S*s were informed that their reaction to the interfering stimulus had priority over mediator development. The sequence of events for a presentation cycle was identical to that in Experiment I (except for the extra 2 sec). Written recall was tested by presenting stimulus pair members at a rate of 1 per 5 sec.

5.2.4. Procedure and design

Instructions were the same as in Experiment I, with the exception that only those *S*s working under intentional learning conditions were informed prior to list presentation that recall would be tested. *S*s under both learning conditions were told that the orienting task served the purpose of gathering data on latencies of mediator generation. Actually no such measurements were collected.

Following the experimental design 8 subgroups of 9 *S*s each were selected on the basis of their score on the abbreviated version of Betts' Questionnaire. The grand average score for the High imagers was 72.3 (SD=10.8); the four subgroups of High imagers were approximately matched on this score. For the Low imagers the average score was 106.1 (SD=12.9); again the four subgroups were approximately matched. No overlap in score existed between any two subgroups of High and Low imagers.

5.2.5. Results and discussion

No *S*s in the incidental condition indicated that they had expected the recall test. The 2x2x2x2x2 ANOVA conducted on the percentage of response terms correctly recalled revealed a single main effect and two significant two-factor interactions. The main effects was that of *I* (F=343, df=1/32, p<0.0001), recall for High *I* pairs being almost four times better than that for Low *I* pairs (56.9% versus 15.8%).

The significant interference modality x *I* interaction obtained in Experiment I was replicated (F=14.2, df=1/32, p<0.001); see Fig. 6. For Low *I* pairs recall decreased by about 35% under auditory interference (measured relative to the visual interference condition as a base-line). For High *I* pairs recall improved by about 15%, relative to the visual interference condition.

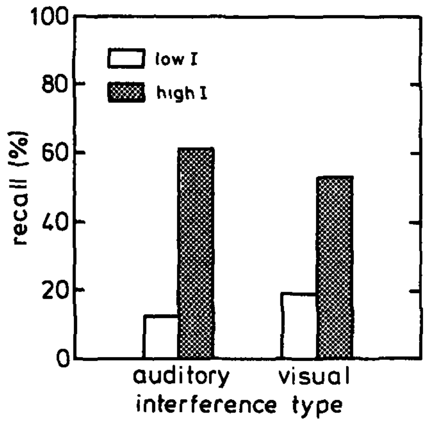

Fig. 6. Confirmation of the interference type x *I* interaction in Experiment II.

The second significant interaction was between task *orientation* and imagery ability (F=5.11, df=1/32, p<0.05); see Fig. 7. Imagery ability was unrelated to intentional learning, but High imagers were superior in incidental learning. This replicates the pattern reported by Ernest and Paivio (1969). Although interesting in itself this interaction does not appear to have any theoretical significance in the context of this study, and it will not be discussed further.

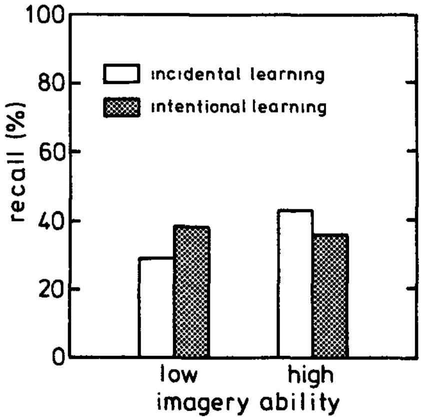

Fig. 7. The interaction between imagery ability and task orientation (Experiment II)

There was a suggestion of an instructional set x I interaction in the data, the pattern being that verbal mediation suffered particularly from auditory interference and that imagery mediation was somewhat worse with visual interference. However, this was not significant (F=1.83, df=1/32, p<0.20).

The absence of any effects involving instructional set or imagery ability together with I or interference modality thus confirms the negative results obtained in Experiment I and again shows the overwhelming influence of the material's position on the imageability continuum. The fact that task orientation (intentional vs incidental) also did not interact with any of these variables except imagery ability provides still further support for the relative unimportance of mnemonic strategy with regard to the selective interference phenomenon.

5.3. EXPERIMENT III. SELECTIVE INTERFERENCE IN FREE RECALL[1]

The purpose of Experiment III was to investigate whether similar findings as in the previous experiments would be obtained in another paradigm, viz. free recall of single nouns.

5.3.1. General design

The variables included in the design were: (a) instructional set, a between-*S*s variable; a broad range of instructions was used in order to generalize possible conclusions on the effects of instructional set; this included instructions to form a visual image to each separate noun (isolated-imagery set); to form a visual image linking several nouns at once (interactive-imagery set); to generate a verbal associate to each separate noun (verbal set); and a control condition in which no mediational strategy was specified; (b) imagery ability (High versus Low); (c) type of interference (none, auditory or visual), a within-*S*s variable; (d) *I* (Low, Medium or High), also a within-*S*s variable.

5.3.2. Subjects

A group of forty-eight *S*s, all students from Utrecht State University, took part in the experiment. Ten of them had also taken part in Experiment I. They were paid Hfl 6,-- per hour and were run individually.

5.3.3. Material

Three experimental lists consisting of 24 nouns each were constructed. In each list there were 8 Low *I* (<3.0), 8 Medium *I* ($4.0<I<5.0$) and 8 High *I* (<6.0) nouns. Two Medium *I* nouns each were added at the beginning and the end of each list.

Lists were recorded on tape and presented through headphones at a 2-sec rate. Interference followed immediately after the presentation of a noun, that is, on the second 'beat' of the presentation interval. *S*s were required to react immediately by calling out the figure that was *not* presented.

5.3.4. Procedure and design

Instructional set was varied among four groups of 12 *S*s each. Isolated-imagery instruction stressed the need to form a visual image to each separate noun so that later retrieval of the noun through the image would be possible.

Interactive imagery instructions asked the *S*s to form images incorporating a sequence of several nouns, the length of which was not specified, so as to be able to retrieve each of them later. Verbal mediational instructions required the *S*s to (silently) produce a verbal associate to each noun as an aid to later retrieval. No mediational strategy was specified for the remaining group of *S*s.

All *S*s were informed that they would be tested for recall immediately after the completion of a list presentation; 90 sec were permitted for written recall. *S*s were free to write the items recalled in any order.

Within each group of *S*s 6 were High and 6 were Low imagers. The grand average score on Betts' Questionnaire for the High imagers was 70.5 (SD=12.3) and for the Low imagers it was 108.3 (13.4). Subgroups within levels of imagery ability were approximately matched with respect to their scores. No overlap in the range of scores existed between any two subgroups of High and Low imagers.

Each *S* was presented all three lists, one under each type of interference. Type of interference was fixed for the presentation of a list. Appropriate counterbalancing over *S*s ensured that all lists occurred equally often under each type of interference.

Learning took place within a single experimental session, which started with a number of familiarization trials.

5.3.5. Results and discussion

The 4x3x3x2 ANOVA carried out on the percentages correct recall revealed main effects of *I* (F=53.1, df=2/80, p<0.0001) and of interference type (F=27.6, df=2/80, p< 0.0001). Percentages recall for the three levels of *I* were 48.3 (Low), 59.9 (Medium) and 62.6 (High). No difference in recall existed between High and Medium *I* nouns, but both were significantly different from Low *I* nouns. The difference between free recall for High and Low *I* nouns had been demonstrated earlier by Paivio, Yuille and Rogers (1969). It was somewhat unexpected that Medium *I* nouns were not recalled worse than High *I* nouns. The suggestion is that the 7-point scale on which the nouns were originally rated for *I* by the norm sample (see the Appendix) is not linearly related to imagery-evoking capacity. This is supported by the latency data presented in the Appendix, which show no impressive further decreases in latencies from ratings for *I*=4.5 upwards (Fig. 18). That there was no difference between the four instructional sets was somewhat unexpected, in particular since Morris and Stevens (1974) have shown that imagery facilitates recall when the images which are formed link images together. The discrepancy may have resulted from the rather fast presentation rate (1 per 2 sec) in the present experiment. A tendency in the expected direction, however, was nevertheless visible in our data (average percent correct: isolated-imagery 53.2, interactive imagery 58.6, verbal mediation 54.6, and no strategy specified 58.5%).

The pattern found in the PA-experiments was confirmed by the presence of a significant interaction between type of interference and *I* (F=3.75, df=4/160, p<0.01), which is shown in Fig. 8. An extension of the pattern found in the PA-experiments was provided by the behavior of the Medium *I* nouns, for which the datapoints assumed neat positions between the datapoints for Low and High *I* nouns.

Again there was an absence of reliable interactions between type of interference on the one hand and instructional set or imagery ability on the other. This confirmed the findings of the PA-experiments.

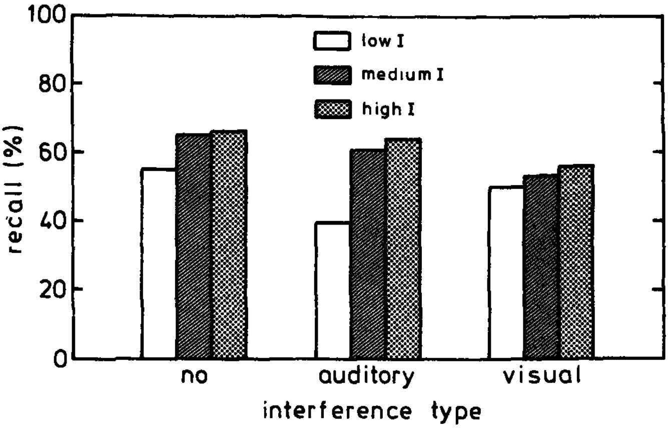

Fig. 8. The interference type x *I* interaction in Experiment III.

5.4. EXPERIMENT IV. SELECTIVE INTERFERENCE DURING RETRIEVAL(2)

The experiments described thus far have concentrated on the acquisition stage of learning, i.e., the stage in which mediators are generated. The aim of Experiment IV was to establish whether selective interference would also occur during the *retrieval* stage. If so we would have evidence that what was retrieved from memory was, at least partially, stored in a format containing sensory features. It would then follow that the visual components of images generated at the acquisition stage are not wiped out by subsequent coding processes (although, of course, the possibility would not be eliminated that images generated at the time of acquisition are translated into some other code and are generated anew at retrieval on the basis of that code).

5.4.1. General design

The experiment once more involved a one-trial mixed-list PA-memorization task. Variables investigated for their effect on retention were: (a) instructional set (imagery versus verbal mediation), which was a between-*S*s variable; (b) interference type at retrieval (none, auditory or visual), a within-*S*s variable; (c) *I* (both nouns Low *I* or both High *I*), also a within-*S*s variable.

5.4.2. Subjects

Twenty-six students from Utrecht State University were hired at Hfl 6,-- per hour and were run individually. All of them had previously taken part in Experiment I.

5.4.3. Material

Experimental lists consisted of 16 noun pairs each, 8 of these being of High *I* value (>6.0) and 8 of Low *I* value (<3.0). Four Medium *I* pairs (4.0<*I*<5.0) were added to each list, two at the start and two at the end.

Three such lists were constructed and recorded on tape. They were presented through headphones at an 8-sec rate. At the written recall test stimulus terms were presented auditorily at a 10-sec rate. On the third second of the recall interval the interfering stimulus was presented, to which *S*s had to react by calling out the digit that was *not* presented. Interference modality was fixed during recall of a list.

5.4.4. Procedure and design

Instructional set was varied between two groups of 13 *S*s each. Imagery and verbal mediation instructions were given as in the previous PA-experiments. Every *S* worked through all three lists, each of these preceded by a number of practice pairs. Learning took place in three experimental sessions separated by breaks lasting about ten minutes.

5.4.5. Results and discussion

A 2x3x2 ANOVA was performed on the percentages of correct recall. Two by yet fairly trivial main effects were obtained. First, there was the usual effect of *I* (F=171, df=1/24, p<0.0001). Second, there was the expected main effect of interference type (F=3.83, df=2/48, p<0.025), which showed that auditory and visual interference degraded performance relative to the no-inter-

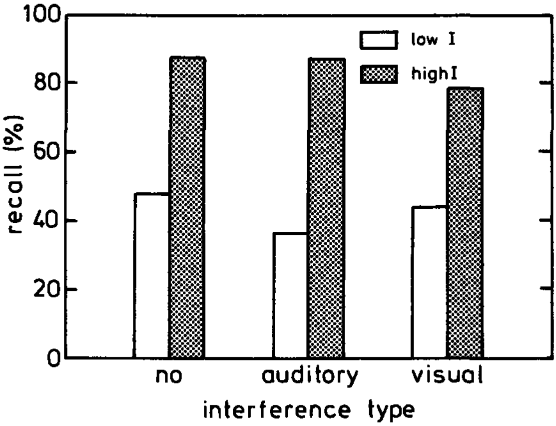

Fig. 9. The interference type x *I* interaction at retrieval (Experiment IV).

ference condition by an overall equal amount.

Two highly relevant interactions reached significance. One was the *I* x interference type interaction (F=4.36, df=2/48, p<0.025). The relevant data are shown in Fig. 9. The second significant interaction was between interference type and instructional set (F=4.35, df=2/48, p<0.025); see the data in Fig. 10. The instructional set x *I* interaction was not significant (F<1).

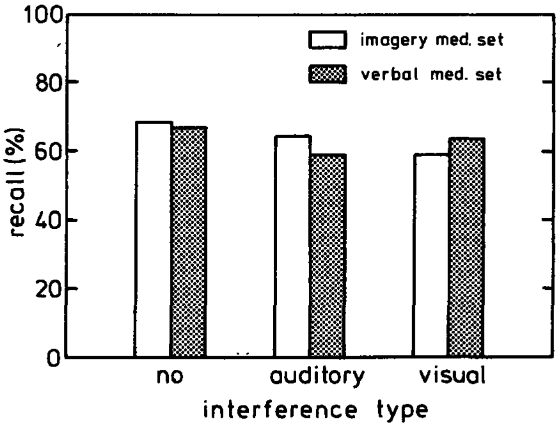

Fig. 10. The interference type x mediational set interaction at retrieval (Experiment IV).

Selective interference manifested itself in the results both with respect to the imageability dimension and with respect to the mediational strategy applied by the *S*s. That is, High *I* material suffered especially from visual interference, in particular when an imagery strategy had been applied. Low *I* pairs, on the contrary, suffered selectively from auditory interference, in particular after the use of a verbal mediating strategy.

The finding of an *I* x interference modality interaction confirms what has been found for the acquisition stage of learning. It indicates once more that at least part of the features retained when verbal material is stored in memory by means of a mediation strategy is sensory in character.

The finding of an interference modality x mediational set interaction was somewhat unexpected, since mediational set had been shown not to be subject to selective interference in the acquisition stage (Experiments I, II and III). Thus, the same stimulus that produces selective interference with mediational sets during the retrieval stage is apparently not sufficiently strong to do so during mediator generation at the acquisition stage. One reason for this may be that retrieval in general requires more effort than acquisition, so that whatever effects of interference there are have a better chance to become manifest at retrieval. Another possibility is that mediator retrieval (both of images and verbal mediators) involves processes which are of an even more modality-specific character than mediator generation, so that selective interference in the form of an interference modality x mediational set interaction would be easier to demonstrate at retrieval. According to this view the search for an image in memory would have to be carried out by a scanning mechanism which relies heavily on the identification of sensory features in order to find those images which are critical for recall.

The conclusion to be drawn on the basis of the present experiment is that modality-specific interference occurs during the retrieval of visual images. Since the previous experiments have shown that it also occurs during the acquisition stage of learning one may suspect, therefore, that the sensory characteristics of visual images are retained along the entire route from acquisition to retrieval. An alternative which remains to be eliminated, however, is that images generated at the time of acquisition are translated into some other code and could be generated anew at retrieval on the basis of that code.

5.5. EXPERIMENT V. SELECTIVE INTERFERENCE AND INTERFERING STIMULATION WITH A SPATIAL COMPONENT

The pattern of selective interference should occur at its clearest, according to our theoretical reasoning, when *both* tasks have either a strong spatial or nonspatial component; it should not, or hardly, be present at all when one task is mainly spatial and the other mainly nonspatial.

The final experiment to be described in this chapter tested this prediction by extending the types of interference used thus far (auditory or visual presentation of a digit) with a spatial visual-motor task. If the prediction is correct there should be no extra effect of a spatial task on the retention of High *I* pairs. That is, there should be no interaction between *I* and the spatial/nonspatial variable. Auditory digit presentation, however, should show a larger difference in recall between Low and High *I* pairs than both visual tasks.

5.5.1. General design

The one-trial mixed-list PA task involved the following variables: a) instructional set (imagery versus verbal mediation), a between-*S*s variable; b) interference type (auditory, nonspatial visual or spatial visual), a within-*S*s variable; c) *I* (both nouns Low *I* or both High *I*), also a within-*S*s variable.

5.2.2. Subjects

Fifty-four students from Utrecht State University were hired at Hfl 6,-- per hour. They were run in groups of nine.

5.5.3. Material

Three experimental lists consisting of 16 noun pairs each were constructed as in the previous experiments. Auditory presentation rate was one pair per 10 sec. Auditory and nonspatial visual interfering stimuli were presented as in Experiments I and II. No reaction was required from the *S*s. Spatial visual interference consisted in tracking irregularly drawn lines on a piece of paper with a pencil. Lines had their origin at the left-hand side of the paper and were to be tracked to their end point at the right-hand side (see Fig. 11). *S*s were instructed to work on this task in the interval between successive pair presentations.

Type of interference was fixed during the presentation of a list. Immediate written recall was tested by auditorily presenting stimulus members from tape at a 5-sec rate.

5.5.4. Procedure and design

Instructional set was varied between two groups of 27 *S*s each. The procedure was identical to that of Experiment I. Learning took place in a single experimental session. The three lists and the three interference conditions were combined and distributed over *S*s according to a Latin square design.

5.5.5. Results and discussion

The ANOVA yielded two significant main effects. One was that of *I* (F=282.0, df=1/52, p<0.00001), the other that of type of interference (F=114.0, df=2/104, p<0.00001). The latter effect showed that the spatial visual task was considerably more difficult than both other tasks.

These main effects were qualified by the significant *I* x type of interference interaction shown in Fig. 12 (F=5.04, df=2/104, p<0.01).

The theoretically important aspects of this interactive pattern are (1) the nonspatial visual interfering task degrades performance relative to the auditory interfering task for High *I* but not for Low *I* pairs, (where it does the opposite) - a replication of the pattern found in the previous experiments; and (2) the spatial interfering task only subtracts a constant amount from the performance obtained under the nonspatial interference condition. That is to say, spatial interference has no specific extra effect on the retention of concrete material lacking spatial organization. It has only a general effect, to be interpreted as being due to an increase in general processing load. We conclude, therefore, that the result of this experiment supports the theoretical distinction between spatial and nonspatial features in visual images.

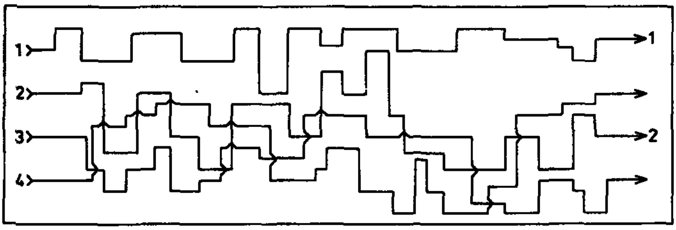

Fig. 11. Sample of the distractor task used in Experiment V.

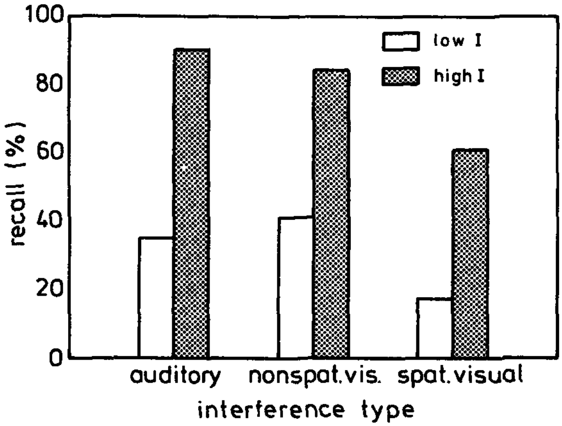

Fig. 12. Interference effects for a relatively nonspatial task (Experiment V).

5.6. CONCLUSIONS

The results of the five experiments described in this chapter can be summarized as follows:

(1) Modality-specific (selective) interference is a reliable phenomenon occurring both at the acquisition and the retrieval stage of memorization. It is to be found in PA learning as well as in free recall.

(2) Selective interference at acquisition manifests itself as an interaction between *I* and modality of the interfering stimulus. At retrieval the instructional set x interference modality interaction also occurs.

(3) Imagery ability is not a variable involved in the selective interference phenomenon.

(4) The occurrence of selective interference does not depend on whether memorization is incidental or intentional.

(5) With the nonspatial type of memorization task studied there is no extra effect of spatial visual interference (compared to nonspatial visual interference) on the retention of High *I* noun pairs as compared to Low *I* pairs.

Results (1) and (2) support the notion that the images that are generated in certain common memory tasks are of a visual nature, as indicated by the disruption caused by a simultaneously performed visual perception task. A necessary further qualification of this statement is provided by result (5), which shows that the visual features that play a role in this kind of image are *not* of the spatial type. Thus, taken together results (1), (2) and (5) provide at least tentative evidence for the viewpoint that there are relatively independent spatial and nonspatial components in visual images and that these may indeed rightfully be discribed as 'visual'.

Results (3) and (4), as well as the result that mediational strategy could not be shown to be a relevant variable at acquisition, are evidence that the processing of stimuli which differ on the I-dimension is a relatively autonomous activity. That is, the properties of the internal representation ultimately evoked are not affected by the strategy by which access is gained to it.

CHAPTER 6

THE SPATIAL COMPONENT OF THE VISUAL IMAGE

Summary

This chapter examines the spatial features of visual imagery. Most crucial for the theoretical ideas presented earlier is Experiment VI, in which it is shown that spatial visual stimulation interferes selectively with spatial imagery, while the effect of nonspatial visual stimulation works in particular on non-spatial imagery.

Experiment VII demonstrates a small effect of the opportunity to make eye movements on the ease of generating visual images to isolated static nouns. The effect was considerably larger in Experiment VIII, in which Ss had to imagine moving objects.

6.1. EXPERIMENT VI. THE CRUCIAL INTERACTION

The notion that visual images may possess spatial attributes has not received abundant attention in the psychological literature, although many mnemonical techniques from antiquity are known to have relied on it. Informal evidence for the role of such components in some kinds of imagery, however, can be found in some places. Consider this example from Paivio: "Occasionally, when I have to list the names of my colleagues from memory, I have found myself visualizing the hallways in which their offices are located, systematically moving past these offices, then picturing and naming the occupant" (1971, p. 3). Another example is a request for the reader to enumerate the windows in his house (Shepard, 1966). Most people report that they have to imaginally move around the house, visualizing and counting the windows. Meudell (1971) presents evidence that response latency measured when people are asked this question does increase linearly with the number of windows counted. Berlyne (1965) as an other example suggests that, if a person is asked to name the States of the U.S.A. in a line from California to New York City, he would most likely do it in stages by successively imagining areas in a West to East direction and that the " ... stages will be linked to one another by processes that are clearly equivalent to the eye movements ... which he would have used if he had been examining an actual map of the United States and reading off the names of the states from it" (p. 142).

The final experiment reported in the previous chapter already yielded some evidence on the distinction between the spatial and nonspatial aspects of visual images. This chapter contains the results of three studies aimed somewhat more directly at the spatial component of visual imagery. The first experiment is an extension and modification of Byrne's experiments (1974) discussed in section 4.4.

Byrne (1974) showed that visual conflict occurred whenever items (words or pictures) were arranged spatially and that it was relatively independent of item concreteness. However, he always used a *spatial* interfering task (which was compared to a *verbal* interfering task). Highly relevant to the model of the image as a feature network would be the experiment in which spatialness/nonspatialness of the visual imagery task is factorially combined with the spatialness/nonspatialness of the visual interfering task. If the distinction between independent spatial and nonspatial factors is valid an interaction should emerge. Experiment VI was designed to test this prediction.

6.1.1. General design

While Byrne measured categorization times the present experiment was designed as a memorization study in order to maintain continuity with the other experiments reported in this thesis. Variables were: (a) the format of the stimulus presentation (spatial versus nonspatial); (b) the mode of categorization during stimulus presentation (spatial versus nonspatial). Both were between-*S*s variables.

6.1.2. Subjects

Four groups of 10 Utrecht State University students acted as paid volunteers (Hfl 6,-- per hour). *S*s were run individually.

6.1.3. Material

The matrix of drawings employed in Byrne's Experiment V (1974), (indicated as "PIGMATRIX"), was used (see Fig. 13). Separate drawings of each object were prepared for presentation in the nonspatial condition.

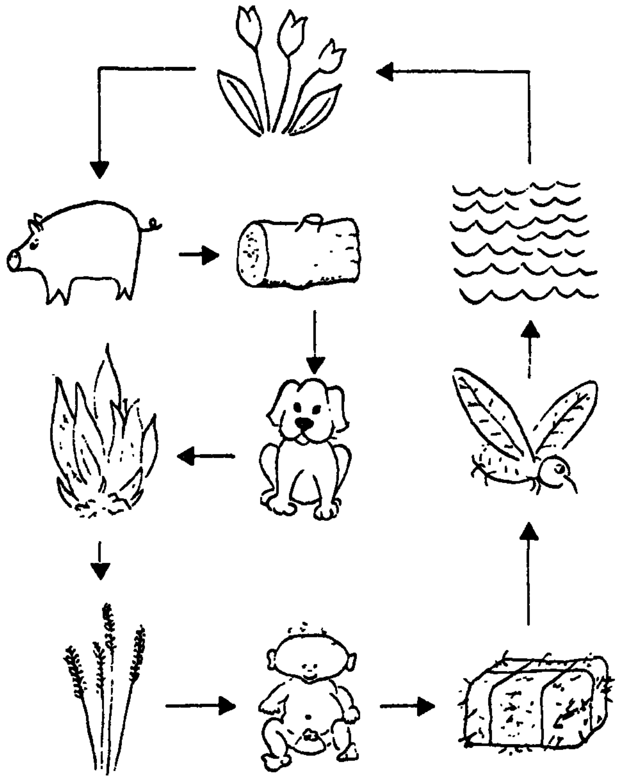

Fig. 13. "PIGMATRIX" (from Byrne, 1974).

6.1.4. Procedure

The procedure breaks into three main parts: (1) introduction to and practice in categorizing words during stimulus presentation; (2) presentation of the matrix drawing (spatial format) or the separate drawings (nonspatial format) in combination with either the spatial or the nonspatial categorization response mode; and (3) immediate written recall of the names of the items.

Half the *S*s (the spatial group) received instruction and practice in categorizing items and at the same time memorizing them from a matrix drawing. E informed the *S* that he would show him a matrix drawing and that he could be asked whether or not each individual drawing referred to an animal. The matrix contained drawings of the following items: *snow, cat, train, boy* and *bus*.
To half the *S*s in the spatial group E demonstrated the pointing categorization response. He first pointed to the individual drawings at a 3-sec rate and sig-

naled the appropriate response for the category *animal* by pointing to a response sheet in the fashion indicated in Fig. 14. The *S* demonstrated his understanding for the category of *man-made* objects in the same way.

The other half of the *S*s in the spatial group were merely told to watch E's pointings for both the categories *animal* and *man-made* and to check how many errors he made. E in fact made some errors on purpose in the practice stage, with the expectation that this would maintain *S*'s alertness for the forthcoming tasks.

At this point all *S*s in the spatial group were required to memorize a new matrix (consisting of drawings of *mouse, chair, rock, horse* and *table*) while E pointed to the individual drawings at a rate of one per 3 sec. *S*s were instructed to memorize as many items as possible by means of maintaining a visual image of the entire matrix of drawings. Half the *S*s were required to check the E's categorization at the same time. E made one error on purpose. The other half of the *S*s categorized by pointing to a response sheet themselves. Categorization bases that were practiced were *animal* and *man-made*.

The acquisition phase of the memorization task for this spatial group was as follows: E placed "PIGMATRIX" before *S*, having announced to him that it constituted the material to be learned, and that he had to apply visual imagery to memorize the entire matrix. E started at a different point in the matrix for each *S*, but always followed the arrows linking the drawings. Categorization was in terms of *animal*. As described above either E or the *S* himself pointed to the response array. E did not make errors at the acquisition trial so as not to burden the *S* with having to keep track of the errors made.

The procedure described thus far for the spatial group was duplicated for the group which received separate drawings (the nonspatial group), with the exception that these *S*s were instructed to maintain isolated visual images of each separate drawing.

After the acquisition phase both groups of *S*s were permitted 45 sec for immediate written recall, regardless of original presentation order, of the names of the objects they could remember. After completion of the recall phase E checked *S*'s recall to see whether he (the E) could in all cases identify to which drawing a written response referred. In a very few cases it appeared necessary afterwards to ask *S* which drawing he had meant to indicate.

As an additional measure to the recall scores E recorded the time that elapsed from the start of the recall interval to the moment *S* started writing

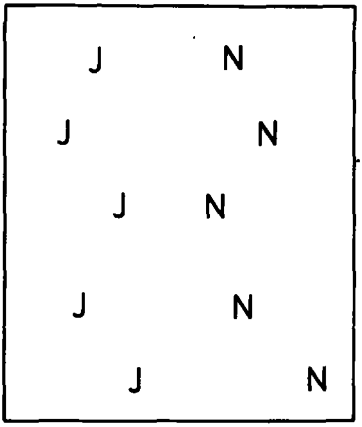

Fig. 14. Form of response sheet for visually guided response. In the main part of the experiment a similar 10-line sheet was used. Pointing was done with a pen. Pointing was done downward from the top of the sheet for each successive item. J = 'yes' (positive instance of category), N = 'no' (negative instance of category).

down his third recalled item. This particular item was selected because it was felt that all *S*s would recall at least three items, an assumption which turned out to be correct.

6.1.5. Results and discussion

Both ANOVAs, that on the recall data and the latencies, showed a significant interaction between the spatial vs nonspatial representation format and the spatial vs nonspatial categorization response (F=9.13, df=1/36, p<0.01 for the recall data; F=7.88, df=1/36, p<0.01 for the latencies). The data are shown in Figs. 15 (a) and (b). The interaction has the same pattern in both cases although only the latency data show an actual cross-over. The data do not contradict the notion that relatively independent spatial and nonspatial features are the components of visual images. A spatial imagery task, or more precisely, an imagery task having a spatial component in addition to a nonspatial component, is interfered with relatively more by a spatial task than a nonspatial imagery task.

In the recall data significant main effects were apparent for the type of imagery (spatial imagery leading to higher recall than nonspatial imagery: F=4.51, df=1/36, p<0.05) and for the type of categorization response (pointing

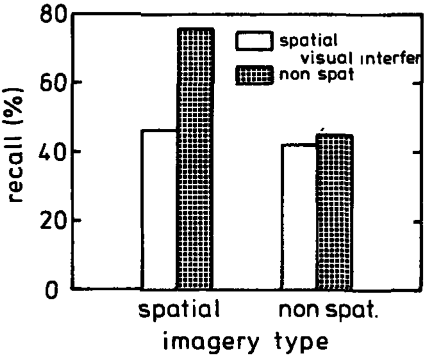

Fig. 15(a). Recall as a function of imagery and interference type (Experiment VI).

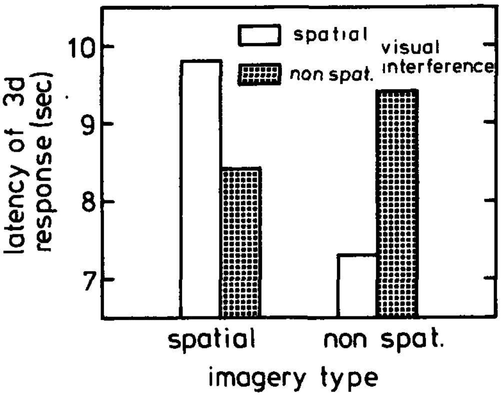

Fig. 15(b). Latency of third written response, ditto.

being inferior to just observing the E: F=4.31, df=1/36, p<0.05). No such effects were found in the latencies.

6.2. EXPERIMENT VII. EYE MOVEMENTS AND VISUAL IMAGERY IN FREE RECALL[3]

In the experiment by Hale and Simpson (1971) discussed in section 4.5 no relationship was found between the opportunity to make eye movements or not and the latency and vividness of image generation. In the experiment by Hall (1974b) such a relation was found in an imagery task in which spatial organization was a salient dimension. The conclusion was that traditional tasks like PA and free recall learning of nouns by means of imagery do not involve a very strong spatial component. Yet we decided to carry out an experiment studying the role of eye movements in visual imagery for single nouns. The purpose of this experiment was to establish what happens if a spatial factor is imposed upon a relatively nonspatial imagery process, and to compare this with the 'bare' nonspatial task. This was attempted to be achieved by explicit instructions to attend to the internal spatial structure of an image, i.e., to scan the image by means of eye movements. This procedure would permit an estimate of the maximum amount of spatial information that a relatively nonspatial image can contain.

The experimental task was free recall of isolated nouns of various I-value (Low, Medium and High I). If instructions to make scanning eye movements strengthen the weak spatial component normally present in the kind of imagery associated with this task this should be reflected in the recall scores.

6.2.1. General design

There were three treatment conditions: (a) the *S*s were instructed to look over and scan their images freely as if they were inspecting the real object (FREE condition); (b) the *S*s were instructed to inspect a checkerboard pattern while imaging (CHECK condition); (c) the *S*s were instructed to fixate on a target while imaging (FIX condition). Treatment conditions were varied within *S*s. Under all treatment conditions *S*s were instructed to form a visual image to each separate noun that was presented. All *S*s were given repeated presentations of lists in order to follow the development of performance over trials under different treatment conditions.

6.2.2. Subjects

The *S*s were 18 Utrecht State University students from the Institute's pool of *S*s, and they were paid Hfl 6,-- per hour.

6.2.3. Material and apparatus

Three equivalent experimental lists of 24 nouns each were constructed. Within each list there were 8 Low *I*, 8 Medium *I*, and 8 High *I* nouns. Average *I*-values were 2.2, 4.5, and 6.6, respectively, with ranges 1.5-2.5, 4.0-5.0, and 6.2-6.9 . An equivalent fourth list was constructed for use in training only. Of the three experimental lists four versions were tape recorded, with a different random word order in each version. Words were spoken at a 2 sec rate and were pronounced within a 1 sec interval. Six sec prior to the first word of a list a 1000 cps 0.5 sec warning tone was presented, and the list was concluded by the same tone at the instant when the 25th word would have occurred.

Horizontal eye movements were monitored by means of electrodes attached to the outer canthus of each eye. The ground electrode was attached to the center of the forehead. The EOG's were amplified and recorded on one of the channels of a Watanabe oscillograph. In order to minimize movement artifacts *S* was seated in dental chair with his head resting in a head clamp. A slide projector located above and behind *S*'s head provided a uniformly lighted field of vision on a projection screen in an otherwise dark room. The screen was approximately 1.5 m in front of the *S*, and its dimensions were approximately 80 x 80 deg. In the FIX condition a removable target of 1 deg diameter was fastened to the center of the screen. In the CHECK condition a checkerboard pattern with 3 x 3 deg black and white squares was projected onto the screen.

In the FREE condition only the blank field was shown. The tape recorder that presented stimuli to the *S* was coupled to one channel of the oscillograph, so that stimuli were graphically represented on the chart paper. A second tape recorder recorded *S*'s oral recall.

6.2.4. Procedure

*The Ss were tested individually. After applying the electrodes and cali*brating the apparatus *S* received his instructions. He was told that he would hear series of 24 nouns and that he would have to form an appropriate image to each word, even though this might be difficult in some circumstances. (As examples E gave the words "chair" and "communist"). *S* was told that he would have to recall as many words as possible, in any order, within a 90 sec interval following the presentation of a list. Order of treatments and lists within treatments was counterbalanced across the 18 *S*s. Each list was presented four times, with a different word order on each trial. A trial with the training list under the appropriate treatment condition preceded the experimental trials. Different treatment conditions were run in separate sessions. Two *S*s were tested alternatively. While one *S* was being tested, the other paused.

Recalibration of the apparatus took place at the start of each treatment session, and also between trials.

6.2.5. Results

Recall performance

Recall scores were obtained from the tape recordings made during the experimental sessions. Although there were four trials only the result of the first trial will be presented here in order to maintain continuity with the other one-trial memorization studies reported elsewhere in this thesis. The reader is referred to Janssen and Nodine (1974) for the analysis of the data for trials 2-4. The 3x3 analysis of variance compared the three treatments and the three types of nouns on the average recall scores[(4)]. The ANOVA showed a significant effect of *I* (F=21.0, df=2/34, p<0.001). By a Newman-Keuls test no difference in recall was found between High and Medium *I* nouns, but both were significantly different from Low *I* nouns.

The FREE condition was found to lead to a somewhat higher recall score than both the other conditions (between which there was no difference in recall). Percent recall was 44.3 for the FREE condition, 37.7 for the FIX condition and 35.2 for the CHECK condition (F=5.90, df=2/34, p<0.01). The treatment by *I* interaction (Fig. 16) indicated that the FREE condition improved recall to High

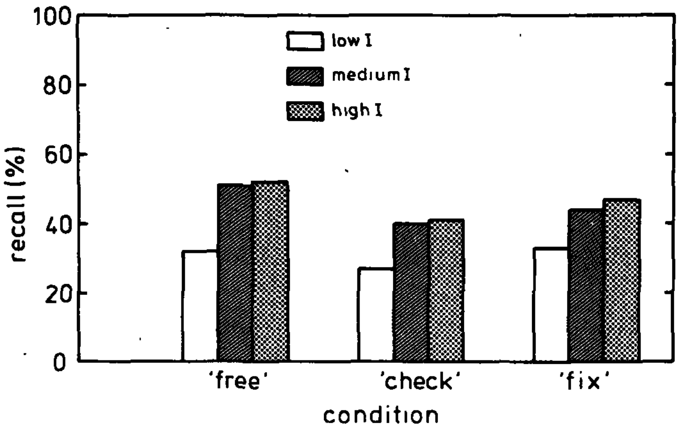

Fig. 16. Recall performance as a function of treatment conditions and *I*.

and Medium *I* nouns more, relative to Low *I* nouns, than the other treatment conditions (F=3.28, df=4/68, p<0.05).

Eye movements

The EOG records were inspected to determine how many eye movements had occurred under different treatments, and in particular, to check whether *S*s had complied to the instructions in the FIX condition. An eye movement was counted whenever there was a deflection of at least 3 deg followed by a fixation of at least 0.2 sec duration. Eye movements were counted over the period from the beginning of the first word to the end of the list as indicated by the tone.

On the average, 0.7 eye movements per *S* were made during a list presentation (a trial) in the FIX condition; 11 *S*s did not make a single movement at all, and the worst *S* made 5 eye movements. In the FREE condition *S*s made an average of 66.0 eye movements per trial, the range being from 31 to 113. In the CHECK condition the average was 57.3, with a range from 3 to 118. The difference between the FREE and CHECK conditions on the one hand and the FIX condition on the other was, of course, clearly significant (t=9.61 and 8.50, df=17, p<0.001). The FREE and CHECK conditions differed at the 0.10 level (t=1.74, df=17), indicating that the attempt to introduce concurrent visual stimulation in order to reduce eye movements was moderately successful.

Product-moment correlations were computed across *S*s, for the FREE and CHECK treatments, between the number of eye movements made during presentation of a noun list and the score on subsequent recall. These correlations were negligibly low (from -0.09 to +0.26, *df*=17); however, all except one were positive. Since these correlations were computed across *S*s, therefore, the eye movement data were examined somewhat more closely in order to investigate the possibility that there were nevertheless underlying relationships between number of eye movements made and performance. This was done only for the FREE condition, as it was judged to be unfeasible to separate eye movements due to imaging activity from those due to inspection of the checkerboard pattern in the CHECK condition.

Numbers of eye movements to individual nouns in the FREE condition were determined by considering activity during the 1 sec silent interval following the presentation of a noun. (This count was possible because the noun presentations were indicated on the chart paper of the oscillograph).

The ANOVA over these data resulted in a significant effect of *I* (F=3.66, df=2/32, p<0.05). The average numbers of eye movements made were 18.3, 17.9 and 16.2, for High *I*, Medium *I* and Low *I* nouns respectively.

The relationship between the amount of eye-movement activity and recall performance was analyzed, for the FREE condition, by dividing the recall score for each *S* on each trial into a part associated with preceding eye-movement activity below the median activity during that trial, and a part associated with activity above the median. Median activity was defined in terms of the distribution of the number of eye movements made to individual nouns by a particular *S* on a particular trial.

On the average 45.8% of a *S*'s recall was associated with eye movement activity below the median, and the remaining 54.2% with activity above the median. By a *t*-test this difference was no more than suggestive of the existence of a relationship (t=1.83, df=16, p<0.10).

6.2.6. Discussion

The main conclusion to be drawn from the analysis of the recall scores is that the effects of eye movement conditions, although statistically reliable, produced only minor differences in performance. While a large number of eye movements was made in the FREE condition, as compared to almost none in the FIX condition, the resulting difference in recall performance was not all that dramatic (44.3 versus 37.7%). And there correspondingly was no dramatic difference within the FREE condition between recall subsequent to eye movement activity below the median (45.8% of total recall) and above the median (54.2%). Clearly, there exist more potent variables which influence the ease of generating images of the present type than control over eye movements.

One reason for the only slight consequences of the opportunity to make eye movements during imagery may be, as indicated earlier, that an image of a single object involves only a relatively weak spatial component. That is, the sensory features representing the object are more potent than the spatial features representing intra-object relationships between its constituent parts. That an effect of eye movements was nevertheless found must be ascribed to the instructions to scan the image, which explicitly directed the *S*'s attention to the minimal spatial features of his image. A much stronger effect of eye-movement conditions may be expected with imagery of the type studied by Byrne (1974) and in our Experiment VI, that is, with imagery of objects organized into a spatial scene; or when imagery is of object movements in space - a type of imagery Experiment VIII will be addressed to.

The opportunity to make appropriate eye movements, as induced by instruction, was responsible for the significant treatments by *I* interaction that was found (Fig. 16). The pattern that is displayed in this interaction, Low *I* nouns showing no improved recall in the FREE condition, is interpretable as follows: it is so hard to generate an image to a Low *I* noun that the opportunity to make eye movements cannot be of any help (at least not within the 1 sec interval that was allowed to find an image in the present experiment).

It is somewhat puzzling that no reliable differences in recall were found between High and Medium *I* nouns, especially since these groups did not overlap in *I*-value. The same was the case in Experiment III (section 5.3) on selective interference in free recall learning. The suggestion is that the 7-point scale on which the nouns were originally rated for *I* by the norm sample (see the Appendix) is not linearly related to imagery-evoking capacity. This is supported by the latency data presented in the Appendix, which show no further decrease in latencies for ratings from *I*=4.5 upwards.

6.3. EXPERIMENT VIII. EYE MOVEMENTS AND IMAGES OF MOVEMENT

Imagery of movement may be particularly influenced by the opportunity to make eye movements. Antrobus et al. (1964) compared the amount of eye movements within a group of *S*s under instructions to imagine moving scenes (such as a tennis match observed from the net) and static scenes. The amount of activity of the eyes was, on the average, about 55% higher when moving scenes were being visualized. Other studies (Deckert, 1964; Brown, 1968; Lenox, Lange and Graham, 1970) have been concerned with imagery of a beating pendulum or a metronome. Still others (Hahn and Barber, 1966; Zikmund, 1966; Graham, 1970) have instructed *S*s to imagine a moving stimulus known to produce optokinetic nystagmus when it is actually observed.

The general conclusion from these studies is that there often is considerable ocular activity during imagined movement. However, in none of the experiments was the opportunity to make eye movements treated as the independent variable. The aim of the present experiment was to do just this in order to observe the effects of this variable on movement imagery.

6.3.1. General design

There were two treatment conditions in this free recall study: (a) the *S*s were instructed to move their eyes as if they were looking at the real object or the real movement of an object; (b) the *S*s were instructed to fixate on a target while imaging. Treatment conditions were varied between *S*s. Three types of material were presented for memorization, and list type also was a between-*S*s variable (see 6.3.3.).

6.3.2. Subjects

The *S*s were forty-eight employees of the Institute for Perception TNO.

6.3.3. Material

There were three lists of verbal material. The first list consisted of 16 High *I* nouns (*I*>6.0). The second consisted of the same nouns as the first list, each now preceded by an adjective denoting movement (e.g. "running woman", "rolling ball"). The third list again comprised the same nouns, now preceded by an adjective not denoting movement (e.g. "young woman", "colored ball"). List II (dynamic adjective) was the one of real concern. List III (static adjective) was included because, since only concrete adjective-noun phrases can be used to denote movement, there was a possible confounding of the factor *concreteness* with the factor *movement*. List I was included as a control.

Lists were tape recorded by a male speaker at a rate of 1 noun (or phrase) every 5 sec.

6.3.4. Procedure

The procedure was identical to that in Experiment VII, except that no actual eye-movement measures were taken. In familiarization trials E observed whether *S* complied to his eye-movement instructions and corrected him when necessary. *S*s were permitted 90 sec to write down as many nouns as they could remember.

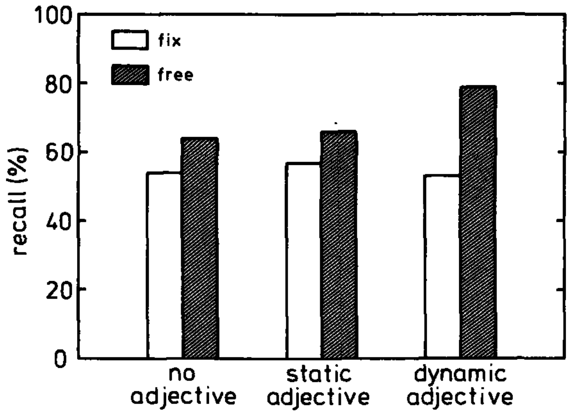

Fig. 17. Recall as a function of imagery type and eye movement conditions (Experiment VIII).

6.3.5. Results and discussion

Two significant effects were observed in the ANOVA of the recall percentages. These were the effects of eye-movement conditions (F=5.68, df=1/42, p<0.05) and of the eye-movement conditions x lists interaction (F=4.63, df=2/42, p<0.05). Instructions to fixate were over-all inferior to instructions to use eye movements, but the difference was considerably larger for the "movement" list than for the other lists (see Fig. 17). We conclude that the movement variable introduces an additional effect on top of that of the concreteness variable. Thus, imaging a moving object apparently benefits from the opportunity to make eye movements.

6.4. CONCLUSIONS

The experiments reported in this chapter have yielded the following evidence:

(1) The distinction between spatial and nonspatial components of visual images is supported.

(2) The spatial features of visual images, i.e., of images of a pattern having a definite spatial component, are at least partly laid down in the form of motor memory traces.

Both these results lend further support to a model of the feature network type, i.e., a model in which separate spatial and nonspatial components and their interrelations are specified.

CHAPTER 7

EPILOGUE

The experiments that we have described obviously were restricted in scope, i.e., they tested only a few general properties of the theoretical format we have proposed for the visual image. It is the purpose of this final chapter to evaluate the relevance and the implications of these relatively crude experimental results for the proposed format and to point to some of the larger gaps that remain to be filled.

If these experiments have yielded anything, it is the insight that one should be careful in using the word 'visual' as an unqualified description of a property of mental images (or as a property of perceptual processes, for that matter). A quotation from Schneider (1969) may once more illustrate the point: '... after preliminary neurological testing of golden hamsters with total ablations of the superior colliculi of the midbrain, I concluded that they were essentially blind (though their pupils still reacted to light). Unlike normal animals, they could find food only by touch and olfaction. I initially assumed that an inability to localize a stimulus in visual space (that is, to make orienting movements of the head or body in the direction of a stimulus within the field of vision) implied an inability to identify shapes and patterns, since shapes and patterns are defined by the spatial arrangement of their parts. But subsequent experiments (...) which required different responses have forced me to drop this assumption, for the "blindness" appeared only when orienting movements were required" (p. 895). We feel that we have demonstrated that a similar distinction Schneider was forced to make must be made when talking of so-called visual images: on the one hand there is a spatial (localization, orienting, ambient) component, and on the other hand there is a nonspatial (sensory, identifying, pictorial, focal) component.

Although there are tasks in which one or the other component clearly prevails it will, admittedly, be a difficult matter to single out the composition, in terms of spatial and nonspatial informating processing, of tasks that do not exclusively rely on one or the other mechanism. At present we have not much to offer with regard to this point, except for the (possibly somewhat premature) suggestion that selective interference techniques may be used now to establish how strong each component in a certain imagery task is. That is, once it is established that selective interference is at its maximum when both tasks are either maximally spatial or nonspatial it becomes possible to turn matters around and to measure how much interference is produced on a certain imagery task by a spatial and a nonspatial perceptual 'reference' task, in order to assess the imagery task's composition.

Obviously other, more sophisticated techniques can be developed to investigate the internal structure of mental images. For example, Kosslyn (1973) showed his *S*s a set of drawings and later asked them to verify pictorial features of the drawings from memory. One group of *S*s was instructed to be able to recall an image of the set of drawings and to focus initially on one specified end of their spatial images during the subsequent verification task. Another group of *S*s was asked to recall a verbal description of each drawing and initially to describe one specified end of the set of drawings during the verification task. It now appeared that time to verify pictorial properties was a function of the spatial distance of a property from an initial focus point for both groups (but *S*s in the verbal description group experienced much greater difficulty in performing the task).

Techniques such as Kosslyn's show that parametric data can be obtained that bear on the structure of mental images: this is indeed a far cry from dogma that rejects the imagery concept as being subjective and qualitative and therefore unscientific in principle!

A second point we feel our experiments have demonstrated is that the spatial and nonspatial features that visual images presumably possess are a direct and minimally interpreted substrate of the perceptual process, i.e., these features are "remembered appearances" (Bower, 1972). Such a conclusion may possibly not be congenial to those who view information processing as a matter of interpretation, transformation and deformation right from the start (i.e., the retina) on. Those, however, may be reassured by the simple fact that no one has as yet succeeded in *completely* wiping out an internal representation possessing visual features by a concomitant perceptual task. This means that what is called the visual image draws at least partially on nonvisual resources, i.e., it is intimately connected to memory stores that contain information in a nonvisual (nonsensory) format, and from which information may be drawn if required. What we have shown is no more than that the image contains at least *some* 'raw', uninterpreted features.

The third noteworthy outcome of our experiments is that *I*, roughly equivalent to position on the abstractness-concreteness dimension, is a variable whose manipulation gives access to the visual image much more easily than the manipulation of mediational strategies. Again this is a conclusion which runs somewhat counter to the mainstream of thinking in cognitive psychology, where there is increasing attention for the tricks and devices people use in order to remember things (and which they bring with them into the psychological laboratory). One possible interpretation of our finding is that mediational strategy is more resistant to interference of any kind than *I*. That is, processing may still go on by means of imagery while the material processed is already loosing some of its features. Such an interpretation is supported by the result of our retrieval experiment (Experiment IV) in which there *was* in fact interference with mediational set.

Thus, one fruitful direction in which to extend the present approach would be to increase the load of the interfering task, for example, by filling more of the inter-pair interval during acquisition with auditory or visual stimulation. It could be expected that, with increasing amounts of interference, a mediational set x interference modality interaction at acquisition would gradually become manifest in the recall data.

The present experiments have no more than touched upon the gross structural characteristics that mental images presumably possess, apart from the spatial-nonspatial distinction.

Certainly much more evidence is needed before the details of a feature-network type of model of the visual image can be specified. The development of a fully adequate description of the components of visual perception appears a necessary and fruitful first step toward an achievement of that kind. For example, only when the description is such that the microstructure of the visual examination of a stimulus is caught in it is it feasible to apply selective interference techniques as a means of testing whether a similar structure exists in the visual image. 'Microstructure' here refers to specific sensory features (which information is extracted in each separate intake episode?), to specific spatial features (which eye movements are made?, is there a grammar of eye movements in the sense that not all possible sequences of movements occur?) and to their interrelations, i.e., the way in which both types of features are organized into a network. Considerable experimental ingenuity will be required to single out these separate elements in order to put them, ultimately, together again.

SUMMARY AND CONCLUSIONS

The present study investigates the nature of the so-called visual mental image. Specifically it is examined to what degree there is a correspondence between the structures of visual images and visual percepts.

After introducing the general problem in Chapter 1 the functional significance of mental imagery in learning and memory processes is treated in Chapter 2. The chapter contains a review of the core empirical results on two of the issues of most concern in present-day research on the significance of imagery in cognitive processes. The first issue is what the effects are of *stimulus imageability (I - roughly equivalent to stimulus position on the abstractness-concreteness dimension)* and how these compare with the effects of other stimulus attributes. Results from recognition, free recall, serial memorization and paired-associate memorization studies indicate that *I* is a variable which is more potent than such long-established variables like *m*, frequency or familiarity. The second issue is what the effects of an imagery mnemonic are on memory performance and how these compare with the effects of other mnemonic strategies. It is concluded that imagery is a strong mnemonic, at least for concrete material.

Chapter 3 deals with the necessity to introduce imagery as an explanatory construct to account for findings like those reviewed in Chapter 2. Pylyshyn's (1973) critique on the appropriateness of the imagery concept is discussed. A format for the visual image is then introduced. The most important distinction to be made when talking about the structure of the visual image, according to this format, is between its spatial and nonspatial (sensory) features. This reflects the fundamental distinction in visual perception between *where* an organism sees something and *what* it sees. A representation in which these two types of features are interwoven is developed and indicated as the feature network format.

Chapter 4 subsequently examines the experimental methods by means of which properties of the feature network could most appropriately be tested. It is concluded that introspection, protocol analysis, the analysis of eidetic imagery and the analysis of the occurrence of sensory after-images and illusions in visual imagery are sub-optimal to this purpose. Methods that appear to bear more promises in them are the analysis of interference between images and percepts (selective, i.e., modality-specific interference paradigms) and the analysis of the role of eye movements in visual imagery.

In Chapter 5 the description is contained of five experiments which have made use of a selective interference paradigm. In all of them an opportunity was created for a conflict between a relatively nonspatial imagery task and a similar perceptual interfering task. Selective interference was obtained in the acquisition stage of two paired-associate experiments as well as in a free recall experiment (Experiment I, II and III). In a subsequent experiment (IV) selective interference was found to occur also at the retrieval stage of memorization. Experiment V showed that a spatial interfering task had no selective degrading effect on memory performance for the nonspatial imagery task, indicating the independence of spatial and nonspatial features as specified by the feature network format.

Chapter VI concentrates on the spatial features of visual imagery. Most crucial for the theoretical ideas presented earlier is Experiment VI, in which it is shown that a spatial visual task interferes selectively with spatial imagery, while the effect of nonspatial visual stimulation works relatively more on nonspatial imagery.

Experiment VII demonstrates a small effect of the opportunity to make eye movements on the ease of generating visual images to isolated static nouns. The effect was considerably larger in Experiment VIII, in which *S*s had to imagine *moving* objects. It is concluded that the spatial features of images of a pattern having a definite spatial component are at least partly laid down in the form of motor memory traces.

SAMENVATTING EN KONKLUSIES

De in dit proefschrift beschreven studie heeft de aard onderzocht van de zogenaamde visuele mentale voorstelling. In het bijzonder is nagegaan in welke mate er een korrespondentie bestaat tussen de struktuur van een visuele voorstelling en van een visueel percept.

Nadat in Hoofdstuk 1 het algemene probleem geïntroduceerd is, behandelt Hoofdstuk 2 het funktionele belang van mentale voorstellingen in leer- en geheugenprocessen. Het hoofdstuk omvat een overzicht van de kern van empirische resultaten die betrekking hebben op twee van de belangrijkste onderwerpen in het hedendaagse onderzoek over de rol van voorstellingen in kognitieve processen. Het eerste punt is wat de effekten zijn van stimulusvoorstelbaarheid (*I* - ruwweg equivalent met de plaats van de stimulus op de abstrakt-konkreet dimensie) en hoe deze effekten te vergelijken zijn met die van andere stimulusattributen. In experimenten met herkenning, vrije reproduktie, seriëel memorizeren en het memorizeren van gepaarde associaties is gevonden dat *I* een variabele is die krachtiger is dan zulke 'established' variabelen als *m* of frequentie van voorkomen in de taal. Het tweede punt is wat de effekten zijn op de geheugenprestatie van het vormen van voorstellingen en hoe deze uitvallen vergeleken bij die van andere geheugenstrategieën. Het blijkt dat het vormen van voorstellingen een krachtig hulpmiddel kan zijn voor het geheugen, tenminste voor konkreet materiaal.

Hoofdstuk 3 behandelt de noodzaak om het voorstellen als een verklarend constructum in te voeren om rekenschap te kunnen geven van resultaten zoals besproken in Hoofdstuk 2. Pylyshyn's (1973) kritiek op de toepasselijkheid van het koncept 'voorstellen' wordt besproken. Vervolgens wordt een theoretische struktuur voor de visuele voorstelling geïntroduceerd. Volgens deze is het voornaamste onderscheid dat men bij het spreken over de struktuur van de visuele voorstelling moet maken dat tussen spatiële en nonspatiële (sensorische) kenmerken. Dit weerspiegelt het fundamentele onderscheid in de visuele perceptie tussen *waar* een organisme iets ziet en *wat* het ziet. Een representatie waarin deze twee soorten kenmerken met elkaar verwerkt zijn wordt ontwikkeld en aangeduid als het 'feature network' format.

Vervolgens gaat Hoofdstuk 4 in op de experimentele methoden die ter beschikking kunnen staan om de eigenschappen van het feature network te toetsen. De konklusie is dat introspektie, protokol-analyse, de analyse van eidetische voorstellingen en de analyse van het voorkomen van sensorische nabeelden en illusies bij visuele voorstellingen voor dit doel niet geschikt zijn. Methoden die meer beloften in zich lijken te dragen zijn de analyse van interferentie tussen voorstelling en percept (selektieve, d.w.z. modalititeitsgebonden interferentie-paradigmata) en de analyse van de rol van oogbewegingen in het visuele voorstellen.

Hoofdstuk 5 beschrijft vijf experimenten waarin gebruik is gemaakt van een selektieve-interferentie paradigma. In alle experimenten werd de gelegenheid geschapen tot het ontstaan van een konflikt tussen een (relatief) nonspatiële voorstellingstaak en een soortgelijke interferende perceptieve taak. Selektieve interferentie werd gevonden in het acquisitie-stadium in twee gepaarde-associatie experimenten alsook in een experiment met vrije reproduktie (Experimenten I, II en III). In een volgend experiment (IV) werd gevonden dat selektieve interferentie ook optreedt bij het ophaalstadium in het memorizeren. Experiment V toonde aan dat een spatiële interferentietaak geen selektief verslechterend effekt uitoefende op de geheugenprestatie voor een nonspatiële voorstellingstaak, hetgeen steun verschaft aan de in het feature network format geponeerde onafhankelijkheid van spatiële en nonspatiële features.

Hoofdstuk 6 koncentreert zich op de spatiële eigenschappen van visuele voorstellingen. Een kruciaal experiment is Experiment VI, waarin gevonden werd dat een spatiële visuele taak selektief interfereert met een spatiële voorstellingstaak, terwijl het effekt van een nonspatiële visuele taak relatief meer bleek te drukken op een nonspatiële voorstellingstaak.

Experiment VII demonstreert een klein effekt van de gelegenheid oogbewegingen te maken op de vlotheid waarmee visuele voorstellingen op geïsoleerde, statische zelfstandige naamwoorden gegenereerd kunnen worden. Het effekt was aanzienlijk groter in Experiment VIII, waarin de proefpersonen zich *bewegende* objekten voorstelden. Hieruit valt te konkluderen dat de spatiële features van voorstellingen van een patroon dat een duidelijke spatiële komponent bevat tenminste gedeeltelijk opgeslagen worden in de vorm van motorische geheugensporen.

APPENDIX

THE COLLECTION OF I-RATINGS AND TWO SIMPLE VALIDATION EXPERIMENTS [5]

Anglo-Saxon ratings of *I* have been available since 1968, when Paivio et al. published *I*-values for 925 nouns obtained from 30 Canadian *S*s. Ratings for American samples have been published by Walker (1970). Morris and Reid (1972) determined *I*-values for British *S*s for a subset of 100 nouns taken from the list of Paivio et al. (1968).

Attempts to take one of these Anglo-Saxon lists as the basis for experimentation with Dutch nouns meet two objections. The first is that it is likely that *S*s living in different cultural settings produce different ratings (even when they would speak the same language). Thus, Morris and Reid found that *I*-values for their group of British *S*s on a subset of the Paivio et al. (1968) nouns were significantly lower on the average than for the Canadian group. Nevertheless, the correlation between Canadian and British ratings was 0.93, suggesting that this average difference may not be so serious as to prevent comparisons between experiments employing different groups of *S*s. A more serious objection is that a translation of English nouns into Dutch proves to be surprisingly difficult. Hardly ever is there only one equivalent in the dictionary for a given English word. Moreover, if one has had the rare luck to find a single Dutch equivalent one almost always finds a multiple English translation when referring back. For these reasons it was decided to determine separate *I*-ratings for Dutch nouns without taking the Anglo-Saxon norms into account.

A1. METHOD AND PROCEDURE

It was judged desirable to have several categories of the frequency of occurrence in the language represented in the sample of nouns to be rated for *I*. To this purpose reference was made to the van Berckel et al. (1965) frequency counts for newspaper-Dutch assembled in 1956. Three categories were arbitrarily distinguished:

a) F>8 per 44299 words counted ('High F');

b) F=6, 7, 8, per 44299 ('Medium F');

c) F<6 per 44299 ('Low F').

In each category 100 nouns were selected semi-randomly, i.e., in the 'Low' and 'Medium' categories there were equal numbers of nouns per individual frequency. In the 'Low' category, for example, 20 nouns each were selected for the frequencies of 5, 4, 3, 2 and 1 per 44299.

The list was completed with 40 nouns selected for several other reasons. Among these were words which could be expected to yield either extremely high or extremely low I-values and nouns which the experimenter was just curious about to know their I-value (such as GHOST and HEAVEN).

The procedure described by Paivio et al. (1968) was followed. *S*s received the instruction and the nouns to be rated together as a booklet. The instruction was a translation of that of Paivio et al., containing the request to indicate how fast and how easily each noun evoked a visual image.

Apart from the instruction and a front page the booklet contained 18 A4 pages, with 20 nouns on each page, each noun being accompanied by a 7-point scale ranging from 1 (low imageability) to 7 (high imageability). To obtain an impression of the reliability of the ratings 20 nouns were contained twice in the sample. The order of the 18 pages was varied over *S*s.

*S*s were 25 employees of the Institute for Perception TNO, who filled the booklets out individually. After *S*s had completed the ratings it appeared that not all words could unambiguously be qualified as nouns. For example: the word 'DRUK' is both an adjective or adverb (with meaning: 'busy') and a noun (with meaning: 'pressure'). In all there were 13 words suffering from this ambiguity. These were removed from the list, leaving a total of 327 nouns in the sample. Table A1 gives information on the distribution of the nouns over the I-scale. The distribution is skewed towards the lower end of the scale. This may be attributed to the type of material from which van Berckel et al. (1965) obtained their frequencies: newspapers contain a lot of material on politics, economics, social issues, and so on, which are not very concrete.

The reliability of the ratings, expressed as the average correlation coefficient over the 25 *S*s for their ratings of the 20 nouns occurring twice, was r=0.98. This is exactly the correlation reported by Paivio et al. (1968).

The correlation between I and F, although significant at 326 df, was low: r=-0.16. This is not in agreement with the weak positive correlation (r=0.23) reported by Paivio et al. (1968). The simplest explanation of this discrepancy lies in the overrepresentation in our list of High F, but abstract nouns: in Paivio et al.'s sample there was an overrepresentation of concrete words.

Table A1. Number of nouns per category of I.

Category	Number of nouns in sample
$I \leq 2.00$	8
$2.00 < I \leq 3.00$	77
$3.00 < I \leq 4.00$	75
$4.00 < I \leq 5.00$	60
$5.00 < I \leq 6.00$	55
$I \geq 6.00$	52

A2. AN ILLUSTRATIVE PAIRED-ASSOCIATE EXPERIMENT

To obtain an initial impression of the usefulness of the ratings it was decided to try to replicate two well-established findings obtained with Anglo-Saxon material, namely (a) the superiority of High I over Low I noun pairs in paired-associate (PA) learning and (b) the interaction between mediator type (imaginal versus verbal) and I found in latency measurements. The former experiment is described first.

From the ratings two sets of noun pairs were selected, one consisting of High I pairs (I>6.00), the other of Low I pairs (I<3.00). In each group there were three High F, three Medium F and three Low F pairs. The two sets were put together in random order to obtain a list of 18 noun pairs. The composition of the material is shown in Table A2.

Table A2. Average I- and F-values of nouns used in illustrative PA-experiment.

	High F	Medium F	Low F
High I	I = 6.5 F = 18.7	I = 6.6 F = 6.9	I = 6.5 F = 1.7
	I = 2.6 F = 18.3	I = 2.6 F = 7.0	I = 2.7 F = 1.6

Six employees of the Institute for Perception TNO served as *S*s. The experiment was conducted as a group session. *S*s were told that this was a memorization experiment, and that they would be asked after one presentation of the total list to reproduce (in writing) the second word of a pair upon presentation of the first. (In the test the order of stimulus nouns was not the same as in the original presentation).

*S*s were instructed to generate an interactive image in the time between pair representations. This was illustrated and practised with a few pairs.

The pairs were read by the E with a 5 sec interval between pairs and a 2-sec interval between the stimulus and response terms. At the test 5 sec were allowed to write down the response term.

The results are given in Table A3.

Table A3. Percentages correct responses as a function of *I* and *F*.

	High *F*	Medium *F*	Low *F*	Average
High *I*	72.2	62.5	72.2	66.7
Low *I*	44.4	11.1	27.8	27.8
Average	58.3	36.8	50.0	47.1

The effect of *I* is exactly as expected, recall for High *I* pairs being on the average more than twice that for Low *I* pairs. The effect of *F*, also in accordance with the literature, is less simple (Paivio, 1971, pp. 203-205).

A3. LATENCIES FOR MEDIATOR DISCOVERY

In section 2.3 we discussed the implication of Paivio's two-process theory of meaning and mediation that the availability of imaginal, but not verbal, mediators is related directly to stimulus concreteness. An interaction should occur in that the availability of verbal mediators should not be affected very much by *I*, while images should be considerably easier to generate to concrete than to abstract stimuli.

One way used to test this prediction is to measure latencies of mediator discovery. Paivio (1966) obtained the interaction when he presented *S*s with concrete and abstract stimulus nouns and required them to press a key either when a mental image or an implicit verbal associate occurred to the word. Yuille (1973) replicated the finding in a paired-associate setting.

The second experiment of this Appendix tried to replicate the interaction in an attempt to illustrate the validity of the *I*-ratings obtained.

The 7-point *I*-scale was divided in 11 intervals in steps of half a unit (from $1.5<I<2.0$ to $6.5<I<7.0$). Three nouns were taken from each interval, so that the stimulus list comprised 11 x 3 = 33 nouns in all. The material was recorded on tape at a 10-sec rate and was presented through headphones. The stimulus triggered a voice-key which started a counter. A button in front of *S* stopped the counter, which was then reset by E.

There were two groups of 14 *S*s, all of them students at Utrecht State University. One group was instructed to press the button the moment a verbal associate to the stimulus came to mind. The other group did so the moment visual image came to mind.

Latencies were measured from the onset of the stimulus nouns. They were corrected for pronunciation time of the stimuli by measuring stimulus duration on the tape by means of a storage oscilloscope. These durations were subtracted from the raw latencies to obtain corrected latencies. (It appeared that the pattern present in the data was not affected by whether raw or corrected latencies were used). Average corrected latencies for each group of *S*s are shown in Fig. 18. The expected *I* x mediational set instruction is clearly present in the data, sufficiently demonstrating the applicability and validity of the *I*-ratings.

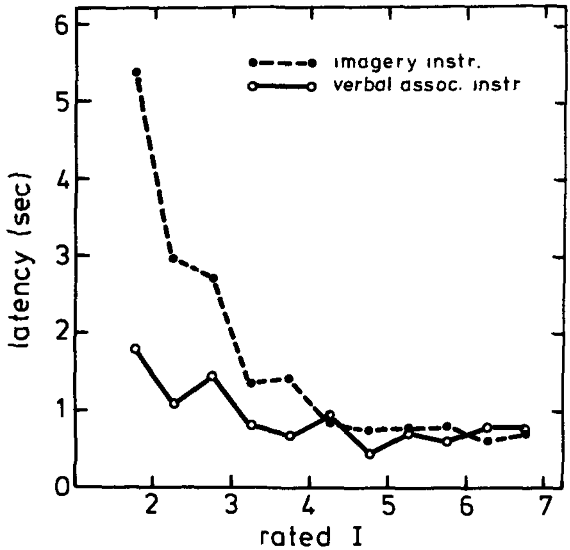

Fig. 18. Response latency as a function of instructions and of *I*.

A4. TABULATED *I*-RATINGS

The 327 *I*-ratings obtained by the procedure described in this Appendix are tabulated below. Nouns are entered with their *I*-value, the standard deviation of their *I*-value (n=25), and their frequency of occurrence per 44299 words according to van Berckel et al. (1965). Nouns that are not in the van Berckel et al. count (*F*<1 per 44299) are marked by -.

Noun	*I*		*F*	Noun	*I*		*F*
	M	SD			M	SD	
Belang	1.52	0.71	9	Begrip	2.24	1.33	7
Aanleiding	1.72	0.74	11	List	2.28	1.06	1
Geval	1.76	1.09	10	Ontwikkeling	2.28	1.17	7
Gelegenheid	1.80	1.15	10	Dienst	2.28	1.21	10
Feit	1.84	1.07	14	Advies	2.32	1.31	8
Mogelijkheid	1.88	1.01	6	Konjunktuur	2.32	1.38	1
				Karakter	2.32	1.41	7
Kwestie	2.00	1.00	10	Zuurstof	2.36	1.41	-
Geest	2.00	1.22	2	Inzicht	2.36	1.41	6
Beleid	2.04	1.24	7	Macht	2.40	1.12	9
Oorzaak	2.08	1.22	9	Positie	2.40	1.12	15
Aard	2.08	1.47	7	Ongenoegen	2.40	1.38	1
Kriterium	2.12	1.13	-	Voorbereiding	2.44	1.39	6
Werkelijkheid	2.12	1.30	6	Oordeel	2.44	1.66	4
Ekonomie	2.16	1.07	4	Kritiek	2.48	1.00	2
Verantwoordelijkheid	2.16	1.07	6	Wanhoop	2.48	1.05	3
Indruk	2.16	1.28	12	Malaria	2.48	1.42	-
Vertolking	2.16	1.55	3	Aanbod	2.48	1.42	7
Toestand	2.20	1.12	9	Hoop	2.48	1.56	2
Aanzien	2.20	1.19	7				
Initiatief	2.20	1.26	4	Twijfel	2.52	1.19	10
Unie	2.20	1.47	5	Standpunt	2.52	1.23	10
Hereniging	2.20	1.61	18	Medewerking	2.56	0.96	6
Maatregel	2.24	1.09	6	Stemming	2.56	1.12	8

Noun	*I*		*F*	Noun	*I*		*F*
	M				M	SD	
Raad	2.56	1.56	20	Vrees	2.96	1.54	4
Bedrijfsleven	2.60	1.22	8	Wetenschap	2.96	1.57	7
Aandacht	2.60	1.35	12	Jaar	2.96	1.72	79
Belangstelling	2.64	0.33	11	Steun	2.96	1.84	8
Moed	2.64	1.41	6				
Uitvoering	2.64	1.47	15	Samenzwering	3.00	1.41	3
Plan	2.68	1.41	18	Organisatie	3.00	1.58	8
Verdrag	2.68	1.44	21	Scheiding	3.00	1.78	1
Verzoening	2.68	1.46	1	Tempo	3.04	1.34	5
Waardering	2.68	1.46	5	Aantal	3.04	1.59	22
Konklusie	2.68	1.46	8	Vraag	3.04	1.64	16
Behandeling	2.72	1.51	6	Samenwerking	3.08	1.58	7
Pleidooi	2.72	1.54	3	Titel	3.12	1.70	3
Voorbeeld	2.72	1.54	6	Maand	3.12	1.76	9
Verzoek	2.76	1.27	5	Funktie	3.12	1.90	4
Overeenstemming	2.76	1.56	8	Overleg	3.16	1.57	7
Soort	2.76	1.83	7	Antwoord	3.16	1.62	13
Beschuldiging	2.80	1.32	1	Politiek	3.16	1.72	29
Tijd	2.80	1.55	40	Kracht	3.20	1.19	10
Krisis	2.80	1.63	3	Kommissie	3.20	1.41	5
Handel	2.84	1.21	14	Kernfysika	3.20	1.68	1
Venijn	2.84	1.34	-	Aktie	3.20	1.76	5
Taak	2.84	1.34	8	Verklaring	3.20	1.79	15
Probleem	2.84	1.55	10	Terreur	3.24	1.16	13
Bijdrage	2.88	1.33	8	Groei	3.24	1.45	2
Opbouw	2.88	1.56	7	Kennis	3.24	1.83	6
Goedheid	2.88	1.81	1	Delegatie	3.28	1.28	6
Orgaan	2.92	1.53	1	Winst	3.28	1.34	8
Oplossing	2.92	1.60	8	Aandeel	3.28	1.67	5
Deel	2.92	1.73	24	Filosoof	3.28	1.79	1
Kommunisme	2.96	1.24	6	Begin	3.28	1.90	7
Verlegenheid	2.96	1.37	4	Middenstand	3.32	1.03	8

Noun	I M	SD	F	Noun	I M	SD	F
Hulp	3.32	1.25	9	Naam	3.72	1.88	12
Emigratie	3.32	1.60	6	Opstand	3.76	1.42	8
Meerderheid	3.32	1.65	7	Partij	3.76	1.56	33
Gebied	3.32	1.68	8	Voorsprong	3.76	1.86	8
Geloof	3.32	1.84	2	Kant	3.76	1.90	10
Vraagstuk	3.32	1.84	5	Houding	3.80	1.71	8
Systeem	3.32	1.91	8	Ruimte	3.84	1.60	5
Uitslag	3.44	1.66	5	Leven	3.88	1.86	22
Staat	3.44	1.66	14	Afdeling	3.88	2.07	5
Einde	3.44	1.85	13	Verslag	3.92	1.66	5
Procent	3.44	2.40	12	Beweging	3.92	1.66	6
Verdachte	3.48	1.50	8	Gemeenschap	3.92	1.71	11
Leiding	3.48	1.83	17	Psalm	3.92	1.98	4
				Testament	3.96	1.37	6
Zaak	3.56	1.89	31	Kursus	3.96	1.49	2
Minuut	3.56	1.94	16	Droom	3.96	1.54	1
Bevolking	3.60	1.29	4	Geleerde	3.96	1.64	3
Betoog	3.60	1.50	3	Tiran	3.96	1.72	5
Diskussie	3.60	1.58	6	Leider	3.96	1.97	21
Vijand	3.60	1.89	4				
Uur	3.60	1.91	27	Zwavel	4.00	1.58	-
Vorm	3.64	1.41	8	Zenuwarts	4.00	1.58	2
Volk	3.64	1.52	11	Strijd	4.04	1.67	20
Gordeldier	3.64	2.18	-	Bezoek	4.04	1.72	9
Plaats	3.68	1.60	28	Prijs	4.08	1.44	9
Revolutie	3.68	1.68	6	Gemeente	4.12	1.74	7
Bestuur	3.68	1.73	6	Bedrag	4.12	1.74	9
Kunst	3.72	1.65	3	Werk	4.12	1.81	26
Koers	3.72	1.74	10	Premier	4.12	1.99	15
Basis	3.72	1.79	8	Richting	4.16	1.60	8

Noun	*I*		*F*	Noun	*I*		*F*
	M	SD			M	SD	
Afstand	4.16	1.70	6	Beiaardier	4.56	1.89	6
Uitgeverij	4.16	1.77	1	Regering	4.60	1.47	40
Helft	4.16	1.84	6	Vergadering	4.60	1.61	7
Doel	4.16	2.03	12	Ambassade	4.64	1.68	5
Bedrijf	4.20	1.44	7	Stem	4.64	1.93	9
Staking	4.24	1.45	8	Rapport	4.68	1.49	15
Bericht	4.24	1.56	5	Oorlog	4.68	1.86	8
Jeugd	4.24	1.56	6	Kongres	4.76	1.33	17
Rust	4.24	1.59	8	Heer	4.76	1.69	29
Korrespondent	4.24	1.81	8	Bemanning	4.80	1.44	2
Hindernis	4.32	1.55	2	Sultan	4.80	1.66	-
Aanvaller	4.32	1.57	1	Terrein	4.84	1.57	6
Klant	4.32	1.65	3	Reis	4.84	1.57	11
Minister	4.32	1.77	37	Hogeschool	4.84	1.65	4
Artikel	4.32	1.89	12	Journalist	4.88	1.51	7
Effektenbeurs	4.36	1.47	2	Prins	4.88	1.72	7
Wereld	4.36	1.91	26	Student	4.88	1.79	-
Gesprek	4.40	1.53	6	Pers	4.88	1.79	10
Komponist	4.40	1.61	5	Mevrouw	4.96	1.72	10
Zijde	4.40	1.91	8				
Spook	4.40	2.18	-	Salaris	5.00	1.55	-
Landbouw	4.44	1.33	4	Landing	5.04	1.88	-
Konferentie	4.44	1.73	8	Land	5.08	1.71	27
Voorzitter	4.48	1.53	12	Luchtvaart	5.12	1.33	2
Programma	4.48	1.61	12	Portret	5.12	1.79	2
Figuur	4.48	1.71	7	Grens	5.12	1.79	4
Stilte	4.48	1.76	4	Aanvaring	5.16	1.62	4
				Burgemeester	5.16	1.70	9
Dag	4.52	1.58	19	Stof	5.20	1.61	2
Groep	4.56	1.56	9	Weekblad	5.32	1.44	1
Spel	4.56	1.61	13	Hemel	5.32	1.52	1
Examen	4.56	1.66	1	Leger	5.32	1.52	2

Noun	*I*		*F*	Noun	*I*		*F*
	M	SD			M	SD	
Koning	5.32	1.60	9	Stad	5.84	1.03	16
Verband	5.36	1.66	10	Doelpunt	5.88	1.51	6
Hoogleraar	5.36	1.70	12	Dorp	5.92	1.00	9
Orkaan	5.40	1.15	-	Diner	5.92	1.04	3
Landschap	5.40	1.47	1	Vliegbasis	5.96	1.10	2
Afgrond	5.44	1.16	2	Snaar	5.96	1.24	-
Winter	5.44	1.19	2	Dirigent	5.96	1.27	8
Priester	5.44	1.61	-	Kelder	5.96	1.31	2
Markt	5.44	1.71	15				
Gezin	5.48	1.23	3	Pudding	6.00	1.04	-
Meter	5.48	1.66	12	Tabak	6.00	1.08	-
Alkohol	5.48	1.69	1	Orkest	6.00	1.08	7
				Fabriek	6.00	1.22	2
Avond	5.52	0.26	8	Gans	6.00	1.41	-
Rekening	5.52	1.16	7	Brand	6.04	1.14	6
Grond	5.52	1.33	10	Slang	6.08	0.59	-
Machine	5.52	1.36	7	Drank	6.08	1.08	1
Strafschop	5.52	1.39	6	Formulier	6.08	1.08	3
Post	5.52	1.48	8	Rijksweg	6.08	1.22	1
Zeeman	5.56	1.23	3	Bibliotheek	6.12	0.88	1
Aarde	5.56	1.26	1	Hotel	6.12	1.24	1
Blok	5.56	1.56	6	Film	6.16	0.99	6
Koncert	5.60	1.29	11	Non	6.16	1.25	-
Gletscher	5.60	1.35	-	Blad	6.16	1.25	8
Schaduw	5.60	1.38	-	Punt	6.16	1.37	8
Theater	5.64	1.15	1	Man	6.20	0.91	23
Zuster	5.64	1.19	4	Werphengel	6.20	1.08	1
Nacht	5.64	1.25	4	Orgel	6.20	1.15	3
Geld	5.68	1.18	4	Karnemelk	6.24	1.01	7
Politie	5.72	1.14	12	Vlag	6.24	1.09	4
Chauffeur	5.76	1.27	3	Kerk	6.28	1.06	38
Generaal	5.76	1.36	6	Hoofd	6.28	1.28	5

Noun	I		F	Noun	I		F
	M	SD			M	SD	
Nek	6.32	0.69	1	Oog	6.56	0.77	8
Macaroni	6.32	0.75	-	Bloem	6.60	0.76	4
Bar	6.32	0.99	2	Deur	6.64	0.64	3
Geweer	6.36	0.86	-	Fles	6.68	0.48	1
Boerderij	6.40	0.71	2	Gulden	6.68	0.48	7
Kamer	6.40	0.76	11	Kind	6.68	0.56	7
Berg	6.40	0.82	3	Olifant	6.68	0.63	-
Vuur	6.44	0.65	5	Huis	6.76	0.44	10
Bureau	6.44	1.04	5	Piano	6.80	0.41	-
Water	6.48	0.71	8	Hand	6.80	0.41	20
Vrouw	6.48	0.71	9	Schoen	6.84	0.37	-
Bloemkool	6.48	0.96	2	Fiets	6.84	0.37	3
				Bal	6.84	0.37	5
Brief	6.52	0.51	5	Trein	6.84	0.37	11
Hoed	6.52	0.77	2	Auto	6.88	0.33	6
Schop	6.56	0.51	7	Boek	6.92	0.28	4
Boot	6.56	0.65	7	Paard	6.92	0.28	7
Radio	6.56	0.77	1				

NOTES

1. Parts of the description of this experiment have appeared in 'Acta Psychologica' (Janssen, 1976a).
2. A description of this experiment is in press in the 'Quarterly Journal of Experimental Psychology' (Janssen, 1976b).
3. This study has been published as Janssen and Nodine (1974), in 'Acta Psychologica'.
4. Since there were a few missing data (6 out of 162 data points), not all with the same *S* or under the same treatment conditions, due to failures of the recording apparatus, the *df*'s in the ANOVA are slightly different from what would be expected on the basis of the experimental design.
5. A description of the collection of the *I*-ratings has been published before in the 'Nederlands Tijdschrift voor de Psychologie' (Janssen, 1973).

REFERENCES

Anderson, J.R. and G.H. Bower. *Human associative memory.* Washington: Winston & Sons, 1973.

Antrobus, J.S., J.S. Antrobus and J.C. Singer. Eye movements accompanying daydreaming, visual imagery and thought suppression. Journal of Abnormal and Social Psychology, 1964 (69), 244-252.

Apter, J.T. Eye movements following strychninization of the superior colliculus of cats. Journal of Neurophysiology, 1946 (9), 73-86.

Atkinson, R.C. and R.M. Shiffrin. Human memory - A proposed system and its control processes. In: K.W. Spence and J.T. Spence (Eds.), *The psychology of learning and motivation: Advances in research and theory, Vol. II.* New York and London: Academic Press, 1968.

Atwood, G.E. An experimental study of visual imagination and memory. Cognitive Psychology, 1971 (2), 290-299.

Baddeley, A.D., S. Grant, E. Wight and N. Thomson. Imagery and visual working memory. In: P. Rabbitt and S. Dornic (Eds.), *Attention and Performance V.* New York and London: Academic Press, 1975.

Barber, T.X. Imagery and 'hallucinations': Effects of LSD contrasted with the effects of hypnotic suggestions. In: S.J. Segal (Ed.), *Imagery: Current cognitive approaches.* New York and London: Academic Press, 1971.

Bartlett, F.C. *Remembering.* London: Cambridge University Press, 1932.

Van Berckel, J.A.Th.M., H. Brandt Corstius, R.J. Mokken and A. van Wijngaarden. *Formal properties of newspaper Dutch.* Amsterdam: Mathematical Centre Tracts 12, 1965.

Berlyne, D.E. *Structure and direction in thinking.* New York: Wiley, 1965.

Binet, A. and C. Féré. *Animal magnetism.* London: Kegan Paul, Trench, Trubner and Company, Ltd., 1891.

Bower, G.H. Mental imagery and associative learning. In: L.W. Gregg (Ed.), *Cognition in learning and memory*. New York: Wiley, 1972.

Brooks, L.R. The suppression of visualization in reading. Quarterly Journal of Experimental Psychology, 1967 (19), 289-299.

Brooks. L.R. Spatial and verbal components in the act of recall. Canadian Journal of Psychology, 1968 (22), 349-368.

Brown, B.B. Visual recall ability and eye movement. Psychophysiology, 1968 (4), 300-306.

Brown, W.P. and D.M.J. Ure. Five rated characteristics of 650 word association stimuli. British Journal of Psychology, 1969 (60), 233-249.

Byrne, B. Item concreteness vs spatial organization as predictors of visual imagery. Memory & Cognition, 1974 (2), 53-59.

Calkins, M.W. Short studies in memory and in association from the Wellesley College psychological laboratory. Psychological Review, 1898 (5), 451-462.

Deckert, G.H. Pursuit eye movements in the absence of a moving stimulus. Science, 1964 (143), 1192-1193.

Deese, J. Frequency of usage and number of words in free recall: The role of association. Psychological Review, 1960 (7), 337-344.

Delin, P.S. The learning of criterion of a serial list with and without mnemonic instructions. Psychonomic Science, 1969 (16), 169-170.

Den Heyer, K. and B. Barrett. Selective loss of visual and verbal information in STM by means of visual and verbal interpolated tasks. Psychonomic Science, 1971 (25), 100-102.

Downey, J.E. An experiment on getting an afterimage from a mental image. Psychological Review, 1901 (8), 42-55.

Elliott, L. Imagery versus repetition encoding in short- and long-term memory. Journal of Experimental Psychology, 1973 (100), 270-276.

Engel, F.L. Visual conspicuity, directed attention and retinal locus. Vision Research, 1971 (11), 563-576.

Epstein, W., I. Rock and C.B. Zuckerman. Meaning and familiarity in associative learning. Psychological Monographs, 1960 (74), (4, Whole No. 491).

Ernest, C.H. and A. Paivio. Imagery ability in paired-associate and incidental learning. Psychonomic Science, 1969 (15), 181-182.

Fincke, G. Word characteristics, associative-relatedness, and the free recall of nouns. Journal of Verbal Learning and Verbal Behavior, 1968 (7), 366-372.

Van Galen, G.P. *Ambient versus focal information processing and single-channelness*. Nijmegen: Stichting Studentenpers, 1974.

Galton, F. *Inquiries into human faculty and its development.* London: MacMillan, 1883.

Goldthwait, C. Relation of eye movements to visual imagery, American Journal of Psychology, 1933 (46), 106-110.

Gorman, A.M. Recognition memory for nouns as a function of abstractness and frequency. Journal of Experimental Psychology, 1961 (61), 23-29.

Goss, A.E. Verbal mediating responses and concept formatión. Psychological Review, 1961 (68), 248-274.

Goss, A.E. and C.F. Nodine. *Paired-associate learning: The role of meaningfulness, similarity, and familiarization.* New York: Academic Press, 1965.

Graham, K.R. Eye movements during visual mental imagery. Paper presented to the Eastern Psychological Association, Atlantic City, April 1970.

Grindley, G.C. and V. Townsend. Visual search without eye movement. Quarterly Journal of Experimental Psychology, 1970 (22), 62-67.

De Groot, A.D. *Thought and choice in chess.* New York: Basic Books, 1965.

Gupton, T. and G. Frincke. Imagery, mediational instructions, and noun position in free recall of noun-verb pairs. Journal of Experimental Psychology, 1970 (86), 461-462.

Hahn, K.W., Jr. and T.X. Barber. Hallucinations with and without hypnotic induction: An extension of the Brady and Levitt study. Harding, Mass.: Medfield Foundation, 1966.

Hale, S.M. and H.M. Simpson. Effects of eye movements on the rate of discovery and the vividness of visual images. Perception and Psychophysics, 1971 (9), 242-246.

Hall, D.C. Eye movements in scanning iconic imagery. Journal of Experimental Psychology, 1974 (103), 825-830 (a).

Hall, D.C. Eye fixation and spatial organization in imagery. Bulletin of the Psychonomic Society, 1974 (3), 335-337 (b).

Haslerud, G.M. *Transfer, memory and creativity: After-learning as perceptual process.* Minneapolis: University of Minnesota Press, 1972.

Hebb, D.O. Concerning imagery. Psychological Review, 1968 (75), 466-477.

Herman, T., I.G. Broussard and H.R. Todd. Intertrial interval and the rate of learning serial order picture stimuli. Journal of Genetic Psychology, 1951 (45), 245-254.

Herrington, R.N. and P. Schneidau. The effect of imagery on the waveshape of the visual evoked response. Experientia, 1968 (24), 1136-1137.

Ingle, D. Two visual mechanisms underlying the behaviour of fish. Psychologische Forschung, 1967 (31), 44-51.

Iscoe, I. and I.J. Semler. Paired-associate learning in normal and mentally retarded children as a function of four experimental conditions. Journal of Comparative and Physiological Psychology, 1964 (57), 387-392.

Janssen, W.H. Imagery values of 327 nouns. (In Dutch). Nederlands Tijdschrift voor de Psychologie, 1973 (28), 465-475.

Janssen, W.H. Selective interference in paired-associate and free recall learning: Messing up the image. Acta Psychologica, 1976 (40), 35-48 (a).

Janssen, W.H. Selective interference during the retrieval of visual images. Quarterly Journal of Experimental Psychology, 1976 (28), in press (b).

Janssen, W.H. and C.F. Nodine. Eye movements and visual imagery in free recall. Acta Psychologica, 1974 (38), 267-276.

John, E.R. *Mechanisms of memory*. New York: Academic Press, 1967.

Kahneman, D. *Attention and effort*. Englewood Cliffs: Prentice-Hall, 1973.

Kaplan, S., R. Kaplan and J.R. Sampson. Encoding and arousal factors in free recall of visual and verbal material. Psychonomic Science, 1968 (12), 73-74.

Kendler, H.K. and T.S. Kendler. Mediation and conceptual behavior. In: K.W. Spence and J.T. Spence (Eds.), *The psychology of Learning and Motivation: Advances in research and theory, Vol. II*. New York and London: Academic Press, 1968.

Kintsch, W. Abstract nouns: imagery versus lexical complexity. J. Verb. Journal of Verbal Learning and Verbal Behavior, 1972 (11), 59-65 (a).

Kintsch, W. Notes on the structure of semantic memory. In: E. Tulving and W. Donaldson (Eds.), *Organization of Memory*. New York: Academic Press, 1972 (b).

Kirkpatrick, E.A. An experimental study of memory. Psychological Review, 1894 (1), 602-609.

Kirsch, R.A. Computer interpretation of English text and picture patterns. IEEE Trans. Electronic Computers, 1964 (13), 363-376.

Kosslyn, S.M. Scanning visual images: Some structural implications. Perception and Psychophysics, 1973 (14), 90-94.

Ladd, C.T. Contribution to the psychology of visual dreams. Mind, 1892 (1), 299-304.

Lenox, J.R., A.F. Lange and K.R. Graham. Eye movement amplitudes in imagined pursuit of a pendulum with eyes closed. Psychophysiology, 1970 (6), 773-777.

Marks, D.F. Visual imagery differences and eye movements in the recall of pictures. Perception and Psychophysics, 1973 (14), 407-412.

Meudell, P. Retrieval and representations in long-term memory. Psychonomic Science, 1971 (23), 295-296.

Michon, J.A. On the internal representation of associative data networks. Nederlands Tijdschrift voor de Psychologie, 1968 (23), 428-457.

Miller, G.A., E. Galanter and K. Pribram. *Plans and the structure of behavior.* New York: Holt, 1960.

Miller, R.J., R.M. Lundy and G.G. Galbraith. The effects of the hypnotically induced hallucination of a color filter. Presented at the 10th meeting of the Psychonomic Society, St. Louis, 1969.

Moore, T.V. The temporal relations of meaning and imagery. Psychological Review, 1915 (22), 177-225.

Morris, P.E. and R.L. Reid. Canadian and British ratings of the imagery values of words. British Journal of Psychology, 1972 (63), 163-164.

Morris, P.E. and R.L. Reid. Imagery and recognition. British Journal of Psychology, 1974 (65), 7-12.

Morris, P.E. and R. Stevens. Linking images and free recall. Journal of Verbal Learning and Verbal Behavior, 1974 (13), 310-315.

Mueller, J.H. and E.M. Jablonski. Instructions, noun imagery, and priority in free recall. Psychological Reports, 1970 (27), 559-566.

Murdock, B.B., Jr. The immediate retention of unrelated words. Journal of Experimental Psychology, 1960 (10), 222-234.

Nappe, G.W. and K.A. Wollen . Effects of instructions to form common and Journal of Experimental Psychology, 1973 (100), 6-8.

Narasimhan, R.A. Labeling schemata and syntactic descriptions of pictures. Information and Control, 1964 (7), 151-179.

Neisser, U. Visual imagery as process and experience. In: J.S. Antrobus (Ed.), *Cognition and affect.* Boston: Little & Brown, 1970.

Newell, A., J.C. Shaw and H.A. Simon. Elements of a theory of human problem solving. Psychological Review, 1958 (65), 151-166.

Newell, A. and H.A. Simon. *Human problem solving.* Englewood Cliffs: Prentice-Hall, 1972.

Nickerson, R.S. Short-term memory for complex meaningful visual configurations: A demonstration of capacity. Canadian Journal of Psychology, 1965 (19), 155-160.

Noble, C.E. An analysis of meaning. Psychological Review, 1952 (59), 421-430.

Noton, D. and L. Stark. Scanpaths in sccadic eye movements while viewing and recognizing patterns. Vision Research, 1971 (11), 929-942.

Olver, M.A. Abstractness, imagery, and meaningfulness in recognition and free recall. M.A. thesis, University of Western Ontario, 1965.

Paivio, A. Abstractness, imagery, and meaningfulness in paired-associate learning. Journal of Verbal Learning and Verbal Behavior, 1965 (4), 32-38.

Paivio, A. Latency of verbal associations and imagery to noun stimuli as a function of abstractness and generality. Canadian Journal of Psychology, 1966 (20), 378-387.

Paivio, A. Paired-associate learning and free recall of nouns as a function of concreteness, specificity, imagery, and meaningfulness. Psychological Reports, 1967 (20), 239-245.

Paivio, A. A factor-analytic study of word attributes and verbal learning. Journal of Verbal Learning and Verbal Behavior, 1968 (7), 41-49.

Paivio, A. Mental imagery in associative learning and memory. Psychological Review, 1969 (76), 241-263.

Paivio, A. *Imagery and verbal processes*. New York: Holt, 1971.

Paivio, A. and K. Csapo. Concrete-image and verbal memory codes. Journal of Experimental Psychology, 1969 (80), 279-285.

Paivio, A. and K. Csapo. Picture superiority in free recall: Imagery or dual coding? Cognitive Psychology, 1973 (5), 176-106.

Paivio, A. and D. Foth. Imaginal and verbal mediators and noun concreteness in paired-associate learning: The elusive interaction. Journal of Verbal Learning and Verbal Behavior, 1970 (9), 384-390.

Paivio, A. and S.A. Madigan. Noun imagery and frequency in paired-associate and free recall learning. Canadian Journal of Psychology, 1970 (24), 353-361.

Paivio, A. and M. Olver. Denotative-generality, imagery, and meaningfulness in paired-associate learning of nouns. Psychonomic Science, 1964 (1), 183-184.

Paivio, A., T.B. Rogers and P.C. Smythe. Why are pictures easier to recall than words? Psychonomic Science, 1968 (11), 137-138.

Paivio, A., P.C. Smythe and J.C. Yuille. Imagery versus meaningfulness of nouns in paired-associate learning. Canadian Journal of Psychology, 1968 (22), 427-441.

Paivio, A. and J.C. Yuille. Mediation instructions and word attributes in paired-associate learning. Psychonomic Science, 1967 (8), 65-66.

Paivio, A., J.C. Yuille and S.A. Madigan. Concreteness, imagery and meaningfulness values for 925 nouns. Journal of Experimental Psychology Monograph Supplements, 1968 (76), (1, Pt. 2).

Paivio, A., J.C. Yuille and T.B. Rogers. Noun imagery and meaningfulness in free and serial recall. Journal of Experimental Psychology, 1969 (79), 509-514.

Perky, C.W. An experimental study of imagination. American Journal of Psychology, 1910 (21), 422-452.

Peters, D.H. The relationship between familiarity of words and their memory value. American Journal of Psychology, 1936 (48), 572-584.

Peterson, M.J. and S.E. Graham. Visual detection and visual imagery. Journal of Experimental Psychology, 1974 (103), 509-514.

Pressey, A.W. and A.E. Wilson. The Poggendorff illusion in imagination. Bulletin of the Psychonomic Society, 1974 (3), 447-449.

Pylyshyn, Z.W. What the mind's eye tells the mind's brain: A critique of mental imagery. Psychological Bulletin, 1973 (80), 1-24.

Rey, A. Les images mentales en psychophysiologie. Dialectica, 1958 (12), 130-145.

Richardson, A. *Mental imagery.* New York: Springer, 1969.

Richardson, J.T.E. Imagery, concreteness and lexical complexity. Quarterly Journal of Experimental Psychology, 1975 (27), 211-223 (a).

Richardson, J.T.E. Concreteness and imageability. Quarterly Journal of Experimental Psychology, 1975 (27), 235-249 (b).

Robinson, J.O. *The psychology of visual illusion.* London: Hutchinson, 1972.

Rogers, T.B. Coding instructions and item concreteness in free recall. M.A. Thesis, University of Western Ontario, 1967.

Schifferli, P. Etude par enregistrement photographique de la motricité dans l'exploration, dans la reconnaissance et dans la représentation visuelle. Monatschrift für Psychiatrie und Neurologie, 1953 (126), 64-118.

Schneider, G.E. Contrasting visuomotor functions of tectum and cortex in the golden hamster. Psychologische Forschung, 1967 (31), 52-62.

Schneider, G.E. Two visual systems. Science, 1969 (163), 895-902.

Schnorr, J.A. and R.C. Atkinson. Repetition versus imagery instructions in the short- and long-term retention of paired-associates. Psychonomic Science, 1969 (15), 183-184.

Segal, S.J. Processing of the stimulus in imagery and perception. In: S.J. Segal (Ed.), *Imagery: Current cognitive approaches.* New York and London: Academic Press, 1971.

Segal, S.J. and M. Glicksman. Relaxation and the Perky effect: The influence of body position on judgment of imagery. American Journal of Psychology, 1967 (80), 257-262.

Segal, S.J. and P. Gordon. The Perky effect revisited: Paradoxical threshold or signal detection error. Perceptual and Motor Skills, 1969 (28), 791-797.

Segal, S.J. and S. Nathan. The Perky effect: Incorporation of an external stimulus into an imagery experience under placebo and control conditions. Perceptual and Motor Skills, 1964 (18), 385-395.

Seibel, R., R. Lockhart and C.S. Taschman. The learning of 100 paired associates in a single, self-paced trial. Paper presented at the meeting of the Psychonomic Society, Chicago, October 1967.

Shaughnessy, J.J., J. Zimmerman and B.J. Underwood. Further evidence on the MD-DP effect in free recall learning. Journal of Verbal Learning and Verbal Behavior, 1972 (11), 1-12.

Shaw, A.C. A formal picture description scheme as a basis for picture processing systems. Information and Control, 1969 (14), 9-52.

Sheehan, P.W. A shortened form of Betts' questionnaire upon mental imagery. Journal of Clinical Psychology, 1967 (23), 386-389.

Sheehan, P.W. The role of imagery in incidental learning. British Journal of Psychology, 1971 (62), 235-243.

Sheehan, P.W. and U. Neisser. Some variables affecting the vividness of imagery in recall. British Journal of Psychology, 1969 (60), 71-80.

Shepard, R.N. Learning and recall as organization and search. Journal of Verbal Learning and Verbal Behavior, 1966 (5), 201-204.

Shepard, R.N. Recognition memory for words, sentences, and pictures. Journal of Verbal Learning and Verbal Behavior, 1967 (6), 156-163.

Shepard, R.N. and M. Teghtsoonian. Retention of information under conditions approaching a steady state. Journal of Experimental Psychology, 1961 (62), 302-309.

Short, P.L. The objective study of mental imagery. British Journal of Psychology, 1953 (44), 38-51.

Singer, G. and P.W. Sheehan. The effect of demand characteristics on the figural after-effect with real and imaged inducing figures. American Journal of Psychology, 1965 (78), 96-101.

Smythe, P.C. and A. Paivio. A comparison of the effectiveness of word imagery and meaningfulness in paired-associate learning of nouns. Psychonomic Science, 1968 (10), 49-50.

Sperling. G. The information available in brief visual presentations. Psychological Monographs, 1960 (74), (Whole No. 498).

Standing, L. Learning 10,000 pictures. Quarterly Journal of Experimental Psychology, 1973 (25), 207-22.

Standing, L., J. Conezio and R.N. Haber. Perception and memory for pictures: single-trial learning of 2,500 visual stimuli. Psychonomic Science, 1970 (19), 73-74.

Stoke, S.M. Memory for onomatopes. Journal of Genetic Psychology, 1929 (36), 594-596.

Stricker, S. *Studien über die Bewegungsvorstellungen*. Wien, 1882.

Stromeyer, C.F. Eidetikers. Psychology Today, 1970 (4), 76-80.

Stromeyer, C.F. and J. Psotka. The detailed texture of eidetic images. Nature, 1970 (225), 346-349.

Thorndike, E.L. and I. Lorge. *The teacher's word book of 30,000 words.* New York: Bureau of Publications, Teachers College, 1944.

Totten, E. Eye movements during visual imagery. Comparative Psychology Monographs, 1935 (11), no. 3.

Trevarthen, C. Two mechanisms of vision in primates. Psychologische Forschung, 1968 (31), 299-337.

Underwood, H.W. The validity of hypnotically induced visual hallucinations. Journal of Abnormal and Social Psychology, 1960 (61), 39-46.

Walker, M.J. Imagery ratings for 338 nouns. Behavioral Research Methods and Instrumentation, 1970 (2), 165-167.

Wallace, W.H., S.H. Turner and C.C. Perkins. Preliminary studies of human information storage. Signal Corps Project No. 1320, Institute for Cooperative Research, University of Pennsylvania, 1957.

Yuille, J.C. A detailed examination of mediation in PA learning. Memory & Cognition, 1973 (1), 333-342.

Zikmund, V. Oculomotor activity during visual imagery of a moving stimulus pattern. Studia Psychologica, 1966 (4), 254-274.