CONCRETENESS AND LOCATION AS SOURCES OF VISUAL CONFLICT

ITEM CONCRETENESS AND SPATIAL LOCATION AS SOURCES OF CONFLICT BETWEEN RECALL AND CONCURRENT VISUAL PERCEPTION

by

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ABSTRACT

The relative contributions of spatial organization and item concreteness or picturability to recall processes was investigated by attempting to induce modality-specific interference between recall and response. Subjects learned lists of items which were varied in physical or referential visual characteristics. They later signalled information about them either vocally or via a visually-guided response.

Some ways of presenting lists for learning which are traditionally regarded as increasing reliance on mediating visual imagery were effective in generating conflict between recall and the visually-guided response; this effectiveness was limited to presentation conditions and list types which introduced spatial organization into the stimulus material. The concreteness of individual items was not useful in predicting visual conflict. Recall-response interference was eliminated by providing the subject with a response sheet which was spatially compatible with the stimulus array used during the learning phase.

The results are interpreted in the following ways: There are circumstances under which verbal mechanisms alone cannot account for recall processes when the to-be-recalled material is a list of concrete nouns. To account for these results one needs to postulate a mechanism which shares execution and/or control capacity with the visual system. The fact that spatial organization rather than item concreteness predicts visual conflict indicates a need to distinguish between these two factors

in the study of internal visual representation. In subjects' attempts to recall information, spatial location is much more easily interfered with than the internal representation of formal characteristics of single items.

The distinction drawn between the internal representation of location and form in the thesis parallels a similar distinction that has been made with respect to visual perception in studies with humans and other vertebrate species. The results are also discussed in relation to attempts to distinguish semantic and imaginary mediators of learning on the basis of modality-specific interference.

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CHAPTER ONE

INTRODUCTION

People who are learning lists or pairs of words frequently report that they create mental pictures of the words' referents to help them recall the material (Reitman, 1970). For most people a phrase like "nudist devouring a bird" readily evokes visual imagery. If afterwards an experimenter supplies the word "nudist", to which the correct response would be "bird", there may be the distinct feeling that the route to that correct response would be via a mental picture of the rather bizarre referent, that is, that the image mediates the response.

In the study of modes of internal representation, researchers have used several operations to provide evidence for this hypothesis that internal visual representation is a potent mnemonic device. For example, the rated power of a word to evoke a mental picture correlates positively with the word's ease-of-learning in a variety of situations (Paivio, 1969). In addition, when subjects are instructed to form visual images of verbally-presented items, learning is enhanced (Bower, 1968). A third way to try to invoke mediating imagery is to give subjects pictures instead of words, or objects instead of pictures; these manipulations have also proven effective in boosting learning performance (see Paivio, 1969, 1971 for reviews). These kinds of evidence have led to the acceptance of visual imagery as a representational mode distinguishable from, and perhaps rivalling in power, verbal representational processes, processes which are presumably linked to audition and speech.

Is it justified to assume that it is because some experimental conditions engender internal visual representation that they result in better learning? There are reasons for uncertainty on the issue. They centre around the fact that other characteristics of stimulus information covary with rated imagery potential. Item concreteness is one (Paivio, Yuille and Madigan, 1968). Bower, Munoz and Arnold, in a personal communication, advance the argument that highly concrete words (e.g. cat, table) are semantically simple, requiring less analysis in entering the "internal lexicon" than less concrete, more general (and less easily imaged) ones. They argue that this may account for concrete words' superiority in learning experiments. Likewise, we might argue that 'concrete meaningfulness', which characterizes words like "cat" and "table" implies that we know different kinds of things about concrete words than about ones like "democracy" and "justice". Cats and tables have a subjective 'here-and-now' quality that is lacking in abstract concepts. The difference need not be tied to visual qualities in the sense of depending on implicit sensory experiences. But 'here-and-nowness' and visualization are obviously closely related, and it is this confounding that makes for difficulties of interpretation in learning rates. On a priori grounds there is no reason to believe that this subjective feeling, as vague as it is, is less of a sign of the crucial underlying variable than the subjective feeling that one type of word-referent is easily visualized and the other is not. In a similar vein, one might argue that the specificity introduced by showing a subject a picture of a cat makes "cat" easier to remember as part of an experimental set than if the word cat is seen or heard. The picture would carry along with it a lot of information other than nominal identity, (breed, colour, size) which may advance the "memory strength" of the item. On the topic of instructional set, Bower, Munoz and Arnold suggest that telling a subject to create mental pictures of word pairs or lists causes him to seek out semantic relationships among the items, and that the establishment of these aid in subsequent recall.

Probably the most compelling evidence that could be marshalled in support of the imagery hypothesis against such arguments would be the demonstration that the visual perceptual system was actively involved when people were remembering words and pictures under the experimental conditions said to induce mediating imagery. The argument is that if imagery is useful as a mnemonic device, and if imagery really does engage the same machinery as visual perception does (as some have argued - e.g. Neisser, 1968), then we should be able to find evidence that the perceptual system is tied up in memory under certain conditions. As things stand at the moment, evidence for such a state of affairs is lacking, or weak--what there is will be reviewed later. The research to be reported in this thesis is motivated in part by a desire to see if such evidence can be found.

Potential sources of internal visual representation

We now turn to an outline of the second major focus of the present research, for it has to do with how we have formulated hypotheses about the conditions under which we may find evidence of internal visual representation in memory processes.

We distinguish two potential sources, and it is the possibility that these sources contribute differently to the process of imagery that forms a major topic in these experiments. So far in the experimental study of imagery little attention has been paid to whether imagery is best thought of as a single system, or if it is composed of separable components. This failure to attempt to differentiate components of internal visual representation is in contrast to certain distinctions that have been made with respect to visual processing in other contexts.

One source of imagery is the characteristics of the individual items, in particular their potential for evoking mental pictures. As pointed out above, item 'vividness' (rated ease with which a word referent can be pictured) has proven to be a potent variable in learning experiments. In a typical experiment, Tulving, McNulty and Ozier (1965) obtained ratings of the vividness of words and from these constructed three lists, equal in meaningfulness, of high-, medium- and low-rated words. Subjects learned lists of higher vividness more readily than the list of low vividness. A large number of experiments, using various tasks (free recall, recognition, serial recall), with lists constructed in this fashion (i.e., in terms of single-item attributes) have generally found the concreteness-vividness (the terms are typically used interchangeably) variable to account for the largest part of the variance in acquisition performance (see Paivio, 1971).

The other source which may be important in determining a mediating role for visual imagery is spatial organization among a set of items. This variable has received little separate attention as yet in the experimental study of imaginal processes, yet there is a considerable body of evidence which suggests that it is an important factor in that context. This statement requires some justification. Textbooks and articles about visual imagery often appeal to common-sense experience as part of the justification for the enterprise that they are undertaking. Consider this example from Paivio's recent book (1971): "Occasionally, when I have been required to list the names of my colleagues from memory, I have found myself visualizing the hallways in which their offices are located, then picturing and naming the occupants" (p. 3). A commonly-used example is a request for the reader to say how many windows there are in his house (Shepard, 1966; Neisser, 1968). Most people report the need mentally to count the windows, a process that subjectively is similar to actually walking around counting windows. In both examples we can discern two components. One is generating images of things (e.g. colleagues), the other is engaging in an internal spatial search, a directional activity which seems to link the more static images of the things (e.g., imaging moving down a hallway). Berlyne (1965) uses an example which contains the same distinction:

"...[If] a man is asked to enumerate the states over which he would pass in flying from San Francisco to New York City, he will have to make use of imagery unless he has the names of the states readily available as a verbal sequence... No matter how complete his knowledge of the geography of the United States, he could hardly imagine a map in the form of a colored patchwork in which all the states appear equally clearly. He must first have an image in which the area around central California is in clear focus and the rest of the country is depicted rather vaguely. He will then see central California fade and the area immediately to the east of it come into view, allowing him to identify the next state as Nevada, and so on, until he finds himself picturing the approaches of New York City" (p. 142). Berlyne refers to "stages" which are "linked" to one another.

Sometimes the mental picture part of this process may be rather faint. Colleagues of the author were asked to say how many desks were in the room we shared, without looking. All reported "going around" the room but some denied "seeing" anything. Neisser (1968) reports the same phenomenon. Counting windows is accomplished by some without any feeling of lifelike imagery, yet the directional component is invariably reported to be present.

This anecdotal and subjective evidence should make us sensitive, therefore, to the possibility that internal visual representation includes separable spatial and mental picture components. Perhaps they even represent different processes if it is true that the directional aspect can be present without the mental pictures.

For a variety of reasons, various theorists have proposed a distinction which shares features with the one described above. Skinner (1953), for example, is keen to couch visual imagery in terms of internalized observing responses ("private seeing"), and draws a distinction between "discriminative" and "manipulative" responses. "Private problem-solving usually consists of a mixture of discriminative and manipulative responses...In mental arithmetic one multiplies, divides, transposes, and so on, seeing the result in each case, until a solution is reached. Presumably much of this covert behaviour is similar in form to the overt manipulation of pencil and paper; the rest is discriminative behaviour in the form of seeing numbers, letters, signs, and so on, which is similar to the behaviour which would result from over manipulation" (p. 273). We might think of imagining a colleague's face as discriminative and mentally moving along a hallway as manipulative. For reasons to do with the logic of mental events, James (1890, Vol. I, p. 243) refers to the alternations of flights and perchings in thinking, and Berlyne (1965) to situational and transformation thoughts. Berlyne, too, stresses that internal visual representation is like observing the real world, especially the transformational part. About his example of enumerating the states of the U.S.A. he says, "[The] stages will be linked to one another by processes that are clearly equivalent to the eye movements, possibly accompanied by finger movements, that 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). Paivio, in summarizing this kind of reasoning, characterizes the distinction as being between "static" and "dynamic" mental processes. He also is of the opinion that a "motor component somehow facilitates the transition from one substantive part of the stream of thought to another" (p. 31), basing his conclusion in part on the evidence linking dream content which includes movement to appropriate eye movements (see Dement, 1964). Neisser (1967) also concludes that visuo-motor activity is most readily observed when imagery contains transitional aspects.

Whether or not one accepts that the presence of a separate "dynamic" process is signified by evidence of peripheral motor involvement in selected content areas of internal visual representation, there is still reason to believe that manipulative and discriminative factors may contribute separately to visual imagery. Apart from appeals to intuition and authority, there is evidence from mental measurement and from clinical neurology to support the distinction. In psychometrics, separate factors have been isolated for the ability mentally to manipulate things and the ability to visualize things and situations (Guilford, 1967). This means that the two skills remain uncorrelated to some extent. In neurology, cases have been described in which, due to cerebral lesions, patients have lost the ability to "cull up visual images of a topographical or geographical sort", such as streets in the patient's neighbourhood (Critchley, 1953, p. 336), but retain other kinds of visual imagery (e.g., describing a spouse's appearance or the ability to recognize familiar objects.

It makes sense, therefore, that in the experimental study of factors that control imaginal mnemonic processes we should take the hypothesized distinction into account. By way of illustration of how this might be done, consider the following two word-lists;

List 1	List 2
house	chimney
fish	roof
sun	ceiling
car	wall
corn	carpet
book	floor
bird	door
tree	steps
bottle	path
rock	lawn

Both lists are made up of highly concrete items, and people asked to learn them frequently report visualizing the word referents. But in List 2 the subjects additionally report a feeling of "moving down" an integrated, imagined structure. In contrast this strong directional component is rarely reported in List 1, and the overall integration is lacking. Using Skinner's terminology, there are reports of the discriminative responses of private seeing in the recall of both lists, but in List 2 people more frequently also report manipulative responses as they think of moving down an imagined house. List 2 may also encourage more reliance on visualization than List 1.

Some people claim to be able to remember the items of List 2 without any covert verbalization, whereas, in this author's informal investigation, this claim has never been made for List 1. Using concreteness of the single items as the sole predictor of mode of internal representation, we would expect no differences between the two lists. However, on the assumption that spatial cohesiveness exists in List 2, and that it induces an additional, transformational component into visual imagery that could mediate list learning, we would predict differences. In brief, the proposal is that for List 2 we may find evidence of stronger reliance on internal visual representation than for List 1, and a greater likelihood that it would engage mechanisms of visual perception.

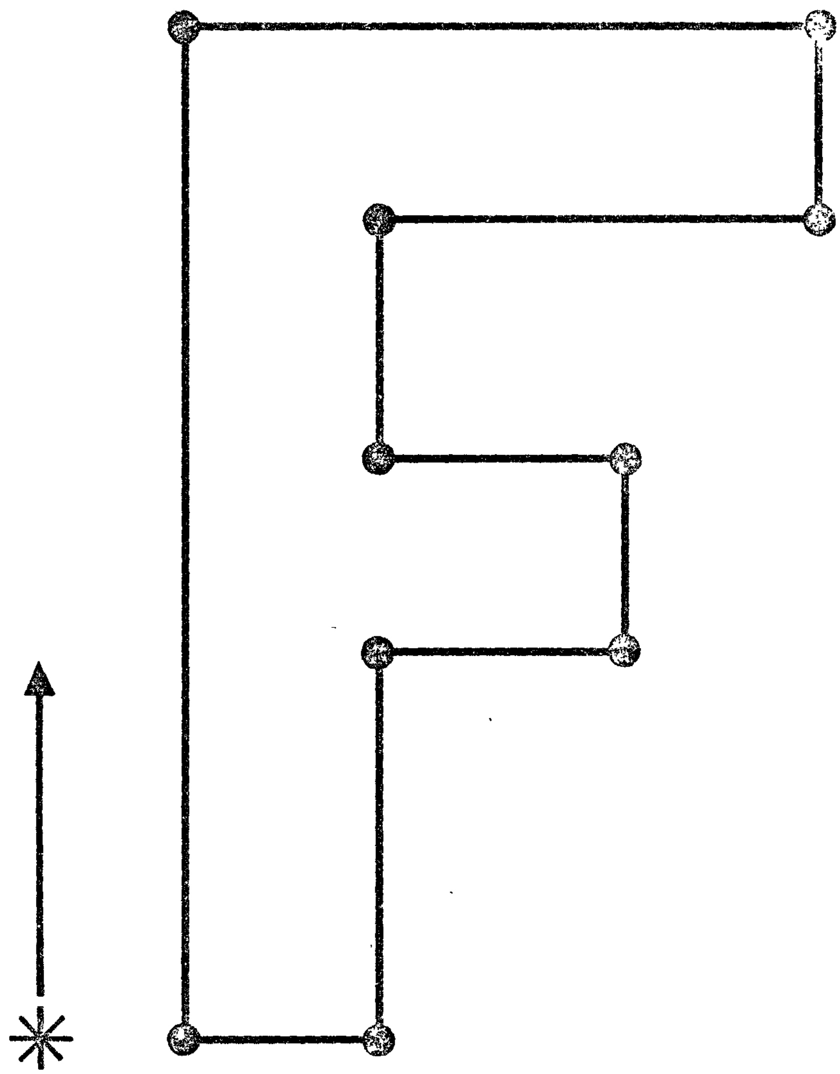
Seeking evidence of the involvement of the visual system in memory

How might we test this proposition? Acquisition rates (e.g., number of trials to reach a certain criterion of recall, number of errors after one exposure to the lists, and so on) are indirect measures of representational mode. In the long run they rely for their interpretability on the experimenter's ability to select differentially acquirable materials where the difference can only be accounted for in terms of the hypothetically important variable. For example, the two lists above differ in what could be called thematic content. The items of List 2 are parts of a superordinate category (house), whereas it is much more difficult to classify List 1 items as referring to a singly-identifiable category. Thus, differences in acquisition rates may be interpretable in several ways, and a large number of control conditions may be needed to tie down the effective variable at all closely. In fact alternative explanations may be quite difficult to eliminate at all, as was argued above. Bower, Munoz and Arnold suggest a way of handling the acquisition superiority of concrete over abstract words (in terms of modern semantic theory) that does not invoke visual imagery as an explanatory concept. They similarly try to deal with the effectiveness of instructions to use imagery in word learning. This is not the place to try to settle these issues. They were raised to show that indirect measures of internal representation modes lead to difficulties of interpretation. They may be solvable as more and more variables are partialed out, but a more direct index of internal events would be desirable.

An adaption of a technique developed by Brooks (1968) is well suited to our purposes. It provides a relatively direct indicator of subjects' reliance on internal visual representation during recall, and it should enable us to determine the degree to which certain types of material encourage reliance on internal visual representation, with evidence of involvement of perceptual mechanisms. In Brooks' experiments subjects were asked to categorize points on a remembered spatial diagram (e.g., the block upper-case F of Figure 1, with extreme upper and lower points being positive, the rest negative instances of the category) a task for which people almost invariably report using visual imagery. They could do this fairly rapidly when asked to say "yes" for positive and "no" for negative instances. The

FIGURE 1

A sample of the spatial diagrams used by Brooks (1968). The asterisk and arrow show the subjects the starting point and direction for both reproduction and categorization. From Brooks (1968).



response was much slower when, instead of a spoken categorization response, subjects pointed to a column of Y's and N's on a card before them, staggered to force close visual monitoring (see Figure 2). The conclusion was that the act of recall and visual control of the response both involve the same equipment at some level of the nervous system, and subjects had to divide attention between two visual tasks, one processing internal, the other external information. Various other experiments in the series supported this interpretation. For example, the relative times for spoken and visually-guided responses were reversed when the to-be-recalled material was verbal (sentences, the words categorized for grammatical class), indicating that silent recall of verbal information conflicts with overt speech more than with visually-monitored pointing. Thus the response-mode inequalities could not be entirely explained on the grounds of inherent differences in execution speed.

This technique can be adapted to the present purposes as follows; word-lists of the type introduced earlier are first learned to criterion. Subjects then categorize each word in turn (e.g., for whether it refers to an animal or not), using each of the response modes. If recall of certain lists induces reliance on internal visual representation, and if retrieval of material thus coded depends on perceptual mechanisms used in guiding the pointing response, that response should take longer than articulation of the response. In part, therefore, the experiments in this thesis represent an attempt to extend Brooks' findings to stimulus material in which the items can be named.

There has already been an adaption of Brooks' technique to memory for words (Atwood, 1971). In that experiment, different

FIGURE 2

A response sheet, similar to the one used by Brooks (1968), and the one used in experiments of Parts A and B.

Y N

Y N

Y N

Y N

Y N

Y N

Y N

Y N

subjects heard either abstract-noun or concrete-noun phrases. "Nudist devouring a bird" is an example of a concrete phrase. Immediately after presentation of each pair they were required to attend to either a visually- or auditorily-presented signal, and to respond appropriately. The signal was always the number 1 or 2 (seen or heard), with the appropriate response to 1 being "two", "one" if the number 2 occurred. On a subsequent cued recall test, performance on concrete pairs was found to be adversely affected by the interpolated visual task relative to the auditory task and relative to a no-interference control group. The opposite was true for the abstract pairs - hearing the interpolated signal depressed recall relative to the effects of the visual signal. Atwood interpreted the results as confirming that concrete phrases are coded visually, and are affected by using the visual system for another purpose immediately following presentation. And, since abstract pairs are affected if the auditory/articulatory system is engaged in an auxiliary task, they must be coded verbally.

However, several attempts to replicate these results have failed (Bower, Munoz and Arnold, personal communication; Brooks, personal communication). If there is a real effect present (and that now appears doubtful), it is weak by comparison to the robust effects obtained by Brooks in his earlier studies of modality-specific interference with the processing of spatial information (1967, 1968). There are two main differences between the material used in the original work and its adaption by Atwood (1971) which might explain the differences. One is the use of verbal material in Atwood's work. It may simply be that the visual system does not become involved in the storage of concrete verbal material, or possibly of any stimulus set in which the items are nameable. The other major difference is the high spatial component of Brooks' material, and the lack of it in phrases. Perhaps finding modality-specific interference is predicated on there being a spatial component in the to-be-recalled information.* Interestingly, all tasks used by Brooks to date which have shown a conflict effect (Brooks, 1967, 1968, 1970) have been spatial in one way or another. As well as a change in the nature of the stimulus material, the perceptual tasks in the two situations are obviously different--visually guiding a pointing motion and looking at a number. It is conceivable that only some aspects of the concurrent visual activity interfere with internal visual representation. Perhaps only some tasks load the visual system heavily enough to suppress its use for internalized activity (visual guidance and reading certainly seem to), or there may be separable sub-systems within the visual system such that only concurrent activities <u>within</u> these sub-systems share processing

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*In one sense everything has spatial characteristics--all things that we can visualize fill space. The term is being used here to characterize situations which also have a directional component, a sense of moving from one thing to the next (as along a hallway, or down an imagined house, or around the letter F).

capacity. The present attempt to extend Brooks' findings to nameable stimuli is therefore interesting in its own right. Several theorists have accepted Brooks' results as evidence for the continuity of perception and imagination (Neisser, 1968; Paivio, 1971). Any doubt about how much overlap there is between the two functions should be clarified.

In summary, we are concerned to find out about the conditions under which the visual system becomes involved in recall processes for nameable stimuli, and in particular whether item concreteness and spatial organization in stimulus material make distinguishable contributions to visual imagery. In using the relatively direct measure of visual processing that we have chosen, we hope to discover whether the finding that recall of spatial diagrams conflicts with a concurrent visual task can be extended to the recall of stimuli which can also be encoded verbally. The extent to which imaginal and perceptual activities load a common system and the conditions under which they do so are in need of clarification.

PART A

EVIDENCE FOR THE INVOLVEMENT OF THE VISUAL SYSTEM IN IMAGERY WHICH MEDIATES RECALL OF NAMEABLE ITEMS

CHAPTER TWO

INTRODUCTION TO EXPERIMENTS A1, A2 and A3

The experiments of Part A are directed to the question of whether there is evidence that the visual system is engaged in the recall of nameable stimulus material that is said to be mediated by visual imagery. We are ignoring for the moment the possible separate effects of different potential sources of visual imagery, item concreteness, and spatial organization. As described in the introduction, we try to implicate visual activity in recall by demonstrating conflict between recall and a concurrent visually-guided response. We know this is an effective technique when subjects are generating or recalling spatial diagrams (Brooks, 1967, 1968), but as yet it is not clear that the technique works for recall of material that has potential for being coded as both visual and verbal sequences. It is not a foregone conclusion that we will find evidence of conflict with such material. Consider, for example, the possibility that subjects are highly flexible, able to switch from one code to another easily; when faced with a spoken response they recall from a visual (non-conflictful) store, and work from a verbal sequence while using a visually-guided response. Or more simply that they encode the material verbally, thus avoiding visual conflict.

The experiments of Part A all have the following feature; groups of subjects are compared for visual conflict where one group is taught a list with a method designed to produce more reliance on visual coding than is sought for the other group.

EXPERIMENT A1

In this experiment subjects are taught a list of concrete nouns, those in one group simply being read the words, while subjects in the second group were shown a scene depicting the word list while the words were being read to them. Numerous experiments have demonstrated that showing pictures to subjects facilitates learning (compared with presenting subjects only with names of the pictured objects), and this effect has been interpreted in terms of imaginal processes (see Paivio, 1971). Furthermore, an additional memory advantage has been found for scene-like arrangements of pictures compared with the same pictures independently arrayed (Epstein, Rock, and Zuckerman, 1960; Horowitz, Lampel, and Takanishi, 1969). If the imagery interpretation of these effects is correct we can expect different coding strategies for subjects in the two current experimental groups. Added to this is the intuitive plausibility of claiming that being shown a scene should lead to a stronger visual memory code than simply hearing a "description" of the scene.

Method

Material. The stimulus list for serial recall consisted of the following concrete words (classification categories at right):

	Category	
	Man made	Animal
sun		
bird		+
tree		
house	+	
cow		+
tractor	+	
farmer		+
hill		
windmill	+	
cloud		

The word FARM has been adopted as an identifying name for the list for the purpose of this presentation. In one condition of this experiment, FARMSCENE, subjects were shown the scene in Figure 3 during acquisition. As can be seen, the order of the words follows roughly a counter-clockwise circle through the scene. Two bases of categorization were used. One was the category _man made_, with _house_, _tractor_ and _windmill_ as the positive instances. _Bird_, _cow_, and _farmer_ were positive in the other category, _animals_.

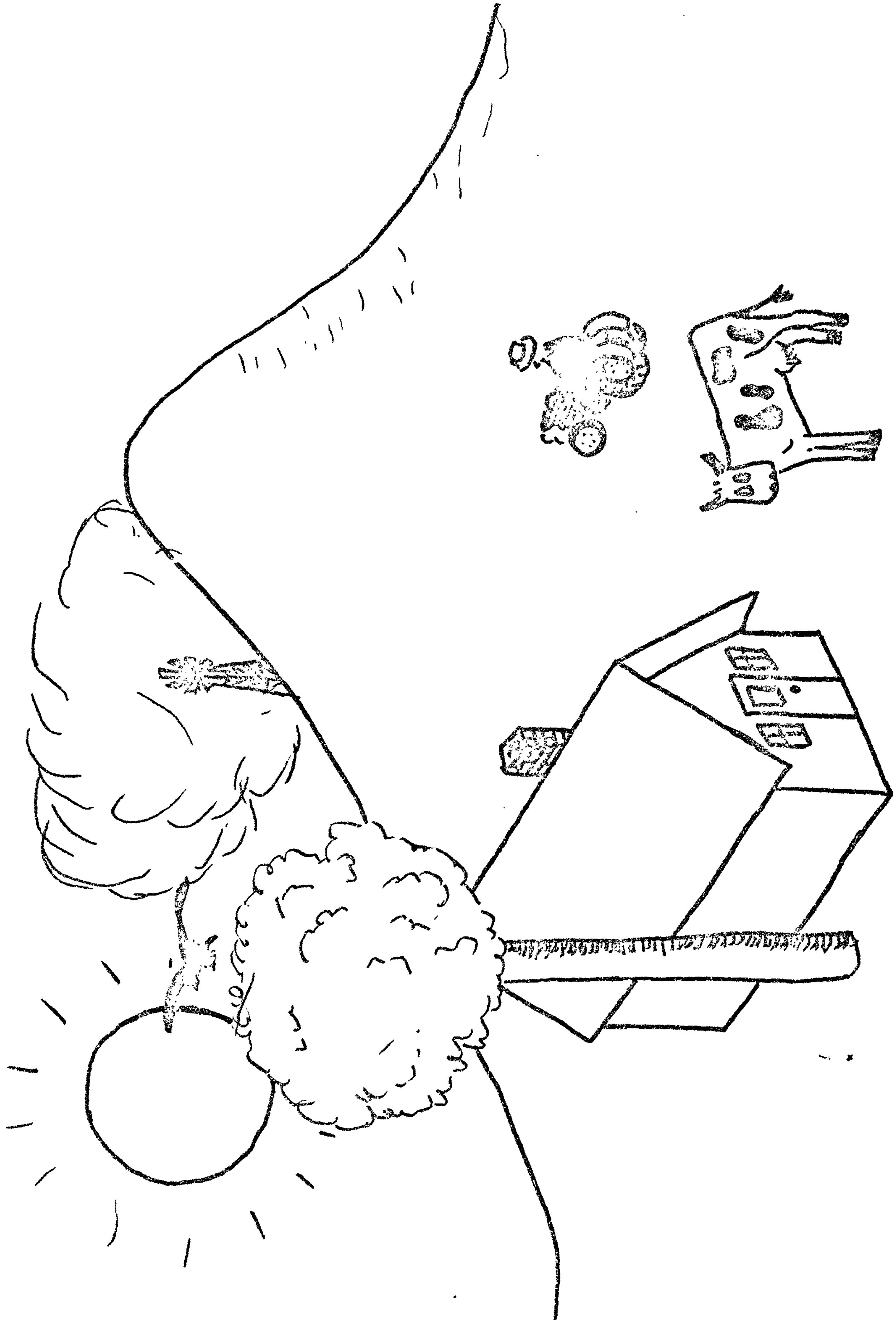
Procedure. All subjects were run individually, in sessions lasting between forty and sixty minutes. In the first stage subjects were introduced to and given practice in the classification task. The following instructions were read to each subject:

> In this experiment you will be required to learn a list of words: To show you what you will be doing with the list, I would like you to look at the short list on this card.

The experimenter then indicated a card with the following words printed on it, one under the other:

FIGURE 3

FARM scene used in Experiment A1.



snow
dog
train
boy
bus

> As you can see there are the names of two animals in that list, dog and boy. If I asked you to tell me whether each thing in the list was an animal or not you would say no, yes, no, yes, no.

At this stage the experimenter was pointing to each word in turn as he categorized it with "yes" or "no". When it was clear that the subject understood what had been done (each one caught on quickly), the experimenter asked that the subject do the same thing, but indicating whether each thing was man-made or not. When the subject had successfully done that (again, little difficulty was experienced - some had trouble deciding if snow could be man-made or not, at which point they were told that in the experiment it would be quite clear what the "yeses" would be), the instructions proceeded as follows:

> There is another way in which you could give me the same information, without saying anything. You could point to this card. I will show you how.

Here the experimenter indicated a Y N card with five lines It was pointed out that Y stood for yes, and N for no.

> On each line you point with this pencil to either Y or N, depending on whether you are trying to tell me yes or no. For example, if you were categorizing the things in the list for whether they were animals or not, on the first line you would point to N, because snow is not an animal.

Here and subsequently, the experimenter pointed to the appropriate spot on the card as he described the method.

> On the second line, the one for dog, you would point to Y. The third line is N again, for train, then Y for boy and N for bus.

When that was understood, the subject was asked to respond in the same way for the category, man-made. They all quickly understood the procedure and were able to do what was asked.

It was then pointed out to the subject that in the actual experiment he would not have the words in front of him, that he would have to work from memory. There followed a practice list, which the subject had to learn. It consisted of the following words:

rock
mouse
book
cat
table

The experimenter read it to the subject three times, and asked the subject to repeat it. When he was able to do so successfully three times in a row he was asked to categorize the words on the basis animal, responding with the words yes and no only (i.e., not repeating the items in the list). Following this, the subject practised the visually-guided response (V-G.) twice, the first time with the category man-made, then animal. Finally, another articulated (Art.) response was required, with category man-made. This procedure was repeated using another five-word list.

It was then explained to all subjects that for the experiment they had to learn another list, which was longer. They were told that during the learning stage they would be presented with the list several times, then asked to recall it; it would be presented again if they made a mistake, followed by another recall attempt, and so on till they knew it "well enough". They were also informed that their recall attempts would be timed, but to proceed at a "natural speed", and not to worry about the timing.

The procedure will now be described for group FARMSCENE. The scene in Figure 3 was placed before the subject, on the table between him and the experimenter. The latter told the subject that "this is the list", and proceeded to name the items, in correct order, pointing to each one as he did so. The naming was done at a rate of three items per two seconds, and was repeated. The subject himself then twice named the items in order, following which the picture was removed. A recall attempt, starting with the word sun, was now made, the experimenter noting the time from the start to finish, or until such time as the subject indicated he could go no further. The number of errors, loosely scored, was also noted. Following an imperfect recall attempt the picture was again placed before the subject while he named the items once. This procedure was repeated to a criterion of three successive error-free recall trials. After this the picture was replaced and the experimenter demonstrated how to use a different starting point.

> If I asked you to begin with house, you would say house, cow, tractor, farmer, hill, windmill, cloud, sun, bird, tree. Do you follow that? Okay, you begin with cow.

The picture was removed while the subject did what was asked. Three more recall trials were carried out, each with a different starting point. Again, response times and errors were noted (few occurred). Once the list was learned and practised this way the subject was informed that he would be returning to the categorization task. He was reminded that the categories were animal and man-made, and firstly asked simply to tell the experimenter the names of the positive instances of each so that "we agree on what they are". If he failed to come up with the right words (few subjects did fail) they were told to him. The following instructions were then given:

> "At the beginning of each trial I will tell you whether to respond by saying yes and no (speaking) or by pointing to that card (Experimenter indicates the response card shown in Figure 2.). Then I will say whether you are to classify for animals or for man-made things. Finally I will tell you which item to start with, and you are to proceed through the entire list. At this point I will start the timer. The idea is for you to go as fast as you can. Don't rush so that you force yourself to make mistakes - go as quickly as you can consistent with being accurate. Do you understand?"

If the subject had no questions, he was then told that on the pointing trials he was to start pointing with the top line on the card, irrespective of where he was told to start in the list. He was then asked to repeat the list once more, starting with sun, to refresh his memory.

The main part of the experiment then proceeded. Response modes were alternated in pairs - i.e., two of one type, two of the other, etc. Half of the subjects started with Art., the rest with V-G. Starting points were randomized with the restrictions that no item occurred twice in a row as the starting point, and each was used n times before any other was used n + 1 times. Categories were randomized, with the restriction that each occurred five times in every ten trials. Response times were recorded, beginning as soon as the last instruction had been given (the starting point) and continuing until the subject either said "yes" and "no" ten times for Art., or reached the last line on the response card for V-G. Errors were noted, and if possible, the durations of erroneous trials were also recorded. (This was not possible of course if a subject was unable to finish a trial). For the purposes of the alternating of response modes, starting points and categories, no distinction was made between correct and erroneous responses. The data collection continued until fourteen error-free trials with each response mode had been obtained (twenty eight in all), half of which were for the category animal, half, man-made. Subjects were given a short rest about halfway through these trials.

Questioning followed. The aim of the questions was to find out how the subject had coded the list, which of the response modes he found easiest, and why. Answers were recorded in sufficient detail for later analysis. All subjects were then told of the purpose of the experiment, paid, and dismissed.

The other group in this experiment, FARMSPOKEN, differed only in that the subjects at no stage saw the FARM picture. Instead of the naming procedure, the experimenter simply read the list to them four times, at the same rate (3 words per 2 seconds).

Subjects. Twelve McMaster undergraduates acted as subjects in each group, six males and six females (twenty-four in all). Each was paid at the rate of $2 per hour. Anything less than an hour earned the flat rate of $2. Only one subject took longer than one hour.

Results and discussion

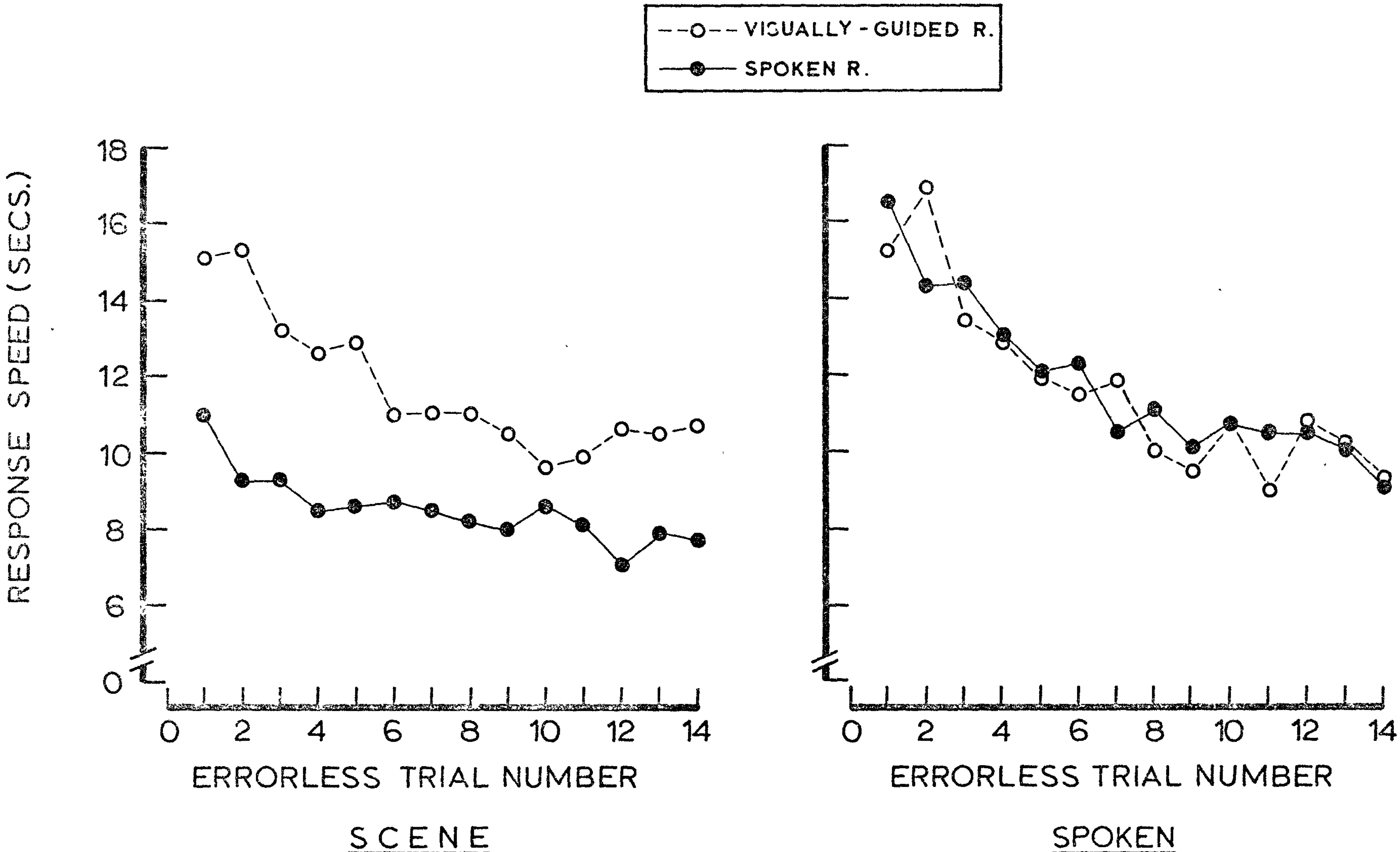
The results are presented graphically in Figure 4. For the subjects who had seen the pictorial display, there was a clear categorization difference in favour of Art. Almost complete overlap between Art. and V-G. occurred in condition FARMSPOKEN. The mean within-subject output time difference in FARMSCENE was 3.2 seconds, $t_{11} = 4.899$, $p<.01$. All subjects took longer on V-G. than on Art. The response difference was sustained throughout the length of the session, as can be seen by inspecting Figure 4. There is a slight decline in the size of the difference, but not enough to question seriously the robustness of the phenomenon over trials. In contrast, for FARMSPOKEN the mean categorization response mode difference was .15 seconds, in favour of V-G. Six subjects took longer during V-G., five were slower in Art., and there was one tie. In neither of the conditions did sex of subject make a difference. This is a feature of the whole experimental series.

Thus, presenting a scene as pictorial support during acquisition leads to a type of coding during recall that produces visual conflict, longer V-G. than Art. times. That this difference is not just a function of an inherent response mode inequality is demonstrated in FARMSPOKEN, where no such output difference occured.

The absolute response times are interesting. V-G. times for FARMSCENE are almost identical to both output modes for FARMSPOKEN. This is a pattern which is repeated in later experiments. Where visual conflict occurs it is usually from a drop in Art. times for the group showing conflict relative to response durations for the

FIGURE 4

Output times for both response modes in Experiment A1.


VISUALLY - GUIDED R.
SPOKEN R.
RESPONSE SPEED (SECS.)
18
16
14
12
10
8
6
0
0 2 4 6 8 10 12 14
ERRORLESS TRIAL NUMBER
SCENE
0 2 4 6 8 10 12 14
ERRORLESS TRIAL NUMBER
SPOKEN

FARM ITEMS

the appropriate control group and to V-G. times for the conflict group itself, all three of which tend to overlap. It is as if when unequal response times occur something in the V-G. response takes away a special advantage enjoyed by one group, an advantage which can only make itself felt when a vocal response is permitted.

Subjective reports support the contention that visual conflict results from a coding strategy which makes use of the visual information in the pictorial display presented. In FARMSCENE subjects uniformly claimed that they were using at recall an image of the scene as shown to them. Some felt that they had used this image exclusively, with no feeling of saying the names to themselves. Others reported varying degrees of simultaneous covert naming; one saying that he needed the names to keep order, the remainder claiming that naming was secondary to visualization. The descriptions of recall strategy were more mixed for FARMSPOKEN subjects. There were more reports of reliance on naming, with only one subject claiming that he relied solely on a generated image. Most subjects also had some pictorial component in mind. These components were mostly sub-groups of items - e.g., a sunbird, "something Mexican"; a bird in a tree-house, etc. Some subjects had a sense of the word-forms themselves, arranged in a vertical or horizontal array.

All subjects were asked which response mode they found easier. Table 1 gives the results of that question for this experiment and for the others in Part A. The figures for FARMSCENE and FARMSPOKEN are consistent with the above output times and subjective reports of coding strategy. For FARMSCENE all but two subjects found Art. easiest, which fits with the proposition that they were primarily relying on an

TABLE 1

Numbers of subjects preferring each response mode

in five experimental conditions

Condition and experiment	Art. preferred	V-G. preferred	Equal, can't tell
FARMSCENE (A1)	10	1	1
FARMSPOKEN (A1)	4	7	1
FARMSPOKEN & IMAGERY INSTRUCTIONS (A2)	8	4	0
PIGMATRIX (A3)	10	1	1
HOGMATRIX (A3)	6	5	1

internal visuo-spatial representation of the stimuli, and that active concurrent visual perception is in some degree incompatible with such reliance. In fact most of the subjects spontaneously gave reports of conflict. Examples follow:

> "I couldn't see it (the image) as well when pointing; I couldn't move my eyes back and forth on the page (response card) and back and forth on the (imagined) picture."
>
> "The picture switched itself off when I was looking at the paper (response card)."
>
> "The picture was not as vivid when I was pointing."
>
> "The picture was interrupted by pointing."

There were some reports like these in FARMSPOKEN, notably from subjects who claimed clear visual components to their memories. Others gave accounts which sounded like verbal conflict. They implied that Art. was hard because they had to say two things at once, meaning covert naming of the list items plus the overt "yes" and "no". Overall, however, there was no great uniformity to subjective reports about output mode preferences for the FARMSPOKEN group.

Finally, in the description of results, it is worth noting that FARMSCENE subjects learned the list faster than those in the other group. The former group took an average of 3.4 trials to reach criterion, reflecting the fact that eight subjects learned in minimum time, three recall trials. The mean number of trials to criterion for FARMSPOKEN subjects was 4. This difference is significant ($t_{22} = 2.175$, $p<.05$). Viewing a scene which the list items describe results in faster list learning as well as in more widespread reliance on visualization as a component of recall. The data are consistent with the proposition that we have here a way of affecting the internal modality of information representation. Against the background of other experimental work using pictorial presentation, of the learning rates in this experiment and of the subjects' own reports of memory content, the relative categorization times provide evidence that the technique is sensitive to visualization as a major component of recall of concrete noun lists.

EXPERIMENT A2

In this experiment subjects are presented with the same material as the FARMSPOKEN group, but with the additional instructions to use visual imagery as an aid to learning and recall. It has been found that imagery - mnemonic instructions enhance acquisition and recall performances in a variety of experimental situations (e.g., Bugelski, 1968; Bugelski, Kidd, and Segmen, 1968; Bower, 1968), and the core of most memory improvement courses as well as of ancient mnemonic systems is the instruction, visualize! (see Paivio, 1971, ch. 6, for a review). It can be expected therefore, that if imagery is in fact the basis for these enhancement effects, and the conflict technique is sensitive to recall of visually-stored material, visual conflict should occur in this way of presenting the FARMSPOKEN condition, which did not show conflict in experiment A1.

Method. The materials and procedure were the same as those used for the word list group in the previous experiment, except that the following instructions were inserted just prior to presenting the subject with the FARM list.

> I want you to notice that all the words in this list refer to things that you can picture in your mind. As well, the things can be put together to form an entire scene. We've found that it helps you to learn the words if you try to build up a mental picture using the things referred to in the list. Try to make a coherent picture from the whole list.

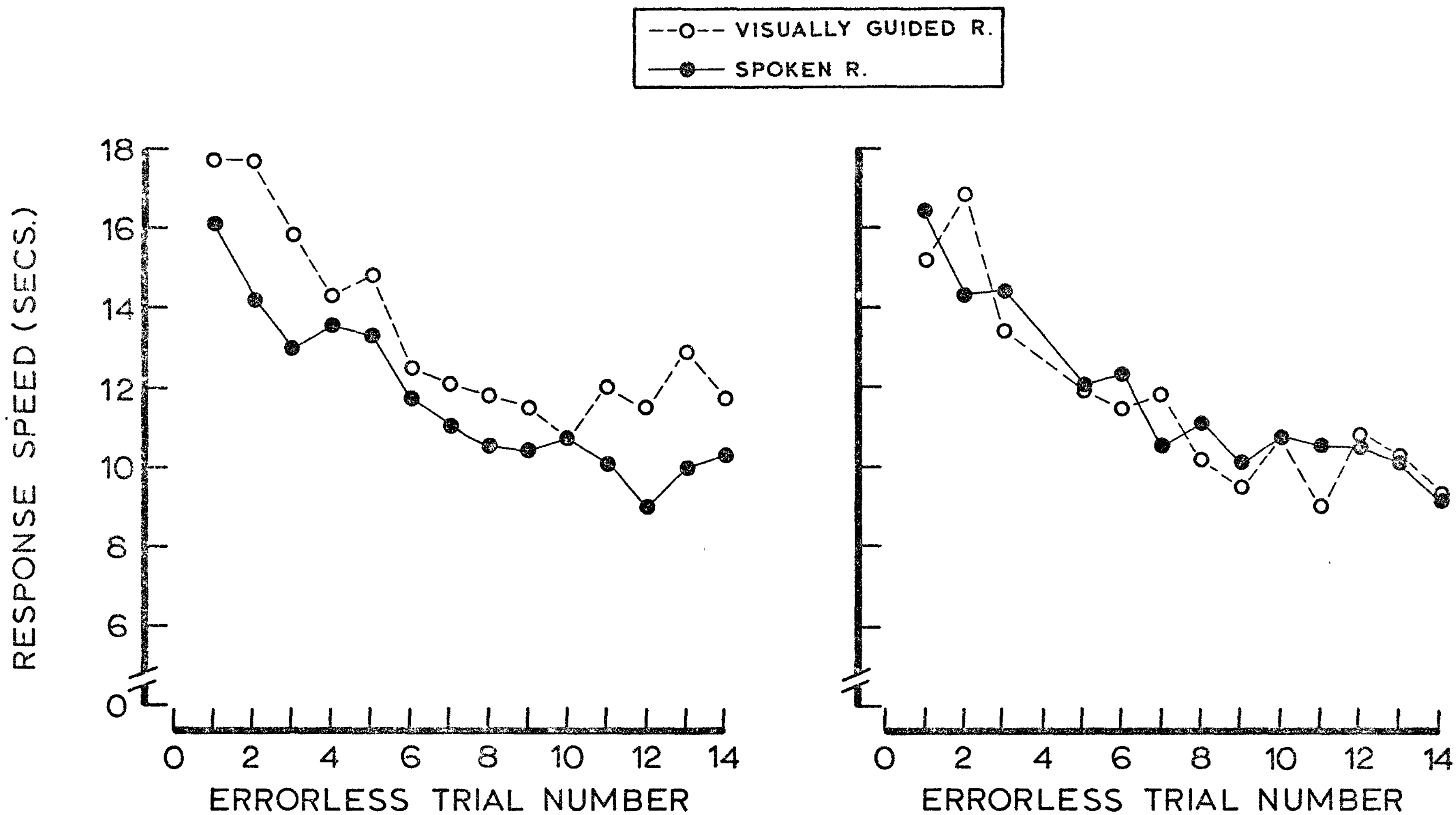
Subjects. Twelve McMaster undergraduates served in this experiment, paid at the rate of $2.00 per hour.

Results and discussion. As in Experiment A1, the results are graphically presented alongside those for FARMSPOKEN from experiment A1 (Fig. 5). There is clear evidence of visual conflict (longer V-G. than Art. response times over the course of the experiment). A statistical analysis backs up the impression gained from the graph. The mean response-time difference was 1.6 seconds, with a standard error of .45 seconds and a resultant t-ratio of 3.588 ($p<.01$). Only one subject had longer Art. than V-G times.

Again, subjective reports are consistent with the data and with the interpretation that visually-based recall shares processing capacity with a visually-guided response. Most subjects reported that they in fact did generate a coherent, imaginal representation of the list referents. Two claimed to have created sub-scenes, and two to have relied mostly on covert verbal sequences. Table 1 shows the numbers preferring each response mode. The two subjects who claimed heavy reliance on covert naming also found Art. a harder response. Reports that V-G. response suppressed visualization were again common.

FIGURE 5

Output times for both response modes for two experimental groups (from A2 and A1).



SPOKEN + IMAGERY INSTRUCTIONS

SPOKEN

FARM ITEMS

The results once more indicate the dependent variable, relative Art. and V-G. response times, to be sensitive to a manipulation of presentation conditions that on intuitive and experimental grounds would be expected to encourage a visuo-spatial component in recall.

EXPERIMENT A3

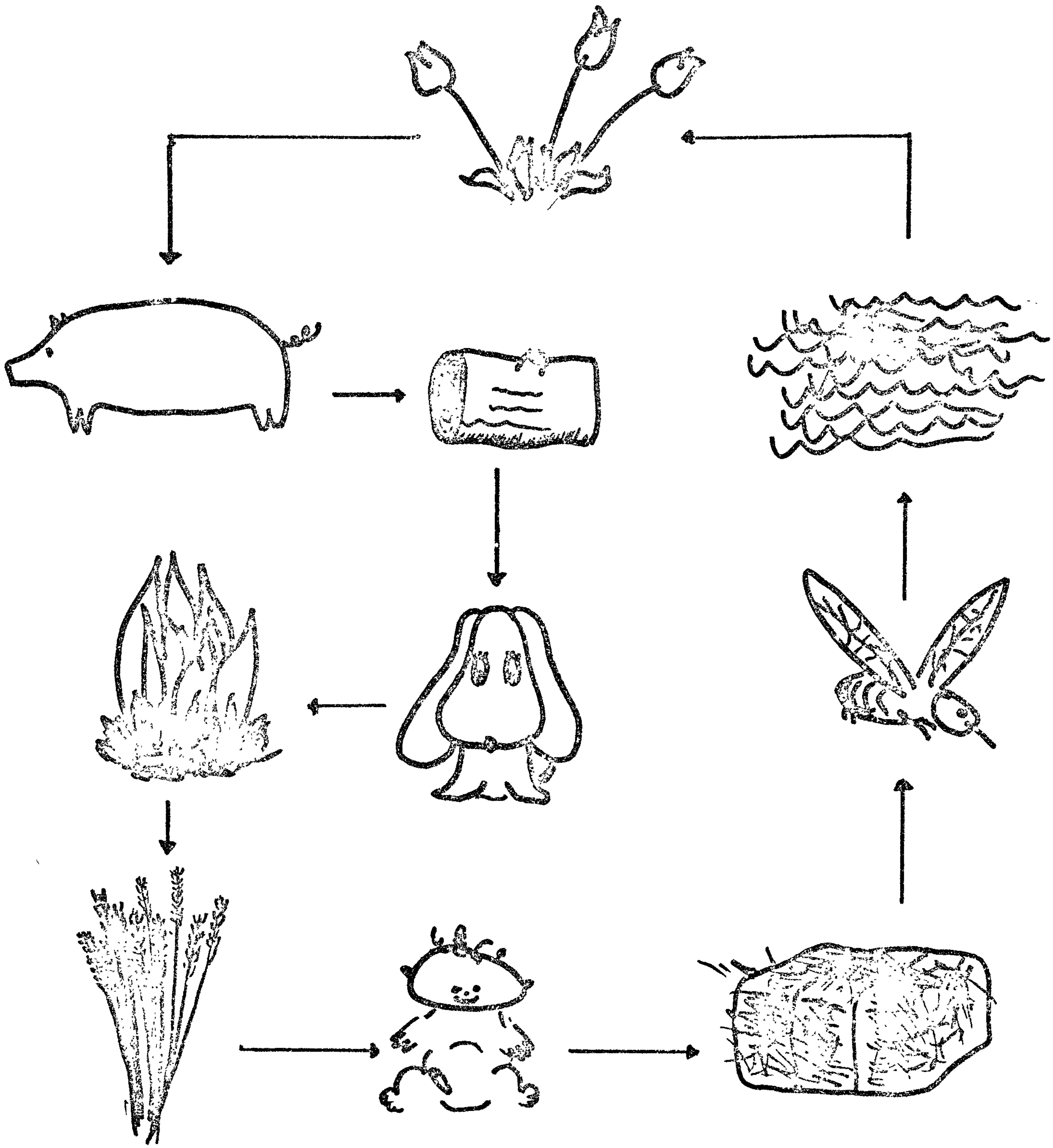
The final experiment in this section has a two-fold aim. Firstly, we hope to influence the degree of reliance on visuo-spatial coding by varying the memorability of the descriptive sequence available for subjects' use. We hypothesize that subjects will have to rely less heavily on a visuo-spatial store in list recall if the words in the list embody some verbal mnemonic device like rhyme than if they do not. It is predicted that visual conflict at recall will be of a lower magnitude in the former case than the latter. The second aim is reflected in a change of stimulus material. It is still a spatially-arrayed pictorial list, but in this case it lacks the scene properties of FARM. Figure 6 shows this display. This selection of material represents an attempt to discover how much of the FARM conflict effect was due to those scene characteristics, remembering the results from the studies which demonstrated a recall advantage for scenes over other ways of displaying pictorial material (Epstein, Rock, and Zuckerman, 1960; Horowitz, Lampel, and Takanishi, 1969).

Method

Material. The following two synonymous lists, describing the picture matrix of Figure 6, were made up (categories at right)

FIGURE 6

Matrix of pictures used in Experiment A3.



Rhymning list	Non-Rhymning list	Categories: Plant	Animal
(code named HOG)	(PIG)		
hog	pig		+
log	trunk	+	
dog	dog		+
heat	fire		
wheat	wheat	+	
Pete	child		+
hay	bale	+	
bee	insect		+
sea	ocean		
tulip	tulip	+	

Procedure. The two conditions, HOGMATRIX and PIGMATRIX, differed only in the word lists used. The administration of both was in the same form as that for FARMSCENE.

Subjects. Twenty-four McMaster graduate and undergraduate students participated, twelve in each group. The usual rate of pay applied ($2.00 per hour).

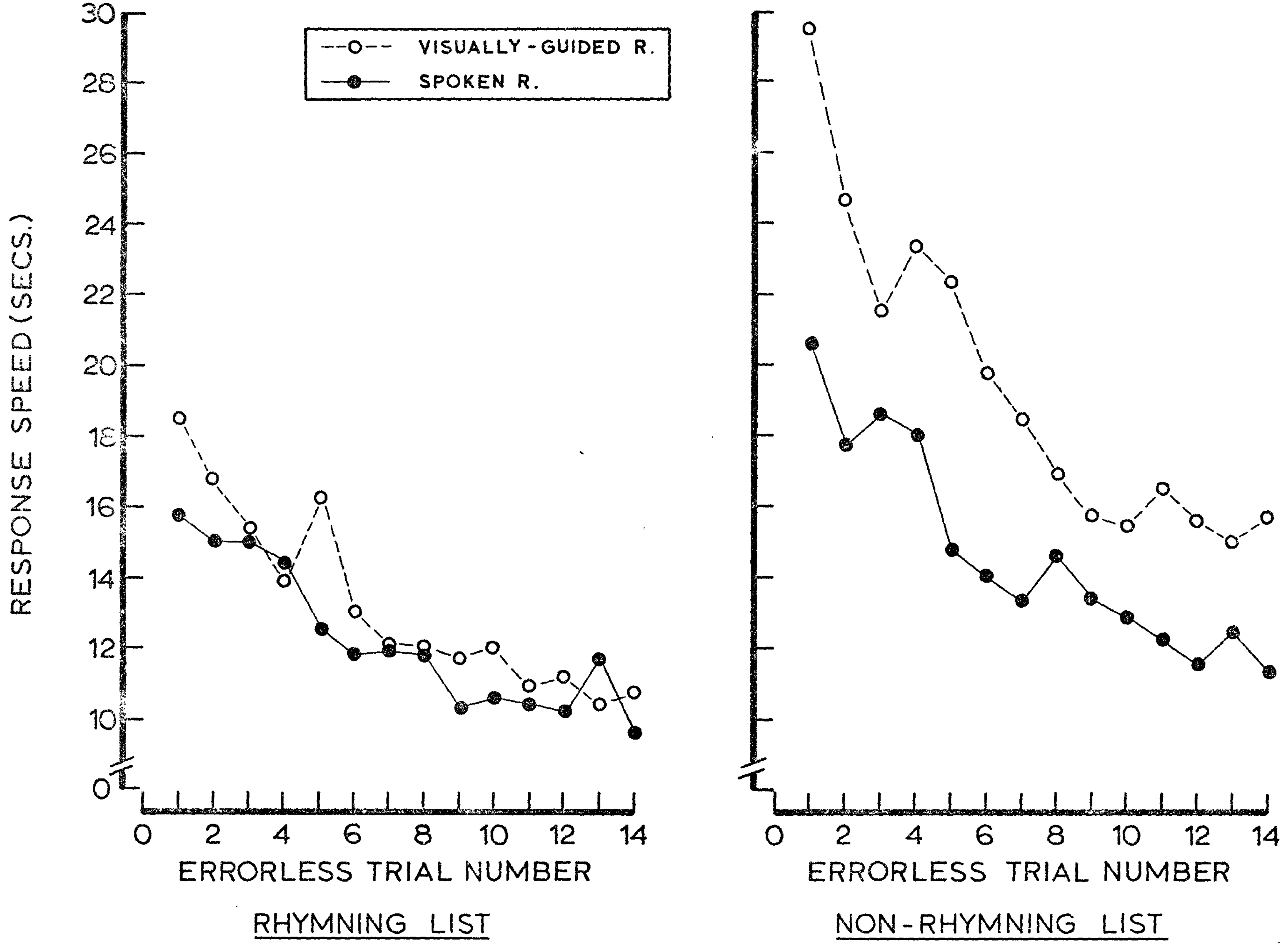
Results and discussion

Response times are plotted in Figure 7. It is obvious that visual conflict exists for PIGMATRIX in a way that it does not for HOGMATRIX. The relevant statistics are as follows; for PIGMATRIX mean difference (V-G. - Art.) = 4.4 seconds (t_{11} = 5.407, p<.001), for HOGMATRIX $\bar{d}$=1.0 seconds (t_{11} = 1.307, p<.10).

Acquisition data support the contention that HOG was a more easily remembered list; mean trials to criterion was 3.3 (minimum 3) compared with 5.1 for PIG (t_{22} = 3.196, p<.01). Again, response-mode preferences were consistent with finding greater visual conflict with

FIGURE 7

Output times for both response modes in Experiment A3.



PIG PICTURE MATRIX

PIGMATRIX than HOGMATRIX, as shown in Table 1. Subjects in HOGMATRIX were almost evenly divided between Art. and V-G., while PIGMATRIX subjects clearly found Art. the easiest response mode.

Subjective reports, acquisition rates and response-mode preference all suggest that on the average subjects exposed to the non-rhyming PIG list relied more heavily on a visual mnemonic than a verbal one, with relatively more dependence on the verbal sequence being exhibited by subjects in HOG condition. If this assumption is accepted we can again see that the visual conflict is produced by dependence on visuo-spatial coding at recall.

It is clear from this experiment that visual conflict can be produced by a stimulus array lacking the unity of a scene. Hence we might conclude that the forms of coding are the same in both cases. Yet differences still exist in the rates of acquisition. Subjects in FARMSCENE took an average of 3.4 trials to reach criterion which compares favourably with the 5.1 trials it took for PIGMATRIX subjects to reach the same level of learning. (Comparison of FARMSCENE and HOGMATRIX is not a fair one because of the rhyming nature of the HOG list). This difference is statistically significant ($t_{22} = 3.26$, $p<.01$) but it is not possible to be sure to what to ascribe it. Formal organization may be important. Items overlap and butt onto each other in the FARM scene whereas the PIG matrix does not have this feature. Another obvious difference is the greater thematic coherence of FARM.

Whatever the reason for the superior acquisition rate of the FARMSCENE group, the point remains that once each group had learned the appropriate lists, their performances during categorization had the same response mode difference in favour of speaking, although the absolute response times were higher for PIGMATRIX. (A similar picture emerged in another experiment, not reported here because it adds no new information. A list and display, built and presented in the same ways as PIGMATRIX,were used. Subjects took an average of 5.7 trials to reach criterion (5.1 in the case of PIGMATRIX), needed longer to perform the categorization tasks than FARMSCENE subjects but showed response-mode time differences almost identical to FARMSCENE and PIGMATRIX). In so far as similar response-mode differences reflect similar coding strategies, we have in these data a situation in which code types are the same but still the accessibility of items in various lists via that code varies. This is not a rare phenomenon. One can readily think of two verbal sequences which differ in how easily they can be learned and recited (e.g., a list of rhyming words versus a list of non-rhyming synonyms), but in each case there is the distinct feeling that the sequence is organized verbally. Possibly our definitions of "code" are too crude. Maybe there are substantial differences in underlying processes between recalling a rhyming list and one without that feature, or mentally going through the items in a coherent scene and items in an arbitrary picture matrix. These issues warrant further study.

GENERAL DISCUSSION OF PART A

It seems clear that conflict between the act of recall and a visually-guided response occurs when there is reason to believe that recall is based on internal visuo-spatial representation. Pictorial support during learning and an instructional set to use a visual imagery mnemonic have previously been known to enhance learning and recall, and their effects have quite reasonably been interpreted in terms of an imaginal mediating mechanism. In the present work they have both proven effective in generating visual conflict at recall. In addition a memorable verbal sequence eliminates visual conflict. These results clearly implicate the visual system in the act of recall for these materials.

It is also clear that subjects do not always rely on covert verbal processes for recall when the items are nameable. This is especially interesting in view of the fact that recall had to be serial. There is some feeling in the literature that verbal processes are especially suitable for ordered recall (Paivio, 1971).

It is not possible at this stage to deduce what it is that is controlling conflict. The experiments of Parts B and C are designed to narrow down the possible controlling factors by answering the question of whether the visual processing is unitary, that is, not functionally divisible into components differentially sensitive to item form and spatial organization. But several issues need comment before proceeding to those sections.

One issue is whether there are alternative explanations of the phenomenon of visual conflict. It is customary to pit explanations embodying modality-specific concepts (selective interference in this case) against ones which reflect the view-point that learning and recall take place in a general, modality-free system. On this view it might be argued that conflict occurs with more difficult tasks (rather than ones where recall involves visualization) because a relatively unfamiliar response (V-G.) is being imposed on a subject already coping with a difficult task. Thus it might be argued that PIGMATRIX exhibits conflict while HOGMATRIX, the easier of the two lists, does not. This kind of argument as a general alternative to visual conflict can be readily met in the present data by the fact that in the FARM experiment (A1) it was the easier-to-learn list (FARMSCENE) which generated conflict, which of course is in contrast to the state of affairs in experiment A3, where the difficult list produced conflict.

Another question that requires some comment at this point, and which crops up again later, is what it is that zero mean response-time differences (V-G. minus Art.) mean. We can be fairly sure that subjects are using some kind of internal visual representation during recall in experimental situations which do produce significant response-mode differences, but what can we say about these other cases? Logically, zero mean response-mode difference could arise because of inter- or intra-subject factors. It could be, for example, that the results represent the average of two opposing and equal processes. One might consider the world to be peopled by visualizers and verbalizers, represented equally in the present experiments. Unless some strong inclining factors suppress individual differences (as FARMSCENE seems to have done), these two group's styles become evident. Extrapolating from Brooks' (1968) results, we might expect that the visualizers, people who generate visual images as mnemonic devices, would show visual conflict, and verbalizers, verbal conflict (Art. slower than V-G.). (Remember that in Brooks' experiments categorizing the words in a sentence was slower when the response was Art. than when it was V-G.) If this were true, the sum of the whole group's response difference might approach zero, the longer V-G. times for one sub-group cancelling the longer Art. times for the other. However, this should be reflected in high variance between subjects' mean response-mode differences. As it turns out, however, the standard deviation of these differences is 2.3 seconds for FARMSCENE and only 1.8 for FARMSPOKEN. It seems just as reasonable, therefore, to assume that we are dealing as much with one population for FARMSPOKEN as for FARMSCENE, not with a sample of visualizers and one of verbalizers. In other words, there is no reason to attribute the zero mean response-mode difference to two opposing trends; intra-subject factors are at least as tenable. Beyond that, it is difficult to say much about the form in which FARMSPOKEN subjects are recalling the list. At least one can conclude that whatever visual component is there is not sufficiently powerful, or not of the right type, to allow rapid Art. responses. It may be that the primary mode of organization is verbal, with reported visuo-spatial aspects not being crucial for the operating characteristics of the task. But this may not be the case. It may simply be that visuo-spatial organization is central, but is of a different type from that available to FARMSCENE objects.

Some readers might be wondering, if the organization was verbal why did it not show up as verbal conflict? It turns out that verbal conflict is not a particularly easy phenomenon to obtain with word lists. It is clear that it can be produced when sentences are the to-be-recalled material (Brooks, 1968), and with certain well-practised sequences such as the months of the year (Brooks, personal communication). What the crucial variable is is not clear however, because this author has found it difficult to get the effect with fluently learned word lists. In one experiment, for example, subjects learned the HOG list without the aid of pictorial support, a learning situation which intuitively looks as it it would encourage verbal coding. And yet no strong evidence of verbal conflict could be found. Only one or two subjects reported it and gave response times that were consistent with the reports. Thus it is still possible that FARMSPOKEN was organized verbally although no verbal conflict occurred. Clearly there are several interesting issues to be resolved here.

PART B

STIMULUS FACTORS IN VISUAL CONFLICT

CHAPTER THREE

INTRODUCTION TO EXPERIMENTS B1, B2 AND B3

It has been established in Part A that relative response times are sensitive to manipulations regarded as encouraging mediation by a visual component in internal representation. We are now in a position to follow up on the idea, developed in the introduction, that spatial features of stimulus material may contribute a component to memory over and above that attributable to item concreteness. The general approach in the experiments of Part B is to independently vary item concreteness and the spatial relatedness of items in lists that subjects learn and examine the effects on output conflict.

EXPERIMENT B1

In this experiment subjects learned the list used in the introduction to illustrate strong spatial ordering. It was hypothesized that subjects would encode the items with a visuo-spatial component which would conflict with the visually guided response at recall, even though no pictures and no instructions to image the items were given. The relevant contrast with the data from the list from experiment A1 that had equally concrete items but which lacked spatial cohesiveness (FARMSPOKEN) was carried out.

Method

Material. The following list, code-named HOUSE, was used:

	Categories	
	Soft	Vertical
chimney		+
roof		
ceiling		
wall		+
carpet	+	
floor		
door		+
steps		
path		
lawn	+	

Procedure. There was only one condition in this experiment. Except for the material and category bases, it was administered in the same way as FARMSPOKEN (experiment A1); the subjects at no stage were given pictorial support.

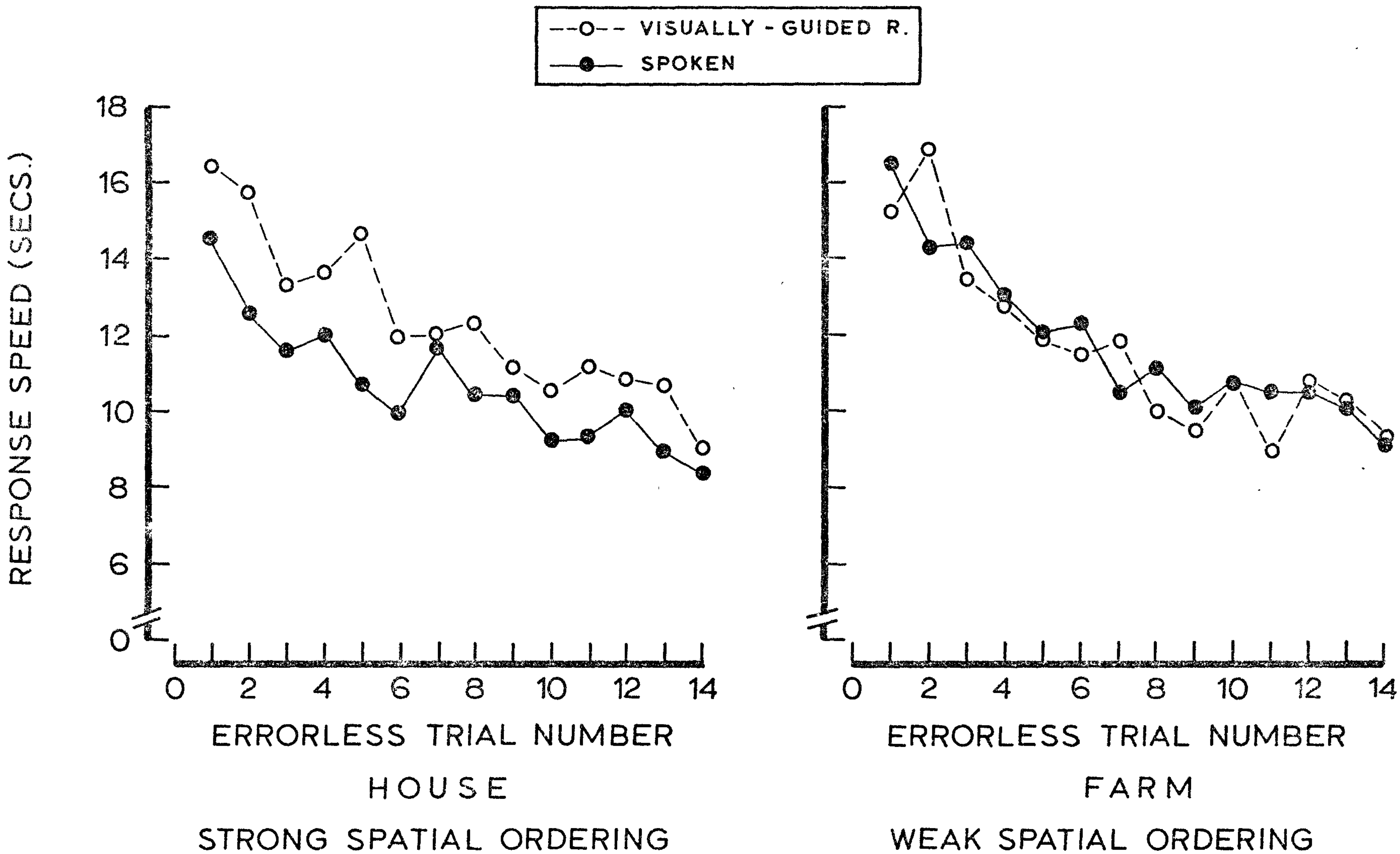
Subjects. Twelve McMaster undergraduates served as subjects, paid at the rate of $2.00 per hour.

Results

The response times for successful categorization for HOUSE are presented in Figure 8 alongside those for the previously presented FARMSPOKEN. As can be seen there is evidence of visual conflict with HOUSE that is lacking for FARM. The mean Art. minus V-G. difference was 1.5 seconds, $t_{11} = 2.789$, $p<.02$ (2-tailed test). The results are consistent with the notion that recall of a list with strong spatial ordering will conflict with a concurrent visual response.

FIGURE 8

Output times for both response modes for two experimental groups (from B1 and A1).



TWO WORD LISTS

Table 2 shows subjects' response-mode preferences. FARMSPOKEN figures are repeated. Ten of the twelve subjects reported imagining,

Table 2

Numbers of subjects preferring each response mode in two experimental conditions

Condition and Experiment	Art. preferred	V-G. preferred	Equal, can't say
HOUSE (B1)	7	4	1
FARMSPOKEN (A1)	4	7	1

and using during recall, some imaginal structure, and all of these, plus one other subject who pictured the things arranged in a circle, indicated a directional component in proceeding through the list (usually down the imagined structure). The other subject simply claimed to be repeating the names to herself each time, with no imagined visuo-spatial component (interestingly, this subject took a mean of 3 seconds longer to respond with Art. than with V-G., and, consistently, claimed V-G. was easier).

There is an aspect of subjects' reports that is interesting. While most reported some sense of "going down" a house in recall, not all had the feeling that they were seeing anything. Typical of a highly concrete report is:

> "I had a picture of moving down a house from sky to ground, via the inside of the house. I thought of things in the rooms."

Compare this with:

> "I was working down from the top of a house. I didn't picture the things. I felt I was also saying the names to myself."

Both of these subjects reported that V-G. was a more difficult response, with Art. allowing them to "just see the picture" (first subject) and "think of moving down" (second). While too much stock cannot be placed in verbal reports because of variations in accuracy, personal criteria of visualization, and so on, the latter introspection lends some support to the notion that spatial-transitional processes can be distinguished from representational aspects of visualization.

Apparently no learning advantage accrued to HOUSE from the nature of the list. Mean trials to criterion was 4.75 for HOUSE as compared to 4.7 for FARMSPOKEN.

EXPERIMENT B2

In this experiment subjects again learned FARM with pictorial support, but the items were drawn separately and presented successively on top of one another, that is, with no spatial differentiation. The aim was to keep the concreteness and pictorial quality of individual items as high as it was in FARMSCENE, but to eliminate the spatial component in the display.

Method

Material. The items from FARM were individually drawn on separate cards.

Procedure. The procedure was similar to that for FARMSCENE, except that the subject was shown the pictures one at a time as the experimenter recited their names at the usual rate. The pictures were successively laid on top of each other in front of the subject. In the correction procedure, following an incorrect recall trial during acquisition, the cards were again placed before the subject as he named them. Thus, everywhere the subjects in FARMSCENE saw the scene these subjects were shown the items individually, in the same spatial location. The condition was code-named FARMSTACK.

Subjects. Twelve McMaster undergraduates served as subjects, paid $2.00 per hour.

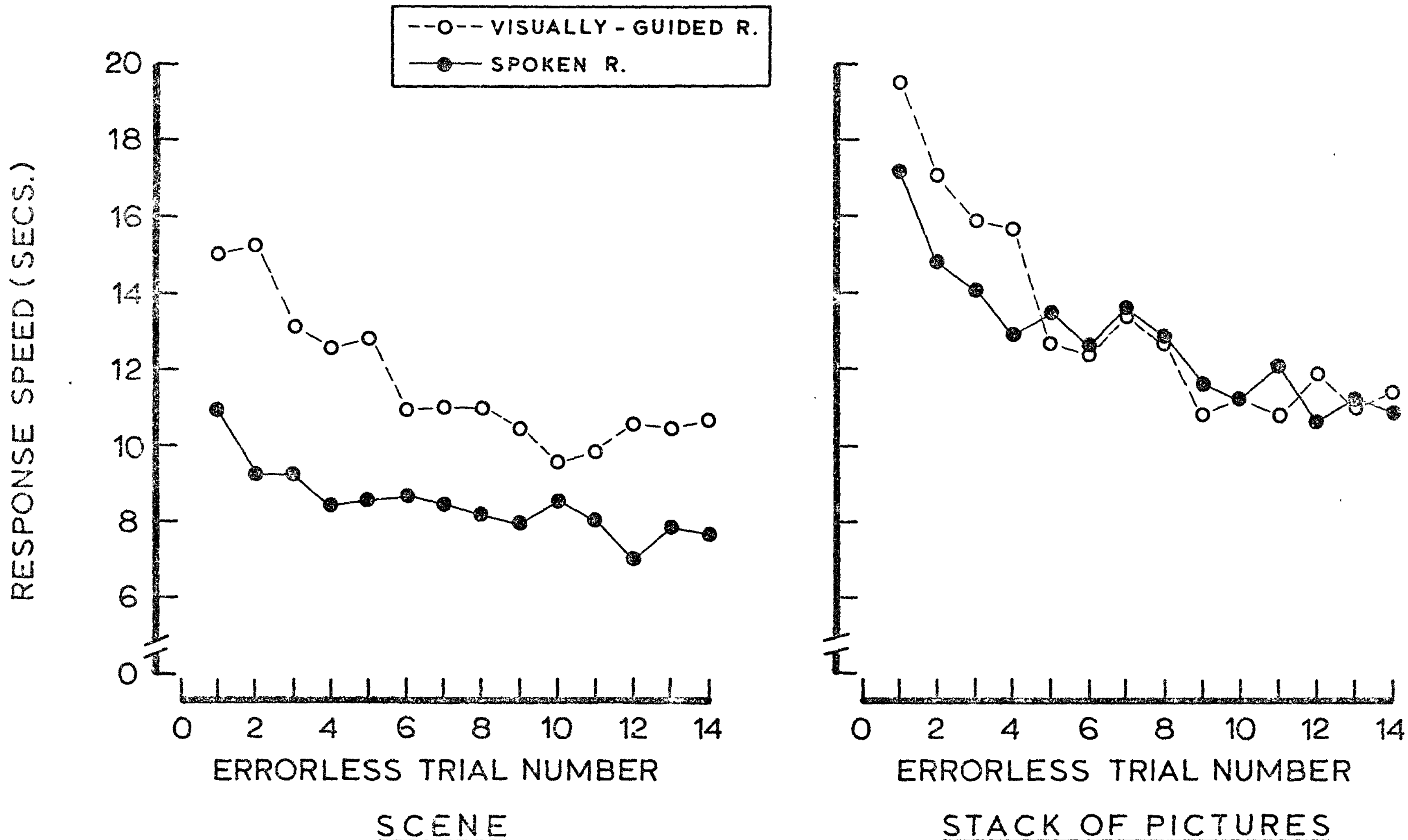
Results

In Figure 9 response times for FARMSTACK are plotted along with those for SCENE. Obviously there is a high degree of overlap between the two response modes in FARMSTACK, reflected in a non-significant difference (mean Art. minus V-G. response speeds, .6 seconds, $t_{11} = 1.005$, $p > .05$).

The majority of subjects claimed use of covert naming in recalling the order of the items, but reports of an additional visual component were common. Two subjects amalgamated the items into a scene, some into subscenes, and subjects often claimed to be using a mixture of words and pictures during recall. It is worthwhile noting that no subject reported visualizing the items in the form in which they were presented (singly, flipping up in the same location). All imagery that was reported incorporated a spatial aspect.

FIGURE 9

Output times for both response modes for two experimental groups (from A1 and B2).


--O-- VISUALLY - GUIDED R.
—●— SPOKEN R.
RESPONSE SPEED (SECS.)
20
18
16
14
12
10
8
6
0
0
2
4
6
8
10
12
14
ERRORLESS TRIAL NUMBER
SCENE
ERRORLESS TRIAL NUMBER
STACK OF PICTURES

FARM ITEMS

Table 3

Numbers of subjects preferring each response mode

in two experimental conditions

Condition and Experiment	Art. preferred	V-G. preferred	Equal, can't say
FARMSTACK (B2)	7	3	2
FARMSCENE (A1)	10	1	1

The majority of subjects found Art. the easier response, and some of these said V-G. suppressed their mental pictures.

We can conclude then that some aspect of the SCENE display induces visual internal representation different in degree and/or kind from that generated by a display in which the items were equally concrete but which lacks the spatial cohesion of SCENE at presentation. The results for FARMSTACK are closer to those for FARMSPOKEN than they are to SCENE.

EXPERIMENT B3

It seems from experiment B2 and earlier experiments that visual conflict occurs only when spatial organization is or can be easily imposed on the stimulus list. Individual items may be quite easy to visualize but a series of them will be retrieved in some way that does not produce conflict when spatial organization is lacking in the stimulus material as a whole. This assumption would be strengthened if it could be shown that subjects utilize spatial coding even for lists of items traditionally regarded as low in concreteness if given the opportunity. This experiment examines this possibility.

Method

Material. Abstract words were selected as the list items in this experiment. It has been argued that they do not readily arouse visual imagery in learning experiments, and are regarded as being low in concreteness. The words, with classification bases, are presented below.

	Categories	
	Good	Bad
distance		
truth	+	
depression		+
weather		
freedom	+	
addiction		+
justice	+	
cheating		+
height		

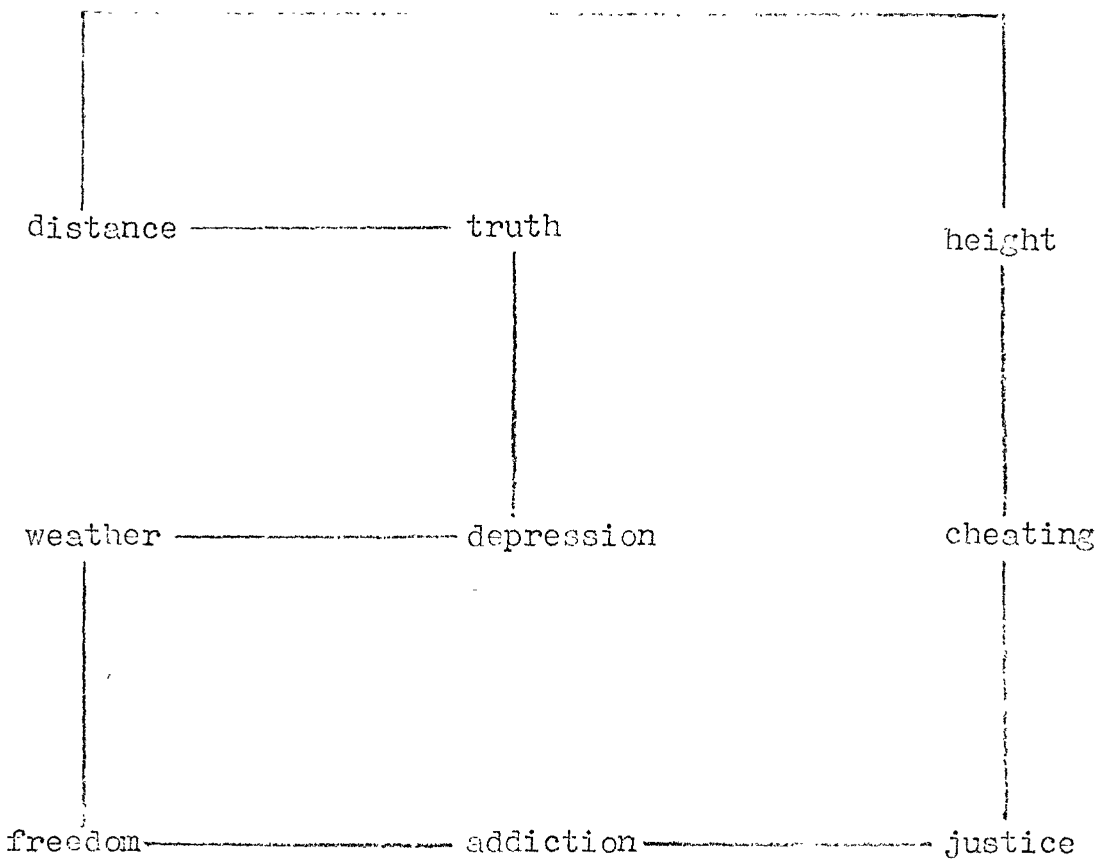
Because of the extra learning difficulty typically associated with low-concrete items, only nine words, one less than usual, were used in this study. The essential feature of the experiment was that the words were presented in a spatial array (Figure 10).

Procedure. This was identical to that in previous experiments using pictorial presentation, except of course for the stimulus material.

Subjects. There were twelve subjects selected from McMaster graduate and undergraduate students.

FIGURE 10

Matrix of abstract words used in Experiment B3.


distance
truth
height
weather
depression
cheating
freedom
addiction
justice

Results

A consistent and long-lasting response-mode time difference occurred, as can be seen in Figure 11. A visually-guided response concurrent with recall slows down successful categorization of even abstract words if they are presented spatially during acquisition. All subjects but one reported a visuo-spatial component in recall. Phrases like the following occurred.

> "I had a graphical structure in mind."
>
> "I remembered the words by their position - the position first, then the word."
>
> "I saw them as typed, as shown."
>
> "I ran around the list with my eyes - for speaking. I couldn't see it as well for pointing because I was staring at this [the response card]."
>
> "The shape helped. I thought of the location if I got stuck."

As with HOUSE there were suggestions from some subjects that location could serve them as a cue in the absence of their actually visualizing the word.

Again, subjects tended to report that Art. was the easiest response mode. Subjects averaged 6.9 trials to criterion during the

---

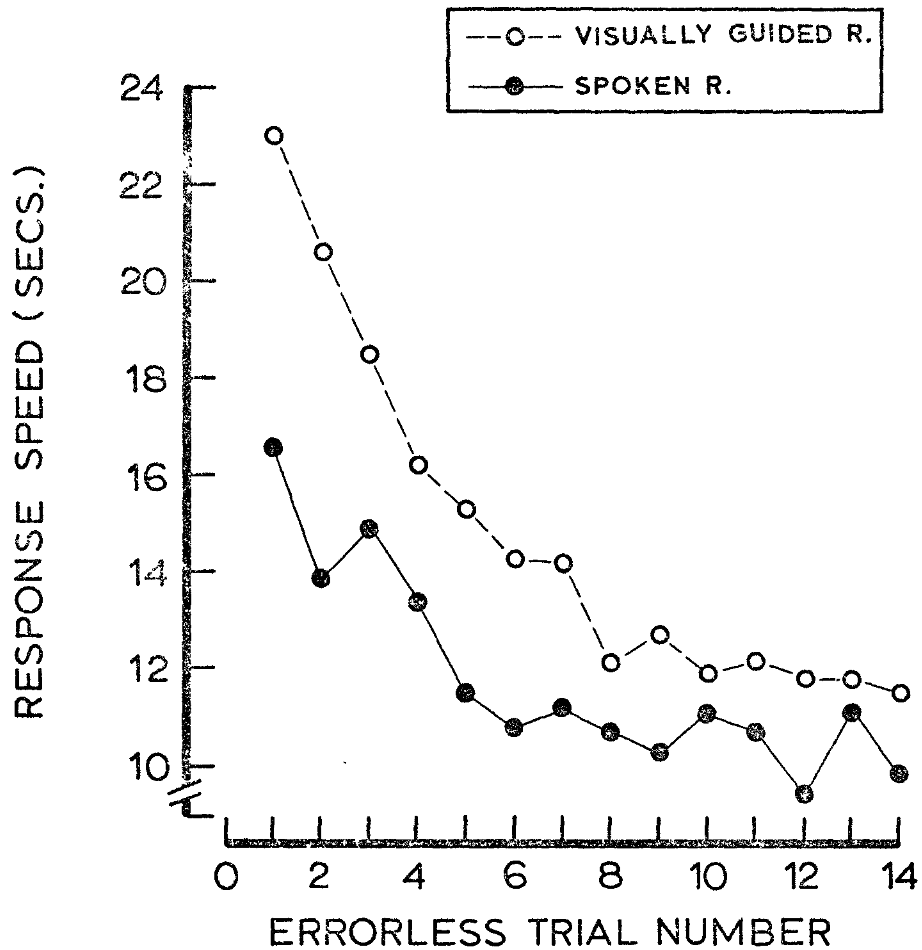
Table 4

Number of subjects preferring each response mode.

Condition and Experiment	Art. preferred	V-G. preferred	Equal, can't tell
ABSTRACT WORD MATRIX (B3)	6	2	4

FIGURE 11

Output times for both response modes in Experiment B3.



ABSTRACT WORD MATRIX

learning phase.

DISCUSSION OF PART B

The most parsimonious explanation of these experiments is that conflict between recall and a visually-guided response most clearly occurs when subjects have the opportunity to retain spatial information in memory. There appears to be some component in recall, sharing processing capacity with the act of visually guiding a pointing motion, that occurs only when subjects are trying to recall information which is coded with a spatial component. That this component is in fact a part of the recall process is confirmed by the frequent references to directionality in subjects' own accounts of their performances. (Phrases like "going around the picture", "following the line", and so on were common). There were also appropriate directional movements of the head, eyes and other body parts. These are discussed in more detail below.

The functions of spatial information

It is appropriate at this point to speculate about the functions that this hypothesized spatial component could have in the present tasks. One is reminded of the emphasis placed on spatial factors in the ancient Greeks' mnemonic device, the "method of loci". The core of this memory aid is that the would-be mnemonist imagines a series of locations in some well-known physical structure (e.g., a building), and places images of things to be remembered in those locations. Recall of these things is accomplished by mentally (or physically) moving

From one part of the structure to the next "so that the order of the places will preserve the order of the things" (from Cicero's De oratore, cited in Yates, 1966, p. 2). The loci have a two-fold function. First, they act as retrieval cues for their content. "...If we wish to recall the genus of a horse, of a lion, of an eagle, we must place their images on definite loci" (from Ad Herennium, cited in Yates, 1966, p. 6). Recalling the loci would bring back the image of the animals. They were aware, that is, of the principles of association in the context of imagery. Secondly, recalling the loci in order would "preserve the order of the things". Running through the loci, from first to last, not only reminds the learner of the things but keeps them in the proper order. Great feats of memory, using such methods, have been reported. (For reviews of classical and modern mnemonic systems see Yates, 1966; Paivio, 1971).

The present experimental task demands that the subject recall things in a fixed order, and thus it is possible to see how retaining information about the items' relative locations would be useful. The parallel with the method of loci is not complete, of course, since the "loci" in the current situation are more abstractly defined and not all previously learned. Instead of being themselves images of concrete things (like parts of a building) they are locations on a page, or in an imaginal structure, defined in terms of relative position (e.g., middle of bottom line, bottom right corner). But to some subjects at least these locations seemed to have a status independent of what was deposited there, just as building parts have independent status. Thus in the ABSTRACT WORD experiment one subject said, "I remembered the words by their positions - the position first, then the word". Another claimed that "the shape (overall diagram) helped. I thought of the location if I got stuck [in thinking of an item]". Thus location appeared to act as a retrieval cue to these subjects. When we add to these reports the ones indicating a directional component in recall we can see that both the retrieval and ordering principles inherent in the method of loci are claimed to be at work in the present experimental tasks.

A possible mechanism underlying the use of spatial information

We return briefly to more anecdotal accounts of imagery mechanisms. Some claim that acts of imagination which involve considering spatially distinct points are accompanied by appropriate movements of receptor adjusting mechanisms. Recall Berlyne's (1965) example of naming the states of the U.S.A. from San Francisco to New York, and his citation of Rey (1958) who claimed that if one fixated a certain place in a well-known (but imagined) room, moving one's eyes to the left would bring into focus things to the left of the fixated area.

Support for this notion comes from observation of subjects during the current experiments. They often executed orienting movements while categorizing lists, at least when using Art. as the output mode. They might make head movements which followed the spatial pattern of the learned material, especially noticeable in conditions using matrices of pictures or words. More subtle eye movements, across, down, back, across, etc., might occur instead of or as well as these head movements. Some subjects actually tapped the table, the points of contact corresponding to the positions of successive locations in the spatial array. All of these activities could be interpreted as the subject's attempt to generate spatially distinct points, represented by successive stopping points in the directional movement of some body part, which would serve to remind him of the items and their order. The fact that the movement tended to trace out the spatial structure of the stimulus list suggests that the preservation and use of that information is a powerful tool in remembering items in order. It also suggests that the retrieval of that information involves a reconstruction, using orienting movements of some body part(s), of the topography of the array. And, as with other peripheralist hypotheses about internal representation, it is possible to hold that absence of observable movement does not necessarily invalidate the hypothesis because it is possible that higher-level control processes may still be involved. Certainly it is true that not all subjects made observable movements of the type described, (which of course may just be a function of the crudeness of the observations made), but that does not mean that central control processes were free.

Visual conflict - an hypothesis about its nature

If it is true that subjects engage in these imaginary (or not so imaginary) spatial transitions during recall, and if this activity brings into play equipment that executes and/or controls receptor adjustments, we may have an explanation for why recall of spatially-coded information is so vulnerable to interference by a concurrent visually-guided response. The response requires subjects to locate the appropriate place on the card to point to, to find the next line, and so on. These orienting movements may be interrupting covert (and overt) orienting movements that are hypothesized to accompany list recall, when spatial information is available. Hence output is slowed while subjects time-share the equipment to do two orienting tasks, one involving the contents of memory, the other, a part of the visual world.

This interpretation of visual conflict is reminiscent of the interpretation of the Stroop effect (Stroop, 1935) as response competition. If a person has to name the colours of the inks in which words in a list are printed he takes longer if the words themselves are the names of the ink colours than if they are other colour names, other words, or other printed stimuli (e.g., a line of X's)(Klein, 1964). Generally this has been taken to mean that the tendency to respond on the basis of reading the colour name (when emmission of these names has been "primed" by the nature of the task) conflicts with the appropriate response, both involving a motor component. In some experiments (e.g., Hock and Egeth, 1970) the response is not a colour name, but classification of whether the ink colour is a member of a certain set or not (with "yes" or "no" as the responses). The fact that interference still exists is interpreted by these authors as meaning that it occurs at the stage of colour identification rather than being due to overt response competition. Nevertheless there may be some response component present in identification of a colour as a member of the positive set that is something like covertly naming the colour. If this is true the argument for response competition still holds, though in a re-defined way. It is conceivable, that is, that covert response competition exists.

Thus there is precedent for the notion that visual conflict is a response phenomenon, due, in this case, to competition between covert and overt receptor adjustments, competition, that is, for a common motor channel. Verbal conflict, found by Brooks (1968), can be similarly interpreted. It is well known that covert speech has a motor component (see McGuigan, 1970, for a review). Forcing subjects, therefore, to say one thing to themselves and a different thing out loud, as Brooks did, may generate competition for production mechanisms, and thereby slow subjects down as they are forced to time-share these mechanisms.

This is a rather more selective interpretation of shared perceptual and imaginary processes than is implied by the blanket statement that the processes of vision are those of imagery. It is being proposed that conflict possibly arises because an aspect of visual perception interferes with an aspect of imagination. Recall of the items may be suppressed indirectly, via suppression of the series of retrieval cues, rather than because of direct competition between item visualization and the visually-guided response.

This formulation gives rise to a number of testable predictions about visual conflict which are pursued in Part C as part of the programme of investigating what kinds of distinctions can be drawn between representational and transitional-spatial imagery.

Whatever interpretation of the previous experiments is correct, it is still true to say that spatial cohesiveness among items affects recall processes in a way that is distinct from the effects of item concreteness. In particular, recall of spatially-organized items involves aspects of the visual perceptual system that apparently are not utilized when spatial organization is lacking, even when item concreteness is high.

PART C

RESPONSE FACTORS IN VISUAL CONFLICT

CHAPTER FOUR

INTRODUCTION TO EXPERIMENTS C1 AND C2

It has been proposed that during the act of recall, in the experiments which show visual conflict, subjects generate an imaginary series of spatial locations which aids them in remembering the list items and their order. Furthermore, the suggestion was made that recreating this spatial information involves, at some level of execution or control, the receptor-adjusting mechanisms used in the visually-guided response, and that the dual utilization of this equipment accounts for the slowed non-verbal response. The aim of this chapter is to test the assumption that this spatial information is in fact useful to subjects, and that its generation is the major determiner of visual conflict. Two experiments are reported in full, and pilot data bearing on the issues is also described. In one experiment subjects are permitted to point to a response sheet which is spatially compatible with the stimulus array. The second experiment is a variation on the first, with Y N pairs embedded in drawings of the stimulus items in "incorrect" positions. The rationale for these manipulations will be explained in the appropriate sections. The general aim of the experiments, and of the subsequently-reported pilot data, is to compare various possible sources of visual conflict as a way of testing the hypotheses generated by the previous experiments.

EXPERIMENT C1

In the crucial part of this experiment the spatial information that the subject is hypothesized to be generating is provided for him as a series of Y N pairs laid out in the same way as the stimuli used (PIGMATRIX) (see Figure 6). If our view of visual conflict is accurate recall-response conflict should be reduced with this response card for one of the following reasons; by relieving the subject of the necessity of generating the hypothetically useful spatial information; by ensuring that the neuro-muscular equipment engaged in any imaginary activity necessary can concurrently be guiding the spatially-compatible perceptual response.

Method

Material. The list was PIG presented as in PIGMATRIX, that is, with the aid of the picture matrix of Figure 12. Two types of V-G. responses were used. One is where the Y N pairs were arranged with the same spatial organization as the picture matrix. It can be seen in Figure 12, and is called the spatially compatible response (SpC). The spatially incompatible response card (SpI) can be seen in Figure 13. It differs from the card used in earlier experiments in that within each pair the letters are closer together. This was done to make it more like SpC. Arrows link the pairs on both cards.

Procedure. The introduction to categorization and the list learning procedure were identical to PIGMATRIX. There were changes beyond that stage. Since the purpose of the major manipulation was

FIGURE 12

Spatially compatible response sheet (SpC) used in Experiment C1.

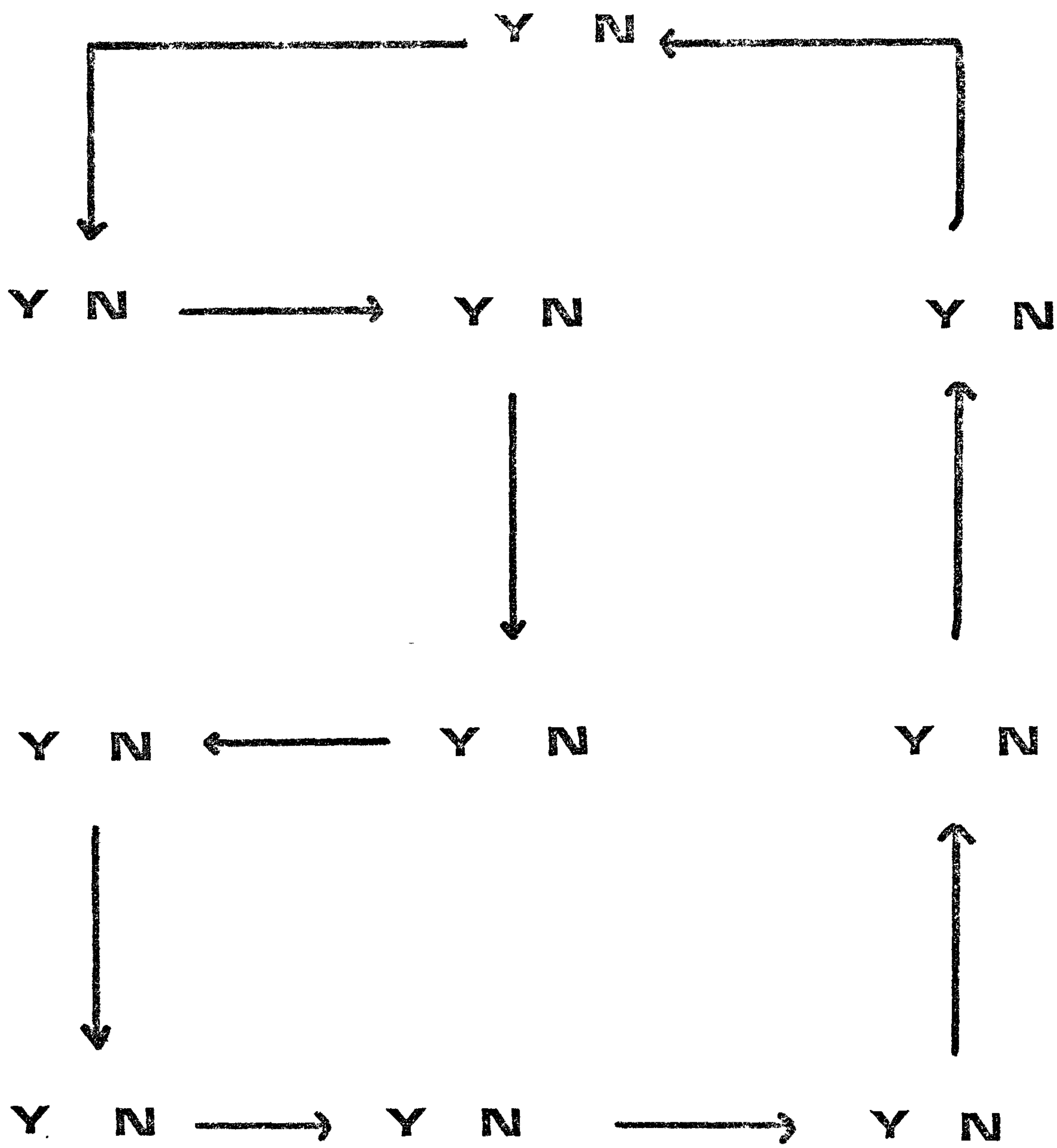
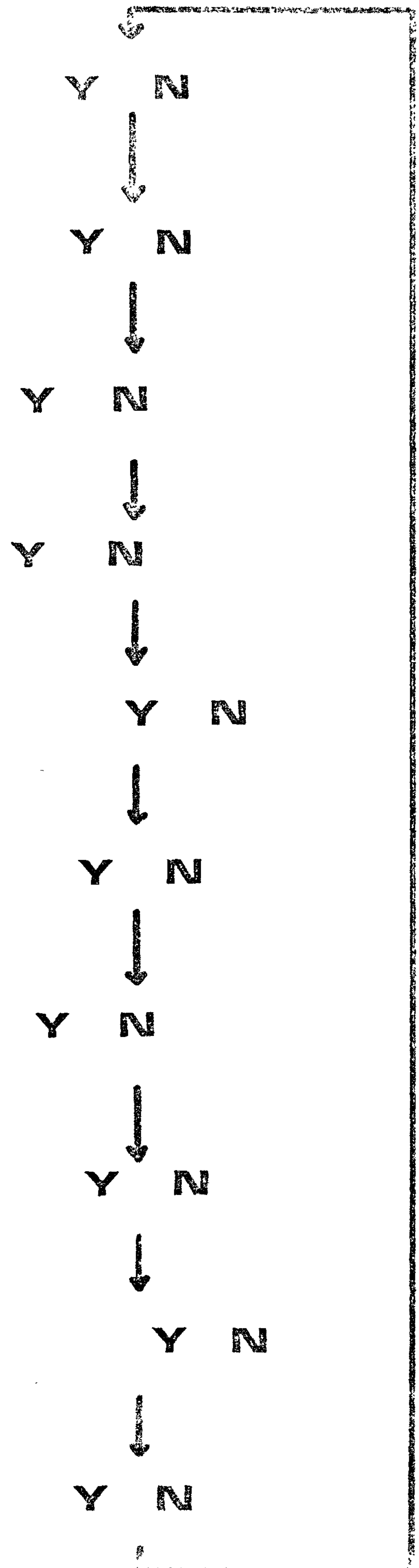

Y N
Y N
Y N
Y N
Y N
Y N
Y N
Y N
Y N
Y N

FIGURE 13

Spatially incompatible response sheet (SpI) used in Experiment C1.


Y N
Y N
Y N
Y N
Y N
Y N
Y N
Y N
Y N
Y N

to reduce conflict, more precautions were taken to insure that visualization was being used as a mnemonic strategy. On the assumption that the speaking response mode would allow maximum use of visuo-spatial representation, six error-free Art. trials were first collected from each subject. These trials also served to generate a base-line against which subsequent V-G. responses could be evaluated. Subjects were then divided into two groups. Group A moved first to the SpC response for four errorless trials, followed by four trials with SpI. For Group B the order of V-G. response types was reversed. These visually-monitored responses differed from all earlier ones in that list items were uniquely associated with Y N pairs. This had to be done for SpC of course, because the point of the experiment was to provide subjects with the spatial information of the matrix. It was therefore done also with SpI. Thus the instructions at this stage went as follows:

> "We are now going to try some pointing. Here is what you will be using. (At this point the appropriate response sheet was placed in front of the subject.) At the beginning of each trial, when I tell you which item to begin with, I will simultaneously point to its spot on the card, and you will start pointing there and proceed following the arrows. For example, if I asked you to start with pig, I would also point here (experimenter indicates the appropriate Y N pair, which, in the case of SpI, was the top line for pig). Trunk would begin here, dog here, and so on. Do you understand?"

Any questions were answered, and the experiment proceeded.

Subjects. Twenty McMaster undergraduates served as subjects, ten in each group. They were paid \$2.00 per hour, which meant that most received \$1.00 for their time.

Results and discussion

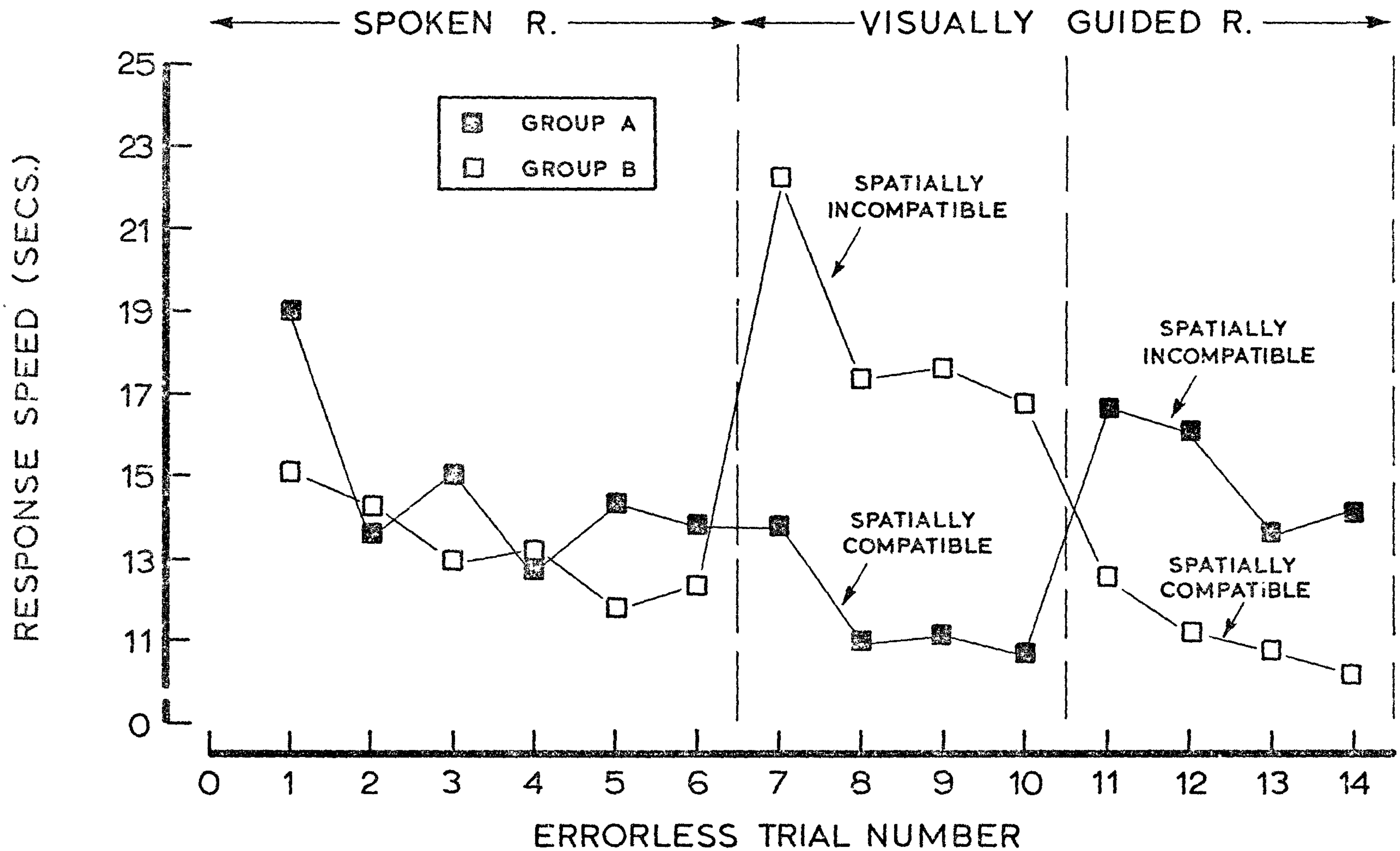
Output times are plotted in Figure 14. The results are quite clear - for every subject in both groups the change to SpI caused a marked slowing of responses. This is in fact the visual conflict effect. In contrast, SpC responses for both groups simply look like continuations of the Art. response. All subjects reported SpI to be the hardest response, with about an equal division on the question of whether Art. or SpC was easier. Most subjects felt that this latter difference (Art. versus SpC) was a small one. Some of the subjects' comments were as follows:

> SpC "was easy because it was all laid out as it was in your mind."
>
> SpC "followed the same pattern as what I was picturing."
>
> "I had imaged in that (SpC) order. I imagined the pig in the right place, etc."
>
> SpC "is like the picture".
>
> "At first I used words down a column; when I got to SpC I used pictures. I dropped the list and pictured words in each position in (SpC)."

The results are consistent with the notion that spatial information available in a stimulus array can be utilized during recall of items in that array. If it were otherwise no particular advantage should accrue to the SpC response over any other type of response layout. The reports of subjects also fit the hypothesis. They often implied that SpC responding coincided with the technique of recall that they were using with the other responses. The results are also consistent with the view that visual conflict is largely due to spatial factors, as developed in Part B.

FIGURE 14

Output times for all response modes in Experiment C1.



PIG PICTURE MATRIX

A feature of the results that came as somewhat of a surprise to the author is the apparent complete lack of a recall-response conflict with SpC. The response was still, after all, visually guided, and could easily have suppressed some part of the representational imagery that the subject was engaging in. That is, even though the spatial structure of the response card was designed to avoid conflict with transitional aspects of imagery, the subjects' ability to visualize the separate items could still be inhibited to some degree, and hence that some residual conflict would occur. The fact that it did not raises the possibility that one aspect of internal visual representation can be suppressed by concurrent perceptual activity while another aspect is independent. This is an interesting possibility for two reasons. One is that may mean that internal visual representation is in fact divisible into functionally distinct processes, as has been suggested by Berlyne and others. The other is that the assumption that imagery and perception are continuous may need qualification if it can be shown that some aspects of the one are compatible with the other (or some aspects of it).

However, the lack of any apparent recall-response conflict when the SpC response card was used may have arisen for a number of other reasons. One is that the visuo-spatial system's capacity was not exceeded because subjects did not have to generate the series of spatial retrieval cues. Thus with the SpC response card they needed only to generate images of the items themselves, and not of their locations. If this is true, however, it still means that spatial information is in a unique position with respect to other visual information since it loads the system more heavily than does image generation. A second possibility is that subjects did not engage in any internal visual representation of the items. This is conceivable in view of the fact that the categorization task can be done on the basis of knowing each item's identity, and its particular formal manifestation is not crucial to the task. Again, however, the separation of spatial and item-formal aspects of visualization is still implied if it is true that the former but not the latter is present in a particular act of recall.

EXPERIMENT C2

The final experiment to be reported in full is an attempt to further test the hypothesis, suggested by this study, that the major source of recall-response conflict in these experiments is the generation of incompatible orienting responses. A spatially-compatible response card is used again, but this time the Y's and N's are embedded in drawings of the stimulus items in the "wrong" places (Figure 15). Subjects still have to respond to each Y N pair appropriately on the basis of the original stimulus array (PIGMATRIX). This response card could interfere in several ways. Firstly it might be argued that the subject's "visual load" is increased by having him point to an embedded Y or N. Thus there is more chance than in the last experiment that the visual system's capacity will be exceeded. Secondly there may be a Stroop-like effect (Stroop, 1935) such that the subject will tend to respond to the item that is drawn in a particular place on the response card rather than the one that "belongs" there (in the referent stimulus array).

Method

Material. PIGMATRIX was again used as stimulus material. The response card is shown in Figure 15.

Procedure. The experiment was run in a fashion similar to C1, except that no spatially incompatible condition was included. After learning, data for six errorless speaking trials were collected, followed by four pointing trials. The pointing was introduced exactly as SpC had been. If subjects asked about the background drawings (e.g., should they ignore them?) they were simply told to respond as quickly as possible.

Subjects. Ten McMaster undergraduates and graduate students served as subjects.

Results and discussion

Response times are presented in Figure 16. The major feature of interest is that there is no evidence of conflict at anywhere near the level that is produced by a spatially incompatible response card. There is a significant slowing on the first visually-guided trial, but the other data points are indistinguishable from the speaking times. Most subjects claimed that they could ignore the background figures quite easily, although a few said that they found them "confusing". One subject reported that he "couldn't look at both things at once", meaning his image and the background figure. His times did not reflect conflict, however. Another gave a similar account, that "another picture kinds of masks" the image but produced V-G. times of about the same order as Art. times.

FIGURE 15

Spatially compatible, item incompatible response sheet used in Experiment C2.

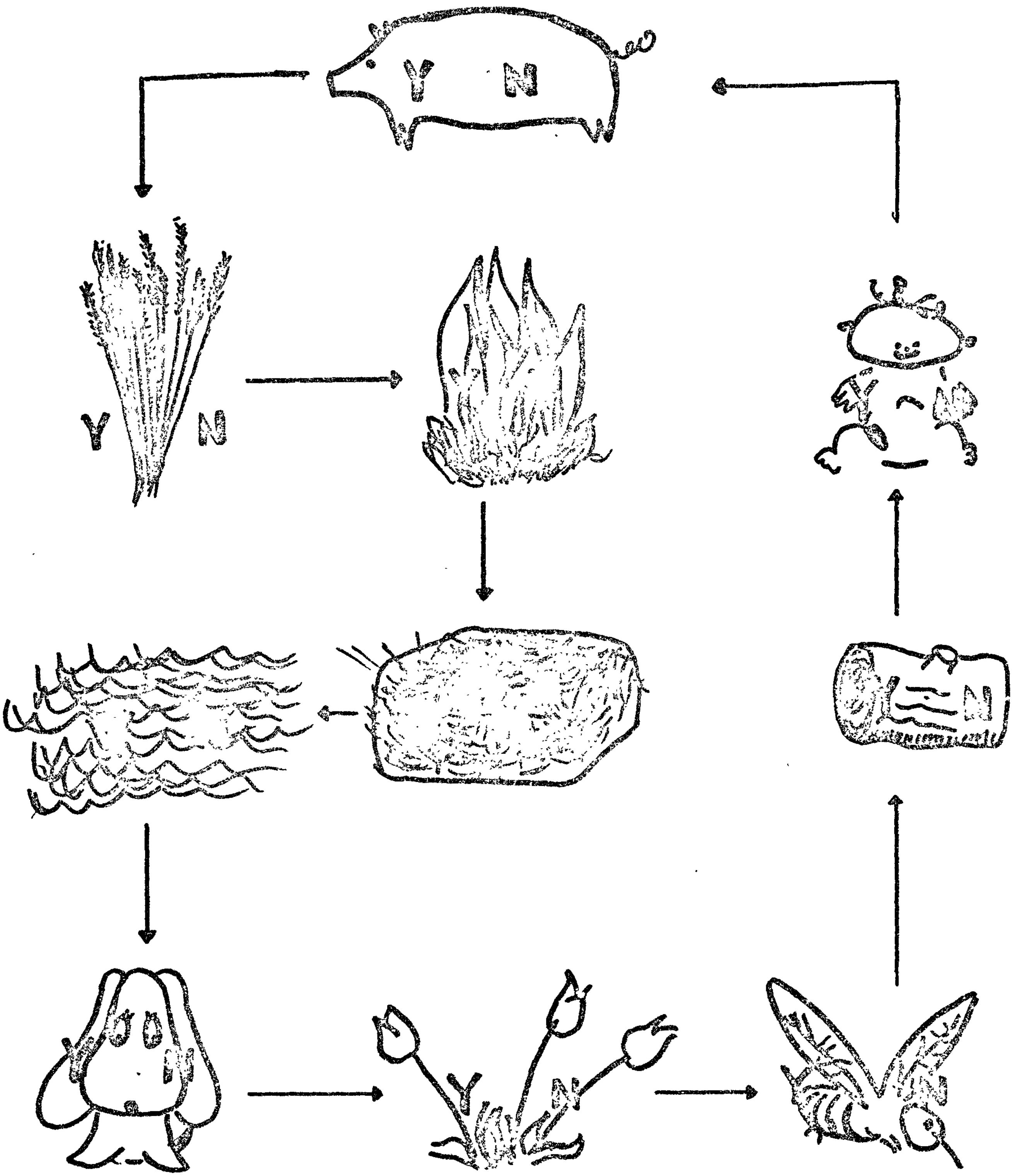
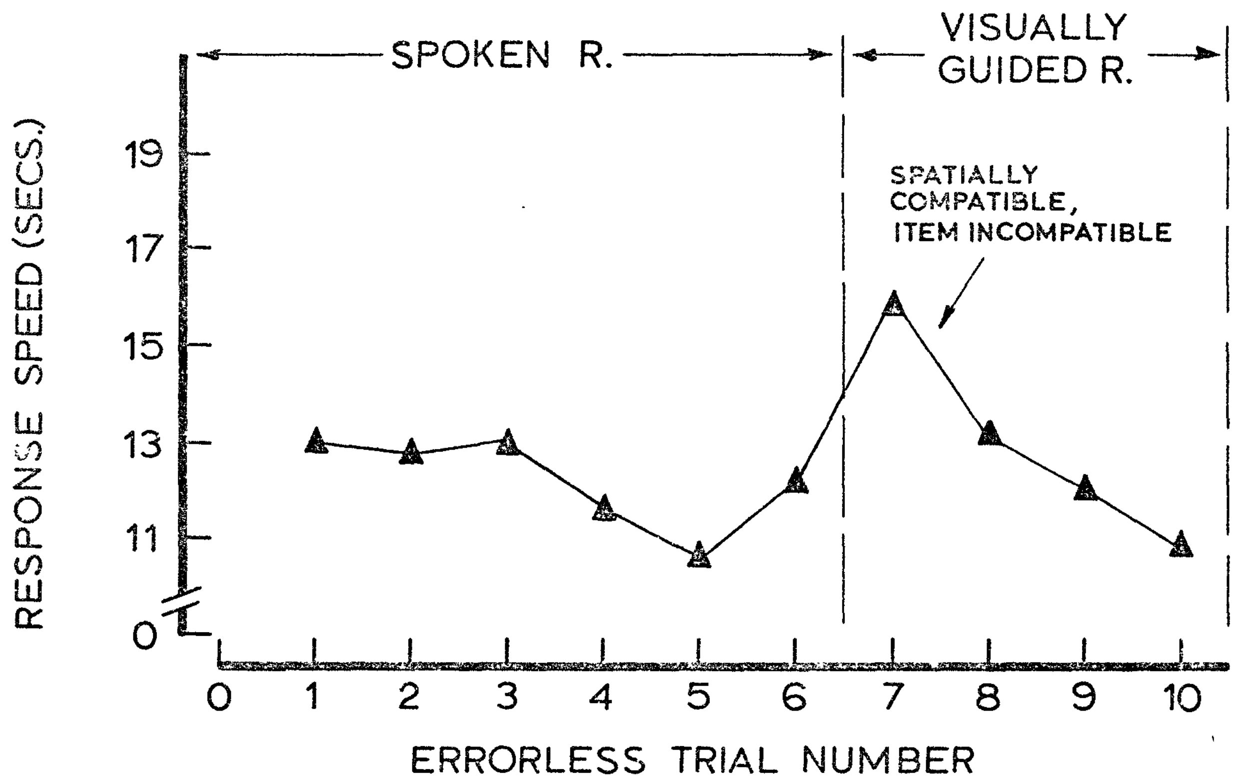

Y N
Y N
N
Y N

FIGURE 16

Output times for both response modes in Experiment C2.

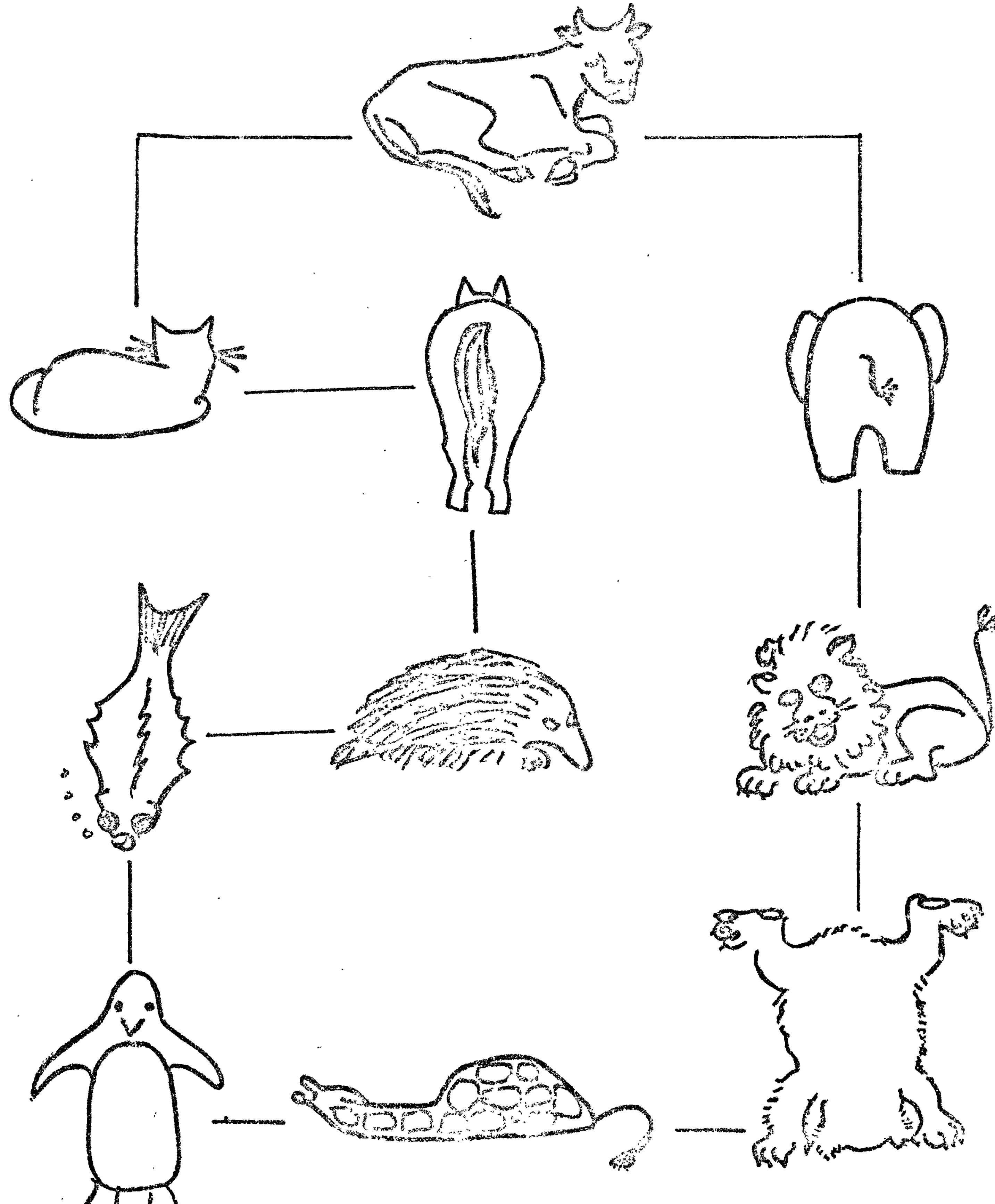


PIG PICTURE MATRIX

Again, it seems that whatever the process involved in item retrieval for categorization it does not heavily load the non-spatial visual system. There is some effect, but it is short lasting. Presumably it is due to one or both of the factors mentioned as possible sources of conflict - greater visual load or a tendency to respond inappropriately. The point is that the effect is small compared to that which occurs when the response card is spatially incompatible. The argument is not that conflict will never occur unless these spatial factors are present. Segal and Fusella (1970), for example, found that imagining a vivid scene suppressed detection of a visual signal, despite neither task (imaging or detecting) being spatial in the way the term is used in the current work. It may even be possible to find conditions within the present tasks that produce conflict that could not be attributed to spatial factors. But from pilot work done recently in our laboratories it seems that the search may not be fruitful. For example, subjects were asked to categorize items, learned from the picture matrix shown in Figure 17, for formal attributes (e.g., is the animal facing right). No conflict was generated when a spatially-compatible response card was used. In this case we can be reasonably sure that the subject was visualizing the items to some degree because he could not respond on the basis of their names alone. Unwieldy verbal descriptions would have been needed to circumvent imagery. There is some possibility that conflict may have been present when a disjunctive formal categorization base was used (e.g., is the animal facing right or facing down), but even here the effect was small and it might have been attributable to the

FIGURE 17

Matrix of pictures used in pilot experiments where categorization was on the basis of formal properties of items.



increased difficulty of the categorization task combined with the strangeness of V-G. Furthermore, subjects rarely gave reports suggesting conflict. Such reports were common in earlier studies. Work is continuing on these problems. Again, however, these effects, if found and confirmed, and the effect in Segal and Fusella's task, are orders of magnitude slighter than the robust conflict phenomenon described in the present work. If they are there they are hard to find, and need much more sensitive measures to show them up. Thus it remains true to say that spatial location is incorporated into memory in a way that is distinguishable from other types of visual information about items, even if the distinction is only in terms of how heavily the former information, compared to the latter, loads a modality-specific system.

CHAPTER FIVE

GENERAL SUMMARY AND CONCLUDING DISCUSSION

In exploring aspects of mental imagery, several questions have been investigated: (a) whether conditions which are claimed to induce visual imagery as a mediating code for memory tasks do in fact engage the mechanisms of visual perception, (b) if so, which types of stimulus material are thus mediated, and (c) what aspects of the visual system are so engaged. The selection of types of material has been largely governed by the hypothesis that the concreteness of the items in a stimulus set and their spatial organization make separable contributions to visual imagery.

Summary of main findings

Extending the phenomenon of recall-response conflict. When subjects learned an item list under conditions which they reported induced mediating imagery they took longer subsequently to signal information about the items using a visually-guided response than a spoken response. Showing subjects a scene depicting the list items and instructing them to imagine such a scene both led to this response inequality. When they learned the items auditorily with no imagery instructions the mean times for both response modes were the same. The outcome of a further experiment, which attempted to vary dependence on mediating imagery by manipulating the memorability of the item names, was consistent with these results.

The results are interpreted as being an extension of Brooks' (1968) findings, described above, and as meaning that the technique of selective interference is sensitive to internal visual representation during the act of recalling material which can be named.

Stimulus properties controlling visual conflict. In addition to the scene, imagery instructions, and picture matrix conditions of the first set of experiments, the following stimulus material produced visual conflict during categorization; an auditorily presented list with strong spatial ordering among the word referents; a matrix of printed abstract words. Conflict was absent when items were pictorally presented, one at a time, with no spatial differentiation.

On the basis of these results it is concluded that an item list must have, or refer to, a spatial layout in order to induce visual conflict.

The selectivity of conflict. Subjects using a visually-guided response which had the same spatial layout as the referent stimulus array responded as rapidly as when speaking. This was true even when the response card to which the subjects pointed contained drawings of the stimuli in "incorrect" positions, and, preliminary work indicates, when categorization was on the basis of formal properties, a task which cannot be accomplished on the basis of the items' names.

These findings are interpreted as meaning (a) that subjects can utilize spatial retrieval cues, and (b), that forcing the subjects to generate the cues themselves loads the visual system heavily.

Attempts to generate conflict with non-spatial aspects of visualization have so far failed. It may be possible, however, to obtain the effect with heavier loads on memory and/or perception. Experimental work is proceeding on this problem.

In the experimental study of imagery the special contribution of spatial factors is rarely singled out. The current research indicates a need to do so. Coherent spatial organization among a set of items, whether embodied in the referents (as in HOUSE) or as part of the presentation technique (as in FARM, PIGMATRIX and ABSTRACT WORDS), influences what activity can be coordinated with the recall process, more so than does item concreteness in these experimental tasks.* Thus spatial organization should be added to the already existing list of variables said to affect how people internally represent information.

Two kinds of imagery?

The significance of the experimental series for understanding the process of visual imagery is open to speculation. Of particular interest in this context are the results of Part C, and the pilot data reported there. No evidence of conflict occurs when the response-card layout is spatially compatible with the stimulus array, and even when the categorization task presumably encourages subjects' visualizing

* We will consider later the question of whether the effects of these organizational factors are likely to be limited to the present set of experimental tasks.

individual items little or no sign of conflict is present. We might think of two types of explanations for this finding. One is that the act of visually guiding a response does not share neural mechanisms with the act of visualizing separate items. This would imply a two-process theory of internal visual representation, for we have already argued that visual guidance and generating a series of imaginary spatial locations do share mechanisms, motor perhaps. The other account of this failure to produce conflict rests on a capacity notion, that is, that the visual system is not overloaded in these circumstances. Such an explanation is compatible with a view of internal visual representation as a single process.

The first of these two possibilities is interesting in the context of some recent work on the vertebrate visual system. Currently some workers consider it to be composed to two major subdivisions, one concerned with orienting to location in space and the other with identifying objects. For example, in a variety of neurological and visual discrimination tests, Schneider (1967, 1969) has been able to show that, in the hamster, damage to the optic tectum (superior colliculus) interferes with ability to orient correctly in visual space, to orient to where an object is; however, it leaves intact the ability to discriminate two objects on the basis of form, to tell what it is. Ablations of the visual cortex have the reverse effect - location is unaffected while visually-based discrimination of separate forms is poor. Using conditioned avoidance learning, Ingle (1967) has shown that the goldfish will treat two stimuli as equivalent, in interocular transfer tests, when the left-right orientation is maintained intact and when the stimuli fill relatively few degrees of visual angle. However, when the stimulus field is enlarged the fish switches to a "front-back" mode of interocular equivalence, treating, for example, a left-pointing form seen via one eye as equivalent to a right-pointing one viewed by the other.

> "With smaller figures, the shape is taken in as a unit, and the orientation is analyzed in terms of 'relative' rather than 'absolute' position of the parts... (We) may speak of a shape-analyzing process as distinct from an orientation process that takes (body-centered) spatial position into account" (p. 48).

Trevarthen (1968) suggests that in primates also there may be a functional differentiation between two kinds of vision, one involved in the analysis of formal properties of things (such as would lead to a distinction between crosses and circles) and the other sensitive to changes over a wide area of the visual world.

It is not meant to imply that the possible distinction between recall of spatial information and remembering what a single item looks like is exactly analogous to the locating and identifying functions that is distinguished by the just-mentioned researchers. For one thing, the locating functions in the species studied generally are thought of as guiding _gross_ bodily orientation and locomotion. The present author knows of no work which has attempted experimentally to dissociate _fine_ visuo-motor control from form-analyzing functions.

Furthermore, this animal work has largely concerned itself with visual perception, and implies that incoming information about identity is handled differently from information about location. The current suggestion differs in that the distinction is applied to imagined visual space, and that it shows up as the ease with which recall of a spatially organized sequence can be disrupted by a concurrent visually-guided response compared with the stability of visualizing items in the face of the same response. The research is presented, however, as an interesting way of partitioning visual processing, one that in a general way fits one interpretation of the present results.

Recently a translated review of some Russian work, distinguishing perception of form and position in humans, has appeared (Leushina, 1971). The claim made in the review is not only that form and position represent logically different judgements but that they are handled in separate channels in the visual system. For example, subjects were apparently able to identify the form of a tachistoscopically presented stimulus in cases where their judgments of its position (out of four, five degrees of visual angle apart of the horizontal and vertical axes) were wrong. There were also many cases of correct identification of position when form was judged erroneously. In addition, anecdotal evidence suggests than one can know identity without location. When one is glancing through a newspaper sometimes a particular word will momentarily "stick out" but it takes some time of active searching to locate it. One knows one has seen the word, but one cannot tell where. Several people to whom the author put this agreed that the phenomenon exists.

Again, this evidence may only be related indirectly to the present work. Nevertheless, a growing body of data suggests a distinction between processing systems for form and location, and one way to interpret the current studies is that the distinction also applies when form and location are internally generated.

Some comments on distinguishing verbal and imaginal mediators

Demonstrations of modality-specific interference have been used to support the imagery interpretation of enhancements in retention due to (a) instructions to visualize (Bower, 1968) and (b) use of concrete (versus abstract) word pairs (Atwood, 1971). As will be remembered, in Atwood's experiment subjects listened to either concrete or abstract phrases (a noun pair in each phrase), and were given either a visual or auditory distraction task immediately after presentation. Recall of concrete pairs was adversely affected by the visual task, little (compared to a no-distraction control group) by the listening task. The opposite effects were found for abstract pairs.

As described in the Introduction, several attempts to replicate Atwood's findings have failed (Brooks, personal communication; Bower, Munoz and Arnold, personal communication). From their failures, and from an independent experiment, Bower et al. conclude that it is not possible operationally to distinguish the imagery hypothesis from one which utilizes semantic concepts to explain the superiority of concrete stimuli. They appear to favour the latter somewhat.

However, while there is uncertainty about how conflict is generated, especially with regard to representational imagery, it may be inappropriate to lean towards a verbal hypothesis on the grounds of finding no modality-specific interference. Perhaps the visual system is actively involved in encoding and storage, but its capacity simply is not exceeded when the perceptual task is added. Or, on a multi-process view of the visual system, different components are being activated in memory and perception and thus competition for processing capacity is skirted. Interpreting failures to find modality-specific interference looks like being a tricky affair, more so if continuing attempts to find conflict fail when formal characteristics are the classification bases. It is under these circumstances that task requirements, combined with subjects' own claims of imaging, lead us to be reasonably confident that subjects are engaging in internal visual representation of the items themselves.

These considerations can be exemplified by one comparison in the present research, Experiment B2. FARMSTACK and FARMSPOKEN both showed overall zero response-mode differences. Does this mean that the recall processes were the same in both cases? Perhaps, or it may just reflect the insensitivity of the technique to certain kinds or degrees of visualization. We might have expected a stronger visual component for the FARMSTACK subjects, who were shown drawings of the referents during acquisition.

Limitations and generalizations

The basic task has not been varied in this experimental series. It is characterized by the serial recall of well-learned list of items. How restricting is that on the generality of the conclusions?

A point of theory arises when we consider the fact that the lists were all learned to the same criterion, and that only errorless categorization trials were used. It could be that the effectiveness of spatial organization with nameable stimuli is limited to the retrieval phase of the present tasks, and plays little role during acquisition. In the terminology introduced by Tulving and Pearlstone (1966), information was both available and accessible (stored and retrieved), and thus it is not clear whether spatial organization affects items' availability, their accessibility, or both. We might consider, for example, the hypothesis that location serves as a retrieval cue only, (affects accessibility) and that availability of an item (its "strength" in memory) is under the control of other factors such as familiarity, meaningfulness and imagery value. On the other hand it might be that storing an item along with a location advances its trace strength as well by increasing its distinctiveness, or through some other process.

How could we test between these notions? The acquisition data from the present experiment do not tell us anything other than the none-too-surprising fact that spatial organization isn't everything. For example, the most difficult material to learn was ABSTRACT WORDS (6.9 trials to criterion). PIGMATRIX, by comparison, took significantly fewer trials (5.1, $t_{22} = 2.45$, $p<.05$). Both sets of stimuli were arrayed spatially. But the locus of action of spatial factors is not narrowed down by such comparisons because the method of measuring learning (trials to criterion) confounds availability and accessibilty by requiring subjects to retrieve the items. It might be argued that the way around this would be to use a recognition measure of availability because there is a substantial body of opinion which holds that recognition eliminates the retrieval process (Bower, Clark, Lesgold, and Winzenz, 1969; Kintsch, 1970). Thus any effects spatial organization has on item availability (as against accessibility) should show up in recognition scores. This hope is supported by evidence showing that semantic organization enhances recognition (Bower, Clark, Lesgold, and Winzenz, 1969; Mandler, Pearlstone and Koopmans, 1969), although other studies have provided negative results (see Tulving and Madigan (1970) for a review). But recent work by Tulving and Thomson (1971) casts doubt on recognition as being a retrieval-free measure of item availability. Recognition scores for words show context effects, that is, depend on how nearly the conditions of acquisition are reinstated at the time of test. "These context effects suggest that retrieval or utilization of stored mnemonic information in a recognition-memory task depends on both availability and accessibility of this information" (p. 116). Thus, trying to tie down exactly how spatial organization has its effect may prove a difficult task.

It should be added at this point that the process whereby people retrieve well-learned material is interesting in its own right. Furthermore, most of the work which has established the potency of various factors (e.g., concreteness) in the processing of nameable material has concentrated on the acquisition phase. Mostly the dependent variables in such studies have to do with error, and hence are probably tapping the mental processes at a different stage from experiments where the subjects know the material well. Thus, even if the effectiveness of our experimental manipulations is limited to tasks utilizing reasonably well-learned material, we are still investigating a little-studied, but important, process.

A second limiting factor on the conclusion is the fact that a sequential task was used throughout. It may be that the visuo-spatial system becomes involved in internal representation because of the need to maintain order among a set of items. We might conceive of factors such as concreteness etc. controlling availability and accessibility of individual items while spatial organization is utilized in ordering them into the correct sequence. On this view, location may not even act as a retrieval cue except in the sense of cueing which of several already-accessed items comes next, serving, in other words, only as an ordering device.

The experiments needed to extend the generality of our conclusions beyond ordered recall are ones in which an advantage for spatially distributed material exists when non-ordered recall is asked for. Thus, the recognition experiments proposed above would serve the purpose provided that the single item was the unit of recognition. Free-recall might also fill the bill, but it may be the case that subjects would in fact order the items, in effect turning the task into serial recall. (The author has made informal observations on how people learn a display like PIGMATRIX when simply told to study it until they know it. Even though no arrows linking items are present, people almost invariably report imposing a fixed order on the material during rehearsal. If this is a common practice in directed learning, the possibility that our experimental effects may be limited to ordered-recall tasks may be less limiting than it first appears.) It would be desirable to show that spatial organization not only enhances learning but is less use as a recall aid when a concurrent visuo-spatial task is being carried out. We are working on ways of achieving this.

Brooks' original finding of conflict between visualization and output (Brooks, 1968) has been taken as evidence for the continuity of imagination and perception (e.g., Neisser, 1968). The burden of this thesis has been that the only strong evidence for such continuity occurs when spatial organization is present in the remembered material. But this does not mean that the original observation is now relegated to the position of an experimental curiosity, because, for example, it is unlikely to have power as an analytic tool beyond situations where such spatial factors are operative. While it may be thus limited, it is probably true that spatial imagery is widespread as a form of mental representation. Huttenlocher's data (1968) implicates spatial imagery as a strategy in solving syllogisms, and a variety of neurological data demonstrates that mental processes not normally throught of as spatial may be disrupted when spatial abilities are affected by cerebral insult (e.g., aspects of arithmetic, "mental" or otherwise, which involve laying out the numbers in columns and rows, on paper or in imagination - Hecean & Ajuriaguerra, 1964). Similarly, tasks classified as based on visual imagery may have strong spatial components. As pointed out in the Introduction, Critchley (1953) reports failures of place recognition and of descriptions from memory of what should have been familiar surroundings (e.g., a patient's own bedroom) in cases of parietal damage, chiefly characterized by loss of spatial skills. The evidence is suggestive of a high degree of overlap between imagery and spatial ability. In many such patients visual imagery of a non-topographical nature may persist unimpaired (e.g., the patient who lost the ability to describe the district of his residence but could satisfactorily describe his wife's appearance). The point is that the distinction between spatial and non-spatial aspects of imagery normally goes unnoticed, but selective brain damage shows it up and also demonstrates the extent to which spatial factors are a part of what is normally referred to by the general term, "visual imagery". The same point was made earlier with respect to examples of visually imagery commonly presented as intuitively plausible examples of the process (e.g., counting mental windows).

Finally, a comment is required on our use of the term "spatial". It has been used narrowly, to refer to distribution of stimulus items through space, topographical information. But we have also suggested that use of this stimulus characteristic in internal representation may be part of a general class of internal operations that could be defined as transformational, or dynamic. We have further suggested that the act of internally generating this spatial information utilizes mechanisms, probably motor in nature, that are involved in spatial or transformational operations in the visual world. The question thus arises as to whether in fact the processes tapped by our experimental procedures would be brought into play by other stimulus material and tasks that might also be thought of as transformational or dynamic. The most obvious candidates would be spatial manipulations such as imaginary operations on things (e.g., slicing a cube in each of three planes - Skinner, 1953), or imaginery rotations of objects about various axes. If these operations really are acts of "private seeing", and if they are of the same class as generating a series of spatial locations, then the methods used in the experiments reported in this thesis should prove useful in investigating them.

BIBLIOGRAPHY

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

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

Bower, G. H. Mental imagery and associative learning. Paper read at Fifth Carnegie-Mellon Symposium on Cognition. April, 1968. To be published in L. Gregg (Ed.) Cognition and Learning. New York: Wiley, in press.

Bower, G. H., Clark, M. C., Lesgold, A. M., and Winzenz, D. Hierarchical retrieval schemes in recall of categorized word lists. Journal of Verbal Learning and Verbal Behaviour, 1969, 8, 323-343.

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

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

Brooks, L. R. An extension of the conflict between visualization and reading. Quarterly Journal of Experimental Psychology, 1970, 22, 91-96.

Bugelski, B. R. Images as mediators in one-trial paired-associate learning. II: Self-timing in successive lists. Journal of Experimental Psychology, 1968, 77, 328-334.

Bugelski, B. R., Kidd, E., and Segmen, J. Image as a mediator in one-trial paired associate learning. Journal of Experimental Psychology, 1968, 76, 69-73.

Critchley, M. The parietal lobes. New York: Hafner, 1953.

Dement, W. C. Eye movements during sleep. In M. B. Bender (Ed.), The oculomotor system. New York: Harper and Row, 1964.

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

Guilford, J. P. The nature of human intelligence. New York: McGraw-Hill, 1967.

Hecaen, H., and de Ajuriaguerra, J. Left-handedness. Manual superiority and cerebral dominance. New York: Grune and Stratton, 1964. Translated by Eric Ponder.

Hock, H. S., and Egeth, H. Verbal interference with encoding in a perceptual classification task. Journal of Experimental Psychology, 1970, 83, 299-303.

Horowitz, L. M., Lampel, A. K., and Takanishi, R. N. The child's memory for unitized scenes. Journal of Experimental Child Psychology, 1969, 8, 375-388.

Huttenlocher, J. Constructing spatial images: A strategy in reasoning. Psychological Review, 1968, 75, 550-560.

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

James, W. Principles of psychology. New York: Holt, 1890. (Reprinted by Dover, 1950).

Kintsch, W. Models for free recall and recognition. In D. A. Norman (Ed.), Models of human memory. New York: Academic Press, 1970.

Klein, G. S. Semantic power measured through the interference of words with color naming. American Journal of Psychology, 1964, 77, 576-588.

Leushina, L. I. Sources of information in the perception of visual spatial relations. in G. V. Gersuni (Ed.), Sensory processes at the neuronal and behavioral levels, translated by Jerzy Rose, New York: Academic Press, 1971.

Mandler, G., Pearlstone, Z., and Koopmans, H. S. Effects of organization and semantic similarity on recall and recognition. Journal of Verbal Learning and Verbal Behavior, 1969, 8, 410-423.

McGuigan, F. J. Covert oral behavior during the silent performance of language tasks. Psychological Bulletin. 1970, 74, 309-326.

Neisser, U. Cognitive psychology. New York: Appleton-Century Crofts, 1967.

Neisser, U. Visual imagery as process and as experience. Paper presented at the Center for Research in Cognition and Affect, New York, June, 1968.

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

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

Paivio, A., Yuille, J. C., and Madigan, S. Concreteness, imagery, and meaningfulness values for 925 nouns. Journal of Experimental Pschology Monograph Supplement, 1968, 76, No. 1, Part 2.

Reitman, W. What does it take to remember? In D. A. Norman (Ed.) Models of human memory. New York: Academic Press, 1970.

Schneider, G. E. Contrasting visumotor 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.

Segal, S. J., and Fusella, V. Influence of imaged pictures and sounds on detection of visual and auditory signals. Journal of Experimental Psychology, 1970, 83, 458-464.

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

Skinner, B. F. Science and human behavior. New York: MacMillan, 1953.

Stroop, J. R. Interference in serial verbal reactions. Journal of Experimental Psychology, 1935, 18, 643-661.

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

Tulving, E., and Madigan, S. A. Memory and verbal learning. Annual Review of Psychology, 1970, 21, 437-484.

Tulving, E., McNulty, J. A., and Ozier, M. Vividness of words and learning to learn in free-recall learning. Canadian Journal of Psychology, 1965, 19, 242-252.

Tulving, E., and Pearlstone, Z. Availability versus accessibility of information in memory for words. Journal of Verbal Learning and Verbal Behavior, 1966, 5, 381-391.

Tulving, E., and Thomson, D. M. Retrieval processes in recognition memory: Effects of associative context. Journal of Experimental Psychology, 1971, 87, 116-124.

Yates, F. A. The art of memory London: Routledge and Kegan Paul, 1966.

APPENDICES

APPENDIX A

Mean output times, within-subject differences and standard deviations of differences for each trial for FARMSCENE.

	Trial #													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
V-G.	15.1	15.3	13.2	12.6	12.9	11.0	11.0	11.0	10.5	9.6	9.9	10.6	10.5	10.7
Art.	11.0	9.3	9.3	8.5	8.6	8.7	8.5	8.2	8.0	8.6	8.1	7.0	7.9	7.7
$\overline{D}$	4.1	6.0	3.9	4.1	4.3	2.3	2.5	2.8	2.5	1.0	1.8	3.6	2.6	3.0
S_D	6.4	5.2	5.2	2.2	3.3	2.0	3.5	3.0	4.4	3.3	2.4	2.6	2.8	3.6

Mean within-subject differences across trials (V-G. - Art.) (secs.)

Subject #			
1	2.7	7	3.3
2	3.2	8	1.3
3	2.4	9	.4
4	3.5	10	2.2
5	1.5	11	3.9
6	9.3	12	4.5

APPENDIX B

Mean output times, within-subject differences and standard deviations of differences for each trial for FARMSPOKEN.

	Trial #													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
V-G	15.2	16.9	13.4	12.8	11.9	11.5	11.9	10.0	9.5	10.8	9.0	10.8	10.2	9.3
Art.	16.5	14.3	14.4	13.0	12.0	12.3	10.5	11.1	10.1	10.7	10.5	10.5	10.1	9.1
$\overline{D}$	-1.3	2.6	-1.0	-0.2	-0.1	-.8	1.4	-1.1	-0.6	0.1	-1.5	0.3	0.1	0.2
S_D	5.5	4.5	3.5	5.5	4.1	5.4	6.4	2.8	3.2	3.0	3.2	6.3	3.7	2.5

Mean within-subject differences across trials (V-G. - Art.) (secs.)

Subject #		Subject #	
1	1.4	7	-0.8
2	1.0	8	-1.0
3	0.4	9	2.4
4	1.0	10	-1.3
5	-2.1	11	-4.1
6	1.3	12	0.0

APPENDIX C

Mean output times, within-subject differences and standard deviations of differences for each trial for FARMSPOKEN and IMAGERY INSTRUCTIONS.

	Trial #													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
V-G.	17.7	17.7	15.8	14.3	14.8	12.5	12.1	11.8	11.5	10.7	12.0	11.5	12.9	11.7
Art.	16.1	14.2	13.0	13.6	13.3	11.7	11.0	10.5	10.4	10.7	10.1	9.0	10.0	10.3
$\bar{D}$	1.6	3.5	2.8	0.7	1.5	0.8	1.1	1.3	1.1	0.0	1.9	2.5	2.9	1.4
S_D	4.2	2.4	4.5	3.8	3.8	5.9	2.8	3.5	2.8	4.2	2.4	2.4	4.2	3.1

Mean within-subject differences across trials (V-G. - Art.) (secs.)

Subject #			
1	5.3	7	0.5
2	1.0	8	-0.1
3	0.7	9	2.8
4	0.8	10	3.7
5	0.5	11	1.3
6	1.1	12	1.9

APPENDIX D

Mean output times, within-subject differences and standard deviations of differences for each trial for HOGMATRIX.

	Trial #													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
V-G.	18.5	16.7	15.4	13.9	16.2	13.0	12.1	12.0	11.7	12.0	10.9	11.2	10.4	10.7
Art.	15.8	15.0	15.0	14.4	12.5	11.8	11.9	11.8	10.3	10.6	10.4	10.2	11.7	9.6
$\overline{D}$	2.7	1.7	0.4	-0.5	3.7	1.2	0.2	0.2	1.4	1.4	0.5	1.0	-1.3	1.1
S_D	6.7	4.6	4.5	8.5	2.2	5.8	4.5	3.5	1.7	4.5	3.1	2.1	5.5	3.1

Mean within-subject differences across trials (V-G. - Art.) (secs.)

Subject #		Subject #	
1	2.4	7	-0.5
2	2.9	8	2.6
3	-1.9	9	2.0
4	-5.6	10	1.9
5	0.8	11	4.1
6	1.7	12	1.4

APPENDIX E

Mean output times, within-subject differences and standard deviations of differences for each trial for PIGMATRIX

	Trial #													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
V-G.	29.7	24.6	21.5	23.3	22.3	19.7	18.4	16.9	15.7	15.4	16.5	15.6	15.0	15.7
Art.	20.8	17.7	18.6	18.0	14.7	14.0	13.3	14.6	13.4	12.9	12.2	11.5	12.4	11.3
$\overline{D}$	8.9	6.9	2.9	5.3	7.6	5.7	5.1	2.3	2.3	2.5	4.3	4.1	2.6	4.4
S_D	9.2	5.6	8.0	11.0	4.8	8.4	5.0	7.0	2.6	6.3	4.7	3.1	4.7	4.7

Mean within-subject differences across trials (V-G. - Art.) (secs.)

Subject #			
1	3.6	7	1.3
2	4.0	8	2.6
3	2.5	9	5.4
4	8.1	10	8.9
5	2.5	11	0.8
6	4.2	12	8.6

APPENDIX F

Mean output times, within-subject differences and standard deviations of differences for each trial for HOUSE.

	Trial #													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
V-G.	16.4	15.7	13.3	13.6	14.6	11.9	12.0	12.3	11.1	10.5	11.1	10.1	10.6	9.0
Art.	14.6	12.6	11.6	12.0	10.7	9.9	11.7	10.4	10.4	9.2	9.3	10.0	8.9	8.3
$\bar{D}$	2.2	3.1	1.7	1.6	3.9	2.0	0.3	1.9	0.7	1.3	1.8	0.1	1.7	0.7
S_D	6.1	5.1	6.2	3.5	4.6	2.5	4.8	3.6	3.7	2.7	3.1	3.1	2.4	2.6

Mean within-subject differences across trials (V-G. - Art.) (secs.)

Subject #			
1	2.9	7	2.4
2	2.2	8	0.5
3	3.0	9	-0.9
4	3.5	10	2.7
5	1.5	11	1.1
6	2.2	12	3.0

APPENDIX G

Mean output times, within-subject differences and standard deviations of differences for each trial for FARMSTACK.

	Trial #													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
V-G.	19.5	17.1	15.9	15.7	12.7	12.4	13.4	12.7	10.8	11.2	10.8	11.9	11.0	11.4
Art.	17.2	14.8	14.1	12.9	13.5	12.6	13.6	12.9	11.6	11.1	12.1	10.6	11.2	10.9
$\overline{D}$	2.3	2.3	1.8	2.8	-0.8	-0.2	-0.2	-0.2	-0.8	0.1	-1.3	1.3	-0.2	0.5
S_D	6.0	4.1	4.1	7.0	3.3	3.2	4.5	3.2	2.6	3.8	4.2	4.7	4.4	3.7

Mean within-subject differences across trials (V-G. - Art.) (secs.)

Subject #		Subject #	
1	-0.1	7	2.4
2	2.9	8	-0.8
3	0.0	9	0.8
4	2.8	10	0.4
5	-3.2	11	0.6
6	-1.7	12	2.5

APPENDIX I

Mean output times and between-subject standard deviations for each trial in Experiment Cl

Group A

	Art.						SpC				SpI			
Trial #	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Means	19.0	13.6	15.0	12.7	14.3	13.8	13.7	11.0	11.1	10.7	16.6	16.0	13.6	14.1
Standard deviations	12.8	7.2	9.4	5.8	8.3	6.5	6.5	3.1	4.0	4.1	5.0	6.2	5.5	4.5

Group B

	Art.						SpI				SpC			
	15.1	14.3	12.9	13.2	11.8	12.3	22.2	17.3	17.6	16.7	12.6	11.2	10.8	10.2
Standard deviations	5.9	7.0	4.5	5.4	3.5	5.2	8.4	7.7	4.8	4.5	4.3	3.1	4.7	2.4

APPENDIX H

Mean output times, within-subject differences and standard deviations of differences for each trial for ABSTRACT WORDS.

	Trial #													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
V-G.	23.0	20.6	18.5	16.2	15.3	14.3	14.2	12.1	12.7	11.9	12.2	11.8	11.8	11.5
Art.	16.6	13.9	14.9	13.4	11.5	10.8	11.2	10.7	10.3	11.1	10.7	9.4	11.1	9.8
$\overline{D}$	6.4	6.7	3.6	2.8	3.8	3.5	3.0	1.4	2.4	0.8	1.5	2.4	0.7	1.7
S_D	5.4	7.0	5.2	4.0	5.4	5.1	5.9	4.9	3.8	2.6	4.7	2.3	4.1	2.5

Mean within-subject differences across trials (V-G. - Art.) (secs.)

Subject #			
1	0.2	7	0.8
2	3.1	8	3.2
3	1.8	9	7.7
4	3.9	10	5.0
5	-0.9	11	2.7
6	-0.1	12	7.7

APPENDIX J

Mean output times and between-subject standard deviations

for each trial in Experiment C2

	Trial #									
	Art.						SpC, item incompatible			
	1	2	3	4	5	6	7	8	9	10
$\bar{X}$	13.0	12.8	13.0	11.8	10.8	12.4	15.9	13.2	12.1	10.9
S	3.5	5.7	6.5	4.3	4.4	7.5	5.5	6.3	4.5	4.6