MEMORY FOR TEMPORAL AND SPATIAL INFORMATION: HEMISPHERIC ASYMMETRIES AND AUTOMATICITY

by

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ABSTRACT

It has been observed that information about the temporal order of events and the spatial location of stimuli is remembered easily, "automatically", even under incidental conditions. Other lines of research have shown that the two hemispheres of the brain are differentially involved in processing temporal and spatial material, the left hemisphere being more involved with temporal, and the right with spatial, information processing. The present study was an attempt to determine, firstly, whether similar hemispheric differences exist for **memory** of temporal and spatial attributes of stimuli; secondly, how such differences might relate to the well-known verbal/nonverbal hemispheric asymmetries; and thirdly, whether memory for the temporal and spatial attributes of stimuli is indeed "automatic" and therefore distinguishable from recognition memory for the stimuli themselves. In two controlled-visual-field experiments, line drawings of common objects (Experiment I) and words and photos of faces (Experiment II) were tachistoscopically presented. Subjects made forced-choice recognition judgements of the stimuli themselves, and of their temporal order and spatial locations. No side differences in accuracy of memory for temporal or spatial material were uncovered in either experiment. Further, there were no verbal/nonverbal differences in Experiment II. These results may have been due to the complexity of the task, which would have required widespread brain activation. Some support for the concept of automatic memory processing was found. The data suggest that little additional cognitive capacity, beyond that required for recognizing the items themselves, was needed to remember their temporal and spatial attributes.

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DEDICATION

This thesis is dedicated to my husband, Kenneth Leason, who has cheerfully given up so much to help me pursue my goals.

Introduction

Many people, at the end of the day, can easily recall the time sequence of the day's events, although no conscious attention had been paid to the order of their occurrence. Similarly, often people have had the experience of reading a certain item in a newspaper and later being able to recall the location of that item on the page, even though that location was not consciously attended to at the time of the initial reading. Thus it appears that certain kinds of information are held in memory even when no deliberate effort is made to record that information. Could it be that the process by which we remember this information is fundamentally different from the more active memorization we use to remember other things?

Review of the Literature

Automatic Memory Processes

The recent proposal that different memory processes vary in attentional requirements has attracted interest. Hasher and Zacks (1979) have hypothesized a continuum of mental operations, ranging from those processes that occur with only minimal attentional capacity being allocated to them from the general pool of energy available for mental operations ("automatic" processes) at one extreme, to those requiring considerable attentional capacity ("effortful" processes) at the other. In this framework, information about the temporal order, spatial location and frequency of occurrence of stimuli are encoded automatically, without much conscious effort, whereas retention of information about the items themselves through imagery, rehearsal or other mnemonic techniques, requires more deliberate or effortful encoding. Hasher and Zacks have conceptualized automatic memory processes as those in which:

1. The information is encoded without intention.
2. The addition of intention does not improve the efficacy of the encoding process.
3. Training has no effect.
4. There are minimal individual differences in the

encoding of the information.

5. Similarly, there are minimal age differences.
6. The encoding of the information is not disrupted by factors which reduce cognitive capacity (eg. illness, depression) or by competing cognitive demands.

(Zacks, Hasher, Alba, Sanft, & Rose, 1984)

These ideas have been put to the test in many studies which have explored the validity of Hasher and Zacks's criteria for automaticity.

Memory for the temporal order of occurrence of events meets several of Hasher and Zacks's criteria. It has become evident that conscious intention to remember temporal order is not necessary, since recall of temporal order is above chance even under incidental learning conditions (criterion 1: Hintzman & Block, 1971, 1973; Proctor & Ambler, 1975; Zimmerman & Underwood, 1968). Furthermore, instructions to attend to the temporal order of stimuli do not improve recall over incidental levels (criterion 2: McCormack, 1981; Toglia & Kimble, 1976; Zimmerman & Underwood, 1968).

Criterion 5, that automatic processes show little developmental change, is supported by studies of developmental trends which generally find no improvement in accuracy of temporal judgments in children after age 7 or 8

(Bakker, 1972; Brown, 1973; von Wright, 1973), although one study has found improvement up to age 12 (Mathews & Fozard, 1970). In adulthood, no differences are seen between young and elderly adults in memory for temporal order (McCormack, 1981; Perlmutter, Metzger, Nezworski, & Miller, 1981). Evidence that remembering temporal order requires little or no cognitive capacity comes from studies in which memory for stimulus words (an effortful task requiring considerable cognitive capacity) was not affected by the additional task of intentional learning of their temporal order of occurrence (criterion 6: Toglia & Kimble, 1976; Zimmerman & Underwood, 1968). Had the additional task also required capacity, a portion of the limited supply of cognitive capacity would have had to be reallocated from the learning of words themselves to the learning of their order of occurrence. This would be expected to result in a decrement in the learning of stimulus words that was proportional to the amount of the capacity required to learn temporal order. Since there was no decrement, it can be inferred that the additional task required little or no capacity.

Criteria 3 and 4 have been contradicted by the research, however. One study found that retention of temporal order does improve with practise, and that reliable individual differences in performance exist and are correlated with academic ability (Zacks et al., 1984).

In summary, while not all the criteria are fully supported, the bulk of the evidence confirms that remembering temporal order requires little attentional capacity.

Although the evidence concerning automatic processing for spatial location is at times conflicting, Hasher and Zacks's framework finds some support in this area also.

Most importantly, as is the case with memory for temporal order, it is clear that spatial location can be remembered without conscious intention (criterion 1). There is considerable evidence that information about the location of words and pictures is recalled at levels well above chance even when no instructions to remember location are given (Park & Mason, 1982; Park, Puglisi & Lutz, 1982; Park, Puglisi & Sovacool, 1983; Rothkopf, 1971; Schulman, 1973; von Wright, Gebhard & Karttunen, 1975; Zechmeister, McKillip, Pasko & Bespalec, 1975), although instructions to remember location sometimes result in improved performance (criterion 2: Light & Zelinski, 1983; Park et al., 1983).

Memory for spatial location appears to require only minimal processing capacity, in that it often does not interfere with an effortful cognitive task, item recall (criterion 6). Levels of item recall or recognition accuracy are usually not lowered by the additional requirement to remember item location, whether the stimuli are drawings (Light & Zelinsky, 1983), objects (Mandler, Seegmiller & Day, 1977; von Wright et al., 1975), words

(Park & Mason, 1982), or prose passages (Zechmeister et al., 1975), although the addition of a spatial memory component has been found to affect recognition adversely in some studies (Park et al., 1982; Park et al., 1983; Schulman, 1973).

Criterion 5, that there is little developmental change in spatial memory, has not been supported by the data, however. Studies which have addressed this issue have been cross-sectional in design, and have usually shown a regular improvement in location memory with increasing age in children (Mandler et al., 1977; von Wright et al., 1975) and a decline in aging adults (Light & Zelinski, 1983; Moore, Richards & Hood, 1984; Park et al., 1982; Park et al., 1983; Perlmutter et al., 1981; Pezdek, 1983), although at least one study found no decline in the elderly (McCormack, 1982).

Thus, not all of Hasher & Zacks's criteria have been supported, and it is likely that their model requires some modification. Nevertheless, in the case of memory for temporal order and spatial location, there is strong support for the most basic and most important criterion: that information can be encoded without intention, and that incidental memory is much better than could be explained by chance alone. This suggests that memory for these types of information is somehow different from intentional learning.

If we accept the existence of memory processes which are to some degree automatic, it becomes an interesting question as to why some types of information should be encoded automatically, whereas others are not. Hasher and Zacks (1979) speculate that the human nervous system might be genetically "prepared" to process certain types of information with very little effort, in the same way that some animal species are "prepared" to learn very easily certain associations which have survival value (Seligman, 1970). It has been noted that automatically-encoded attributes such as temporal order and spatial location are fundamental aspects of almost all information processed by the brain (Underwood, 1969). Immanuel Kant (1724-1804) suggested that the mind is structured such that everything presented to it is perceived in temporal and/or spatial form. Thus, our phenomenal world is based on time and space (Hospers, 1967). It may be that since the brain is constantly bombarded with information of these types, it has developed information-processing styles based on them. These styles might be called the "temporal-order style" and the "spatial-location style". Consequently, when the brain processes information using the temporal-order style, for example, information about temporal order is recorded automatically. In other words, the brain records information about temporal order and spatial location as a byproduct of its style of dealing with stimuli, just as a tree automatically records information about its growth rate in rings, which are a byproduct of its response to the environment.

Another aspect of temporal/spatial information processing, separate from the issue of automatic memory processes, has also been the subject of considerable research effort - that is, the question of cerebral specialization for temporal and spatial functions.

Hemispheric Asymmetries

Accumulation of clinical and experimental evidence over many years has shown that the two hemispheres of the brain differ in their cognitive functions. However, it has proven very difficult to determine the essence of this difference. It has been demonstrated repeatedly that, for the great majority of strongly right-handed people, the left hemisphere is better able to deal with verbal stimuli than is the right. For its part, the right hemisphere appears superior to the left in processing certain types of nonverbal stimuli (eg. Kimura, 1961; Milner, 1974). These observations have led to the proposal that the hemispheres are specialized along at least one dimension: the verbal/nonverbal one. However, difficulty in defining what constitutes a verbal versus a nonverbal stimulus, and evidence which shows that the verbal/nonverbal characteristics of a stimulus may be less important for hemispheric specialization than the type of processing the stimulus undergoes (Bradshaw and Sherlock, 1982), have led theoreticians to consider more basic parameters of stimuli. One hypothesis that has been put forward is that verbal stimuli necessarily involve an analytic, sequential, or temporal component, while nonverbal stimuli are generally more holistic in nature. Thus, the left side of the brain may be specialized for sequential, and the right for holistic, processing (Bogen, 1969; Nebes, 1974; Semmes, 1968).

Converging results from several studies which have investigated different types of temporal, or sequential, abilities support the hypothesis that temporal processing is primarily a function of the left hemisphere. For example, patients with left hemisphere lesions were impaired relative to patients with right hemisphere lesions and to normal control subjects in perception of the temporal order of sequences made up of audible clicks, tones of different pitches, and colored light flashes (Carmon & Nachshon, 1971; Efron, 1963a; Swisher & Hirsh, 1972). Patients with left-hemisphere lesions were significantly impaired compared to right-hemisphere lesion patients on a verbal task in which the patients had to point to representational pictures in the same sequence as that in which the examiner had named them (Albert, 1972; Goodglass, Gleason & Hyde, 1970).

Investigations using normal subjects have also found a left-hemisphere advantage for temporal processing. In a psychophysical study in which subjects judged the temporal order of electric shocks and light flashes presented to the two sides of the body, it was concluded that temporal perception occurs in the language-dominant hemisphere (Efron, 1963b). Similarly, studies of auditory processing have yielded a left-hemisphere advantage for processing temporal information. When dichotic clicks were used to measure thresholds for auditory discrimination of temporal order in the two ears, the left hemisphere was found to be the location for temporal processing (Mills & Rollman, 1980). Other dichotic listening studies have found a right ear (left hemisphere) advantage for processing nonspeech, nonphonetic rhythmic patterns in normal subjects (Robinson & Solomon, 1974), and that as the temporal complexity of the stimulus increases, the right-ear advantage becomes stronger (Halperin, Nachshon & Carmon, 1973).

Taken together, these studies provide evidence that the left hemisphere plays a dominant role in temporal perception. In contrast to this position, however, some researchers who have used both verbal and nonverbal stimuli within a temporal processing task, have reported that the characteristics of the stimulus also play a role in determining lateral asymmetries, so that during temporal processing the left hemisphere is more involved with verbal, and the right with nonverbal, stimuli. In one such investigation, patients with lateralized cerebral lesions were administered two verbal (Digit Span and Word Span) and two nonverbal (Knox Cubes and a 4x4 block test) sequencing tests. The left-hemisphere lesion patients were inferior on the verbal tests and superior on the nonverbal tasks in comparison to the right-hemisphere lesion patients (Kim, Royer, Bonstelle & Boller, 1980). Material-specific effects have also been found in normal subjects. Bakker (1972) lightly stimulated his subjects' fingertips in a sequential order. Subjects reported the order of stimulation either verbally, by using numbers to name the fingers touched, or nonverbally by pointing to the individual fingers on a drawing of a hand. When a verbal response was given, right hand performance was superior to left hand; the opposite pattern was found for nonverbal responses.

Overall, studies of temporal processing seem to show that the left hemisphere is predominantly involved in handling temporal information. Thus, it is reasonable to expect that the automatic retention of temporal order information might also be a function of the left hemisphere. Type of stimulus, whether verbal or nonverbal, appears to be a relevant consideration, however. Which of these two factors, type of processing or type of stimulus, is of primary importance in determining cerebral asymmetries, has not been addressed by the aforementioned studies.

The role of the right hemisphere in processing spatial information is well-established. For example, clinical studies have shown that damage to the right cerebral hemisphere impairs spatial processing ability. Patients with right posterior lesions performed more poorly on a task requiring a spatial skill (mental rotation) than did patients with left hemisphere lesions, and normal control subjects (Ratcliff, 1979). Patients with right hemisphere lesions had more difficulty than did those with left hemisphere lesions in reproduction of a tactual array (Faglioni, Scotti & Spinnler, 1971). In the visual modality, patients with posterior right-hemisphere damage were inferior to normal controls and posterior left-hemisphere lesion patients on the Corsi block span, a spatial memory task (DeRenzi, Faglioni & Previdi, 1977). Also, patients who had undergone a right temporal lobectomy including a large hippocampal excision were impaired relative to patients who had undergone equivalent left temporal lobectomy and to normal subjects, on the Corsi block supra-span learning task (Milner, 1971), on learning a stylus maze (Milner, 1965), and on the incidental recall of object location (Smith & Milner, 1981).

Studies with normal subjects also support the contention that the right hemisphere is involved in spatial processing. In the tactual modality, nonverbal nonsense shapes felt by the left hand (right hemisphere) are more accurately identified than those palpated by the right hand (Witelson, 1976). Reading of Braille, a tactuospatial system of letter symbols, is faster and more accurate with the left hand than with the right (Hermelin & O'Connor, 1971). This result is particularly interesting in view of the linguistic nature of the stimuli, which might lead to the prediction of a left-hemisphere advantage. In the visual modality, the role of the right hemisphere in spatial processing has been repeatedly demonstrated. For example, the spatial locations of single dots are more accurately reproduced when the dots are exposed to the right hemisphere than to the left (Kimura, 1969). Subjects required to make same/different judgements about matrices were able to do the task more quickly when stimuli were presented to the right hemisphere than to the left (Gross, 1972). In free-field studies, it happened that incidental recall of location was significantly better for those stimuli that had been displayed originally on the left side of the array than for those on the right (Mandler et al., 1977; Zechmeister et al., 1975). Although these were not controlled-visual-field studies, they suggest that spatial memory is more efficient for stimuli which occur in the left half of space, possibly because they are processed mainly by the right hemisphere.

Unfortunately, the question of material-specific cerebral asymmetry for spatial processing has failed to garner much attention from researchers. Almost all studies dealing with lateralization of spatial ability have used nonverbal stimuli. However, there is strong evidence that the right hemisphere is primarily involved in spatial processing of at least nonverbal stimuli. Thus, it is reasonable to expect that the right hemisphere will be predominantly involved in automatic memory for spatial location.

The foregoing studies in which temporal and spatial information were processed preferentially by the left and right hemispheres respectively, suggest a model of cerebral asymmetry based on processing style. Several studies have tested this model by comparing hemispheric asymmetries for temporal and spatial processing within the same subjects. The results support the hypothesis of left cerebral dominance for temporal, and right for spatial, processing.

In one such study, lesion patients and normal control subjects viewed visuospatial patterns which were sequentially illuminated, segment by segment, until the complete pattern was displayed. Patients with left-hemisphere lesions were impaired in recognizing the sequence of illumination regardless of the spatial complexity of the pattern, while patients with right-hemisphere lesions were not impaired in perceiving the sequence until the spatial pattern became more complex (Carmon, 1978). A visual study with normal subjects was done using a tachistoscope to present light flashes either in a temporal sequence or all together in a spatial arrangement. Subjects indicated on each trial whether the stimulus had been temporal or spatial in nature. Both accuracy and reaction-time measures revealed a left-hemisphere advantage for temporal, and a right-hemisphere advantage for spatial, processing within the same subjects (Brandeis & Babkoff, 1984). Another study compared sensorimotor abilities in the two hands. The fingertips of normal subjects were stimulated either sequentially or spatially, and subjects reproduced the pattern of stimulation by pressing microswitches located under the fingertips. Sequential stimulation was reproduced better by the right hand, and spatial by the left hand (Nachshon & Carmon, 1975).

These studies support the temporal/spatial processing model for nonverbal stimuli. Comparable experiments using verbal stimuli have not appeared in the literature. There has been a report of the development of a computer program in which digits can be displayed either sequentially or in a spatial arrangement either in the left or right visual field of the computer screen (Riss, 1984). Preliminary results are reported to be consonant with the model, although no data or statistical analyses have been given.

Thus, although there are some gaps in the evidence, the research to date provides good support for a temporal/spatial processing asymmetry in the brain. It seems a reasonable hypothesis that this asymmetry extends also to automatic memory for temporal and spatial information, so that automatic retention of temporal information might be primarily a function of the left hemisphere, and retention of spatial information a function of the right.

The present study put this hypothesis to the test in order to determine whether cerebral aymmetries for automatic memory exist. This study further attempted to fill in some of the gaps in current understanding of hemispheric function noted above, including the dearth of data on the spatial processing of verbal material, and the uncertainty about which factors are most important in determining cerebral asymmetries. To this end, this study used an adaptation of the automatic memory paradigm to compare directly two of the current models of hemispheric specialization: the verbal/nonverbal and the sequential/spatial dichotomies. In the verbal/nonverbal model, the nature of the stimuli is what determines hemispheric asymmetry, whereas in the sequential/spatial model it is the style of processing which is important, regardless of the type of stimuli. By carrying out a study in which both verbal and nonverbal stimuli are processed either sequentially or spatially, it should be possible to determine whether it is the nature of the stimulus or the nature of the processing which is more important in determining hemispheric asymmetries.

The present study first addressed the possibility of differential hemispheric involvement in the automatic retention of temporal order and spatial location of stimuli. The first phase of the study was aimed at determining whether there are hemispheric differences in accuracy of memory for spatial location and temporal order. The stimuli for this experiment were chosen so as not to favor the processing mode of either hemisphere. The next phase was designed to determine whether the spatial/temporal or the verbal/nonverbal attributes of the stimulus are most important in determining hemispheric asymmetries, or whether these factors will interact. The hypothesis was that the task will be more important than the stimulus type, so that memory for temporal recency will be better in the left hemisphere than in the right, whereas memory for spatial location will be best in the right hemisphere, regardless of the nature of the stimuli. Type of stimulus may be a factor in that temporal order judgements by the left hemisphere may be more accurate with verbal stimuli than with nonverbal, although in both cases superior to temporal order judgements in the right hemisphere. Similarly, location judgements in the right hemisphere may be easier with nonverbal than with verbal stimuli, while still being superior to left hemisphere performance in both cases.

EXPERIMENT I

The purpose of this experiment was to determine whether there are hemispheric asymmetries in memory for temporal recency and spatial location.

Method

Subjects. Subjects were 20 right-handed male undergraduate students at the University of Victoria who had volunteered to participate as subjects in psychological experiments. All subjects wrote with the right hand, obtained a score of not less than 11 out of 13 on the University of Victoria Lateral Dominance Examination (see Appendix 3), and had normal or corrected-to-normal vision.

Materials and Apparatus. The stimuli for this experiment were 254 line drawings of nameable objects (Snodgrass & Vanderwart, 1980). This type of stimulus was chosen because there is no strong hemispheric asymmetry favouring processing by one hemisphere or the other (Levine & Banich, 1982). Of these stimuli, 43 were used as practice items, and the remaining 211 were test items. Each stimulus was drawn in black ink on a white 4" x 6" card, so that it covered an area which extended from 2 degrees of visual angle either to the left or right of centre, and out peripherally no further than 4.4 degrees from centre, depending on the shape of the drawing. Within these areas of the card, the stimuli were placed in one of 3 positions: top third, middle third, or bottom third. Two complete sets of cards were prepared, one the mirror image of the other, so that every stimulus that occurred in the left visual field in Set A, occurred in the same position but in the right visual field in Set B. These sets were used with alternate subjects to eliminate the potential confounding factor of disparity in item difficulty between visual fields. A Gerbrands 3-channel tachistoscope equipped with an automatic card changer was used to present the stimuli.

Response sheets were prepared for temporal recency, spatial location, and recognition questions. Each question was on a separate sheet. In the temporal recency questions, exact copies of two of the stimuli previously viewed in the same visual field were presented on a sheet of paper, one positioned above the other. The subject's task was to point to the stimulus seen most recently. Verbal answers were not allowed. In the spatial location questions, the subject was presented with a sheet of paper on which two 3-section grids were drawn side by side, each grid representing the 3 possible positions a stimulus could have occupied on one or the other side of the centre fixation dot. In each grid was an exact reproduction of one of the stimuli which had been previously projected to the subject. In one grid the stimulus occupied the position and visual field in which it was originally presented to the subject, and in the other grid the same stimulus was in a different position and visual field. The subject's task was to point to the original position. In the recognition questions, two stimuli were presented, one above the other as in the temporal recency questions. However, in this case, only one of the two had been seen before. The subject's task was to point to that stimulus. This type of question was included as a check on the accuracy of the subject's memory for the stimuli themselves, separate from memory for recency of occurrence.

The test stimuli used in the questions were chosen from among the last three stimuli shown before the question was presented. Thus, a test item could have been the stimulus seen immediately before the question was presented (a lag of zero between initial exposure and test), the second last stimulus seen (i.e. one stimulus item interposed between the initial exposure and test, or a lag of one), or the third last (two stimulus items interposed between the initial exposure and test, or a lag of two). Questions with these three lag values were distributed equally among cells, so that there were seven questions of each lag value (0, 1, and 2) for each question type (temporal or spatial) in each visual field.

In the temporal recency questions, in which the subject was to choose the more recent of two different test stimuli, the correct alternative was chosen as outlined in the previous paragraph. The incorrect, or less recent, alternative, had been presented initially from four to six items back in the series of stimuli seen in the tachistoscope (lag of 3 to 5).

In the recognition questions, the lag values for the correct alternatives varied from zero to five, thus covering the entire range of alternatives used in the temporal and spatial questions. The incorrect alternatives were new items not previously seen.

These lag values were chosen on the basis of pilot data gathered from 43 subjects, in which variations of stimulus, exposure duration, and lag value were tested. The present parameters are those that yielded performance rates consistently midway between ceiling and floor.

Procedure. On arrival, all subjects were screened for visual acuity using a Snellen chart. They were then dark-adapted for about ten minutes. During this time, the experimental task was explained (see Appendix 2), and the Lateral Dominance Examination was given. The adaptation time was followed by a practice period of about five minutes, and then the experimental trials which took about 20 minutes. The entire session was approximately 45 minutes long.

The procedure for all subjects was the same, except that half the subjects were shown Stimulus Set A, and the others were shown Set B, mirror images of Set A. The task was to view the stimuli sequentially and, at intervals, make judgements about the temporal recency or spatial location of the stimuli. For each stimulus item, the order of events was as follows: a central fixation dot appeared on the screen for 1000 ms, followed immediately by the stimulus in either the left or right visual field for 180 ms. After stimulus offset, the fixation dot again appeared for 750 ms, and the screen then remained blank for 1075 ms, after which the cycle repeated itself with a different stimulus. Each trial of fixation dot-stimulus-fixation dot-blank screen lasted 3005 ms.

A forced-choice question followed some of the cycles. A sheet of paper with two stimulus items on it was placed on the table before the subject, who pointed to either the most recently seen stimulus (temporal recency question), or the stimulus which was in the correct location (spatial location question), or the stimulus which had been seen before (recognition question). Each stimulus was presented only once on the screen, and at most once more in the questions. Subjects pointed with the left hand for half the trials, and the right hand for the other half. Hand order was reversed in alternate subjects.

Before the experimental trials began, each subject was given practice trials. These were exactly the same as the experimental trials, but the stimuli were not used again in the experiment. In the practice trials, five stimuli were presented in a pre-determined random order. Then, a temporal or spatial location judgement was made. Following this, two more stimuli were again presented randomly, followed by another question. This pattern of two stimuli-one question was repeated twenty times. After a short break for further explanations, the experimental trials were given. These were the same in format as the practice trials, except that a greater number of stimuli and questions was used. Again, five stimuli were presented before the first forced-choice judgement, and thereafter judgements were required after every second stimulus. There were 104 experimental questions.

Data Analysis. The dependent variable was accuracy, measured as the number of errors. From these raw data, laterality indices were calculated for each subject, and these indices were the data used in all further analyses. The laterality index used was the phi coefficient, or the product-moment correlation between a subject's trial-to-trial performance, and the sensory half-field in which a stimulus appears (Levy, 1983; Kuhn, 1973). It takes into account not only mean performance but also trial-to-trial variability in performance. The mathematical formula for this index, and a sample calculation using it, are given in Appendix 4. Use of this index eliminates visual field as a separate factor, since data from both visual fields are used to calculate a single index for each subject. However, visual field advantages are indicated by the sign of the index, in this case a negative sign indicating a LVF advantage. Use of this index also makes it possible to compare performance on two different tests (in this case a temporal and a spatial test), since what is being compared is not raw scores but visual field advantages.

The analysis chosen for Experiment I was a paired-samples t-test,[1] performed on the laterality indices using the SPSS-X statistical package for computers (Norusis, 1985).

Results

Appendix 1 gives, for each subject, the number of errors made in each visual field and for each task (temporal and spatial), as well as the laterality indices. The summarized

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[1] Neither the temporal nor the spatial data distributions differed significantly from the normal distribution, as shown by the Kolmogorov-Smirnov Goodness of Fit test. Thus, the requirements of the t-test were satisfied.

Table 1

Mean Number of Errors in Automatic and Recognition Questions in Experiment I

	Left Visual Field		Right Visual Field	
	$\overline{X}$	(S.D.)	$\overline{X}$	(S.D.)
Automatic Questions [a]				
Temporal Task	4.95	(2.16)	5.20	(1.40)
Spatial Task	3.80	(1.64)	3.65	(1.27)
Recognition Questions [b]				
	1.50	(0.88)	1.80	(1.20)

[a] Maximum number of errors in each condition = 21

[b] Maximum number of errors in each condition = 10

data from this experiment are shown in Table 1, which contains the mean number of errors and their standard deviations, for both automatic and recognition questions. Contrary to prediction, there was no difference between the two visual fields in accuracy of response to temporal recency and spatial location questions ($t(19)=0.91$, $p=0.374$).

Discussion

Using line drawings of common objects, no cerebral specialization in memory for either temporal or spatial information was found.

These results might be interpreted in several ways. The simplest explanation is that both sides of the brain are equally adept in memory for both types of information. However, research results of other investigators do not support this conclusion. Another explanation is that cerebral specialization for processing style exists, but the chosen tasks were not effective in revealing it. This possibility will be examined in the general discussion section.

A third possibility is that hemispheric specialization for temporal and spatial processing is a subtle phenomenon, subject to influence by stimulus type, so that a small asymmetry due to processing can be either augmented by stimuli which lend themselves easily to that style of processing, or diminished by stimuli which do not.

The stimuli used in Experiment I were chosen because they do not yield consistent visual field advantages in recognition studies (Levine & Banich, 1982). Part of the reason for this might be that they are not inherently suited for either temporal or spatial processing. If processing style is indeed a factor in cerebral specialization, its effect might be magnified by use of stimuli whose nature predisposes them to processing in either a temporal or spatial style. This possiblity was tested in Experiment II.

EXPERIMENT II

This experiment was designed to determine whether there are hemispheric asymmetries in memory for temporal recency or for spatial location, with verbal and nonverbal material, and if so, whether the asymmetry due to task demands will override the usual verbal/nonverbal asymmetries, or vice versa.

Method

Subjects. A new group of 40 male right-handed students was recruited according to the same criteria as in Experiment I.

Materials and Apparatus. Two types of stimuli were used, a verbal and a nonverbal set. The verbal set consisted of 127 four-letter English words having low (X=3.34) imagery ratings (Paivio, Yuille & Madigan, 1968). Appendix 5 lists the words used. Words were assigned to visual field on the basis of frequency (Kucera & Francis, 1967), so that the frequency ratings in each visual field were balanced as closely as possible. The stimuli were prepared using black lower-case Letraset letters on white 4" by 6" cards. The words were oriented vertically in order to minimize any tendency to scan left to right while reading them. The words extended from 2.5 degrees of visual angle from the centre of the card, to 3.1 degrees.

The nonverbal stimulus set was comprised of 127 black and white photographs of faces taken from a college yearbook. Examples are shown in Appendix 6. The area covered by the faces extended from 2 degrees to 4.4 degrees from centre.

As in Experiment I, two sets of stimulus cards were prepared, Set B cards being mirror images of Set A cards. The same Gerbrands 3-channel tachistoscope was used to present the stimuli.

Response sheets were prepared as in Experiment I. There were two types of questions in each experiment: recognition questions, in which the subject chose, from either two faces or two words, the one which had been seen earlier, and either temporal recency questions in which the subject was to choose the more recent of either two faces or words from the same visual field; or spatial location questions.

Procedure. The procedure was the same as in Experiment I, except that half the subjects were given only temporal recency and recognition questions, and the other half were given only spatial location and recognition questions. The two types of stimuli, words and faces, were intermingled randomly so that subjects could not predict what the next stimulus would be, and thus could not establish response sets.

Data Analysis. Data from all subjects were analyzed together. Again the raw data were transformed into laterality indices, and these were used in all further analyses. Results from the temporal and spatial questions were analyzed using a 2x2 repeated-measures ANOVA.[2] The between-subjects factor was task (temporal or spatial), and the within-subjects factor was stimulus type (word or face). A similar analysis was carried out on the recognition data.

In addition to the foregoing statistical analyses, an item analysis was carried out on the questions from all three experiments in order to determine the influence of lag value (see page 20) on response accuracy, and to assess the comparability of item difficulty across experiments and conditions.

Results

The summarized data from these experiments are given in the form of mean error scores in Table 2, and displayed graphically in Figure 1. The analysis of the automatic data laterality indices is shown in Table 3. There were no

[2] None of the four data distributions in this experiment (i.e. automatic word and face questions, and recognition word and face questions) differed significantly from the normal distribution, as shown by the Kolmogorov-Smirnov Goodness of Fit test.

Table 2

Mean Number of Errors in Automatic and Recognition Questions in Experiment II

	Left Visual Field		Right Visual Field	
	$\overline{X}$	(S.D.)	$\overline{X}$	(S.D.)
Automatic Questions [a]				
Temporal Task				
Word Stimuli	4.85	(1.90)	5.85	(2.64)
Face Stimuli	6.15	(1.57)	6.40	(2.30)
Spatial Task				
Word Stimuli	4.35	(1.57)	4.70	(1.86)
Face Stimuli	2.70	(1.75)	3.60	(1.57)
Recognition Questions [b]				
Temporal Task				
Word Stimuli	1.40	(0.94)	1.10	(0.97)
Face Stimuli	1.60	(1.05)	1.45	(0.89)
Spatial Task				
Word Stimuli	1.05	(1.10)	1.65	(1.09)
Face Stimuli	1.75	(0.97)	1.10	(0.85)

[a] Maximum number of errors in each condition = 21

[b] Maximum number of errors in each condition = 5

Figure 1

Pattern of Errors from Experiment II - Recognition Questions

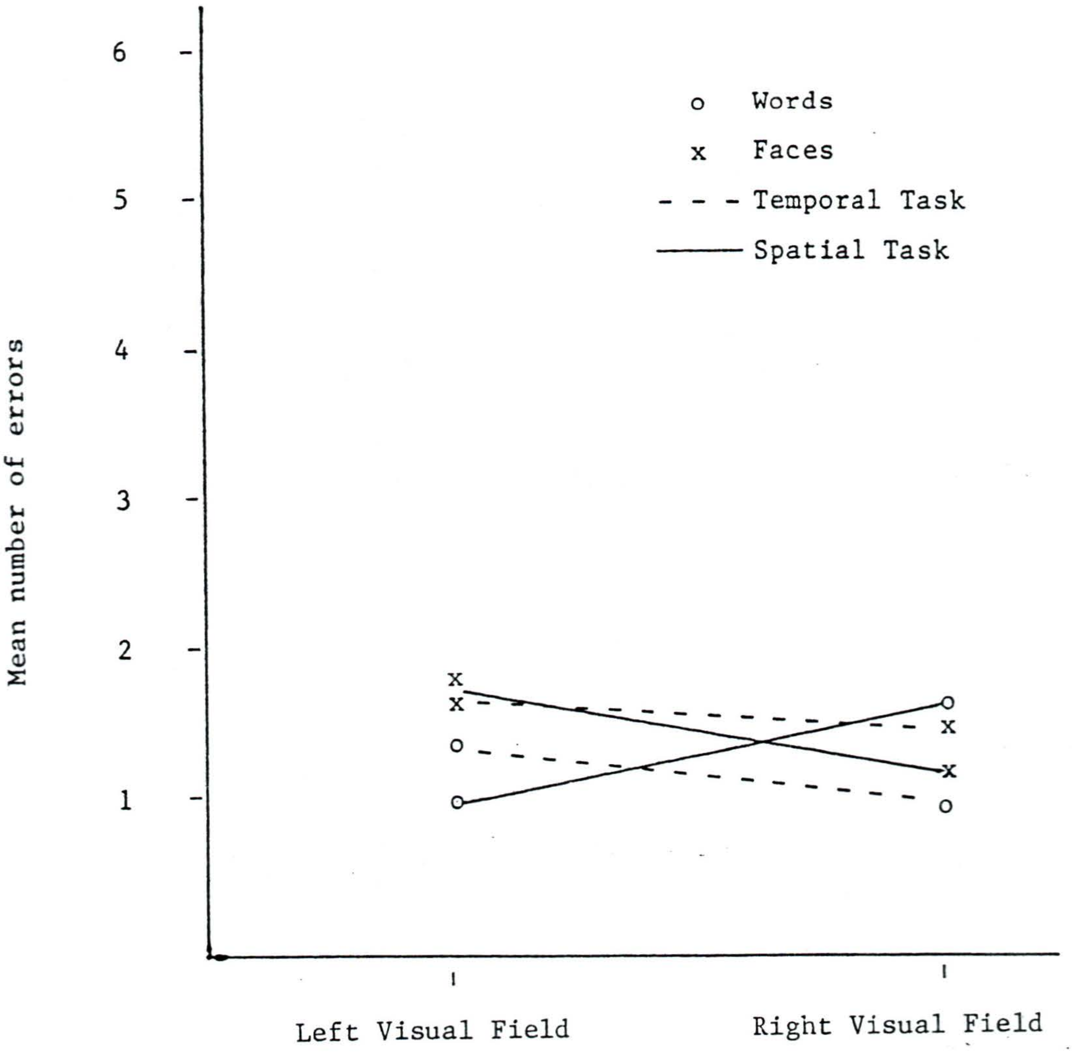

Table 3

Results of Repeated-Measures Analyses of Variance Performed on Data from Experiment II

Automatic Data:

Factor	F	df	p
Between subjects - task	.2235	1	.639
Within subjects - stimulus	.1154	1	.736
Constant - VF advantage	4.3919	1	.043
Task x stimulus	1.3273	1	.256

Recognition Data:

Factor	F	df	p
Between subjects - task	.3571	1	.554
Within subjects - stimulus	3.3333	1	.076
Constant - VF advantage	.5238	1	.474
Task x stimulus	4.9963	1	.031

significant main effects for either task (temporal vs. spatial) or stimulus type (word vs. face), and no significant task x stimulus interaction. There was, however, a significant overall LVF advantage for both words and faces, regardless of task.

The second repeated-measures 2x2 ANOVA, also shown in Table 3, was performed on the recognition data laterality indices. Again there were no significant main effects for task or for stimulus type, although the latter factor approached significance. The task x stimulus type interaction was significant. Examination of mean laterality indices shown in Table 4 reveals that accuracy of recognition memory for words was better in the RVF in the temporal recency task, but better in the LVF in the spatial location task. There was no such difference between visual fields for faces.

Item Analysis.

The results of the item analysis on automatic data for all three experiments are given in Table 5. The proportions of errors are quite consistent across the entire study. The main determinant of error rate was lag value, with larger lag values associated with more errors. Also, there was a trend for more errors in temporal recency questions than in spatial location questions. All percentages of errors are below 50% (chance level) except for the faces condition in

Table 4

Mean Laterality Indices for Recognition Data from Experiment II

Task Type			Stimulus Type	
			Faces	Words
Task Type	Temporal	$\bar{X}$	.0350	.0645
		(SD)	(.3343)	(.3383)
	Spatial	$\bar{X}$	.1510	-.1415
		(SD)	(.2473)	(.3832)

* Negative value = LVF advantage

Table 5

Item Analysis

Percentage of errors for each question type

Automatic Data:

	Experiment I Line Drawings				Experiment II Temporal Recency				Experiment II Spatial Location				
	LVF	RVF	LVF	RVF	LVF	RVF	LVF	RVF	LVF	RVF	LVF	RVF	$\bar{X}$
Lag Value	Temporal		Spatial		Words		Faces		Words		Faces		
0	6.4	6.4	6.4	4.2	12.1	15.7	12.9	13.6	10.7	2.1	0.7	2.9	7.8
1	20.7	21.4	7.8	10.7	20.0	19.2	22.1	26.4	16.4	20.0	7.1	7.1	16.6
2	42.8	46.4	40.0	35.0	37.1	45.0	52.1	51.4	36.4	43.6	30.7	41.4	41.8

Recognition Data:

	Experiment I Line Drawings		Experiment II Temporal Recency				Experiment II Spatial Location				
Lag Value	LVF	RVF	LVF	RVF	LVF	RVF	LVF	RVF	LVF	RVF	$\bar{X}$
			Words		Faces		Words		Faces		
0	6.7	3.3	10	10	20	20	15	15	10	-	12.2
1	7.5	7.5	0	10	30	15	10	20	35	30	16.5
2	17.5	20	50	35	45	55	45	50	35	30	38.3
3	23.3	33.3	25	20	20	0	15	30	-	20	20.7
4	16	26	40	50	36.7	33.3	20	50	47.5	20	34.0
5	30	10	-	-	20	20	-	-	-	10	18.0

Experiment II, for a lag value of 2. It can be seen that a contrasting pattern of errors occurred with temporal and spatial questions in Experiment II. In the temporal task, more errors were made with faces than with words, whereas in the spatial task, the opposite pattern prevailed.

Table 5 also gives the corresponding data for recognition questions. The recognition questions were intended to sample the entire range of lag values used in automatic questions, which varied from a lag of zero, used in both spatial and temporal questions, to a lag of 5, used for some of the less-recent items in temporal questions. Thus, there were 6 possible lag values for recognition questions. An effort was made to keep the experimental sessions reasonably brief, thereby avoiding undue fatigue in subjects which could contribute to experimental error. For this reason, only 20 recognition items were used, 10 in each visual field. In Experiment II the recognition items were further divided between face and word stimuli, so that there were only 5 questions in each visual field/stimulus type/task type combination. Given that these questions were distributed among 6 lag values, there was in most cases only one question for any particular lag value, and some lags were not represented by a question. Because of this small sample size, there is considerable variability in the percentages of errors for each lag value. Nonetheless, some trends are tentatively identified. Lags of zero and one tend to be associated with fewer errors than longer lags, and the mean error rates across experiments are comparable to those found with automatic data. For lags of more than one, error rates seem rather unsystematic. There is no general trend to greater error rates as lag values increase beyond a lag of two.

A summary of the mean percentages of errors across all experiments is given in Table 6, which compares automatic and effortful data collected from all temporal and spatial conditions. The percentages of errors are quite consistent, except for a lower error rate in the case of automatic spatial questions.

Discussion

As in Experiment I, there was no evidence of cerebral specialization due either to task or stimulus type, and further, no interaction between task and stimulus. These findings corroborate the results of Experiment I, in failing to demonstrate hemispheric differences in memory for temporal and spatial information, regardless of the type of stimulus.

Although the results of both experiments are consistent, they are also unexpected in view of previous research which has yielded consistent hemispheric asymmetries on the bases of both task and stimulus type. Are the present findings

Table 6

Mean Percentages of Errors Made on Spatial and Temporal Questions in Both Experiments

	Temporal Questions $\overline{X}$ (S.D.)	Spatial Questions $\overline{X}$ (S.D.)
Automatic Questions	26.18 (15.4)	17.96 (15.4)
Recognition Questions	25.68 (15.8)	26.71 (13.9)

valid or due to experimental error?

A potential source of error in Experiment II is lack of control over the strategies which subjects used to remember the stimuli. There is nothing to indicate that faces were not processed nonverbally as expected, but several subjects spontaneously reported that they had processed words mainly on the basis of shape rather than any semantic property. This had not been considered a serious hazard beforehand, since other studies which used similar combinations of words and faces have obtained the expected hemispheric differences (Hines, 1978; Klein, Moscovitch & Vigna, 1976). One potentially-relevant difference between this study and others is that in the present study the words were presented vertically rather than horizontally. The vertical orientation was chosen in order to minimize lateral scanning patterns. This approach has been used successfully by other researchers who have found a RVF advantage for recognition of vertical words similar in magnitude to that found for horizontal words (Beaumont, 1982). In this case, however, the unusual orientation may have led subjects to process all stimuli in some nonverbal manner. An indication of this can be found in the significant overall LVF advantage for the automatic data, coupled with the lack of a significant main effect for stimulus type. It is possible that the use of such an unexpected strategy could have obliterated any potential field effects due to stimulus type.

This explanation is relevant only to the lack of an effect due to stimulus type; it does not account for the lack of a task effect. The latter result appears to be consistent and valid in this set of experiments.

Turning to the recognition data, an interesting result was obtained: a stimulus by processing interaction. This interaction seems to have occurred solely with words, since words were recognized better in the RVF in the temporal processing milieu, but better in the LVF during spatial processing. An explanation is suggested by the task demands of the word recognition task. While it appears in the main to be very similar, and completely comparable, to the other tasks in this study, it is evident in retrospect that this task is the only one which could not have been done on the basis of shape, or some other holistic property. There are so many physically-similar words in the language that recognition had to be based on some other property - most likely a semantic property. Thus, in this task, the only one in which the salient properties of the stimuli were probably semantic, the predicted temporal/spatial asymmetry was obtained.

This asymmetry may also have been due to a priming effect of the automatic tasks on recognition memory. In this framework, the temporal and spatial processing requirements might act as concurrent tasks to activate the left and right hemispheres respectively. However, if this were the true explanation, the visual field asymmetries should have been found with faces as well as with words. This explanation is also in contrast to previous findings that spatial memory load fails to elicit a priming effect (Hellige, Cox & Litvac, 1979).

General Discussion

An attempt was made in this study to bridge the gap between free-field research in automatic memory, and controlled visual field experiments in cerebral specialization. The objectives were to determine whether automatic memory processes are related to cerebral organization, and also to contrast two theories of hemispheric specialization, one stimulus-based and one processing-based. This is a new approach to automatic memory research, and consequently exploratory in nature. The results obtained are not conclusive, but there were some interesting findings which have implications for the direction of future research.

The Cerebral Specialization Question

The lack of any effect due to processing style has been repeated in both experiments, regardless of stimulus type. Thus, it appears to be a reliable and valid result. However, it is at odds with other studies which have found the predicted cerebral asymmetries during temporal or spatial tasks. In addition, in Experiment II, there were no hemispheric advantages due to stimulus type, even though verbal/nonverbal asymmetries have been repeatedly demonstrated by others. The reason for these discrepancies might be the nature of the experimental task used in the present study.

At issue is the attempt to investigate memory processes tachistoscopically. Most visual field studies have involved perceptual tasks such as identification and matching rather than memory tasks. Perceptual tasks are well-suited to this approach. The cognitive link between visual sensation (due to lateralized visual input) and visual perception (due to processing of that input) appears to be a direct one. Because of the closeness of this cognitive link, it is logical to infer a close anatomic link also. This lends itself well to easy interpretation of visual field differences.

In memory tasks, however, mental processing does not stop at visual perception, but carries on. With each additional link in the chain, the cognitive activity is further removed from simple visual sensation. It is likely that as the cognitive chain grows longer, so does the anatomical, since more and more areas of the brain become involved in the processing.

Related to this is the issue of task complexity. It has been suggested that the brain is lateralized more strongly for tasks requiring higher levels of analysis (Luria, 1974; Moscovitch, 1979). On the other hand, it might be reasonable to expect that as brain activation becomes more widespread, it also becomes less lateralized. In fact, in a review of many such visual field studies, Beaumont (1982) noted that "once the tasks require more sophisticated cognitive manipulations the lateral asymmetry appears to become less stable" (p. 249). The task performed in the present experiments was complex, involving quick perception of detailed stimuli, retention of the stimuli as well as their temporal and spatial attributes in memory, and periodic updating of the memory store as new material was added and old material dropped. Accordingly, the lack of hemispheric differences in the present study may be an accurate reflection of the widespread cerebral activation involved in these "sophisticated cognitive manipulations".

The Automaticity Question

The recognition items were included in the experiment as a check on the ability of subjects to remember the items themselves, independently of their temporal order or spatial location. The results shown in Tables 5 and 6 demonstrate that overall, the proportions of errors were similar for both automatic and recognition questions, with the exception of lower error rates on automatic spatial questions. Excluding this exception for the moment (to be discussed below), the similar error rates suggest that the simple recognition task was equal in difficulty with the temporal memory tasks. Assuming that in the automatic tasks the stimuli had to be recognized before temporal recency judgements could be made, it appears that the additional cognitive requirement of judging recency did not increase the difficulty of the task. If task difficulty is a valid measure of the cognitive demands of a task, then the recognition task required some cognitive capacity, but the temporal task did not use any additional capacity beyond that required for recognition. This interpretation lends support to the notion that memory for temporal recency requires little cognitive capacity.

This finding that error rate is linked to the recognition component of the task suggests a possible explanation for the lower error rates in spatial location, as compared with temporal recency and recognition judgements. In the spatial tasks, subjects were required to recognize only one item and to choose its correct position. However, in the temporal recency and recognition tasks, subjects were presented with two items and had to choose between them. The necessity of recognizing two items rather than just one may have increased the cognitive demands of the temporal and the recognition tasks and consequently resulted in an increased error rate. Support for this interpretation is found in the recognition data, where there is no difference in task requirements between temporal and spatial conditions, and no corresponding differential error pattern.

Although these results are interesting, it should be kept in mind that there was a relatively small number of recognition items included in the study, since a comparison of recognition and automatic memory processes was not the primary goal. Thus, any interpretations drawn from the recognition data can only be tentative. Further studies designed to examine these issues more directly are required before firmer conclusions can be drawn.

Future Directions

The questions the present study addressed about cerebral specialization are interesting and seem worthy of further investigation. An important proscription for future work is to begin with simple tasks. A good approach for a programme of research may be to use simple perceptual tasks involving spatial and temporal components at first, then gradually make the task more complex by adding memory components. In this way the dynamics of cerebral specialization can be explored, allowing observation of how hemispheric differences develop as a task becomes more complex.

More work on the cognitive capacity requirements of automatic processes also seems indicated. A study addressed primarily to this issue might involve pairing automatic tasks with other perceptual and memory tasks varying in their own cognitive demands. Differences in performance in these tasks when done alone (versus in conjunction with an automatic task) would yield an estimate of the additional cognitive load imposed by the automatic task, and thus its relative capacity demands. A continuum of cognitive capacity requirements of various tasks could be constructed.

Thus, while the present study has been unable clearly to answer the questions which it addressed, it provides a basis for further investigations into those interesting issues.

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APPENDIX 1

NUMBER OF ERRORS AND LATERALITY INDICES FOR EACH SUBJECT

EXPERIMENT I

Subject number	LVF - Errors - Spatial	LVF - Errors - Temporal	RVF - Errors - Spatial	RVF Errors - Temporal	LVF - Recognition Errors	RVF - Recognition Errors	Laterality Index - Spatial	Laterality Index - Temporal	Laterality Index - Recognition
01	06	04	06	06	2	2	+.00	-.11	+.00
02	03	05	03	06	1	1	+.00	-.06	+.00
03	03	02	05	05	1	0	-.13	-.20	+.33
04	02	07	03	05	3	2	-.08	+.11	+.20
05	03	01	04	05	0	1	-.05	-.28	-.33
06	05	02	05	03	1	1	+.00	-.08	+.00
07	03	07	03	06	1	4	+.00	+.05	-.60
08	04	04	04	05	1	4	+.00	-.06	-.60
09	03	06	02	07	2	3	+.08	-.05	-.20
10	04	09	05	08	2	3	-.06	+.05	-.20
11	05	07	02	03	1	0	+.20	+.23	+.33
12	07	06	02	06	2	2	+.30	+.00	+.00
13	05	08	06	05	2	2	-.06	+.16	+.00
14	07	04	03	04	3	2	+.23	+.00	+.20
15	03	03	03	05	2	3	+.00	-.13	-.20
16	02	05	04	05	3	1	-.14	+.00	+.40
17	02	04	04	04	1	0	-.14	+.00	+.33
18	04	07	04	04	1	2	+.00	+.11	-.22
19	01	03	03	08	1	2	-.17	-.28	-.22
20	04	05	02	04	0	1	+.14	+.06	-.33

EXPERIMENT II

Temporal Task

Subject number	LVF - Errors - Faces	LVF - Errors - Words	RVF - Errors - Faces	RVF - Errors - Words	LVF - Recognition errors - Faces	LVF - Recognition errors - Words	RVF - Recognition errors - Faces	RVF - Recognition errors - Words	Laterality index - Faces	Laterality index - Words	Laterality index - Recognition - Faces	Laterality index - Recognition - Words
21	04	04	05	05	2	1	1	2	-.06	-.06	+.22	-.22
22	07	03	06	02	0	0	2	1	+.04	+.06	-.05	-.33
23	06	05	06	06	3	1	1	1	+.00	-.06	+.40	+.00
24	09	07	05	03	1	1	1	2	+.20	+.22	+.00	-.22
25	06	04	06	04	2	0	2	1	+.00	+.00	+.00	-.33
26	06	04	05	09	1	0	2	0	+.06	-.26	-.22	+.00
27	06	04	05	06	1	1	0	0	+.06	-.12	+.33	+.33
28	06	04	09	05	2	2	1	0	-.15	-.06	+.22	+.50
29	08	07	11	05	1	1	1	2	-.14	+.10	+.00	-.22
30	05	03	05	08	1	2	2	1	+.00	-.27	-.22	+.22
31	06	05	06	07	2	1	1	3	+.00	-.10	+.22	-.40
32	08	06	06	06	3	2	2	1	+.10	+.00	+.20	+.22
33	04	02	07	05	2	2	0	0	-.16	-.19	+.50	+.50
34	05	09	05	04	0	3	4	1	+.00	+.26	-.82	+.40
35	08	04	07	08	1	0	2	1	+.05	-.21	-.22	-.33
36	03	03	04	04	1	2	1	1	-.07	-.07	+.00	+.22
37	08	09	13	06	4	3	2	0	-.24	+.15	+.41	+.65
38	07	05	04	07	1	2	1	3	+.16	-.10	+.00	-.20
39	05	05	08	03	3	2	1	0	-.15	+.13	+.40	+.50
40	06	04	05	08	1	2	2	2	+.06	-.21	-.22	+.00

EXPERIMENT II

Spatial Task

Subject number	LVF - Errors - Faces	LVF - Errors - Words	RVF - Errors - Faces	RVF - Errors - Words	LVF - Recognition errors - Faces	LVF - Recognition errors - Words	RVF - Recognition errors - Faces	RVF - Recognition errors - Words	Laterality index - Faces	Laterality index - Words	Laterality index - Recognition - Faces	Laterality index - Recognition - Words
41	01	04	01	04	1	0	1	1	+.00	+.00	+.00	-.33
42	03	03	05	06	2	0	0	2	-.13	-.19	+.50	-.50
43	00	05	01	04	4	2	3	3	-.18	+.06	+.22	-.20
44	01	04	05	04	2	2	1	3	-.28	+.00	+.22	-.20
45	03	06	04	05	2	1	1	1	-.07	+.06	+.22	+.00
46	02	03	04	03	3	0	2	3	-.13	+.00	+.20	-.65
47	01	04	06	05	2	1	1	1	-.32	-.06	+.22	+.00
48	03	03	05	03	3	1	1	0	-.13	+.00	+.40	+.33
49	01	04	04	01	0	2	0	0	-.22	+.22	+.00	+.50
50	01	02	05	07	1	2	1	3	-.28	-.28	+.00	-.20
51	03	06	04	03	2	2	0	3	-.07	+.19	+.50	-.20
52	04	03	04	08	1	2	1	0	+.00	-.27	+.00	+.50
53	02	05	03	06	1	1	1	1	-.06	-.06	+.00	+.00
54	06	04	03	05	1	0	2	1	+.19	-.06	-.22	-.33
55	03	09	04	08	2	0	1	2	-.07	+.05	+.22	-.50
56	05	04	02	03	1	1	2	1	+.19	+.07	-.22	+.00
57	06	06	03	07	2	4	2	1	+.19	-.04	+.00	+.60
58	05	04	00	05	3	0	0	2	+.37	-.06	+.65	-.50
59	02	05	04	03	1	0	0	3	-.13	+.13	+.33	-.65
60	02	03	05	04	1	0	2	2	-.19	-.07	-.22	-.50

APPENDIX 2

INSTRUCTIONS TO SUBJECTS

In this experiment I'll be showing you about 250 different line drawings of common objects (Experiment I; for Experiment II, substitute "words and photos of faces" for "line drawings"). (Show examples of stimuli.) They will be on cards like this, in one of these six possible positions (demonstrate the top, middle and bottom positions on the left and right sides of the card). You'll see each picture (Experiment I; for Experiment II, substitute "word or face" for "picture") for only a fraction of a second, and each will be shown only once. Periodically I'll ask you about what you've seen.

The (pictures) will be shown to you one after the other in this machine called a T-scope. We're using it because it's one way of presenting stimuli to each side of the brain individually. It does this by taking advantage of the way that the eyes are connected to the brain (demonstrate using a diagram of the visual pathways). The brain is wired so that what you see on the left side of space goes to the right half of both eyes and to the right side of the brain. In the same way, everything on the right side of space goes to the left side of the brain. In the T-scope, you will see (pictures) off to either the left or the right side of centre. In order for us to know which side of the brain is getting the information, it is important that you look straight ahead in the T-scope, rather than off to the side. To help you do this, before the (picture) comes on you will see a small square right in the centre of the screen. If you focus on this square, you will be looking in the right place. After about one second, the square will go off, a (picture) will flash on very briefly, either to the left or right of centre, and then the square will come on again for about one second, before the screen goes blank. The whole sequence will take about four seconds. Then it will repeat, with a different (picture).

Every once in a while I'll interrupt to question you about what you've seen. The questions will be given to you on pieces of paper like this (show an example of a spatial question). There are three types of questions. This is a question about position. This represents the six possible positions which a (picture) could occupy. In two of these positions is a (picture) which you will have seen previously in the T-scope. However, you will have seen it only once, in only one of these two positions. Your job is to point to the (picture) which is in the correct position, that is, the position it was in when you first saw it in the T-scope. (Show an example of a recency question.) This is an example of a second type of question, about order. Here you see two (pictures), one above the other. You will have seen **both** of these before in the T-scope. Your task is to point to the one which you saw <u>most recently</u>, that is, the one you saw last. (Show an example of a recognition question.) The third type of question is a recognition question, and it looks like this. It looks the same as the recency question, except it has an "R" between the (pictures), meaning that it is a recognition question. In this type, you will have seen only one of the two (pictures) before in the T-scope. The other (picture) is completely new. Here you should point to the (picture) that you recognize as having been seen before.

In all cases, I would like you to point to your answer rather than saying it aloud. Don't spend too much time trying to figure out the right answer - if you're not sure, guess.

We'll begin with a practise session, which takes about five minutes. It will go like this: I'll show you five (pictures) in a row, in the T-scope, and then give you the first question. After you've answered, I'll show you two more (pictures), and give you another question. We'll continue in this way, one question after every two (pictures), until you've answered twenty questions. Remember that the (pictures) in the questions may be taken from the last two (pictures) you were shown, or from earlier in the sequence. Also, remember that you'll be seeing the (pictures) for only a fraction of a second, so that you may not be sure of what you have seen, and so when it comes to answering the questions, you may not be sure. Don't be afraid to guess, as we expect some errors. Any questions? (Give the practice session, with further instructions and explanations as needed.)

Now we're ready to start the experimental session. This will be exactly like the practice session, except that it will be longer, about twenty minutes. Again I'll show you five (pictures) in a row, and then give you a question, and thereafter you'll get a question after every second (picture). Please begin by using your (right/left) hand to point with. When we're halfway through, I'll ask you to change to your other hand.

APPENDIX 3

LATERAL DOMINANCE EXAMINATION

Scoring: Right hand preferred = 1

Left hand preferred = 0

1. Show me how you: throw a ball ________
2. hammer a nail ________
3. cut with a knife ________
4. turn a door knob ________
5. use scissors ________
6. use an eraser ________
7. write your name ________
8. Write your full name:

preferred hand ________ ____seconds

non-preferred hand ________ ____seconds

9. Show me how you look through a telescope:

________eye

10./11. Aim this gun at the tip of my nose.

_________shoulder ________eye

12. Show me how you: kick a football________foot

13. step on a bug ________foot

APPENDIX 4

CALCULATION OF THE LATERALITY INDEX

The mathematical formula for calculating the phi coefficient, or laterality index, is:

$$r_p = \frac{p_r - p_l}{2 (pq^{1/2})}$$

In this equation:

p_r = proportion of correct responses in the RVF

p_l = proportion of correct responses in the LVF

p = proportion of correct responses across both visual fields

q = proportion of incorrect responses across both visual fields

An example calculation

For Subject 03, the spatial laterality index is calculated this way:

Errors in the RVF = 5, $p_r = 15/20 = .75$

Errors in the LVF = 3, $p_l = 17/20 = .85$

Total number correct = 32, $p = 32/40 = .8$

Total number of errors = 8, $q = 8/40 = .2$

Using the formula,

$$r = \frac{.75 - .85}{2 ((.8)(.2))}$$

$$= \frac{-.10}{.8}$$

$$= -.125$$

APPENDIX 5

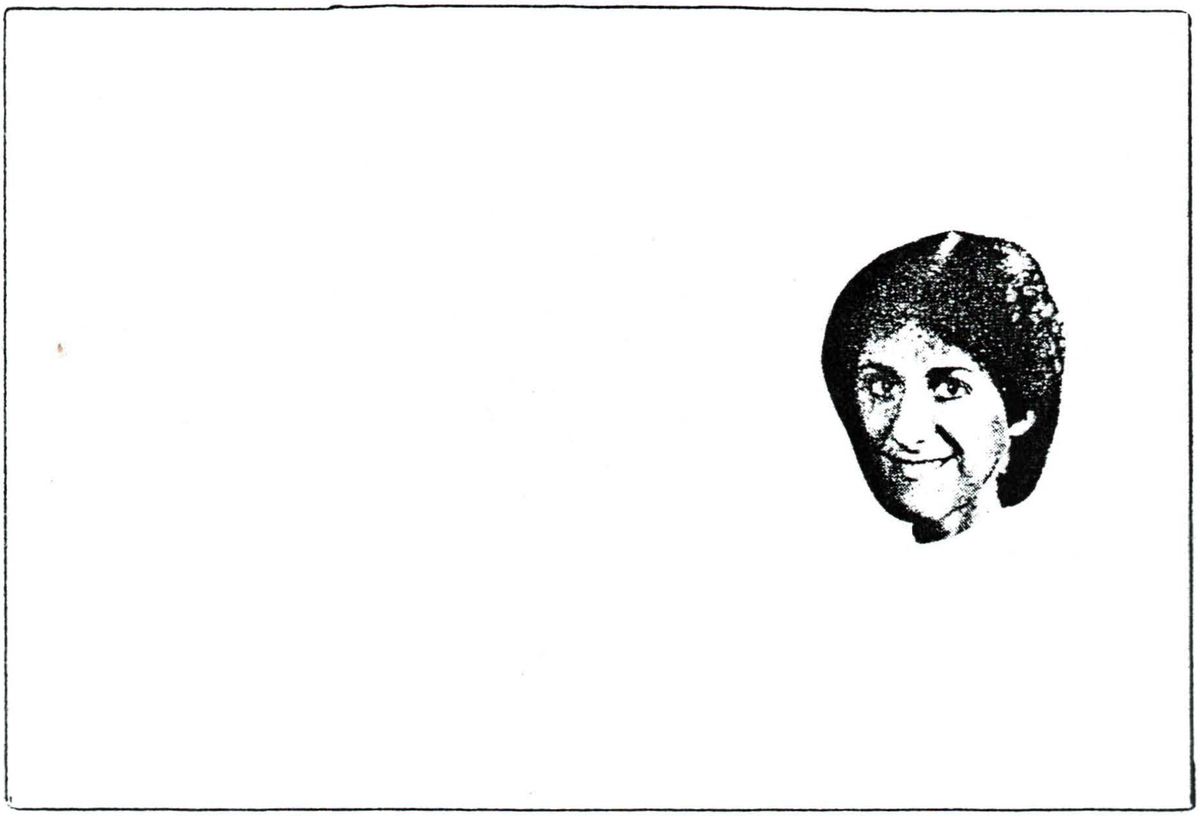
WORDS USED AS STIMULI IN EXPERIMENT II

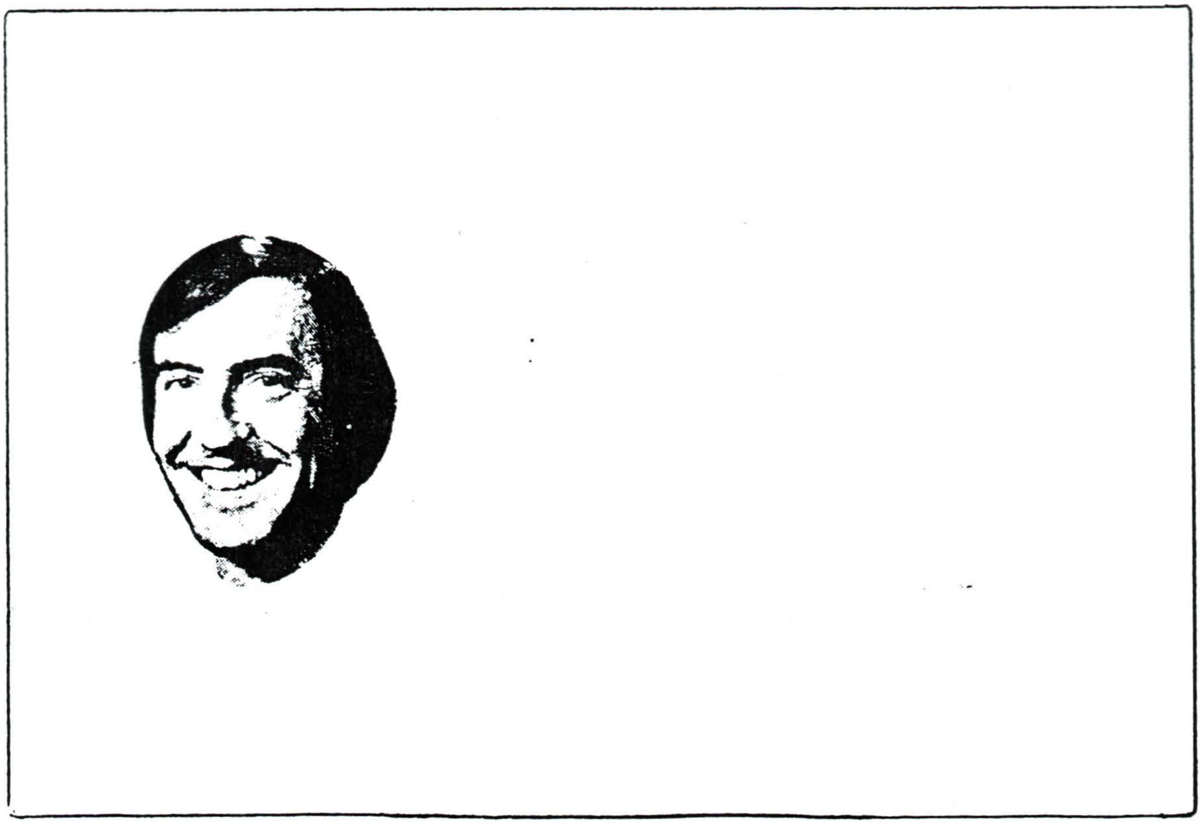
Arranged in alphabetical order

able
avid
back
bake
bard
best
born
both
busy
calm
code
cold
come
cool
cost
crag
dare
deal
deed
deep
does
draw
dull
dumb
duty
easy
else
even
evil
fact
fail
fair
fate
find
fond
form
free
full
fury
gilt
glad
gore
gust
hard
have
hear
here
hide
high
hint
hold
hope
hour
hurt
into
item
join
joke
jump
just
keen
keep
kind
last
late
lazy
left
like
life
lift
live
long
look
main
make
many
mind
miss
mood
more
move
much
near
nice
obey
oboe
open
oral
pact
peek
plan
prim
pure
rest
rich
rude
save
sell
slow
smug
soft
soul
sour
tale
tall
tell
that
then
they
thin
this
time
true
unit
very
wait
want
weak
were
what
when
wide
will
wise
wish
with

APPENDIX 6

EXAMPLES OF FACES USED AS STIMULI IN EXPERIMENT II





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Publications:

Bornstein, R. A., & Leason, M. (1984). Item analysis of Halstead's Speech-Sounds Perception Test: Quantitative and qualitative analysis of errors. *Journal of Clinical Neuropsychology*, *6*, 205-214.

Bornstein, R. A., & Leason, M. (1985). Effects of localized lesions on the Verbal Concept Attainment Test. *Journal of Clinical and Experimental Neuropsychology*, *7*, 412-429.

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