LATERALITY DIFFERENCES IN PERCEPTION

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PREFACE

The author wishes to acknowledge the assistance given by Dr J. A. Gribben and Professor L. B. Brown in preparing this thesis.

Parts of this thesis have appeared, or are to appear as the following articles: Laterality differences in perception: A review, in the *Psychological Bulletin*; Visual field differences and the recognition of alpha-numeric material, in the *Australian Journal of Psychology*; Identification and localization within digit and letter spans, in *Psychonomic Science*; Retinal locus and the letter span error function, in *Perception and Psychophysics*; Order of report and letter structure in tachistoscopic recognition, in *Psychonomic Science*; A signal--detection analysis of laterality differences, in the *Journal of Experimental Psychology*.

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ABSTRACT

The subject of this thesis is laterality differences in perception. The term "laterality difference" refers to an asymmetry in report accuracy for stimuli presented about the center of a person's visual field. A discussion of the literature and experimental findings relevant to this topic is first given. This is followed by a detailed analysis of eight experiments which examine the effects of a number of variables on laterality differences. The main conclusion drawn from these experiments is that perceptual laterality differences are a function of acquired reading habits, the structural characteristics of the stimuli, and the order in which the stimuli are reported. To a lesser extent, they are also related to certain other factors such as differential eye sensitivity and handedness. An interpretation in terms of a "post-exposure trace-scanning" hypothesis is given to account for the experimental findings.

INTRODUCTION

Consider an experimental situation where lines of alphabetic letters are briefly presented across subjects' (Ss') visual fields. If Ss are required to report the letters following each presentation, accuracy of report will tend to be skewed about the center of the visual field. Letters from the left visual field (LVF) will tend to be better reported than letters from the right visual field (RVF). When the presentations consist of letters presented alternately in left or right visual fields, Ss' accuracy of report will tend to be better for the letters presented in the RVF. Such report or recognition asymmetries are referred to as "laterality differences".

The general experimental situation employed in investigating these laterality differences consists of presenting Ss with lines of stimuli (letters, digits, non-verbal stimuli) at very fast speeds and requiring them to report the stimuli. The stimuli are usually presented bilaterally about a fixation point or unilaterally in either the left or right visual fields. The time of presentation is seldom in excess of 150 ms. and the number of stimuli presented at one time range from one to 16. Ss' responses are scored correct if they are either congruent and in the same serial order as the stimuli on E's list (localization) or if they are congruent alone (identification). The task is memory-perceptual-dependent. Ss' performances are directly related to (a) how well they are able to perceive or apprehend the stimuli in the limited time available, and (b) how well they are able to remember the stimuli, from presentation to completion of report.

An exhaustive survey of variables which have been found to affect laterality differences is made in the literature review section. Two broad categories can be distinguished. There are those variables which have been labelled "functional" and which include the type and amount of stimulus information, the physical orientation of the stimulus elements, the order in which the stimuli are reported, eye-movement tendencies, and exposure parameters. Then, there are those variables which have been termed "structural". These are more physiological in quality and include cerebral dominance, sighting and acuity dominance, eye sensitivity, and handedness.

Associated with these categories of variables are two broad classes of theoretical explanation. One seeks to explain observed laterality differences in terms of specific neurological factors. For example, it has been argued that verbal stimuli in the RVF and stimuli in the LVF are differentially transmitted to the cerebral hemispheres. The stimuli from the right field which are transmitted via the the left hemiretinae to the dominant speech hemisphere, the left temporal lobe, are neurologically processed more rapidly than stimuli which are transmitted via the right hemiretinae to the contralateral cerebral areas. This asymmetry in stimulus transmission and brain function is (arguably) responsible for a certain type of laterality difference (Kimura, 1961).

A second class of theoretical explanation seeks to account for laterality differences in terms of acquired reading habits, the directional characteristics of the stimuli and "tendencies to eye-movement". The explanations here are more general and more widely applicable insofar as they are not dependent upon the differential operation of any specific structural factor. The "scanning" hypothesis advanced by Heron (1957), Harcum and Finkel (1963) and others, is the most accepted form of these explanations. It postulates that "the traces set up in the CNS by the stimuli are attended to (i.e., "scanned") post-exposurally in the same direction that they would be if they could be read directly by the eyes. At the same time, in the initial moments immediately after exposure of the stimuli, the traces undergo rapid decay in strength. The recognition differentials are to be explained in terms of how much decay occurs in the time it takes the scanning mechanism to reach critical points (Douglas, 1969, p.1)."

It is obvious that the latter explanation is dependent upon the formulation of a hypothetical model or mechanism, whereas the former type is dependent more or less upon knowledge of specific anatomical structures and physiological processes. The question of which interpretation more adequately satisfies the experimental data will be dealt with in the succeeding chapter. In certain specific instances, where the amount of stimulus information and the intensity at which this information is shown are critically minimal, observed laterality differences have been (equivocally) related to known differences in acuity and cerebral functioning. In the more general case where numbers of stimulus elements are shown within a wide range of stimulus intensities, laterality differences have been successfully related to stimulus, spatial and temporal characteristics, order-of-report, and reading habits. The findings from these more general experimental situations have been applied to the problem of serial order in behaviour.

A model of perceptual functioning. The question arises as to what mediates the stimulus input and the response output in the type of tachistoscopic experiment with which this research deals. Given a situation where Ss are briefly presented with stimulus information, what determines which parts of the information will be successfully reported and which parts omitted or unsuccessfully reported? A strict operationist would be disinclined to answer this, or perhaps be content to state: Given the stimulus and experimental conditions, the responses X_1, X_2, . . X_k were observed. Obviously, one must search at a higher level if one wishes to explain the response sequence in relation to the stimulus conditions. There can be a second answer: The responses are determined by the differential operation of some physiological mechanism. There can also be a third (functional) answer: The responses are determined by the differential operation of some hypothetical scanning mechanism which is of physiological structure.

An argument will be advanced in this thesis that it makes sense to postulate a model or mechanism of behaviour to help explain and systematize behavioural data, when these data are not amenable to more basic (structural) interpretations. Such a case arises in the experimental situation employed here. When Ss receive a brief simultaneous burst of visual information, the information is transmitted via the receptors and optic nerve to the appropriate projection areas. A trace system is activated by this input as is a component to the trace system which orders the general sequence of responding. The quality of the stimulus information, induced sets and attentional processes and well-established learned associations, act to determine the order in which the information is scanned (and behaviourally, reported). The essence of such a trace theory has been stated by Hebb (1949) and Lashley (1951).

Bryden (1967) has given a schema of a proposed model and this is illustrated in Fig.A.1. He describes the functioning:

"If a number of trace systems are simultaneously active, not all can lead to a response at the same time. The problem lies in determining how it is that the responses are ordered in a particular fashion. Consider a simple situation in which three traces A, B, and C, each with different spatial components La, Lb, and Lc, have been activated. Activation of these traces also

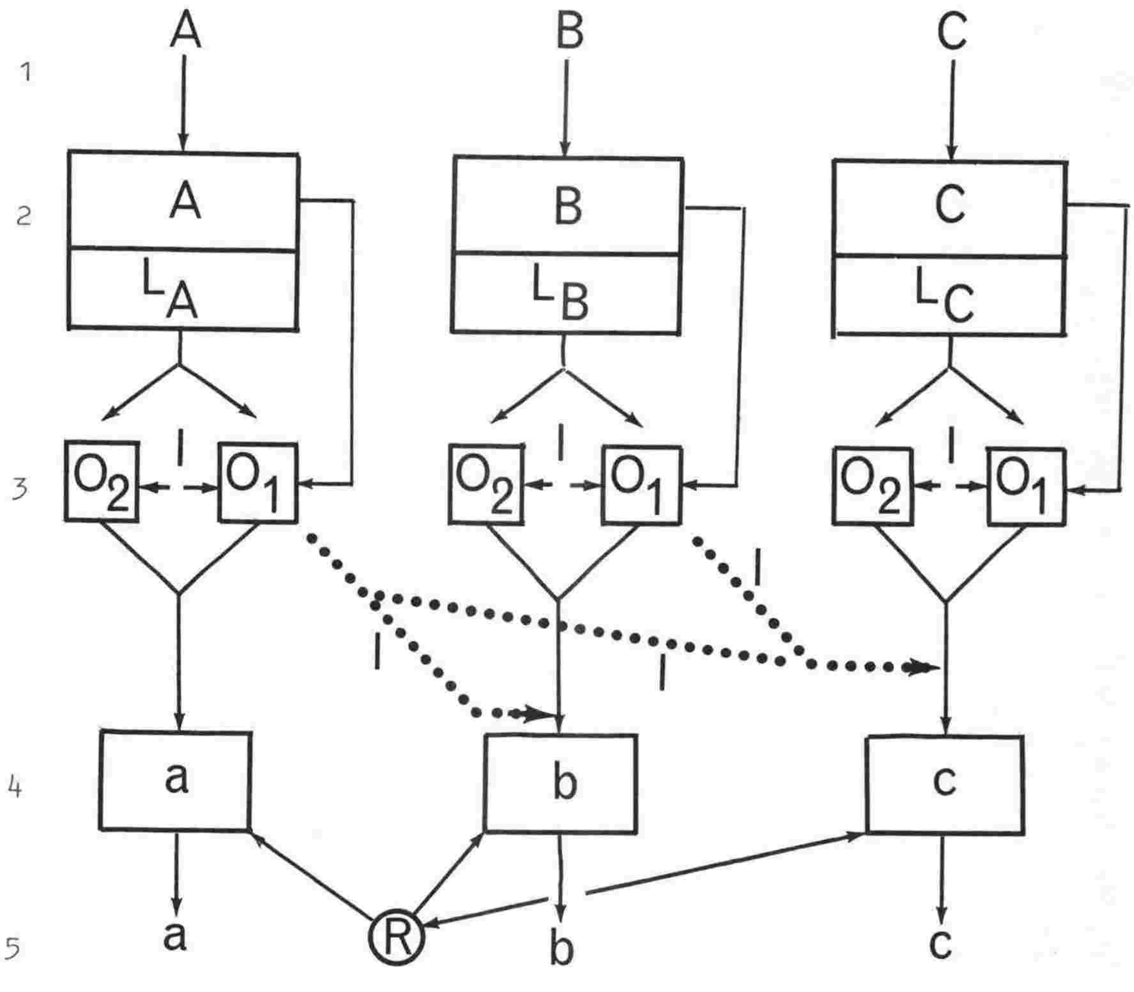

Fig.A.1. Schematic representation of a mechanism for post-exposural scanning (from Bryden, 1967).

1: Stimulus information; 2: stimulus trace; 3: central organizing system; 4: central rehearsal system; 5: output.

produces activity in one of a set of mutually inhibitory ordering systems (O_1, O_2, . . .). These ordering systems control the general sequence of responding. In the present example, O_1 controls left-to-right ordering, while O_2 controls right-to-left ordering. Activity in these ordering systems can be facilitated by the identity of the traces A, B, and C, or by some external set. When alphabetic material is presented, traces A, B, and C strongly activate the O_1 system, making it very difficult for the O_2 system to come into play.

"When the left-to-right ordering system (O_1) has become active, the presence of a trace in any given spatial position will inhibit the output pathway from any trace in a spatial position to the right of it. A will inhibit the output pathway from B and C, and B will inhibit C. A, however, receives no inhibition and is thus reported first. The act of reporting A releases the inhibition on B, which can then be reported, followed by C.

"At a later decision point, an additional central set mechanism, R, determines whether the output is released as an overt response or as a covert (rehearsal) one (1967, pp.45-47)."

Purposes of the present research. The purpose of the present research is to study quantitatively laterality differences paying particular respect to a number of specific variables. It is intended to add new and systematically organized data to what is known about the determinants of these differences. It became evident on reading the relevant literature, that further attention should be paid to the effects of such factors as exposure, order-of-report, partial report, recognition and recall, order of stimulus presentations, stimulus arrangements, handedness and eye dominance.

The experiments reported in this thesis can be summarized thus:

Exposure and material. In Experiment I, combinations of letters or digits were presented at varying exposures, bilaterally and unilaterally in the visual field. The presentation sequence was randomized within trial-blocks.

Locus of fixation. In Experiment II, bilateral and unilateral arrangements of letters were presented about three varied fixation loci.

Half-field report. In Experiment III, bilateral and unilateral arrangements of letters were presented about a central fixation point and *Ss* were cued whether to report the left or right hemifield information.

Experiment IV was similar, excepting that here, the cue was variably delayed.

Order-of-report. In Experiment V, bilateral and unilateral arrangements of letters were presented about a central fixation point and Ss were required to report the letters from left-to-right or from right-to-left.

Recognition. In Experiment VI, unilateral arrangements of letters were presented about a central fixation point and Ss were required to detect the presence of a target letter in the arrangements.

Handedness and viewing condition. In Experiments VII and VIII, the effects of handedness and binocular and monocular viewing on laterality differences were investigated.

LITERATURE REVIEW

This chapter surveys the literature relating to laterality differences and interprets and discusses the implications of reported results and conclusions. In this critical survey, major emphasis will be given to a treatment of the stimulus and experimental variables which have been employed in investigations of laterality differences and to a treatment of the processes which have been suggested to account for laterality differences.

Stimulus and Experimental Characteristics

Type and Arrangement of Stimulus Material

The recall of English words presented bilaterally about the central fixation point is affected by the directional characteristics of the words and letters. Harcum and Filion (1963) found laterality differences were dependent on whether a word was presented in a forward or reversed spelling sequence and on whether the letters were of normal or mirror-imaged orientation. When words are presented unilaterally, recall tends to be better for those presented in the RVF (Harcum & Finkel, 1963; Harcum & Jones, 1962; Mishkin & Forgays, 1952; Terrace, 1959). When, however, mirror-images of words are unilaterally presented, recall is better for those appearing in the LVF (Harcum & Finkel, 1963).*

Yiddish words were used by Mishkin and Forgays (1952) and by Orbach (1953) to study the effects of acquired reading habits, and by Barton, Goodglass, and Shai (1965) to study the role of cerebral dominance. Mishkin and Forgays' results were statistically inconclusive, but Orbach showed that Ss for whom Yiddish was the primary language had superior recall of Yiddish words in the LVF, when presentations were unilateral. Since Yiddish is read from right-to-left these results tend to support the argument that laterality differences are partly a function of early acquired visual training. Barton, Goodglass, and Shai, however, found a RVF superiority when three-letter Yiddish words were unilaterally presented at

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* While Mishkin and Forgays' study was the first specifically dealing with the issue of laterality differences, a number of relevant experiments had been carried out as early as 1911. Woodworth (1938) cites the results of a number of experiments on visual field span, conducted in Germany between 1911-1926. Anderson and Crosland (1933) and Crosland (1931) investigating the "range of attention" also offer indirectly relevant data.

threshold exposures vertically-mounted in the visual hemifields. They interpreted their results in terms of cerebral dominance. Hirata and Osaka (1967) found that Japanese words whether presented bilaterally or unilaterally, were recalled better from the RVF. They attributed this partly to the effects of pre-exposure set which, due to the written characteristics of Japanese, would consistently favour material shown in the RVF.

Mewhort (1966) varied the sequential redundancy of eight-letter pseudo-words. When these stimuli were presented bilaterally, the degree of sequential redundancy was found to interact with laterality difference. Mewhort interpreted his results in terms of sequential processing and memory decay. Stimuli, or parts of stimuli, which are highly redundant are more easily "chunked" and processed before the stimulus trace decays from memory than are low-redundant stimuli. Dornbush and Winnick (1965) using unilateral presentations of various sequentially redundant words, found laterality differences favouring pseudo-words presented in the RVF and an interaction between accuracy of report and degree of redundancy.

When strings of random letters are presented bilaterally, recall is better for letters appearing in the LVF (Bryden, 1966b; Harcum, 1964). Recall of unilaterally presented single random letters is better from the RVF than from the LVF (Bryden, 1966b; Bryden & Rainey, 1963). Harcum (1964) also examined laterality differences for bilateral presentations of symmetrical letters (H, X, Y) and asymmetrical letters (B, G, K). Recall errors were found to be related to the "directional characteristics" of the stimuli as symmetrical letters were harder to recall than asymmetrical letters.

Kimura (1961b) observed a relationship between the recall of aurally presented random digits and cerebral hemispheric activity. One of her groups of Ss had speech represented in the left hemisphere, the other in the right. "Stimuli arriving at the ear contralateral to the dominant hemisphere were more efficiently recognized than stimuli arriving at the ipsilateral ear (p.170)."

Harcum and Dyer (1962) presented bilateral binary displays of filled and unfilled circles to their Ss and found laterality difference effects favouring elements in the LVF. Harcum, Hartman, and Smith (1963) found, with variable response instructions that errors of recall were generally fewer for (binary) elements in the LVF. Ayres' (1966) study, which was a virtual replication of the last-named, found no such effects.

Outline drawings of familiar objects (fish, face) were presented unilaterally by Bryden and Rainey (1963) and by Wyke and Ettlinger (1961) and accuracy of recall was found to be greater for objects presented in the RVF. Wyke and Ettlinger also observed an RVF superiority when stimulus presentations were bilateral. The unilateral presentations of geometric and random forms by Bryden (1960), Bryden and Rainey (1963), Heron (1957), and Terrace (1959) showed negligible differential accuracy scores. Bryden and Rainey also presented letters, geometric forms and outline drawings bilaterally and found Ss' recall to be consistently better for elements appearing in the LVF. They attributed these differential accuracies to order-of-report (bilateral case) and degree of stimulus familiarity (unilateral case).

The spacing between elements of the stimulus display has been experimentally manipulated by Bryden (1966b), Bryden, Dick, and Mewhort (1968), Crovitz and Schiffman (1965), Dick and Mewhort (1967), Harcum (1964), and Mewhort (1966). Increasing the spacing between alphanumeric elements results in a more accurate recall of elements from the center of the stimulus field (Bryden, 1966b). Increasing the spacing between letters results in poorer recall compared with that found for closely-spaced letters although a similar effect is not observed with digits

(Bryden, Dick, & Mewhort, 1968). Increasing the spacing is thought to interfere with the "chunking" and processing of letter sequences. Spatio-temporal characteristics are more important determinants of letter than of digit or form recall (Bryden, 1966b; Dick & Mewhort, 1967; Mewhort, 1966). Barton, Goodglass, and Shai (1965) and Goodglass and Barton (1963) presented vertically mounted words in unilateral sequences. They did this to overcome the component of horizontal scanning in making an assessment of the roles of handedness and cerebral dominance on laterality differences. The visual angle between stimulus and center of field was 2.10°. In both studies, accuracy of recall was found to be better for words appearing in the RVF.

Of the implications arising from these studies, the most important would seem to be that a general interaction exists between visual hemifield and stimulus presentation. When rows of letters or digits are presented across Ss' visual fields and Ss are given "free report", stimulus elements from the LVF are better recalled than are those from the RVF. When these stimuli are presented either in the LVF or in the RVF, elements from the RVF tend to be better recalled.

The results relating to the directional orientation of letters and words and to the presentation of Yiddish material to Yiddish speakers suggest however that the quality of information can on occasions be as important a determinant as presentation. Different strategies may be adopted by Ss according to the spatial and directional characteristics. When stimulus material consisting of rows of English letters or digits is presented in normal sequence, the optimal reporting strategy is one proceeding from left-to-right. When letters and words are in a reversed orientation the best reporting is one which proceeds from right-to-left. Laterality differences may thus be inconclusive, or reversed, depending on the directional orientation of the stimulus material. Forms and binary elements which are virtually non-directional and which demand no optimal strategy could be expected to give negligible laterality differences. The results relating to such material are indeed inconclusive. The importance of directional strategies is partially verified by the results relating to extended spatial arrangements of stimulus elements. Increasing the space between elements affects recall accuracy more for letters than for digits.

Granting the importance of these different strategies and of directional stimulus characteristics, and considering acquired reading habits and memory span limitations, the interaction between visual hemifield and stimulus presentation may be tentatively explained. In bilateral presentations Ss process the left-most stimulus elements (in the LVF) first, reporting and at a sub-vocal level "scanning" the string in a left-to-right direction. Where the load exceeds memory span, as where strings of six to eight elements are used, and where the exposure is of the order 50 ms. to 150 ms., elements occurring late in the scanning sequence are going to suffer through being either not perceived or forgotten before report. In unilateral presentations the scanning of stimulus information in the RVF is easier than is that in the LVF. In both cases the beginning of the display must be sought and the scan proceed left-to-right. In LVF presentations the scan to the left-most element and the scan from the left-most element are in discord; in RVF presentations they are in accord. Hence the accuracy differential favouring alphanumeric material in the RVF when presentations are unilateral. When mirror-image alphabetic material is presented unilaterally however, an LVF superiority is observed. The scanning sequence is presumably reversed.

Certain spatial characteristics other than stimulus orientation may affect laterality differences. Where the spacing between stimulus information in the LVF and the RVF is optimal, an RVF superiority may obtain for bilaterally presented material (Crovitz & Lipscomb, 1963; Kimura, 1959; Wyke and Ettlinger, 1961). In this case, Ss may adopt a strategy which maximizes accuracy for one field only. The brief exposure does not allow for perception or storage of the total stimulus field information, so the information in the RVF (the most readily scanned) is sought at the expense of information in the LVF.

Eye-Movements and Pre-Exposure Attentional Sets

Eye-movements occurring prior to and during stimulus presentation and pre-exposure attentional sets (the reorienting of retinal locus from central fixation to the peripheral hemifield) are two "bugs" of laterality differences research. The latency of eye-movements to a stimulus appearing in indirect vision is within the range of from 125 ms. to 235 ms. according to Diefendorf and Dodge (1908) and Woodworth (1938). Crovitz and Daves (1962) have found that Ss moving their eyes to either side of a central fixation point following a 100 ms. stimulus exposure had scorable initial post-exposure eye-movements from a latency of 150 ms. after stimulus onset.

Exposure durations below the generally held latency figure (150 ms.) are commonly used in laterality studies, though a wide range is evident: Ayres and Harcum (1962) used 200 ms. and 450 ms., Fitzgerald and Marshall (1967) used 300 ms., Harcum (1964) used 250 ms. and 150 ms. The control of eye-movements is designed to eliminate one "artifact" from the data. It has been argued that data from studies employing supra-latency exposure durations may be spurious insofar as the dependent variable scores are arguably related to this artifact (Ayres, 1966). In an experiment where the stimulus exposure is sufficient to allow Ss to move their eyes during exposure to the LVF or the RVF, the observed laterality difference may be directly related to this retinal reorientation (a differential foveal sharpening) and to nothing else. Thus, where trials are composed solely of bilateral presentations and where Ss have the opportunity to set their eyes to the left periphery of the visual field during exposure, an LVF superiority may be considered an artifact of this eye-movement.

As Harcum (1967) points out however: "the existence of an artifact is established only when the positive effect is eliminated by controlling a variable which was inadequately controlled in the original investigation (p.67)." Results from both supra-latency and sub-latency studies (cf. Ayres & Harcum, 1962; Harcum & Dyer, 1962) tend to be in accord rather than discord, as regards the direction of laterality differences, so the artifactual nature of eye-movements as an important component of laterality differences must be questioned.

Ayres (1966) has also referred to pre-exposure attentional sets, occurring before stimulus exposure, as a partial explanation for laterality effects. If Ss have a set to look towards, or start reading from, one part of the visual field, then the stimuli in that part should be better recalled or recognized than stimuli in any other part. For example, a set might exist to look away from central fixation to the left of a horizontal line of verbal elements prior to stimulus exposure in order that rapid left-to-right "reading" might be accomplished. The technique of presenting blocks of bilateral material to Ss may accentuate this predisposition because Ss are aware on every trial where the left-most element is going to appear. Fixation forcers have been employed by Ayres and others to counter such attentional sets.

Further data on pre-exposure sets come from Terrace (1959) and Crovitz and Daves (1962). Terrace claims that eye-muscle potential readings indicate that Ss' pre-exposure attention shifts to the RVF with presentations of unilateral verbal material. When forms were randomized with verbal material this set tendency disappeared. Crovitz and Daves (ibid) found that eye-movements did not occur until after offset of the stimulus exposure. Their Ss were naive with respect to the situation and the stimulus material consisted of bilateral rows of digits.

Heron (1957) ran unilateral presentations of letters singly and in groups on his Ss. For half the trials, Ss were informed prior to exposure which hemifield the stimulus information would appear in and for the other half no such cue was given. Of 22 quoted relevant t values only one was significant, where scores for the left hemifield were higher under the informed than under the uninformed condition. In point of fact, 12 of the 22 raw data comparisons (left uninformed with left informed, right uninformed with right informed) showed a superiority for the uninformed condition.

Harcum, Hartman, and Smith (1963) also give results relevant to this matter. They compared a forced fixation with a non-forced fixation task and found, when conditions allowed for a pre-exposure reorientation of retinal locus, little difference between the forced and non-forced fixation conditions. They concluded, "Our guess is that any fixational 'error' of the magnitude which might be likely to occur in this visual task (bilateral rows of ten filled and unfilled circles were used) is not large enough to affect the distribution of errors (p.272)."

Such results suggest that attentional sets are not of paramount importance in accounting for laterality differences. The issue does, however, have further implications. As will be seen, an explanation in terms of the differential transmission and reception of stimulus information via the optic nerves to the cerebral hemispheres, has been offered to account for laterality effects. This explanation depends on information from a particular visual hemifield impinging on a particular hemiretinae. That is, central fixation is demanded. The fact that foveal fixation may shift and laterality effects still be observed, partially mitigates against such an account, particularly as an explanation where multiple-element displays and supra-threshold exposures are used.

Two further points relating to stimulus intensity and eye-movement may be mentioned. The first is that some studies have adopted the so-called recognition threshold as a criterion for stimulus exposure. Barton, Goodglass, and Shai (1965), Goodglass and Barton (1963), Hayashi and Bryden (1967), Overton and Wiener (1966), and Wyke and Ettlinger (1961), have used their _Ss_' thresholds to which have been added a few milliseconds, as stimulus exposure durations. Their results partly indicate that at minimal exposures certain structural factors such as ocular and cerebral dominance may be related to laterality differences.

A second point has to do with a relationship between post-exposure eye-movement and laterality effects. Crovitz and Daves (1962) presented bilateral rows of six widely-spaced digits to their _Ss_ and recorded post-exposure eye-movements occurring after offset of the stimulus exposure. The direction of eye-movement (to the LVF or RVF) was found associated with hemifield accuracy. That is, post-exposure eye-movements to the RVF were associated with an RVF superiority; eye-movements to the LVF were associated with an LVF superiority. Such "tendencies to eye-movement" have been interpreted as favouring a post-exposure directional scanning mechanism to account for laterality differences. The post-exposure scanning of the stored memory trace is presumed to be parallel and neurologically associated with the motor activity of the post-exposure eye-movement (Winnick & Dornbush, 1965). One question which may be asked of such a relationship is the role that eye-movements play when the response sequence commences before the onset of eye-movement. Crovitz and Daves report that latencies of eye-movements occurred up to 1 sec. No results were given for response latencies but it is known these can be well below 500 ms.

Report Instructions

When English speaking _S_s are presented with displays of rows of letters, and given no instructions as to the order in which the material is to be reported, they invariably report it in a left-to-right direction. Bryden (1960, 1966b) has developed an order-of-report score with a value of 1.0 for a perfect left-to-right sequence (e.g., when _S_s report 'P, Q, R, S, T, U, V, W' in that order to a display consisting of those letters with P the left-most and W the right-most letters) and a value of 0.50 for a random report sequence. Using bilateral displays of eight random letters, Bryden found order scores of .78, .77, .78, and .80 corresponding to exposures of 20 ms., 40 ms., 80 ms., and 120 ms. (1966b).

Some evidence suggests that different stimulus materials and the spacing between stimulus elements affects order-of-report. Bryden (ibid) found that increasing the spaces between stimulus elements effectively altered the normal left-to-right report sequence. These differences have been interpreted in terms of a sequential processor. Letters are more inflexible as regards processing than are digits and for accurate recall must be reported in a left-to-right sequence. Destroying spatial information (the close proximity of letters) also seems to affect letter but not digit recall accuracy (Bryden, Dick, & Mewhort, 1968; Dick & Mewhort, 1967).

The fact that stimulus displays are generally reported in a left-to-right direction has led some investigators to suggest a relationship between order-of-report and laterality differences. Items which are reported early in the report sequence have greater accuracy of recall (or recognition) than items reported late. Hence, in the case of bilateral displays, elements in the LVF which are reported first will have a higher accuracy than elements in the RVF, reported late. Ayres (1966) claims that no hemifield differential accuracy was found in his data when report sequences were manipulated (left-to-right, right-to-left, center-out, optional). That is, when Ss were required to report binary displays from right-to-left, accuracy was greater for elements in the RVF. These results are in disagreement with those of Ayres and Harcum (1962) and Harcum, Hartman, and Smith (1963), where a general left hemifield superiority was observed with different report instructions. Harcum (1967) has however, offered a resolution. In reanalyzing Ayres' results he showed that the lateral positioning and not the order of overt reporting of elements was the critical factor.

There is little doubt that laterality effects and order-of-report are related. Some results indicate that a sequential scanning mechanism is essential to this relationship. Bryden (1960) has shown that directional reporting interacts with stimulus characteristics. Forms are more easily reported in a right-to-left sequence than are letters and Ss tend to covertly rehearse letters in a left-to-right direction even when reporting them right-to-left. Harcum, Hartman, and Smith (1963) have shown that for bilateral binary patterns a left-field superiority obtains even when Ss report in a right-to-left direction, provided report instructions are given after exposure, while Dick and Mewhort (1967) have found that order-of-report is related to letters but not to digits.

These results suggest that the ease of reporting in a consistent left-to-right direction depends upon stimulus characteristics. Forms are more readily reported in a right-to-left direction than are digits which in their turn are are more readily reported than are letters. It is obvious that the directional characteristics of the stimulus material demand certain specific scanning strategies. Normally oriented letters must be scanned in a left-to-right manner even when the reporting sequence is the reverse. Such a scanning sequence is not necessary for forms. Report sequence may be a crucial determinant of laterality differences with letter stimuli but would not seem as important for other types of stimuli. An interaction of scanning sequence with memory decay, rather than of report sequence with memory decay, would seem to provide the better account of the relationship between order-of-report and laterality differences.

A Post-Exposure Trace-Scanning Mechanism

Having considered the research relating to type and arrangement of stimulus information, eye-movements, and report instructions, it is now appropriate to deal with a hypothetical mechanism developed to account for laterality differences.

Harcum and Finkel (1963) have commented: "Heron

(1957) extended the theory of Mishkin and Forgays by proposing what he called a 'post-exposure process' consisting of a sequential analysis of the persisting trace of the stimulus after the tachistoscopic exposure. This perceptual analysis of traces, or scanning process, does not itself include actual overt eye-movements, but it includes the motor activity of the central nervous system which precedes overt movements of the eyes in the manner of the phase sequence suggested by Hebb (1949). It may be thought of as a temporal distribution of attention across the persisting physiological traces of the projected stimulus elements. The sequence of attending to the traces is assumed to correspond to the sequence of successive eye fixations across the visual field with the stimulus present, if eye movements could be made (p.224)."

The data relating to stimulus characteristics offer support for a post-exposure trace-scanning mechanism. Verbal information which is ordinarily read from left-to-right, is presumably scanned in this direction, while the same information when reversed in orientation is presumably scanned from right-to-left. Increasing the spacing between stimulus elements destroys the ordinary spatial arrangement of verbal material and the scanning of the trace is thus handicapped. The results on post-exposure eye-movements also offer indirect support for this scanning mechanism. It has been found that directional eye-movements and differential hemifield accuracy are correlated (Crovitz & Daves, 1962). While it cannot be argued with certainty that the two processes of eye-movement and trace-scanning are neurologically associated, the observed "tendencies to eye-movement" are in accord with what would be expected on the basis of the trace-scanning hypothesis.

In some ways the research which has investigated the role of order-of-report offers results which contradict a post-exposure trace-scanning mechanism although in other ways it offers support. The suggestion of Heron assumes that bilateral displays of stimuli are scanned in a directional sequence such that the scan and associated memory decay favour recall of stimuli in the LVF. Ayres (1966) has found that an LVF superiority is observed when the stimulus information is reported from left-to-right, but that an RVF superiority is found when the information is reported from right-to-left. The reporting and scanning of simple binary elements such as Ayres used, can not, however, be assumed to correspond to the reporting and scanning strategies adopted with more directional and well-learned material such as letters. Ayres' results have also been severely criticised by Harcum (1967).

The notion that laterality differences may be an "artifact" of order-of-report in that elements reported first are better reported than elements reported late, receives scant support from research into the determinants of element localization and identification within digit and letter spans (Crovitz & Schiffman, 1965; Crovitz, Schiffman, Lipscomb, Posnick, Rees, Schaub, & Tripp, 1966; Dorff, Mirsky, & Mishkin, 1965; Mathewson, Miller, & Crovitz, 1968). There is no clear relationship between report sequence position and whether or not an element is correctly reported.

Some Structural Factors

Thus far, consideration has been given to a number of stimulus and experimental factors and their relationships to laterality differences. A further important component of experiments which have investigated laterality differences is whether the viewing condition is monocular or binocular. This point relates to the structural aspects of differential eye sensitivity and visual acuity, and to ocular dominance.

Viewing Condition.

Not a large amount of data has been accumulated comparing viewing conditions, and what data there are are not readily explicable. Most relate to situations where threshold stimulus exposures have been used. Barton, Goodglass, and Shai (1965) presented unilateral vertically-mounted words to their Ss and found a small differential sensitivity between the eyes under monocular conditions. The left eye contributed more to laterality effects than did the right eye. Overton and Wiener (1966) using unilateral presentations of five-letter English words also found laterality differences were significantly greater for the left than for the right eye. Again, Hirata and Osaka (1967) using unilateral and bilateral presentations of Japanese words found consistently greater laterality differences for the left eye, under monocular conditions. These results suggest that the two eyes do not function equivalently under monocular conditions, as the left eye is generally responsible for laterality differences. Adequate explanations of this effect have not been forthcoming but it is reasonable to assume that visual acuity is an important component. It is known that there is a higher percentage of left acuity-dominant than of right acuity-dominant people (Crovitz, 1961) and if it is assumed that a proportional difference exists in subject samples, then (a) the left eye might be expected to perceive stimuli in the RVF better than can the right eye for stimuli in the LVF, and (b) the left eye should show a general superiority. An examination of the above results tends to confirm these points, with the exception that Hirata and Osaka's results showed a general superiority for the right over the left eye.

The results of Crovitz and Lipscomb (1963) from a situation where bilateral rows of six digits were presented monocularly to Ss are in disagreement with those just mentioned. These authors found a greater laterality difference for the right than for the left eye and a total superiority favouring the right eye. A further puzzling feature of their results which contradicts the usual hemifield presentation interaction was that under the binocular viewing condition an RVF superiority was observed. One explanation of these results might be that Ss were adopting some strategy which favoured recall of stimulus information in the RVF. Kimura (1959) found laterality differences switched from an LVF to an RVF superiority with bilateral presentations if the spacing between the information in the LVF and that in the RVF was optimal. Crovitz and Lipscomb's stimulus elements were strung-out at an angle of 7°, the angle between the two middle digits being 3°. The facts that an exposure duration of 100 ms. was used and the mean number of correctly reported digits was in the vicinity of 2.4 (against 4.0 to 4.3 for the typical memory span; Keele & Chase, 1967; Sperling, 1960) suggests that the spacing may account for the discrepancies between the results. Studies which show a differential sensitivity of the eyes invariably use minimal intensities. Harcum and Dyer (1962) who used bilateral arrangements of binary elements and ran monocular and binocular trials, found no eye difference effects with an exposure of 100 ms.

Ocular Dominance

Ocular dominance is defined as "the visual phenomenon where a functional ocular unilaterality exists in binocular vision--some sort of physiological preferential activity of one eye over that of the other when both are used together (Ogle, 1962, p.409)." Various criteria are offered by Ogle as indices of ocular dominance.

Two, the two points at different distances in space adjusted to appear aligned by binocular vision are so actually aligned by the dominant eye, and the eye with the higher visual acuity as the dominant eye, have been used by researchers of laterality differences in assessing its relevance as a contributory factor. Little evidence is offered to suggest that sighting dominance, defined by some score on a sighting test (e.g., Miles, 1929) is a major determinant of or has explanatory value for laterality differences (cf. Anderson & Crosland, 1933; Hayashi & Bryden, 1967; Mangan, 1963). One fact which has confounded results based on a simple ordering of _Ss_ according to sighting dominance is that over twice as many left sighting dominant _Ss_ are left acuity dominant than are right acuity dominant (Crovitz, 1961).

On the other hand, acuity dominance has been successfully related to laterality differences. Hayashi and Bryden (1967) examined the contribution of ocular dominance to laterality differences and found that "acuity dominance has a significant effect on hemifield differences in binocular tachistoscopic recognition, while sighting dominance has little, if any effect.

"The stimulation provided through the eye with better acuity is stronger or less distorted than that provided through the other eye. In addition, there is considerable anatomical and physiological evidence indicating that the crossed optic pathways dominate the uncrossed pathways. This superiority. . .would provide an advantage to the left visual field of the left eye and to the right visual field of the right eye. Taken in conjunction with the effects of acuity dominance and cerebral dominance, it would lead us to expect a large right field superiority in right acuity dominant Ss, for whom the right eye contributes the higher level of stimulation (p.611)."

Handedness

Handedness has been used as a criterion of cerebral dominance for many research purposes and its relationship to laterality differences has been investigated. Handedness refers to the degree to which Ss consistently use a preferred hand in a variety of tasks and is typically quantified through an index from a self-report test (e.g., Crovitz & Zener, 1962).

Bryden (1964) in a summary of relevant results, reported that of 33 left-handers, 49% were right-field superior while of 124 right-handers, 73% were right-field superior on a task involving the recognition of unilaterally presented letters and forms. The same author reports (1965) that of 20 left-handers and 20 right-handers, the right-handers were significantly more accurate in identifying material presented in the RVF while left-handers failed to show any consistent laterality effects. Again, Orbach (1967) observed greater laterality differences for right- than for left-handers in a situation where English and Hebrew words were exposed between 10 ms. and 20 ms. unilaterally in the visual hemifields. Silverman, Adevai, and McGough (1966) also offer some indirect evidence, suggesting that right-handers perform better on a variety of perceptual tasks than do left-handers. Goodglass and Barton (1963) however, found no appreciable laterality differences which could be attributed to differential handedness.

These results suggest that Ss for whom the right is the preferred hand, show greater laterality differences than do Ss for whom the left hand is preferred. One interpretation that can be placed on such a relationship is that handedness and cerebral dominance are interdependent, the former being an index of the latter. As early as 1836, Dax (cited in Penfield & Roberts, 1959) postulated a doctrine of cerebral dominance which holds that language is controlled by the cerebral hemisphere opposite to the preferred hand. Verbal stimuli transmitted to the right hemisphere and those transmitted to the left hemisphere may give different response accuracy scores depending on Ss' handedness. Ss for whom the left hemisphere is dominant (right-handers) will have better recognition of information shown in the RVF which is subsequently transmitted to the left hemisphere, than will those Ss for whom the right hemisphere is dominant.

Such an explanation is neat but the evidence belies its simplicity. For one thing, there is no clear-cut relationship between handedness (which itself is variously defined and measured) and cerebral dominance, which again, is not always a matter of unilateralization. Milner, Branch, and Rasmussen (1964) reported that of 48 observed right-handers, 43 had left hemisphere representation while five had right hemisphere dominance; of 44 left-handed and ambidextrous Ss, 28 were left dominant, seven bilateral and nine right dominant. These figures indicate that although a greater proportion of left-handers have right brain dominance, the majority of Ss (over three-quarters) are left brained. Extrapolating from these data, it may be expected that in a random sample of right-handed Ss, about 90% may be left brained, and in a random sample of left-handed Ss, about 64% may be left brained.

An alternative view on handedness and cerebral dominance is advanced by Penfield and Roberts (1959): "It (now) seems clear that the left hemisphere is usually dominant for speech, regardless of handedness. The reason why the right hemisphere is sometimes dominant for speech remains unclear, but it is not related solely to handedness. . .The representation of speech in the left hemisphere is due to a simplicity of function for the brain. Brain function and handedness may be unrelated except by disease (p.102)."

There is little question that handedness is related in some way to laterality differences. Exactly how this is, and by what means handedness becomes a determining factor of laterality differences remains unclear and speculative. The simple dichotomy of Ss into groups according to scores from one test of handedness would seem inadequate as a basis for identifying one group as left dominant and another group as right dominant. Other factors may relate to handedness more than does cerebral dominance.

One final point concerning handedness is that it may relate to laterality differences only under minimal exposure and information conditions. Bryden (1965) found handedness associated with laterality differences when stimulus exposure was 20 ms., but negligibly so when exposure was 25 ms.*

Cerebral Dominance

The fact that visual and auditory perceptions are contralateral has led some investigators to argue for an interpretation of laterality differences in terms of a functional asymmetry of lateralization. The anatomical basis upon which such an interpretation rests can be

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* Two statements in Bryden's (1965) paper should be clarified. First, he wrote that "it is not surprising that Goodglass and Barton (1963) failed to find a relation between handedness and tachistoscopic recognition using multiple-letter material (p.1)"; yet in his 1966a paper he wrote, "attempts to study the significance of such factors (handedness) should employ single-letter material or vertical rows of letters (p.1134)." Goodglass and Barton did, however, use vertical rows of letters. Second, he wrote, "Since ocular dominance appears to be related to handedness (Fuller & Thompson, 1960), the relation between tachistoscopic recognition and handedness might be due to ocular dominance (p.6)." Fuller and Thompson, however, simply quoted data from Merrell (1957), who in turn concluded, "There is essentially no relationship between ocular dominance and the dominant hand (p.327)."

illustrated with reference to stimuli impinging on the left hemiretinae and on the cochlea. Stimuli from the RVF impinge on the temporal (lateral) half of the left retina and on the nasal (medial) half of the right retina; From these, the optic fibers proceed to the optic chiasma where a partial decussation occurs and then most of the fibers proceed to the left lateral geniculate nucleus. Here they synapse with the cortical projection fibers, proceeding to the occipital lobes ending in the left striate cortex. A comparable transmission is undertaken by auditory stimuli. Here, fibers from both sensors (the cochlea) enter the left lateral lemniscus and proceed via the left medial geniculate nucleus to the left temporal lobe and specifically to the superior temporal gyrus.

If it is argued that a laterality of function exists for spoken verbal material and for non-verbal material and that the crossed dominate the uncrossed pathways (Kimura, 1961a, 1961b, 1964; Landsdell, 1962; Wada & Rasmussen, 1960) an explanation for laterality differences in both visual and auditory modalities is available. In the visual case, stimuli from the RVF are transmitted to the left dominant speech hemisphere, whereas stimuli from the LVF are transmitted to the non-dominant speech hemisphere. Hence the superior recall or recognition of verbal material presented in the RVF and the absence of a recognition difference for non-verbal material whether presented in the RVF or in the LVF (Bryden, 1965; 1966a). In the auditory case, where stimuli arriving at either ear are transmitted to both hemispheres, the functional asymmetry of the temporal lobes may be demonstrated by appropriate lesioning or suppression of one or other of the lobes (Kimura, 1961a, 1961b; Shankweiler, 1966).

A considerable amount of evidence has accumulated relating an asymmetry of the temporal lobes to type of auditory input. The suggestions offered are that the left temporal lobe dominates the right temporal lobe in the perception of verbal material, whereas the right dominates the left temporal lobe in the perception of non-verbal material, and that the crossed auditory pathways dominate the uncrossed pathways.

In two studies, Kimura (1961a, 1961b) found that when groups of digits were dichotically presented to patients with a unilateral temporal lobectomy, (a) digits arriving at the ear contralateral to the locus of lobectomy were better recalled than those arriving at the ipsilateral ear, (b) patients with known hemispheric speech representation had better recall for the digits presented to the ear contralateral to the site of hemispheric dominance, and (c) the recall of digits was impaired more by left temporal lobectomy than by right temporal lobectomy. As corollaries to these findings, Kimura (1964) and Shankweiler (1966) have observed that right temporal lobectomy impairs the recognition of dichotically presented melodies more so than does left temporal lobectomy.

The same general results have also been obtained by Bryden (1965), Cooper, Achenbach, Satz, and Levy (1967), and Shankweiler and Studdert-Kennedy (1967) using dichotically presented digits, consonants and vowels with non-lesioned normal Ss; by Bakker (1967) and Palmer (1964) using verbal material presented successively to the ears of normal Ss. One interesting finding arising out of Shankweiler and Studdert-Kennedy's research was that consonants were better recalled from the right than from the left ear, whereas no difference was observed with respect to the dichotic presentation of vowels. The investigators surmised, "In view of Kimura's finding (1964) of a left ear advantage for musical melody recognition, as against a right ear advantage for spoken digits, the neutral status of steady-state vowels, midway, as it were, between speech and music, is perhaps not surprising (p.60)."

The results relating cerebral lateralization to visual field asymmetry are not as clear-cut or as conclusive as are comparable auditory results. Part of the problem undoubtedly resides in the neglect of visual testing of lobe-damaged patients. Most of the evidence relates to normal Ss. Kimura (1963) and Meier and French (1965) have however, found that patients with right temporal lobe damage are impaired in identifying or interpreting complex visual forms and non-verbal patterns but are not so impaired in the recognition of alphabetic material. Dorff, Mirsky, and Mishkin (1965) have also found that when unilateral and bilateral presentations of alphabetic material are presented to patients with unilateral temporal lobectomy, laterality differences are related to the site of lesion. Generally, the visual hemifield resulting in poorer recognition was contralateral to the locus of lobectomy.

A relationship between cerebral dominance and locus of auditory stimulation has been fairly well demonstrated but the same cannot be said for a relationship between dominance and visual stimulation. The following points may be considered as contributing to the nature of the disparate results: (a) laterality differences researchers do not demonstrate hemispheric lateralization as unequivocally or nearly as often as do researchers of audio asymmetry. The former tend to rely upon handedness as an empirical index of speech lateralization. (b) The weight of evidence relating dominance to auditory functional asymmetry rests on dichotic listening experiments where competing stimulation is fed to both ears. With the exception of a few studies (e.g., Corballis, 1964; Sampson, 1964; Sampson & Horrocks, 1967) visual input is invariably presented under non-competitive conditions. There is an opinion which holds that when input is fed simultaneously to the sensors, the stimuli transmitted along the contralateral pathways occlude those transmitted along the ipsilateral pathways, but that when information is presented separately the contralateral and ipsilateral pathways function more or less equally well (Kimura, 1964). If this is indeed the case, it is not surprising that under conditions of non-competing stimulation, negligible laterality differences are observed. (c) The nature of the dichotic listening task defines it more as a memory task (up to 3 sec. from initial input to response for any one trial) than as a perceptual-recognition task (500 ms. as a comparable span in the laterality difference experiment). Functional asymmetry may thus be directly related to the ability to "hold" stimulus information rather than to the ability to immediately process it. (d) The nature of the non-verbal visual stimuli as "non-verbal" is questionable. Bryden (1966a) suggests geometric forms are non-verbal, but clearly, verbal labels may readily be ascribed to the percepts of a triangle and a star. Such an analysis is more difficult with patterns of melodies (Kimura, 1964) and morse code (Bakker, 1967).

Finally, a major difficulty contingent upon a dominance interpretation of laterality differences must be mentioned. When verbal stimuli are presented bilaterally about the center of the visual field, a superiority favouring elements in the LVF is usually found. A consistent "dominance" hypothesis would predict an RVF superiority. Bryden (1966a) has pointed out that the factor of "horizontal scanning" of multiple element displays tends to destroy or confound pure assessments of the role of cerebral dominance. He argues that using single letter displays and unilateral presentations, obtained RVF superiorities can be interpreted in terms of hemispheric dominance.

SUMMARY

Laterality differences in perception are a composite function of many factors. Whether a left or a right visual hemifield superiority in recall accuracy is found depends on (a) the type of stimulus presentation, (b) the amount, quality, and spacing of the stimulus elements, (c) the intensity at which the stimuli are shown, (d) the order in which the stimuli are reported, (e) the viewing condition employed and the ocular dominance of the Ss, and (f) the handedness and speech lateralization of the Ss.

Some of these factors seem to be of greater importance in determining laterality differences in some situations than in others. Two general categories of experimental conditions can be distinguished. One where the stimulus information consists of multiple element displays and is shown at exposure durations well above "threshold" in the vicinity of 50-150 ms. The other where the stimulus information is made up of single element displays and which is presented at threshold durations. In the former condition, laterality differences are seen to be mainly a function of the type od stimulus present-

ation, the order in which the material is reported, and different processing strategies which are related to the directional and spatial characteristics of the stimuli. Here, a left visual hemifield superiority is usually found for bilateral presentations and a right visual hemifield superiority for unilateral presentations. A general explanation for this phenomenon has been advanced in terms of a directional post-exposural trace-scanning mechanism.

In the second general experimental condition, other, higher order processes may operate more effectively than any post-exposural scanning. Here, structural factors, have been related with varying degrees of success to laterality differences. It is to be expected that as stimulus information and exposure durations tend towards the minimal, these factors should dominate a scanning process which itself demands maximal information and time to process it. The problem faced in this latter condition is more of a purely perceptual problem, that is, getting reception of the stimulus information (the ease of activating a stimulus trace) than it is of a perceptual-memory problem, that is, getting the information retrieved.

GENERAL METHOD

Apparatus

Stimuli were presented in a locally manufactured three-field tachistoscope. Two fields can serve as stimulus fields and the third field as an adaptation or delay field. The distance from the eyepiece to the centers of the three fields is 121.92 cm., and the visual areas of the three fields are in each case 16.2 cm. (horizontal axis) by 11.4 cm. (vertical axis) or 7.62° by 5.37° visual angle. Both stimulus fields have card magazines attached immediately behind and cards are changed by means of mechanical slides. The adaptation field consists of a card of the same material as used for the stimuli. This field is blank excepting for a small fixation dot of 0.05° centered in the field and which coincides with the centers of the stimulus fields.

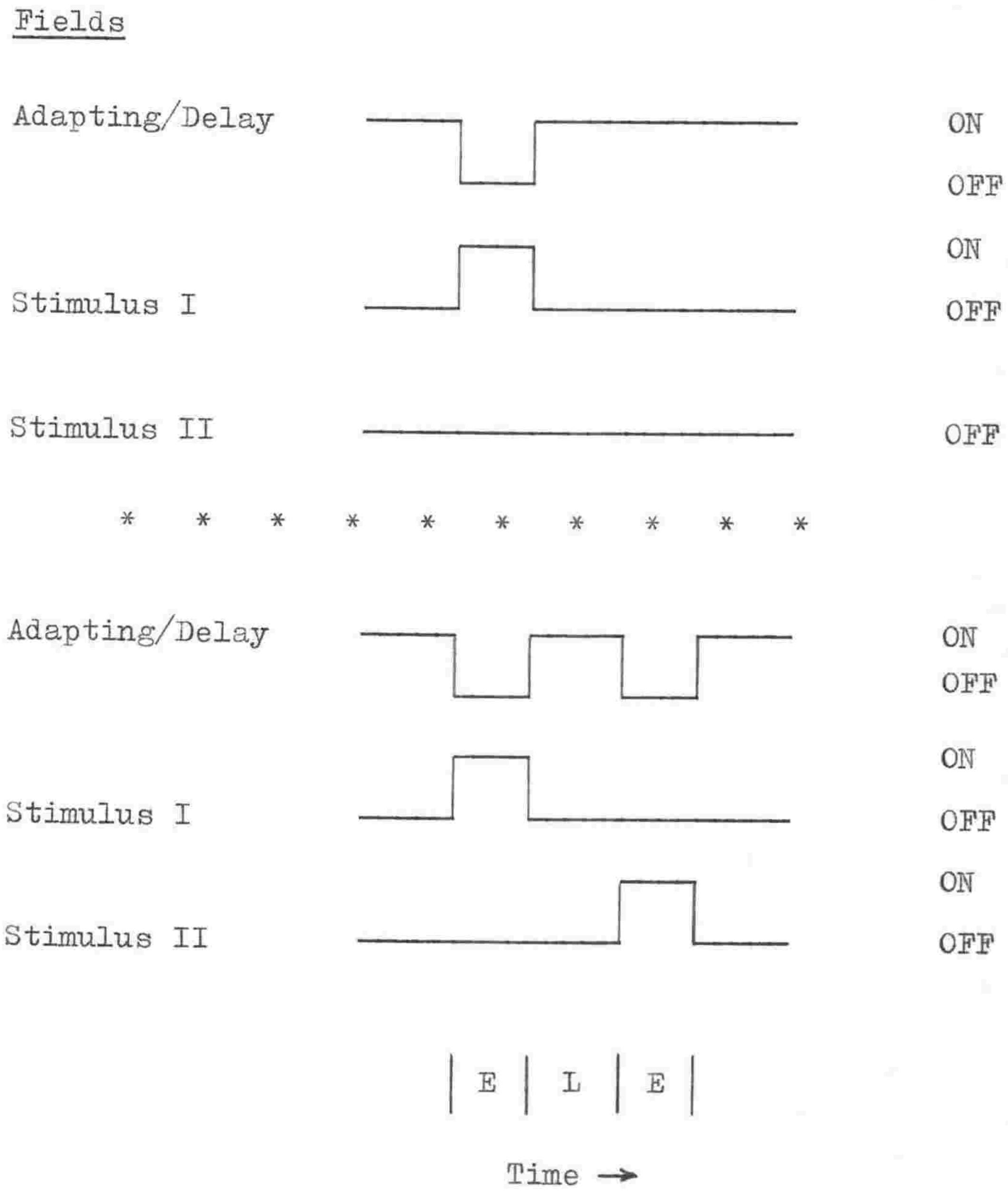
Fields are illuminated by mercury-argon cold cathode tubes with white phosphor coating. For the exposure durations used in the experiments, these tubes have rapid rise and decay times. Peak illumination is reached in less than 0.5 ms. and decays within 0.3 ms. The luminances of all fields were matched at 1.5 ft-L.

The variable exposure and delay lags are controlled by a solid-state 5-decade counter with three predetermining selector switchbanks which gated the output of an internal 1 kc. oscillator to three thermionic power amplifiers supplying the lamps. Exposures and delays of from 1 ms. to 100 sec. in 1 ms. steps are obtainable.

The events accompanying the two principal exposure conditions are schematized in Diagram G.1. All trials were initiated by Ss' pressing a microswitch. As Eriksen and Collins (1965) have pointed out, this procedure "results in very stable recognition functions for tachistoscopically presented stimuli. It succeeds in eliminating variations in accomodation which account for considerable variability in tachistoscopic presentations (p.345)."

Stimulus materials

Stimuli were mounted on 5 x 7 in. off-white cards. The letters and digits used in Experiments I-V were drawn with a Standardgraph stencil 203/7 with pen No. 56. Each element was approximately 0.30° visual angle high and 0.28° wide. A bilateral arrangement of elements subtended an angle of 5.73° when viewed in the tachistoscope.



Diag.G.1. Events occurring in the adaptation-delay and the two stimulus fields and their relative chronological relationships during a single trial. E: variable exposure; L: variable inter-stimulus-interval lag.

Elements were separated by an angle of 0.80°. The letter stimuli used in Experiments VI-VIII were drawn by means of Letraset Instant Lettering No. 287. Each element was approximately 0.24° visual angle high and 0.16° wide. In Experiment VI, the unilateral arrangements subtended an angle of 1.80° on either side of central fixation. In Experiments VII and VIII the elements were mounted in vertical arrangements, the centers of the arrangements from fixation being 2.20° (VII), 2.20° and 1.10° (VIII).

The stimulus populations used in each experiment were:

I: D F G H J L N R S T V X Z. Digits 1-9.

II: D F G L N R S Z.

III: As for I.

IV: As for I with digits omitted.

V: As for II and the mirror-images of these letters, plus a third set, A H M O T U V X.

VI: A H M O T U V Y

VII: A H M O T U V X Y

VIII: As for VII and a second set, E G K L N P R S Z.

Examples of stimulus displays are shown in Figures G.2a-2d.

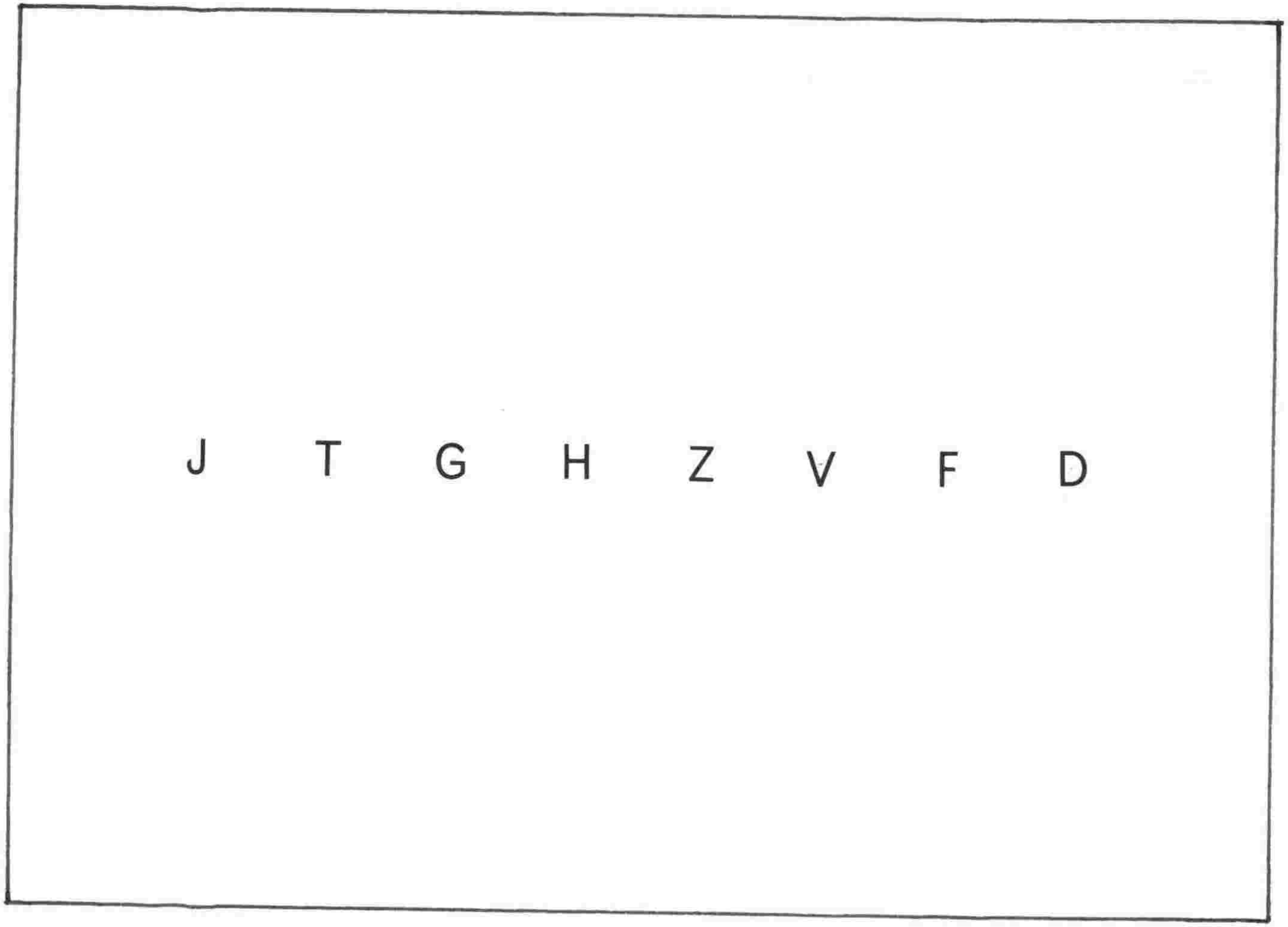


Fig. G. 2a. Example of a bilateral stimulus display from Exp. I.
Approximately actual size.

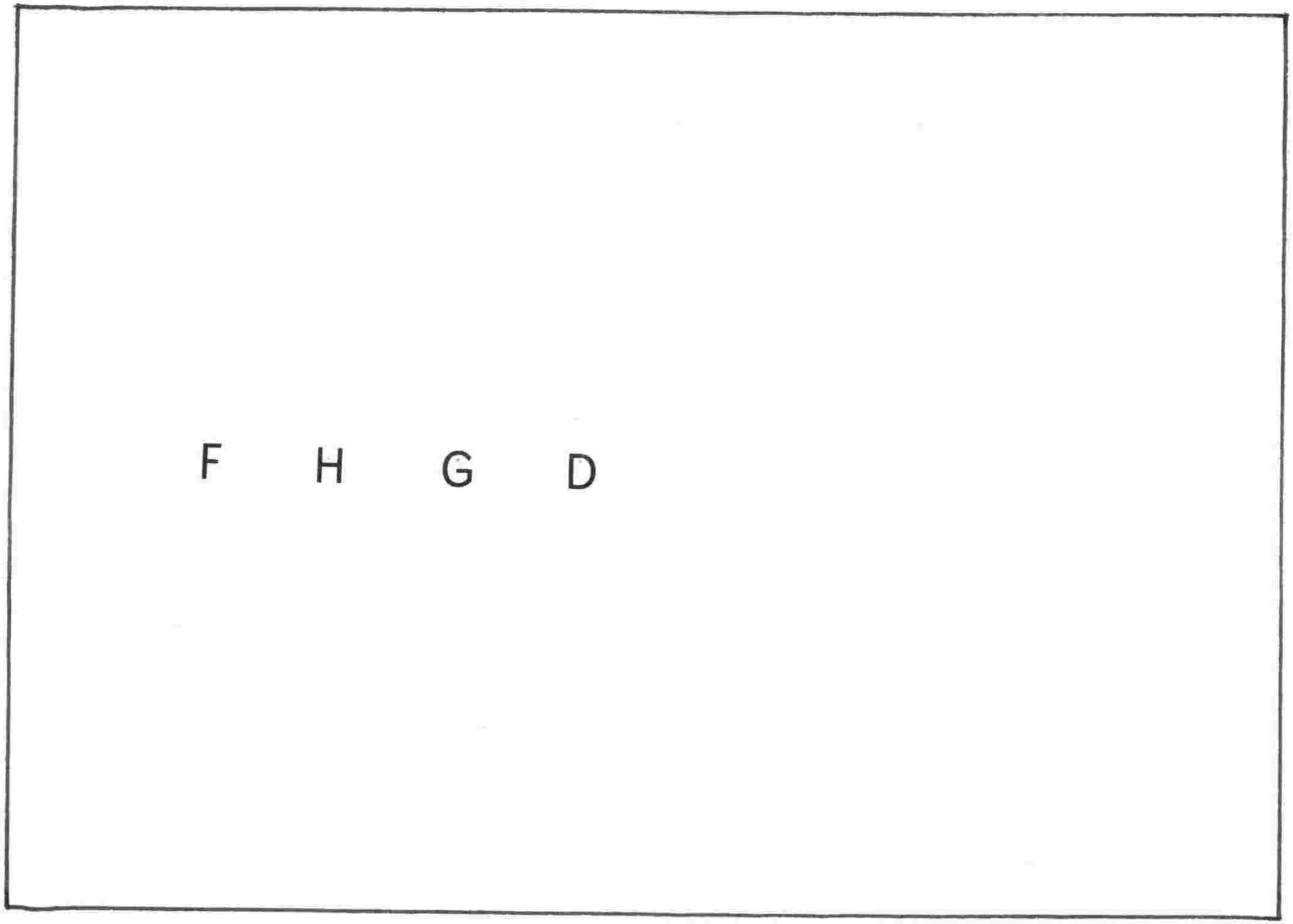


Fig. G. 2b. Example of a unilateral stimulus display from Exp. I.

Approximately actual size.

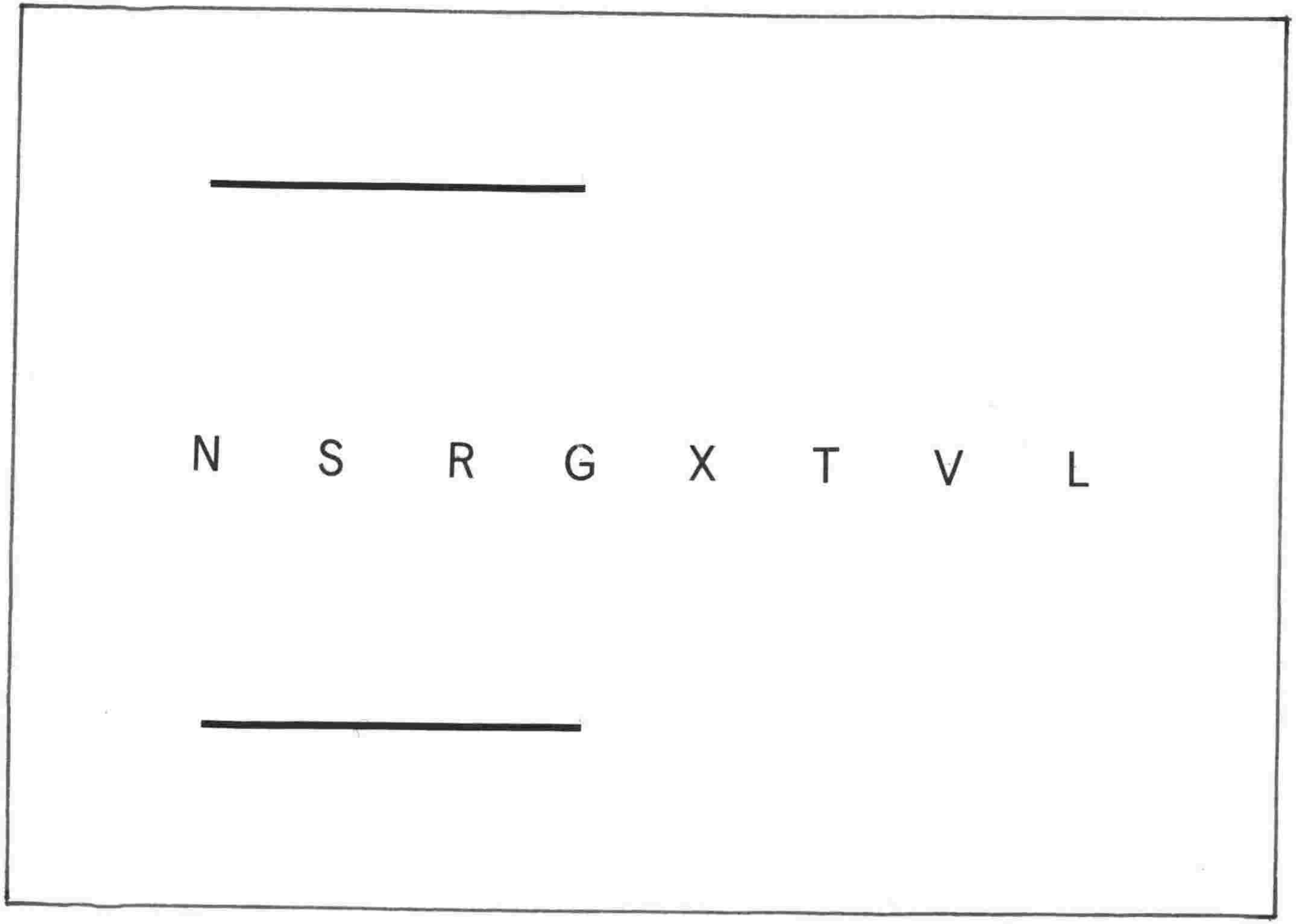


Fig. G. 2c. Example of a bilateral stimulus display from Exp.III. Approximately actual size.

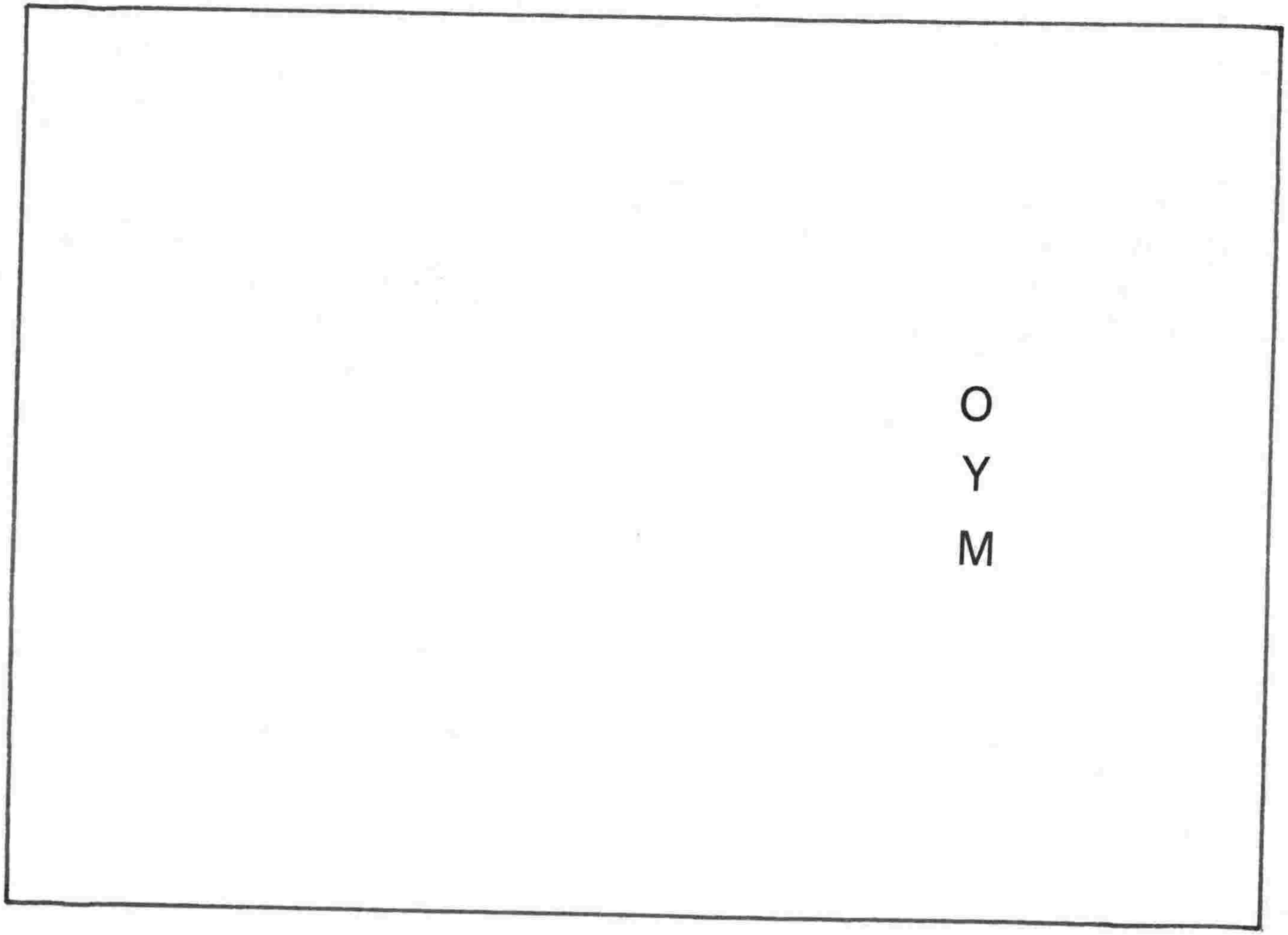


Fig. G. 2d. Example of a stimulus display from Exp. VII. Approximately actual size.

Subjects

Subjects were unpaid university graduate and undergraduate students of British ethnic origin whose native language was English. All had had previous experience with tachistoscopic procedures and all had corrected or uncorrected normal vision. No S was used who displayed any marked acuity differences determined by Sloan chart readings. In Experiments I-VI, Ss were all right-handed and right sighting dominant.

Practice trials

Ss were run on a sequence of appropriate practice trials before commencing any experimental trials. Feedback was supplied only for these practice runs. They were also shown examples of the stimulus cards, outside the tachistoscope. In all experiments, a card showing the stimulus population was available for Ss to refer to. Ss were thus able to correct some errors of confusion.

Variables used in the present study

Presentation. The presentation variable was of two kinds. One where the stimulus information was mounted either to the left or to the right of the central fixation point in the left or right visual hemifields, the other where the information was mounted across the card in both visual hemifields. The former is referred to as the "unilateral presentation condition" and the latter as the "bilateral presentation condition".

Viewing condition. Two viewing conditions were employed, monocular and binocular. When stimulus information was to be presented on a specific retina or hemiretina, the irrelevant eye was occluded by the use of an eye-patch.

Material. Stimuli consisted of bilaterally symmetrical, asymmetrical, and reversed asymmetrical letters, and digits.

Exposure. Exposure durations were varied or fixed within experiments, depending on the particular design. The range of stimulus exposures was from 20 ms. to 100 ms., the upper limit being below what is generally considered the latency of eye-movement (150 ms.) and the lower limit in the range of "threshold" for stimulus materials and lateral positionings used.

Locus of fixation. Fixation was centered in the visual field, except in Experiment II where three fixation loci were used.

Partial report and order-of-report. Partial report was manipulated by requiring _S_s to report either the left or the right hemifield stimuli. Order-of-report was manipulated by requiring _S_s to report the stimuli from left-to-right or from right-to-left.

Handedness. The handedness of _S_s was determined from scores on the Crovitz and Zener (1962) test. Only extreme scoring _S_s were judged as "predominantly" left- or right-handed. This test is shown in Appendix I.

Acuity. Subjects' monocular acuity was assessed by testing on Sloan charts, read at distances of six and one meters. Acuities within the range 0.80 to 1.00 for both eyes were deemed to display no differential acuity.

Sighting dominance. The sighting dominance of _S_s was determined from scores on the Crovitz and Zener test and on the Miles A-B-C vision test (Miles, 1929). The criterion was nine or more of twelve trials consistently classed as left- or right-eyedness on both tests. Appendix II contains details of these tests.

EXPERIMENT I

This experiment was designed to evaluate laterality differences when bilateral and unilateral stimulus presentations were randomized within trial-blocks. Previous researchers have tended to use experimental runs consisting of either all bilateral or all unilateral trials. In these cases the possibility of a pre-exposure set towards a particular part of the visual field is high and may help to account for observed laterality differences. If the case is considered where Ss are aware that each trial is a bilateral presentation, then a set to shift the eyes to the left periphery of the field may exist so that Ss can better "read" the line of elements from left-to-right. Also under investigation here were the effects of stimulus material and exposure.

Procedure

One hundred and twenty cards were prepared consisting of six blocks: (a) 20 cards with eight letters spaced across the card, (b) 20 cards with eight digits spaced across the card, (c) 20 cards with four letters spaced to the right of the card's center, (d) 20 cards with four digits spaced to the right of the card's center, (e) 20 cards with four letters spaced to the left of the card's center, and (f) 20 cards with four digits spaced to the left of the card's center. The four exposure durations used were, 100 ms., 75 ms., 50 ms., and 25 ms. Viewing was binocular.

Each S received eight blocks of trials. A block consisted of 15 cards with one of the two stimulus materials, shown at one of the exposures. Within each block five cards had the material arranged bilaterally and ten cards had the material arranged unilaterally (five cards with four letters or digits to the left of center and five cards with four to the right of center). The order of presentation of blocks x material was counterbalanced over Ss. The blocks were shown in an ascending order of exposure for half the Ss, and for the other half a descending order was used. Eight Ss served in this experiment.

Results and Discussion

Table I.1 shows the distribution of correct and error scores by presentation and material. An analysis of variance (2 presentation conditions x 2 visual fields x 2 materials x 4 exposures) was performed on the localization data. This is shown in Table I.2. For the bilateral condition, scores were lower than for the

Table I.1

Correct and error scores (percentage)

		(a)	(b)	(c)	(d)	(e)	(f)
Visual Field	Pres/ Mater.	CI	CL	CSP	CSR	EO	EC
L	BIL.L	41.1	23.3	17.4	17.8	50.2	8.3
R		35.8	12.8	20.3	23.0	59.2	7.4
L	BIL.D	48.7	25.6	25.2	23.0	46.4	2.9
R		46.4	18.9	26.4	27.5	53.2	2.2
L	UNIL.L	58.1	43.0	14.3	15.1	25.7	16.9
R		56.6	47.8	8.9	8.8	28.8	14.2
L	UNIL.D	64.5	49.9	13.3	14.6	23.1	13.2
R		62.4	51.7	9.2	10.7	23.0	16.3

(a) A correct identification (CI) indicates that the element reported did appear in the display and may or may not have been reported in its correct position. (b) A correct localization (CL) indicates the element reported was in the display and was in its correct position. (c) For any element position the substitution of another element from the display results in a correct substitution by position (CSP). (d) A correct identification but incorrect localization indicates the element was correctly substituted by report in some other position (CSR). (e) For any element position the absence of a report indicates an error of omission (EO). (f) For any element position the presence of a reported element not in the display indicates an error of commission (EC).

Table I.2

Analysis of variance of correct localization of elements

Source	df	MS	F
Subjects (Ss)	7	39.50	
Presentation (P)	1	2008 .16	107.04**
P x Ss	7	18.76	
Visual Field (VF)	1	14.53	<1
VF x Ss	7	48.78	
Material (M)	1	53.47	10.09*
M x Ss	7	5.30	
Exposure (E)	3	624.91	49.64**
E x Ss	21	12.59	
P x VF	1	96.29	8.55*
P x VF x Ss	7	11.26	
P x M	1	1.41	<1
P x M x Ss	7	2.72	
P x E	3	135.94	27.35**
P x E x Ss	21	4.97	
VF x M	1	0.10	<1
VF x M x Ss	7	4.12	
VF x E	3	7.30	1.03
VF x E x Ss	21	7.08	
M x E	3	5.55	<1
M x E x Ss	21	8.18	
P x VF x M	1	9.38	2.56
P x VF x M x Ss	7	3.67	
P x VF x E	3	19.23	3.17*
P x VF x E x Ss	21	6.06	
P x M x E	3	7.84	2.18
P x M x E x Ss	21	3.60	
VF x M x E	3	4.29	1.71
VF x M x E x Ss	21	2.51	
P x VF x M x E	3	7.68	1.63
P x VF x M x E x Ss	21	4.71	
	255		

** $p<.01$ * $p<.05$

unilateral condition (20.2%, 48.1% elements correctly localized). These percentages correspond to mean numbers of elements per display of 1.62 and 1.92.

The scores for digits significantly exceeded those for letters. By guesswork, Ss may be expected to average 7.12 digits correctly identified from an eight-digit string, where the population sampled was nine digits. Similarly, 4.92 letters may be had by guessing from an eight-letter string, where the population sampled was 13 letters. The actual figures of 3.80 (digits) and 3.08 (letters) are in a relationship such as to suggest that any probability of guessing may be discounted as an explanation for the superiority of digit scores. Digits are probably more readily "stored" in memory and more readily recalled than are isolated or random letters. No other effects attributable to differences in stimulus material were observed.

The interaction of presentation x visual field is illustrated in Fig.I.1. The results supported the general tendency observed in laterality difference research: In bilateral presentations more elements were correctly localized in the LVF than in the RVF, while in unilateral presentations elements were relatively better localized when they appeared in the RVF.

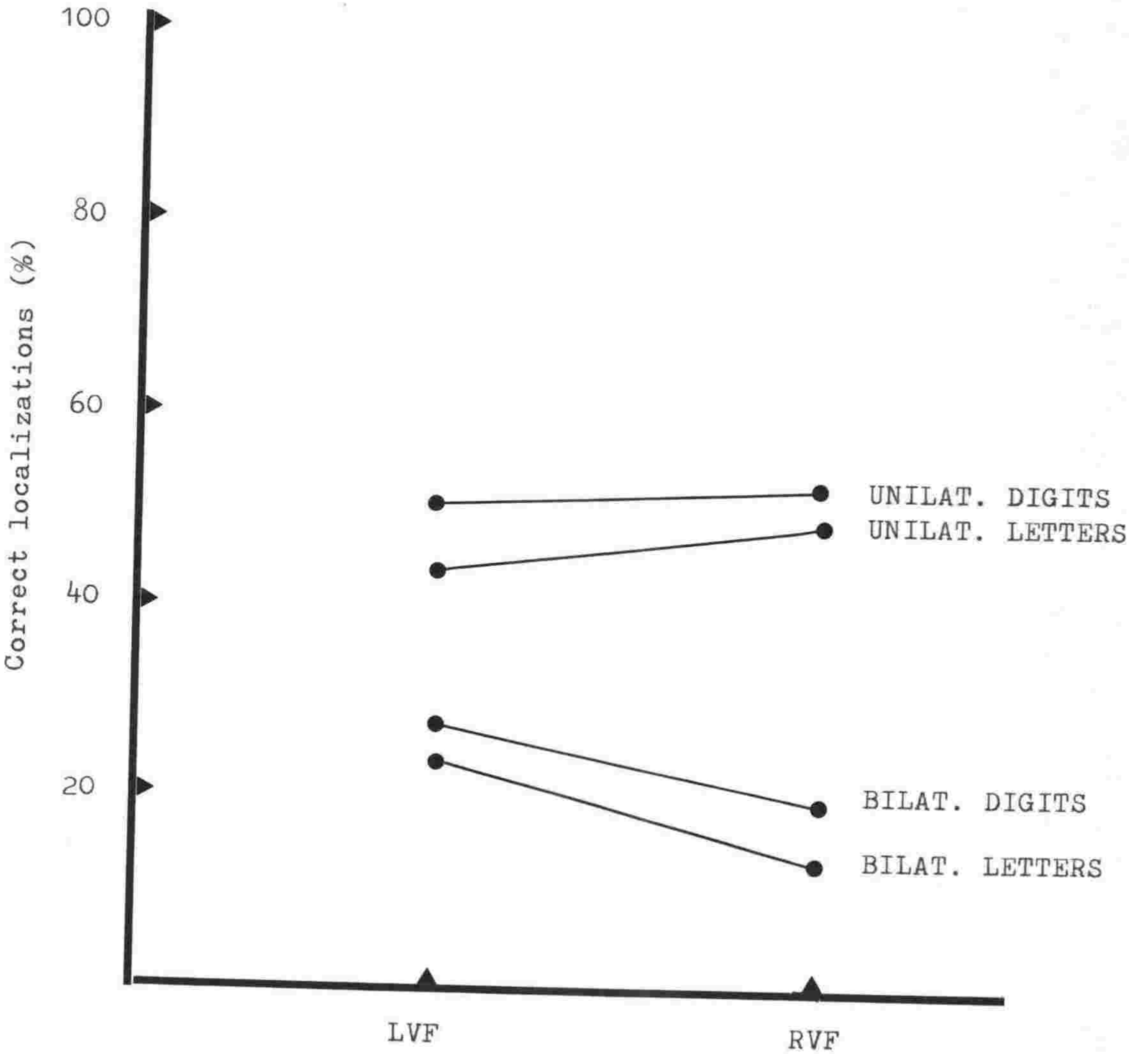


Fig.I.1. Interaction of presentation x visual field.

The number of correctly reported letters was directly related to exposure. Plots of errors of localization by letter position for bilateral and unilateral presentations are shown in Figs.I.2 and I.3. It was clear that increasing exposure allowed for better perception of elements, or, in Chaikin, Corbin, and Volkmann's (1962) words "broadened the effective tachistoscopic field (p.1328)." One interesting feature of these results was that elements near the fixation point tended to be better reported than elements farther to the left. This contrasts with the results of Crovitz and Schiffman (1965) where elements at the left periphery were best reported. The randomizing of bilateral and unilateral presentations within trial-blocks may have contributed to this finding. Subjects were probably less likely to shift their pre-exposure fixation to the LVF under the conditions used here than under the conditions of Crovitz and Schiffman's second experiment.

Fig.I.4 shows the degree with which each element position was first reported in the bilateral condition. For example, at 100 ms. 60% of report sequences commenced with the report of element 1. It was apparent that as exposure increased the trend was to commence reporting farther to the left.

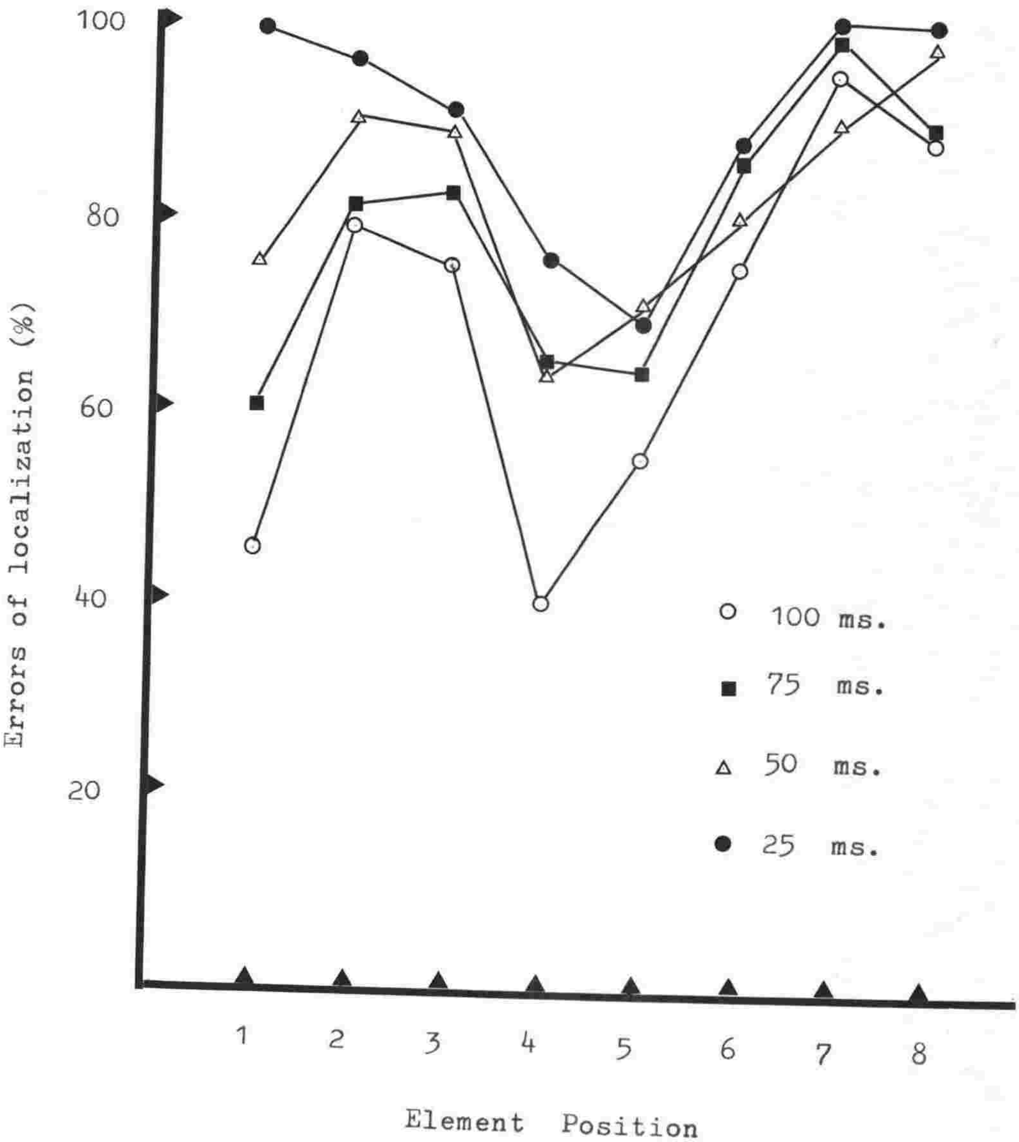


Fig.I.2. Percentage errors of localization for elements in bilateral condition. Results averaged over material.

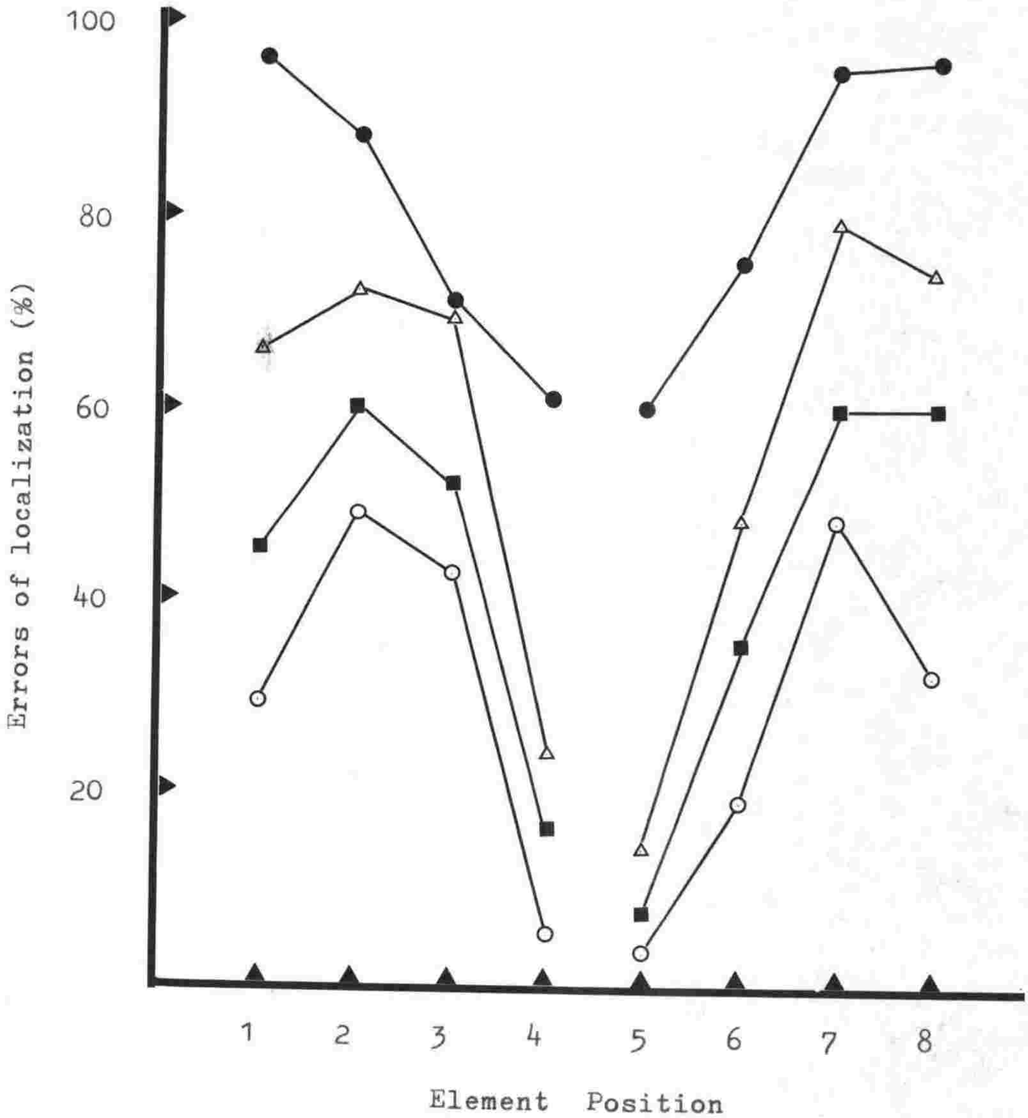


Fig.I.3. Percentage errors of localization for elements in unilateral condition. Results averaged over material. For legend see Fig.I.2.

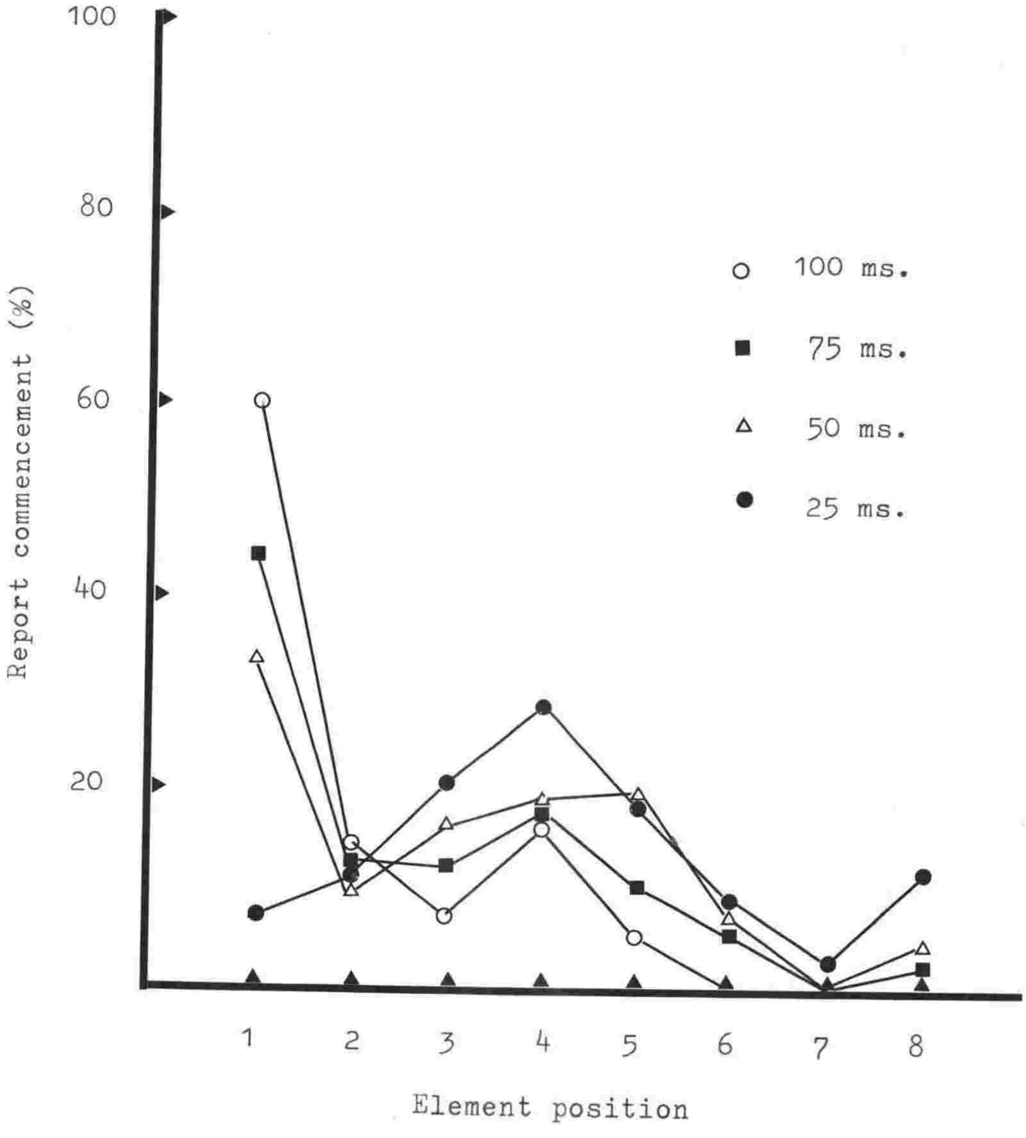


Fig.I.4. Starting position of first correct element reported. Results for bilaterally presented letters and digits

Table I.3

Mean orders of report

Presentation	Material	25 ms.	50 ms.	75 ms.	100 ms.
Bilateral	Digits	.61	.73	.77	.81
	Letters	.80	.74	.81	.90
Unilateral	Digits	.80	.94	.98	.97
	Letters	.94	.86	.88	.97

Table I.3 gives the mean orders of report by presentation and material and exposure. The results show that a strong left-to-right reporting sequence was generally used. This left-to-right reporting tendency increased with increasing exposures. It is interesting to note that in the bilateral condition, letters were reported in more of a left-to-right sequence than were digits.

Fig.I.5 shows the distribution of identification errors for bilaterally presented letters at 100 ms. Below the upper graph appears a plot of error responses against total responses made for each response position. For example, for the first responses for letters, 5% were incorrect identifications and for the second responses

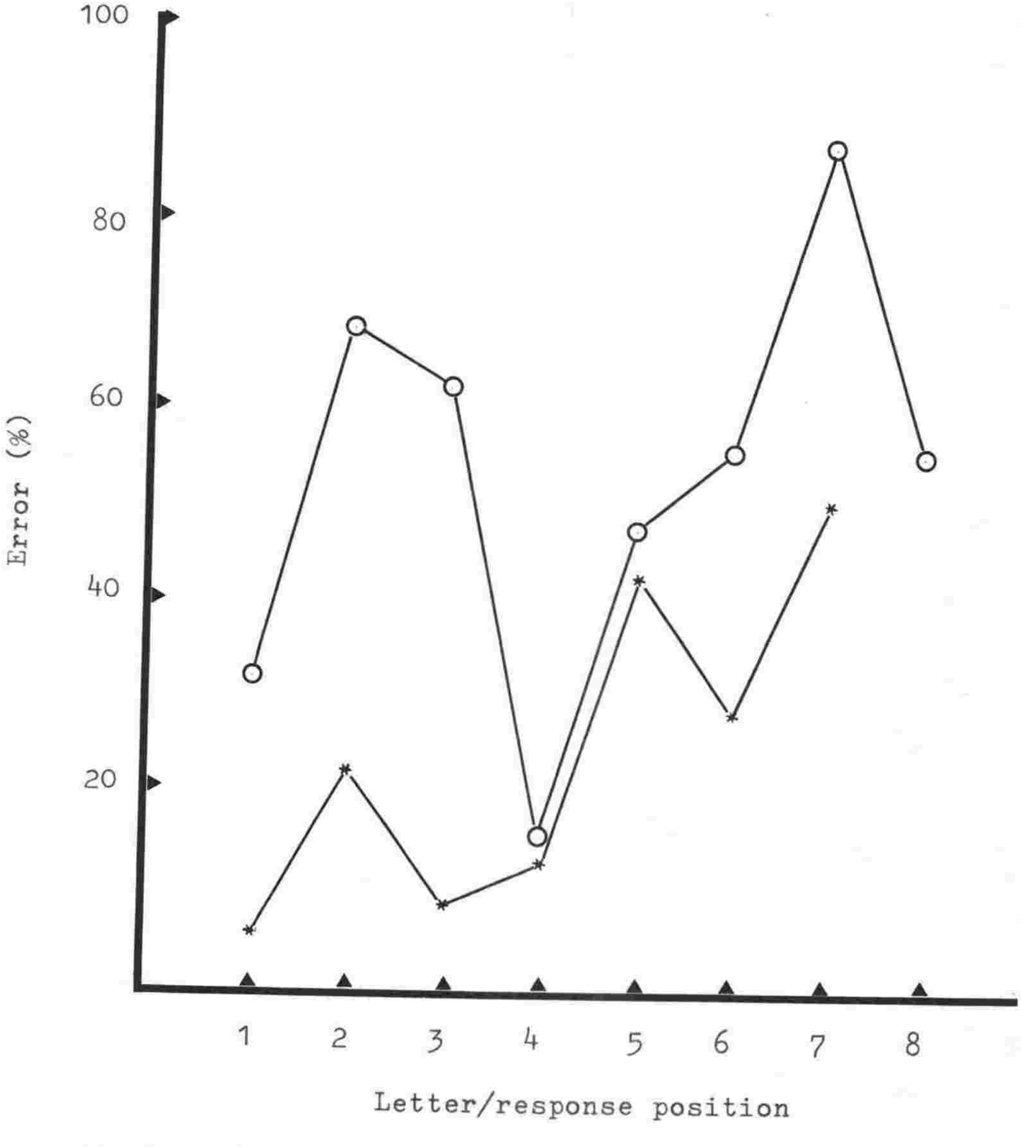


Fig.I.5. Percentage errors of identification for bilaterally presented letters at 100 ms. (upper graph), and percentage incorrect identifications/total responses for reports for this condition (lower graph).

made, 22% were incorrect identifications. Two things were apparent here: (a) Letters reported first in the response sequence were not necessarily reported more accurately than letters reported late, and (b) report-sequence errors were not a monotonically increasing function. Rather, they were dependent on the within-report position of the response. A further illustration of this point can be had from the unilaterally presented digits in the 100 ms. condition. For the left hemifield report sequences, errors per total responses made were, for position 1: 12.5%, position 2: 15%, position 3: 7.9%, position 4: 0%. For the right hemifield report sequences, errors for position 5 were: 0%, position 6: 5%, position 7: 28.2%, position 8: 23.5%.

EXPERIMENT II

In the previous experiment the probability of stimuli occurring to the left or to the right of fixation on any trial was 0.67. It was hoped that the randomization of presentation conditions might counter pre-exposure set toward a particular hemifield. This second experiment extended the "attentional set" factor by requiring Ss to fixate at one of three different loci prior to stimulus exposure. This was done so that the relationship between fixation locus and pattern of recognition scores might be clarified.

Procedure

The stimulus cards consisted of three sets of 12 bilateral, 12 left unilateral and 12 right unilateral arrangements. A bilateral arrangement consisted of eight letters spaced across the card and a unilateral arrangement was four letters spaced to the left or right of the card's center. The stimulus population was restricted to eight letters, to minimize errors of confusion and guessing strategies. Another set of 36 cards was arranged so that on 12 a fixation mark appeared to the left of where the left-most letter of a bilateral display would appear; on 12 this mark appeared between letter positions 4 and 5, and on 12 it appeared to the right of where the right-most letter would appear. The two sets of cards (stimulus and fixation) were randomized and arranged for presentation in such a way that each type of stimulus card was associated an equal number of times with each type of fixation card.

Each S initially attended to an homogeneously illuminated adaptation field. When the microswitch was triggered, the fixation-cue card appeared for 1 sec., and Ss were instructed to shift their focus of attention to the cue-mark during this period. Immediately following the offset of the 1 sec. cue exposure, the stimulus card was exposed for 100 ms. Five practiced Ss who had not served in the first experiment were used in this experiment. Viewing was binocular.

Results and Discussion

An analysis of variance (2 presentation conditions x 8 letter positions x 3 fixation loci) was performed on the data. This is shown in Table II.1. Presentation condition was significant beyond the 0.5% level. In unilateral presentations 61.2% of letters shown were correctly localized. In bilateral presentations 28.2%

Table II.1

Analysis of variance of correct localization of letters

Source	df	MS	F
Subjects (Ss)	4	3.49	
Presentation (P)	1	105.33	90.80***
P x Ss	4	1.16	
Letter Position (LP)	7	7.75	10.20***
LP x Ss	28	0.76	
Fixation (F)	2	7.58	10.68**
F x Ss	8	0.71	
P x LP	7	3.53	5.19***
P x LP x Ss	28	0.68	
P x F	2	4.21	12.03***
P x F x Ss	8	0.35	
LP x F	14	12.30	102.50***
LP x F x Ss	56	0.12	
P x LP x F	14	1.32	1.07
P x LP x F x Ss	56	1.23	
	239		

*** $p < .005$ ** $p < .01$

of letters shown were correctly localized. These percentages corresponded to mean numbers of letters correctly localized per display of 2.45 and 2.26 respectively. Letter position was significant at the 0.5% level. Letters in positions 1 and 8 at the end of displays were best reported (70%, 54.2% of total shown) followed by letters occupying positions 2, 5, and 4 (49.2%, 49.2%, 40.8%). Letters occupying positions 7, 6, and 3, were poorest reported (36.7%, 35.0%, 30.8%). Letters in positions 2, 3, 6, and 7 probably suffered most from spatial masking effects.

Locus of fixation was significant at the 1% level, and the interactions of presentation x letter position and presentation x locus of fixation were significant at the 0.5% level. The importance of locus of fixation may be best seen by considering the presentation x fixation interaction. For unilateral presentations, letters were best reported when fixation was centered (75.0%), next when fixation was to the left (58.1%), and poorest when fixation was to the right (50.6%). (For central fixation, the stimuli subtended angles of 2.86° to the left and right of fixation. For end fixations, the angle subtended was 5.73° to the left or right of fixation). For bilaterally presented lines, letters were best reported when fixation was to the left (33.1%), next when fixation was centered (28.7%) and poorest when fixation was to the right of the visual field (22.5%). Collectively, these results suggest that letters nearest fixation were generally better reported than letters farthest from fixation and also that letters shown to the right of fixation were better reported than letters shown to the left of fixation (48.5%, 40.8%, respectively).

The presentation x letter position interaction was similar to that observed in the first experiment. In bilateral presentations, letters in positions 1-4 were better localized than letters in positions 5-8, while in unilateral presentations, letters in positions 5-8 were relatively better localized. This interaction is shown in Fig.II.1.

The interaction of letter position x fixation for the three loci is plotted in Fig.II.2. Here, letter position 1 refers to the extreme left and letter position 8 to the extreme right letters of a bilateral display. Three features of these results are important. First, when fixation was centered, in bilateral presentations

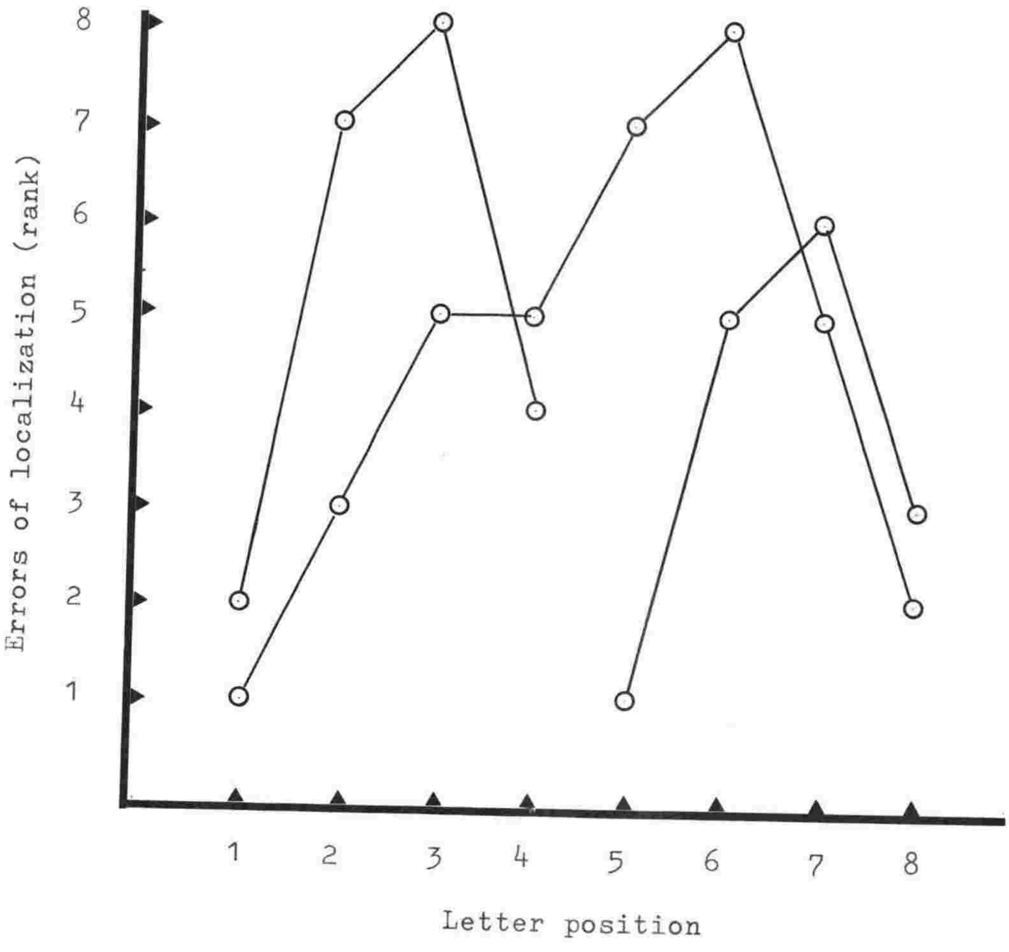


Fig.II.1. Presentation by letter position interaction.

Rank 1, fewest errors; rank 8, most errors.

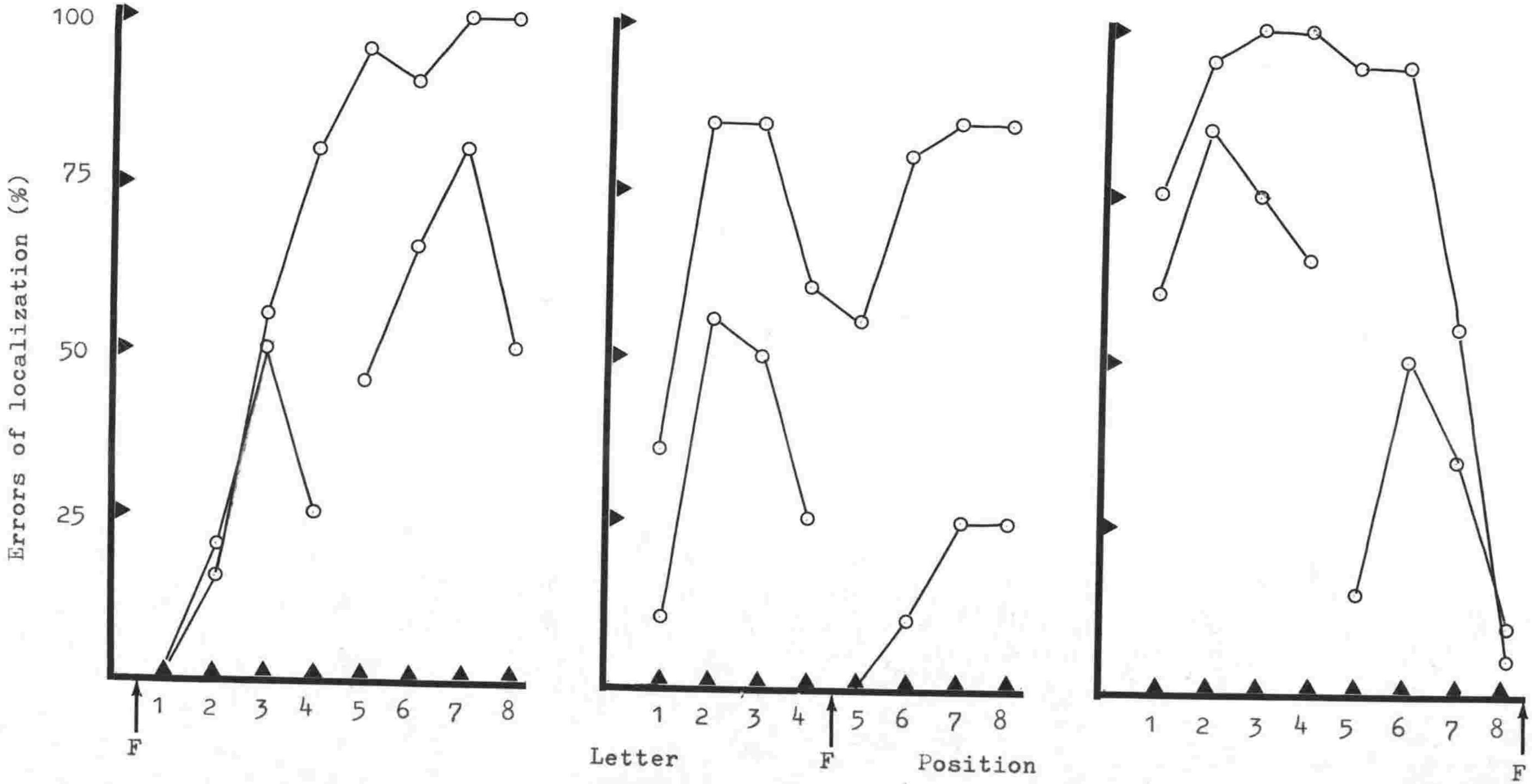


Fig.II.2. Errors of localization by letter position for three fixation loci.

errors were fewest in the LVF while in unilateral presentations errors were fewest in the RVF. Even though the left-most letter suffered fewer errors than those nearer fixation (cf. Experiment I) errors for the latter were still well below those given by Crovitz and Schiffman (1965). Second, the shape of the unilateral error curves suggests that position within the line of elements is a crucial determinant of whether a letter will be correctly reported. This is irrespective of locus of fixation. Third, the shapes of the bilateral error curves indicate that letters were more readily reported when the letters appeared to the right rather than to the left of fixation. For both left and right fixations, the letters were reported in a left-to-right sequence, the order-of-report indices being .93 and .79 respectively.

In this experiment, the analysis of data was based on the correct localization of letters. A plot of identification scores was made to see whether the error functions were peculiar to the method of scoring. For the bilateral condition, 53.1% of the total letters shown were correctly identified. In this condition there were 46.9% errors of omission and 0% errors of confusion. For the unilateral condition, 78.8% of letters shown were correctly identified and there were 11.4% errors of omission and 9.8% errors of confusion. The biggest proportion of errors was attributable to errors of omission and not to errors of serial positioning. The plots of identification scores by letter position for each locus of fixation were not appreciably different from those shown in Fig.II.2.

EXPERIMENT III

Heron (1957) presented stimuli consisting of rows of letters in one visual hemifield and a heavy black line in the other hemifield. He found accuracy was greater for stimuli presented in the RVF, that is, when the arrangement was, black line (LVF)--letters (RVF). This finding contrasted with that found when stimuli were presented simultaneously in both visual hemifields and accuracy was found greater for stimuli presented in the LVF. To explain this hemifield change in accuracy, Heron concluded that "stimulation in the right hemifield must be of a rather specific nature to enhance the scores of the left field. . .before the post-exposure process operates discrimination of the stimulus materials must occur at some level in the system (p.47)." Heron suggests that when letters are presented simultaneously in the LVF and in the RVF, the tendency is to "scan" the stimulus string from left-to-right. Some sort of pre post-exposural mechanism "scans" the stimulus field and dictates, on the basis of the stimulus arrangement, where the post-exposural scan is to commence.

The results of Experiments I and II have shown the following: Under a free report strategy, (a) LVF stimuli are better reported than RVF stimuli when presentations are bilaterally arranged, (b) RVF stimuli are better reported than LVF stimuli when presentations are unilaterally arranged, (c) stimuli are better reported overall when they appear to the right than to the left of fixation, and (d) stimuli are consistently reported in a left-to-right direction. Experiment III examined whether full-field alphabetic or numeric stimulation enhances LVF scores when half-field report is required, and whether the reporting of half-field information in bilateral presentations is similar to that of half-field information in unilateral presentations.

Procedure

Sixty-four cards were prepared, consisting of (a) 16 cards with eight letters spaced across the card, (b) eight cards with four letters spaced to the right, (c) eight cards with four letters spaced to the left of the card's center, (d) 16 cards with eight digits spaced across the card, (e) eight cards with four digits spaced to the right, (f) eight cards with four digits spaced to the left of the card's center. Eighteen bilateral cards had cue-marks above and below the four left hemifield elements and 18 had cue-marks above and below the four right hemifield elements. All unilateral cards had cue-marks, corresponding to the respective information locus. Cue-marks consisted of black lines (0.07° thick and 2.52° wide) placed 1.79° above and below the center of the card, running parallel to and for the length of the relevant hemifield information (see Fig.G.2c).

Each S received 64 experimental trials, broken into two blocks which were run successively. Each block of 32 cards consisted of four cards each of the stimulus arrangements. Within each block, the 32 cards were randomized for presentation. Exposure duration was 100 ms., and viewing was binocular. Five practiced Ss served in this experiment. Ss were instructed to report only the cued (half-field) elements.

Results and Discussion

The mean percentages of correctly localized letters and digits for each condition are shown in Table III.1 with whole-report results from Experiment I included for comparison. An analysis of variance (2 visual fields x 2 presentations x 2 materials x 2 blocks) was performed on the data and the results are shown in Table III.2. Visual field effects were significant at the 2.5% level with 54.53% (2.18 elements per display)

Table III.1

Mean percentages of correctly localized elements

		Partial Report		Full Report*	
		Letters	Digits	Letters	Digits
Bilat.	LVF	41.8	46.9	35.0	45.6
	RVF	61.9	61.9	16.9	26.3
Unilat.	LVF	67.5	61.9	68.8	68.8
	RVF	81.9	76.2	73.8	75.6

* Results from Experiment I

of the elements presented in the LVF correctly localized and 70.47% (2.82 elements per display) of the elements presented in the RVF correctly localized. Presentation effects were significant at the 0.5% level with 53.13% (2.13) of bilaterally presented elements and 71.88% (2.87) of unilaterally presented elements correctly localized. A small interaction between presentation x material was observed. In the bilateral condition, 51.88% and 54.38% of letters and digits respectively were correctly localized. In the unilateral condition, 74.69%

Table III.2

Analysis of variance of correct localization of elements

Source	df	MS	F
Subjects (Ss)	4	6.66	
Visual Field (VF)	1	130.05	16.74**
VF x Ss	4	7.77	
Presentation (P)	1	180.00	37.66***
P x Ss	4	4.78	
Material (M)	1	1.25	<1
M x Ss	4	11.47	
Blocks (B)	1	3.20	<1
B x Ss	4	6.61	
VF x P	1	1.25	<1
VF x P x Ss	4	7.84	
VF x M	1	0.80	<1
VF x M x Ss	4	1.58	
VF x B	1	0.05	<1
VF x B x Ss	4	11.02	
P x M	1	8.45	10.70*
P x M x Ss	4	0.79	
P x B	1	0.20	<1
P x B x Ss	4	1.61	
M x B	1	0.45	<1
M x B x Ss	4	2.17	
VF x P x M	1	0.80	<1
VF x P x M x Ss	4	4.96	
VF x P x B	1	11.25	2.26
VF x P x B x Ss	4	4.97	
VF x M x B	1	3.20	<1
VF x M x B x Ss	4	4.61	
P x M x B	1	2.45	<1
P x M x B x Ss	4	8.42	
VF x P x M x B	1	0.20	<1
VF x P x M x B x Ss	4	3.23	
	79		

*** $p<.005$ ** $p<.025$ * $p<.05$

and 69.06% letters and digits were correctly localized.

Figs.III.2 and III.3 show the plots of errors of localization by element position for letters and digits. These errors include errors of identification, omission and commission.

The results shown in Fig.III.1 suggest that when a partial or half-field report technique is used, differences in hemifield accuracy closely approximate those found with a full-report technique and unilateral stimulus presentations. That is, with bilateral presentations and a half-field report technique, accuracy scores are similar to those observed with unilateral presentations and a full-field or half-field report technique. The relatively poorer scores observed in the bilateral presentation condition may be due to some interference effect. The presence of the redundant non-cued information in the bilateral condition interferes with the recall of the cued information. Whether such interference operates to inhibit the percept, or the organization of the memory trace, or to alter response mechanisms, is not clear (cf. Eriksen & Lappin, 1967).

The element position curves shown in Figs.III.2 and III.3 indicate that very similar error functions were

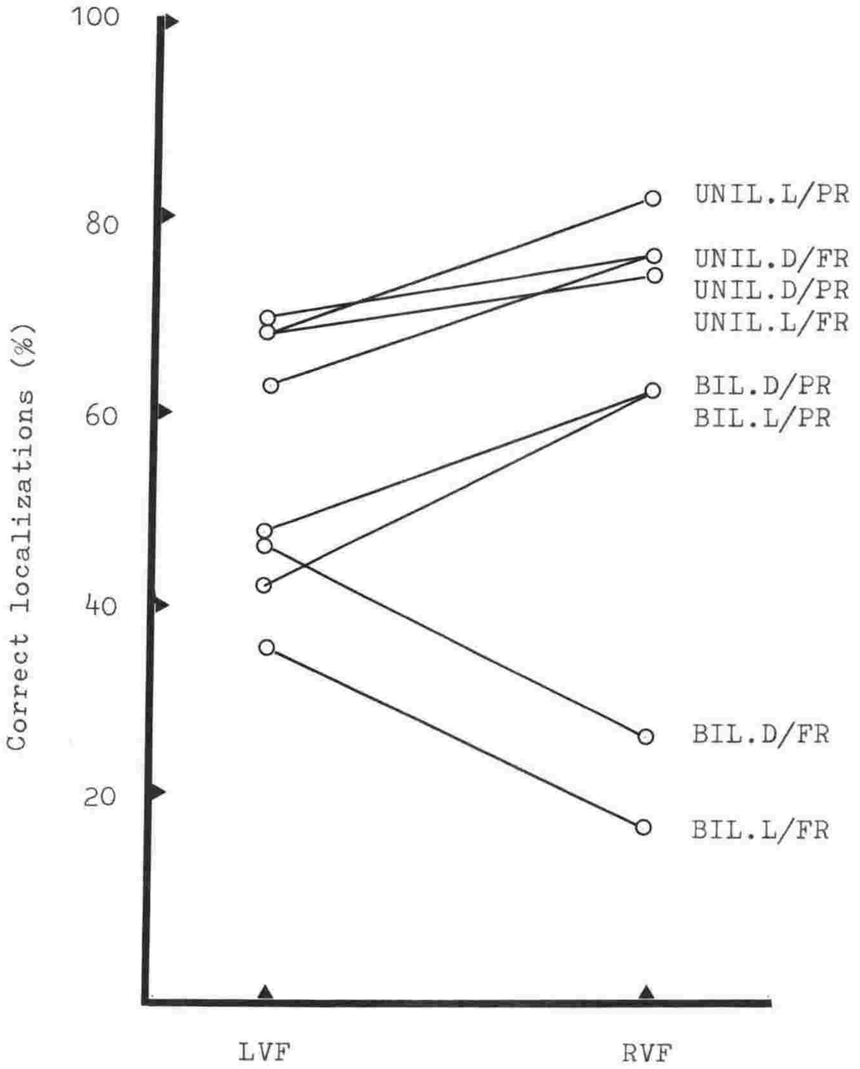


Fig.III.1. Percentage of correctly localized elements by visual field and presentation conditions. PR: partial report (this experiment). FR: full report (Exp.I).

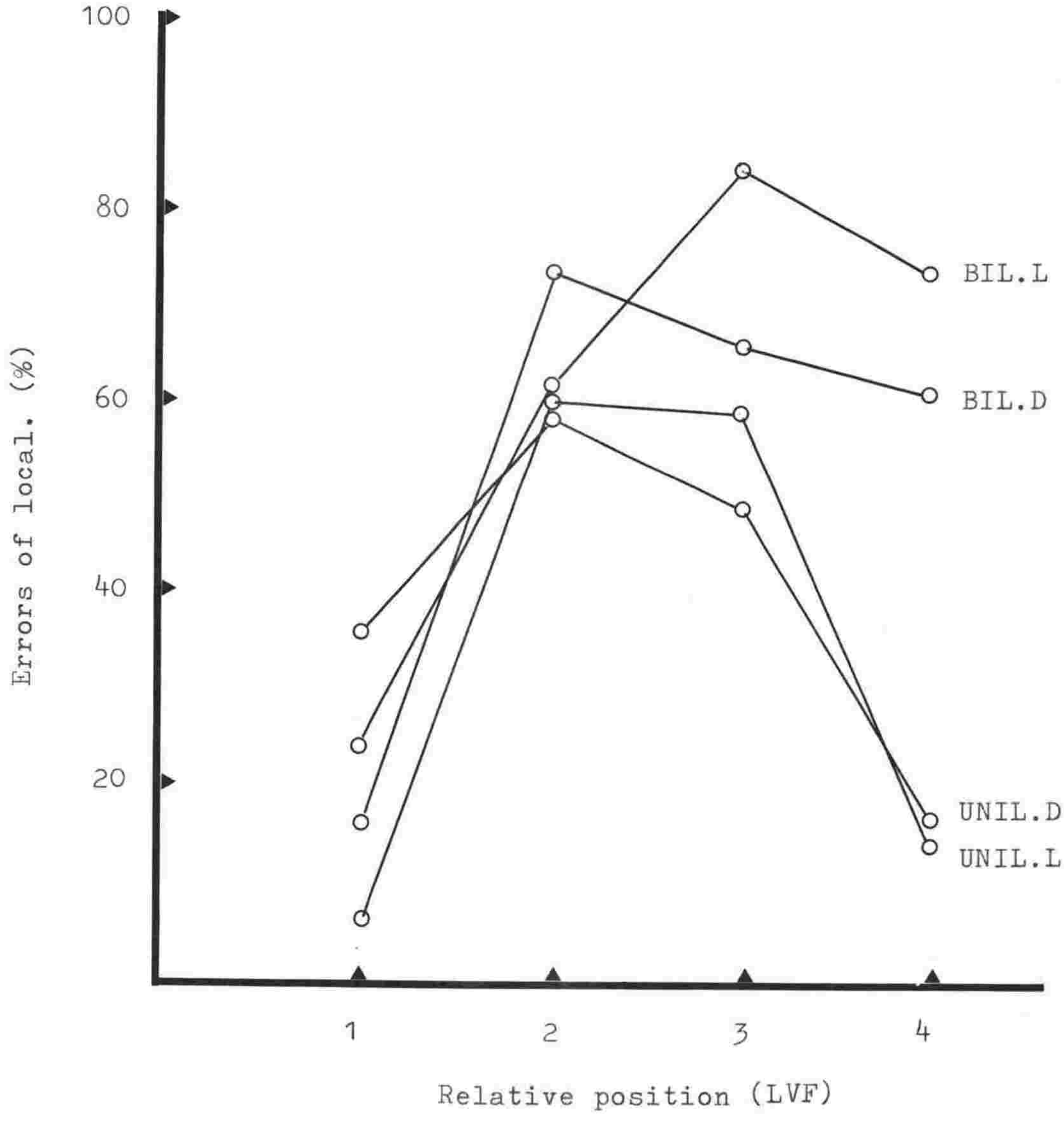


Fig.III.2. Errors of localization by element position for left visual field

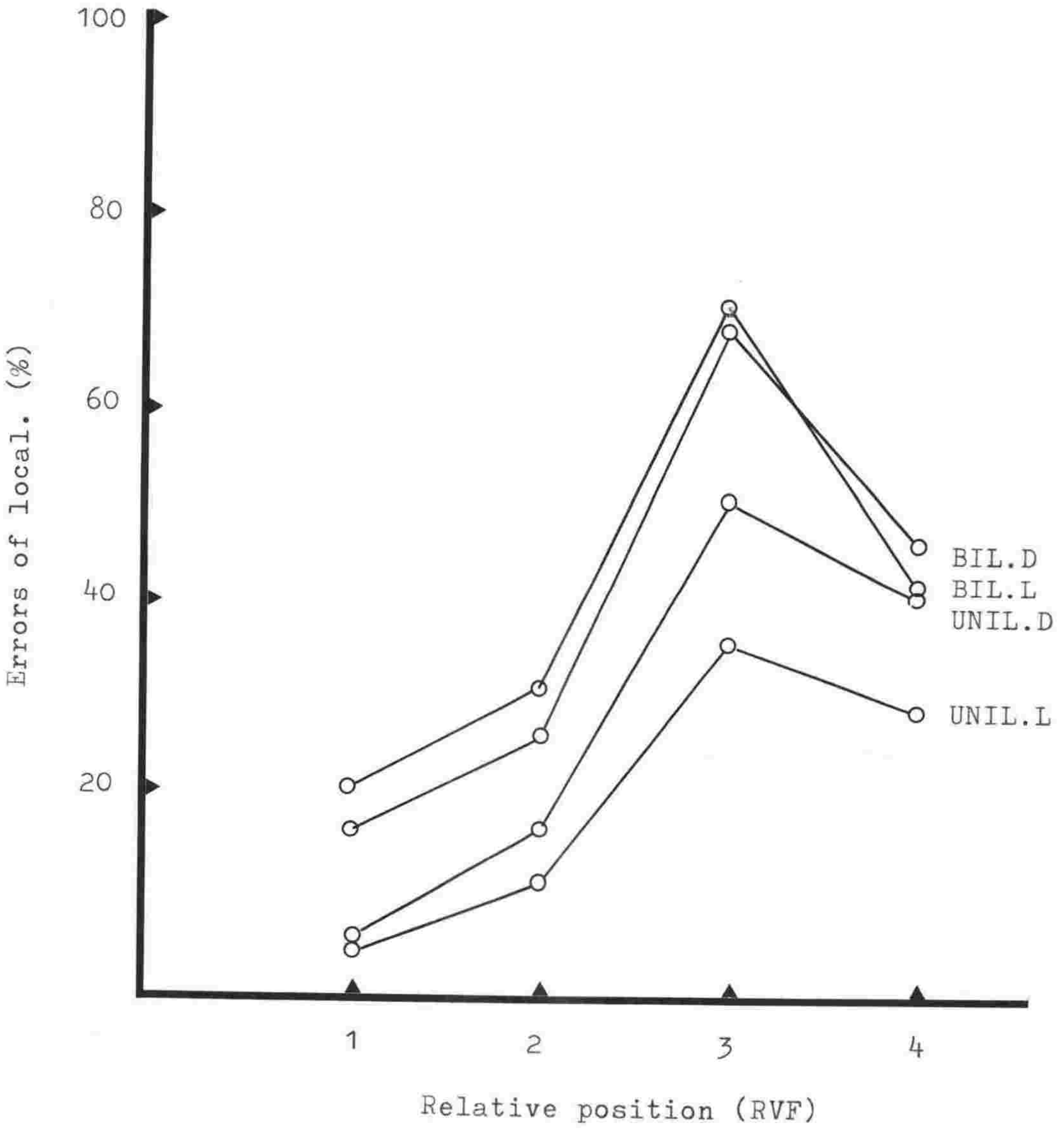


Fig.III.3 Errors of localization by element position for right visual field obtained for unilateral and bilateral stimulus presentations. As in Experiments I and II, errors were not related to the absolute location of an element from its fixation, and the error curves for LVF stimulus presentations were more bow-shaped than those for RVF stimulus presentations. The latter gave a more gradually increasing function outward from fixation.

The results of the present experiment indicate that when Ss are asked to report half-field stimuli from full-field presentations, stimuli in the RVF are consistently better reported. Contrary to Heron's notion, the presence of stimuli in the RVF which are similar to stimuli in the LVF does not necessarily enhance LVF scores. It appears that Ss' information processing systems are capable of making pre-scan or pre-report discriminations. When the partial report cue is presented simultaneously with the stimulus display, the information supplied by the cue is used to determine the commencement and direction of the post-exposural scan. Whether this information must be presented within a finite time for it to be useful is a problem taken up in the next experiment.

EXPERIMENT IV

The purpose of this experiment was to investigate further the relationship between half-field report and differential hemifield superiority. When lines of alphabetic or numeric elements are presented across Ss' visual fields and whole-field report is given, accuracy of element localization is better for the LVF stimuli. When half-field report is given, accuracy is better for the RVF stimuli. This experiment assesses laterality differences under half-field report conditions where the report cue is variously delayed.

Procedure

Forty cards were prepared in the same manner as for the bilateral letter cards of Experiment III. Each card consisted of eight randomly assigned letters spaced across the card. The total was broken into four sets of ten. Subjects were told that after each stimulus card exposure, two horizontal cue lines would appear, directing them to report the left field or the right field letters. Subjects were to withold report until these cues appeared and then report only the cued letters. The stimulus exposures within a specific set were followed by a pre-determined delay leading to the cue exposure. The four delays were 50 ms., 100 ms., 250 ms., and 500 ms. Each set of ten cards was assigned to one of these delays. The order of presentation of delay blocks was 50-100-250-500 for three Ss, and 500-250-100-50 for three Ss. For each set, the five left field and five right field cues appeared in a randomized sequence. The stimulus exposure was 100 ms. and viewing was binocular. Six practiced Ss served in this experiment.

Results and Discussion

Subjects' strategies. Sperling (1960) has noted that differential observing strategies adopted by Ss can lead to divergent results. In Sperling's terms, Ss can divide their (pre-cue exposure) attention equally between the LVF and the RVF, or can anticipate the cue locus, weighting attention in favour of one hemifield. With respect to the last alternative, Sperling has noted a differential error rate for stimulus position for (a) ascending vs. descending trials, and (b) short vs. long delays (1960, pp.8-9).

Fig.IV.1 shows the distribution of correct letter localizations by cue delay for the six Ss tested under ascending and descending conditions. The salient features of these results were that (a) there was little decrement

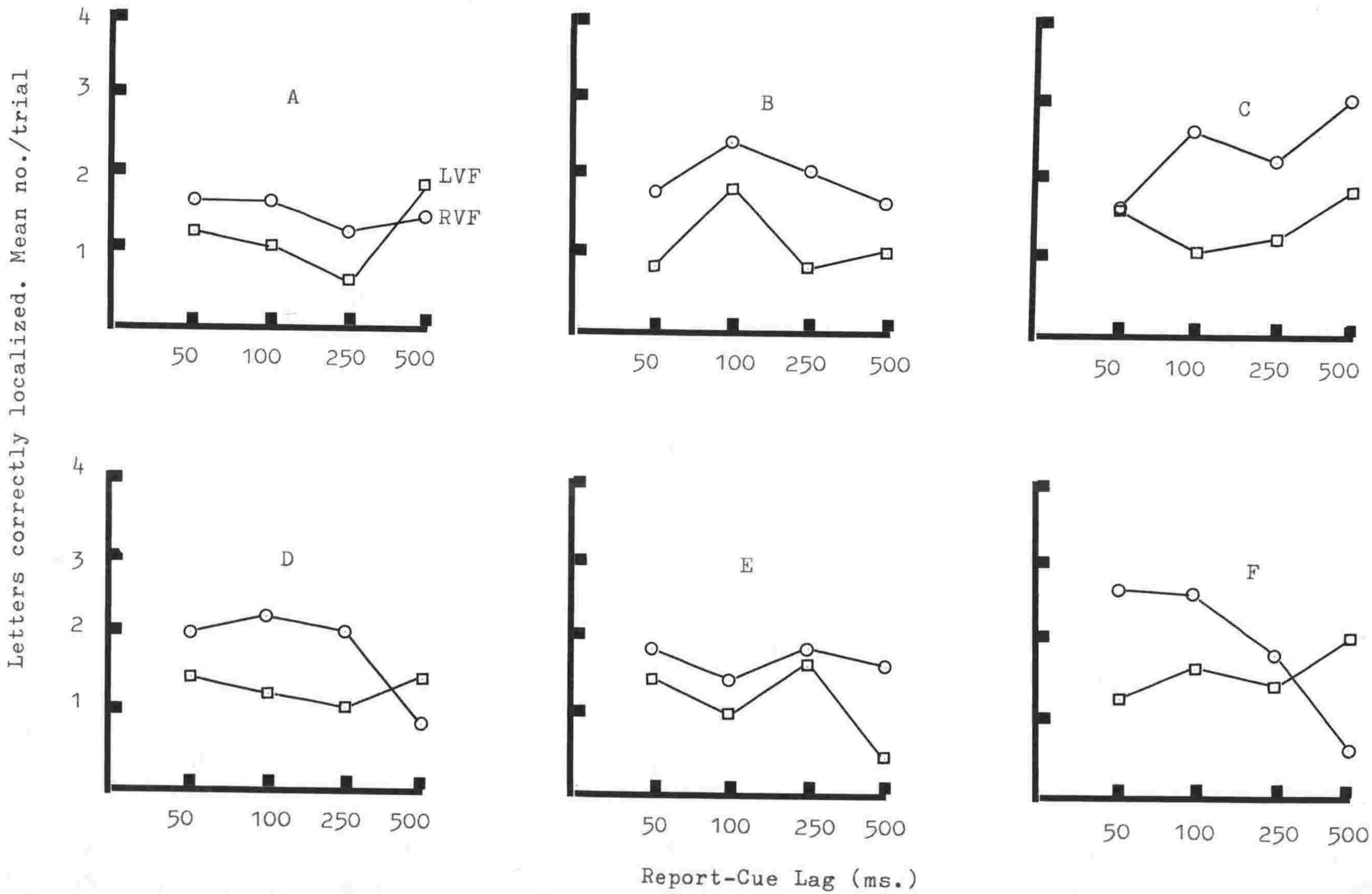


Fig. IV.1. Distribution of scores for six Ss. Top row: ascending trials. Bottom row: descending trials.

in number of letters correctly reported over a 50 ms. to 500 ms. delay lag, (b) with the exception of three _S_s who showed an LVF superiority at the 500 ms. delay, the RVF was consistently reported more accurately, and (c) considerable individual variability in accuracy of report was apparent (cf. Keele & Chase, 1967, p.385).

The fact that little general decrement in correctly reported letters was observed illustrates that the amount of information available to _S_s at a 50 ms. cue delay is essentially the same as that at a 500 ms. cue delay. The individual variability in results does not seem accountable in terms of different observing strategies, as there was no orderly difference between ascending and descending trials, and there was no good reason to assume that at delays in excess of 150 ms. _S_s were adopting a guessing strategy (cf. Sperling, 1960, pp.8-9).

Two conclusions arising from these (individual) results are, first, that information from the RVF is reported more readily than information from the LVF when half-field report is required, and second, that at long cue-delays there is a tendency for some _S_s to report the information in a manner similar to that for full-report bilateral displays.

General considerations. Table IV.1 summarizes the analysis of variance on the data. The results are plotted in Fig.IV.2 and are compared with results from Experiments I and III. The accuracy scores for information shown in the LVF are relatively unaffected by report strategies. In Experiment I where recall of whole-field information was required, the mean percentage of correctly localized letters was 35.8. In Experiment III where half-field report was cued at 0-delay the mean percentage was 41.9. At cue delays of 50 ms., 100 ms., 250 ms., and 500 ms., the percentages were 31.7, 31.7, 27.5, and 35.0. The relative invariance of information accuracy figures may reflect a base-line of information that is available for recall, irrespective of whether this information is cued at 0-delay or at 500 ms. delay, or whether whole-field report is required. That is, whatever determines the rate of processing of LVF information, it is independent of cue delay. Presumably, this determining factor is the rate at which the post-exposural scan is able to process (from center to left to right) the stored trace. The presence of a cue dictating which half-field is to be reported does not facilitate this scanning process.

Table IV.1

Analysis of variance of correct localization of letters

Source	df	MS	F
Subjects (Ss)	5	9.30	
Visual Field (VF)	1	102.08	29.30***
VF x Ss	5	3.48	
Cue Delay (CD)	3	4.61	1.09
CD x Ss	15	4.22	
VF x CD	3	7.92	1.03
VF x CD x Ss	15	7.70	
	47		

*** $p < .005$

The accuracy scores for information shown in the RVF would appear directly related to report techniques. In Experiment I, 16.9% of letters shown in the RVF were correctly localized. At 0-delay in Experiment III, the percentage (for half-field report) was 61.9. At cue delays of 50 ms., 100 ms., 250 ms., and 500 ms., the percentages were 47.5, 53.3, 45.8, and 37.5. Where half-field report cues were given, it would appear that RVF report accuracy is facilitated by the presence of

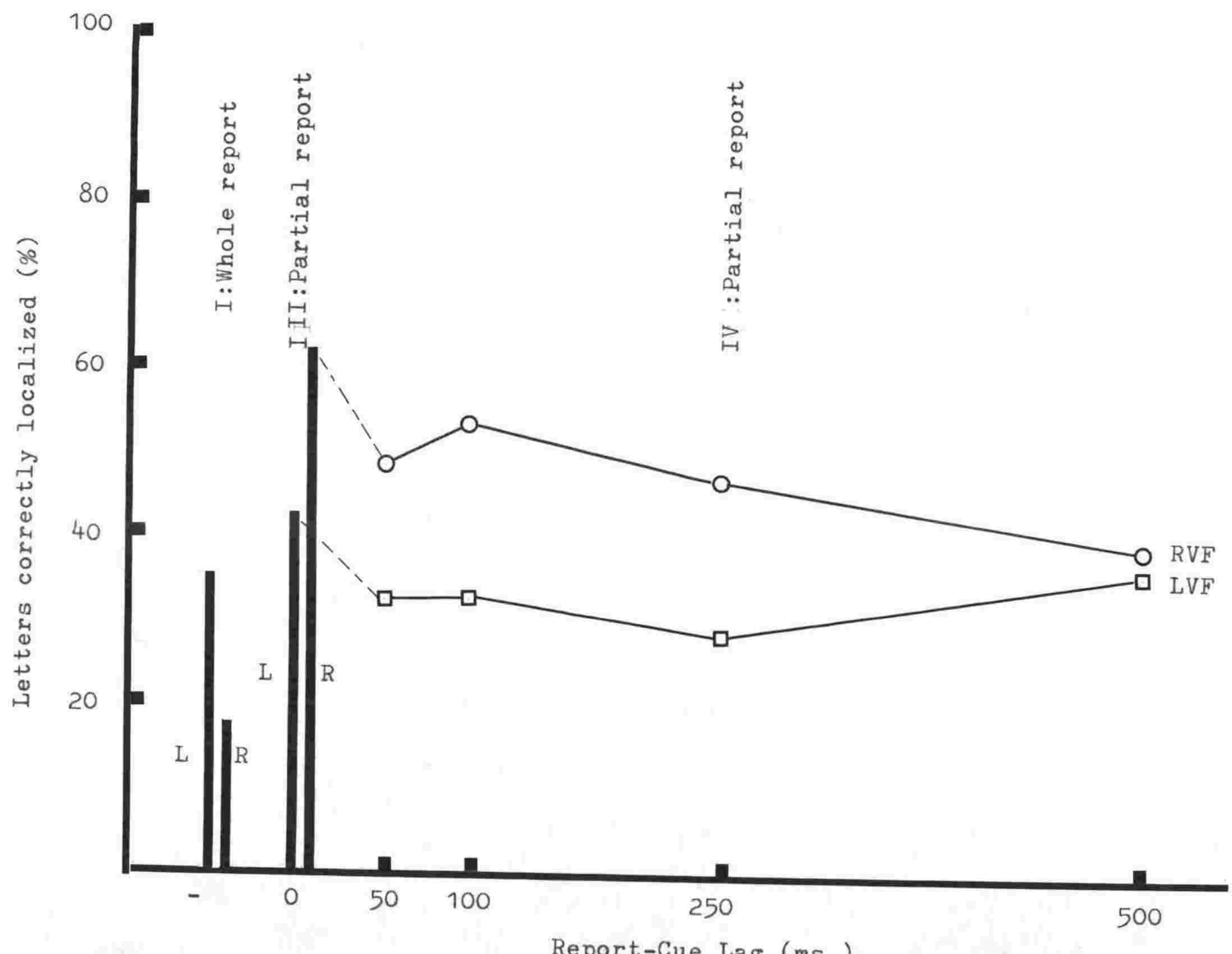


Fig.IV .2. Differential hemifield accuracy as a function of report.

report cues. In short, the difference observed between LVF and RVF accuracy rates may be attributable to the degree with which the RVF information is better scanned or stored than is the LVF information.

Fig.IV.3 shows the plots of errors of localization by letter position. The separate results for each delay condition were obtained first but the difference in errors between each condition for each letter position were small and warranted pooling, except for the 500 ms. RVF data. The distributions of errors were reasonably well matched to those observed in Experiment III. In the present instance, the lower RVF curve had a steeper rise than the corresponding curve in Experiment III. Once again, absolute retinal locus was seen to contribute little to the shapes of these error curves.

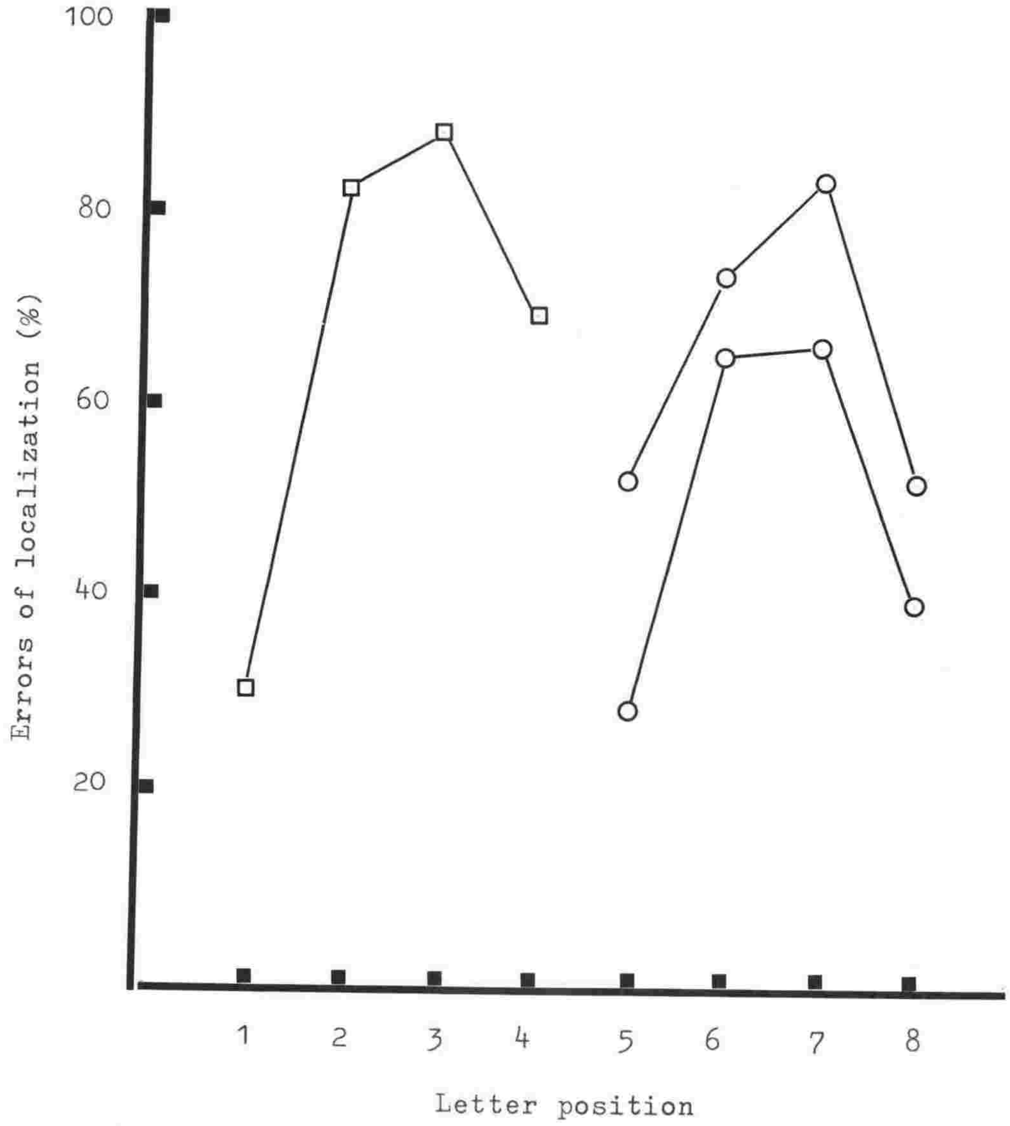


Fig.IV.3. Errors of localization by element position. Left graph: average of LVF data. Right graph: (upper) RVF/500 ms. data; (lower) RVF/50, 100, 250 ms. data.

EXPERIMENT V

One stable feature of the preceding experiments' results is that Ss tend to report the stimuli from left-to-right. Ayres (1966) has suggested that order-of-report may "artifactually" account for laterality differences. Stimuli reported first will be better reported than stimuli reported late. That is, with a right-to-left response sequence, stimuli from the RVF in bilateral presentations will be better reported than stimuli from the LVF. The present experiment examines the contribution of order-of-report to laterality differences, when stimulus displays are composed of bilaterally symmetrical letters, asymmetrical letters, or the mirror-images of asymmetrical letters.

Procedure

Thirty-six cards were arranged in the following manner: (a) 12 had eight letters spaced across the card, (b) 12 had four letters spaced to the right of center, and (c) 12 had four letters spaced to the left of center. Four cards in each of these three sets used bilaterally symmetrical letters (A, M, T, etc.), four cards used asymmetrical letters (L, N, Z, etc.) and four cards used reversed asymmetrical letters (the mirror-images of L, N, Z, etc.). The 36 cards were randomized for presentation.

Each S was told that immediately following stimulus exposure, a card would appear for 2 sec. This card contained a mark placed at the left, or at the center, or at the right of the stimulus string and directed Ss to report the preceding stimuli from left-to-right or from right-to-left. Ss were instructed to report the stimuli outward from the mark. Thirty-six such cards were arranged. Following each trial, Ss localized the letters on a check-sheet and at the same time verbally reported them (in the required sequence) to E. Stimulus exposure was 100 ms. and viewing was binocular. Six practiced Ss served in this experiment.

Results and Discussion

An analysis of variance of the data (2 presentation conditions x 2 visual fields x 3 stimulus materials x 2 orders-of-report) is summarized in Table V.1. For unilateral presentations, 58.8% of letters shown were correctly localized, while for bilateral presentations, 40.3% were correctly localized. Asymmetrical letters were slightly better reported than bilaterally symmetrical letters (55.0% and 53.6%). Reversed asymmetrical letters

Table V.1

Analysis of variance of correct localization of letters

Source	df	MS	F
Subjects (Ss)	5	11.39	
Presentation (P)	1	79.51	39.95***
Visual Field (VF)	1	3.07	1.54
Material (M)	2	20.76	10.43***
Order-of-Report (OR)	1	2.01	1.01
P x VF	1	2.00	1.00
P x M	2	6.17	3.10*
P x OR	1	0.56	<1
VF x M	2	6.93	3.48*
VF x OR	2	0.83	<1
M x OR	2	10.21	5.13**
P x VF x M	2	13.89	6.98***
P x VF x OR	1	0.35	<1
P x M x OR	2	1.27	<1
VF x M x OR	2	0.02	<1
P x VF x M x OR	2	0.08	<1
Pooled interaction	115	1.99	
	143		

*** $p<.005$ ** $p<.01$ * $p<.05$

were poorest reported (40.1%). The significant interactions between material x order-of-report, and presentation x visual field x material are shown in Table V.2.

Little difference in accuracy of report was observed for symmetrical letter displays, whether these were to be reported from left-to-right or from right-to-left. With asymmetrical letter displays however, letters were much better reported when the report sequence was left-to-right. With displays of reversed asymmetrical letters, letters were better recalled under the right-to-left report sequence.

The order-of-report scores, shown in parentheses in Table V.2(a) were calculated as follows: All successive pairs of correct responses were examined for each trial. If N correct responses were given, there were N - 1 such pairs. For the left-to-right condition, the proportion of pairs in which the second response identified a letter anywhere to the <u>right</u> of the letter identified by the first response was determined. For the right-to-left condition, the proportion of pairs in which the second response identified a letter anywhere to the <u>left</u> of the letter identified by the first response was determined. Thus, for the left-to-right condition, a score of 1.00 indicated

Table V.2

(a) Interaction of material x order-of-report and order-of-report scores. (percentage correct)

Material	Left-to-right	Right-to-left
Symmetrical letters	52.6 (0.79)	54.7 (0.57)
Asymmetrical letters	63.0 (0.84)	46.8 (0.48)
Reversed asymmetrical letters	37.5 (0.69)	42.6 (0.71)

(b) Interaction of presentation x visual field x material. (percentage correct)

Material	Unilateral		Bilateral	
	LVF	RVF	LVF	RVF
Symmetrical letters	55.2	63.5	53.1	42.6
Asymmetrical letters	64.6	74.0	47.9	33.4
Reversed asymmetrical letters	46.9	49.0	18.7	45.9

a perfect left-to-right report sequence and a score of 0.50 indicated a random response sequence. For the right-to-left condition, a score of 1.00 indicated a perfect right-to-left report sequence and a score of 0.50 indicated a random report. The mean report scores shown in Table V.2(a) indicate that Ss had little difficulty in reporting all stimuli from left-to-right. Asymmetrical letters were most strongly reported in this direction while reversed asymmetrical letters were least well reported. Under the right-to-left instructions, both symmetrical and asymmetrical letters showed random report sequences. Subjects found it very difficult to report these stimuli consistently from right-to-left. The high report scores for the reversed asymmetrical letters showed however that this material could be reported from right-to-left quite easily. One interesting observation was that Ss reported that they covertly rehearsed the stimuli from left-to-right before reporting them from right-to-left when the required response sequence was right-to-left. This was particularly so for displays of symmetrical and asymmetrical letters.

Table V.2(b) shows that in the unilateral presentation condition, letters appearing in the RVF were overall better reported than letters appearing in the LVF. In bilateral presentations, symmetrical and asymmetrical letters were better reported from the LVF. The trend in these results matches that observed in Experiment I. For bilateral presentations of reversed asymmetrical letters however, letters were better reported from the RVF.

In summary, the present experiment has shown that asymmetrical and symmetrical letters are readily reported from left-to-right but are very difficult to report from right-to-left, while reversed asymmetrical letters are quite readily reported from right-to-left. Report accuracy is dependent upon order-of-report. Asymmetrical and symmetrical letters are best reported under a left-to-right response sequence, while reversed asymmetrical letters are better reported under a right-to-left response sequence. With presentations of reversed asymmetrical letters, letters appearing in the RVF are better reported than letters appearing in the LVF. Order-of-report would not seem as crucial a determinant of laterality differences as is letter structure. Under both left-to-right and right-to-left report instructions, reversed asymmetrical letters are better reported from the RVF while symmetrical and asymmetrical letters are better reported from the LVF with bilateral presentations.

These results may be compared with other order-of-report studies. Ayres (1966) for example, found an association between order-of-report and laterality differences. Stimuli were better identified from the RVF with a right-to-left order-of-report. His stimuli however consisted of rows of filled and unfilled circles (binary elements). The quality of the stimulus information would seem to be an important determinant of how well Ss are able to use different report strategies. Ayres' results are probably not generalizable to studies employing letter stimuli.

EXPERIMENT VI

Common to all laterality difference experiments using multiple-element displays is a task requiring sequential recall of the stimulus information since Ss are required to report the stimuli from the LVF or the RVF or in some directional sequence (e.g., left-to-right, right-to-left). Where the experimental task consists of recalling multiple elements from displays presented at or below 100 ms., memory factors can interact to determine the direction and degree of laterality differences. Indeed, the post-exposure scanning hypothesis advanced by Heron (1957) argues that the rapid decay of stored memory traces is a major determinant of laterality differences. The question arises as to what laterality effects are observed when the total or partial recall of stimulus information is substituted by a task requiring a binary decision as to whether or not a particular letter was in a previous stimulus display. The present experiment was designed to evaluate laterality differences where the "perceptual" and "non-perceptual" components could be meaningfully teased apart. The design and analysis were based on principles of signal-detection theory. The rating procedure described by Egan, Schulman, and Greenberg (1959) was used to develop appropriate receiver operating characteristics.

Procedure

Twenty cards were arranged so that on each card, four letters appeared in four left-of-center positions. On five of these 20 cards the letter "A" appeared at the position 2.40° from center, on five this letter appeared at 1.80°, on five at 1.20° and on five at 0.60° from center. The remaining three letter positions on each card were filled by letters selected at random from the seven letters, H, M, O, T, U, V, and Y. Twenty cards were likewise arranged so that on each card four letters appeared in the four right-of-center positions. These 20 cards were mirror-images of the 20 left hemifield display cards. These 40 cards constituted the signal-plus-noise (SN) stimuli. A corresponding set of 40 cards (four randomly selected letters from the above seven) was arranged with 20 left- and 20 right-of-center display mountings. These constituted the noise (N) stimuli. The choice of "A" as the signal letter was based on

(a) its structural dissimilarity to all noise letters, and (b) keeping signal strength and S/N ratio invariant as opposed to changing the face of the signal from trial to trial (e.g., using "B" as a signal letter).

Each S received 80 experimental trials with 40 SN and 40 N cards. The cards were randomized for presentation except that not more than three cards of a particular hemifield display occurred successively. The a priori probability of signal occurrence was 0.5.

Prior to the experimental trials, Ss were shown eight cards representative of SN and N of left and right hemifield stimuli at an exposure of 150 ms. Feedback was supplied only for these signal-preview trials. Immediately following the stimulus exposure, Ss were required to write on a check-sheet their decision as to whether or not the signal letter was present in the display and to rate their decision on a five-point confidence scale. Ss were informed that one-half of the total presentations would contain the signal letter while one-half would not.

Four very practiced right-handed Ss served in this experiment. Viewing was binocular and exposure was 50 ms.

Results and Discussion

The probability of correct recognition of the signal letter, given by $P(S|s) + P(N|n)$, was .743 for the left visual hemifield condition and .730 for the right visual hemifield condition. No significant difference appeared between correct recognitions for left and right hemifields. Receiver operating characteristics based on the cumulative probability distributions for $P(S|s)$ and $P(S|n)$ are shown in Fig.VI.1. The receiver operating characteristics, fitted by a least squares method, are graphed on normal-normal coordinates. Considering the limited number of trials they are well fitted to the plots. No marked difference was observed between the d_s values, 1.60 and 1.28. The differences in slope may be related to the variance differences of SN and N distributions as shown by the plot scatters. There would appear to be equal sensitivity to a signal letter embedded in a pattern of letter noise, whether the letter appears to the left or right of fixation.

The probabilities of misses, given by $P(N|s)$, of the signal letter for the eight letter positions are shown in Fig.VI.2. Unlike studies which employ serial cues (e.g., Murdock, 1965) no measure of $P(S|n)$ or of $P(N|n)$ were here available for the separate element positions. The error functions observed in the present experiment were more related to an acuity function than they were

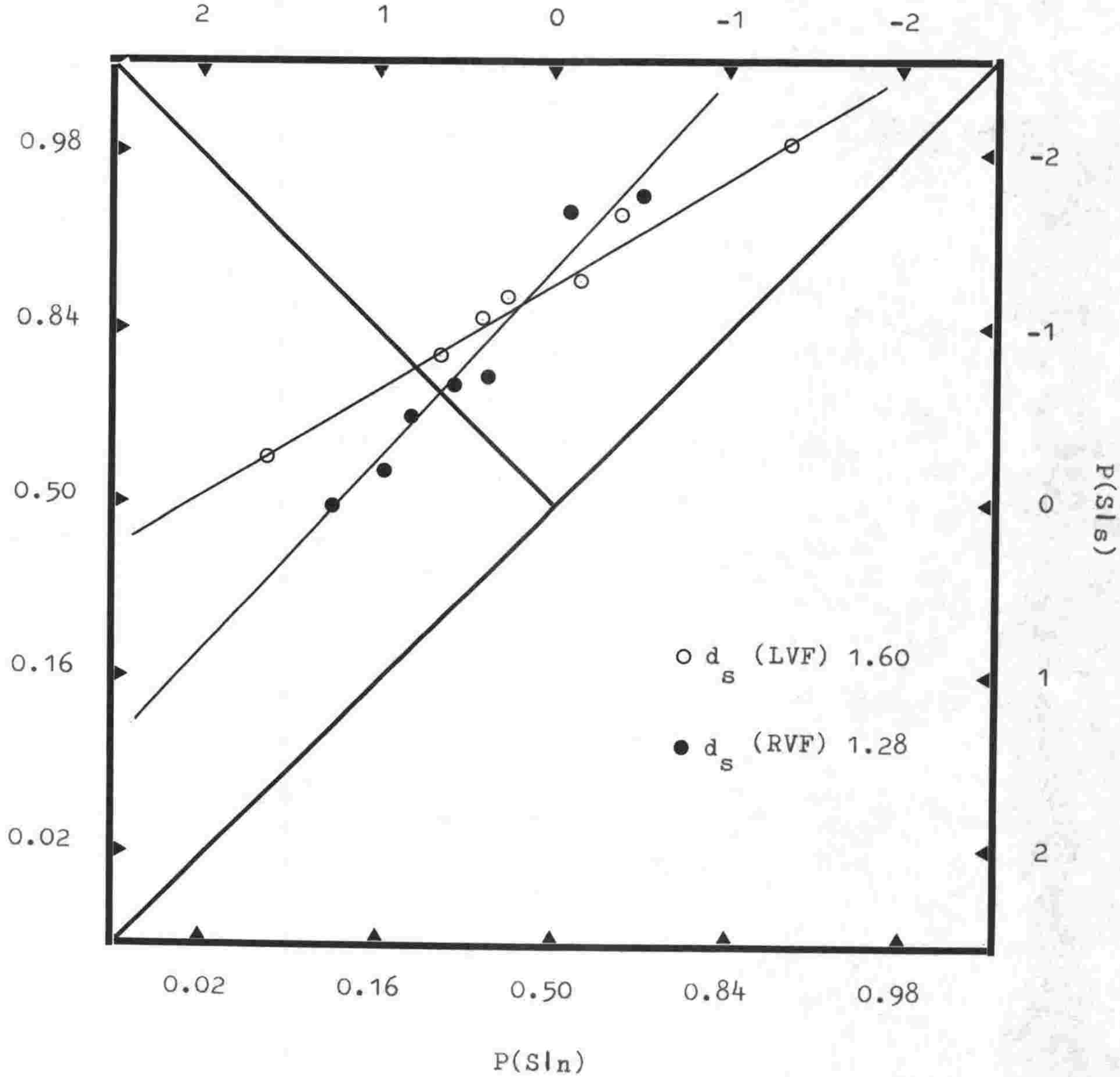


Fig.VI.1. Operating characteristic curves for two sets of cumulative conditional probabilities, plotted on linear normal-deviate coordinates.

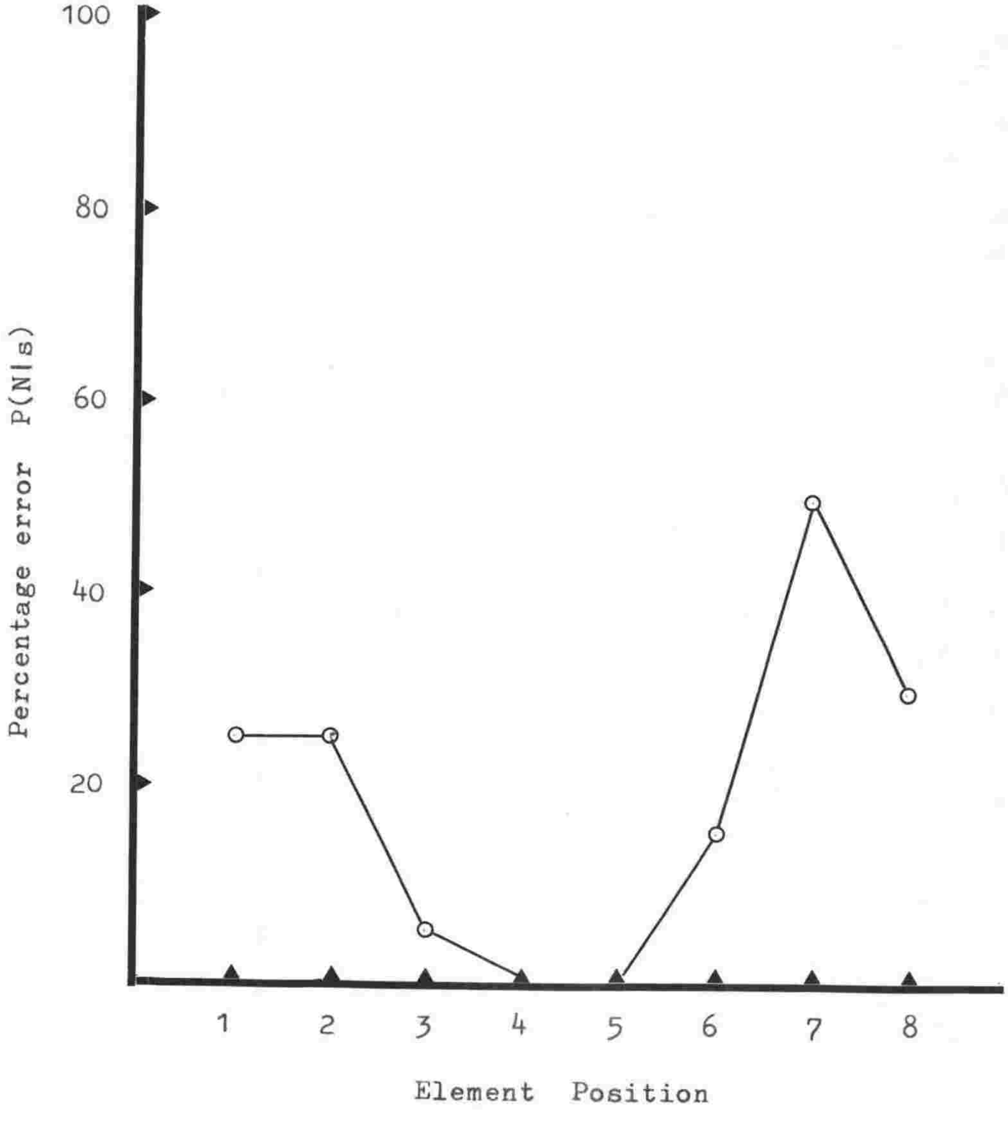


Fig.VI.2. Percentage of errors P(N|s) for signal letter in its absolute location.

bow-shaped (cf. Figs.I.2 and I.3).

The most notable feature of these results is the lack of a laterality difference, demonstrated by the correct recognition scores and the indices of sensitivity, d_s. The findings suggest that some post-perceptual mechanism interacts with the stored trace (or the total information to be reported) to create any laterality differences. Results from an indirectly related study by Winnick, Luria, and Zukor (1967) are in agreement with those found here.

EXPERIMENT VII

The present experiment introduced the variables of handedness and viewing condition to the experimental situation. A number of studies have suggested a relationship between handedness and laterality differences and specifically that right-handers show a tendency to larger visual field differences than do left-handers (pp.37-41 ante). It has also been suggested that the effects of handedness may be demonstrated at certain exposures but not at others (Bryden, 1965). Again, a relationship between viewing conditions and laterality differences has been (equivocally) demonstrated (pp.33-37 ante). Some results indicate that the left eye contributes more to laterality effects than does the right eye. The present experiment investigated the effects of handedness and viewing condition upon laterality differences.

Procedure

There were 54 cards, half with three letters mounted vertically through a point 2.20^{o} to the left of center and half with three letters mounted vertically through a point 2.20° to the right of center. The vertical mounting of letters in this experiment was designed to reduce any "directional scanning" component (cf. Bryden, 1966a). The letters were chosen from the bilaterally symmetrical letters of the alphabet. In addition, nine cards were prepared with three letters mounted vertically through the center of the field. These served as "attentional set" controls. The 63 cards were subdivided into three sets of 21

Subjects were six right-handed and six left-handed persons with no marked differential eye acuity. Acuities were in the range 1.00 to 1.20.

Results and Discussion

An analysis of variance of correctly identified letters is given in Table VII.1 and the distribution of main effects, the interactions between visual field and viewing condition, and between handedness and visual field are shown in Table VII.2.

Handedness was not significantly related to accuracy of identified letters and left- and right-handers performed equally well on the experimental task. A handedness effect was apparent as shown in the data breakdowns in Tables VII.2 and VII.3 and in Figs.VII.1 and VII.2. In Table VII.2 the non-significant interaction between handedness and visual field shows right-handers to have a tendency to greater left-right differences than left-handers. A comparison of the present results with those from a similar experiment (Bryden, 1965) is shown in Table VII.3 and in Fig.VII.1. The present results were not clear-cut and it was conceivable this was due to confounded effects of monocular viewing. The relationship between handedness and laterality differences for the binocular condition is illustrated in Fig.VII.1. It is

Table VII.1

Analysis of variance of correct identification of letters

Source	df	MS	F
Between Ss	11		
Handedness (H)	1	2.67	<1
Ss within groups	10	11.24	
Within Ss	204		
Visual Field (VF)	1	3.63	1.24
H x VF	1	1.85	<1
VF x Ss wg	10	2.92	
Viewing Condition (VC)	2	18.52	22.31**
H x VC	2	2.43	2.93
VC x Ss wg			
Exposure (E)	2	147.50	63.03**
H x E	2	1.76	<1
E x Ss wg	20	2.34	
VF x VC	2	13.92	12.89**
H x VF x VC	2	1.31	1.21
VF x VC x Ss wg	20	1.08	
VF x E	2	3.06	1.92
H x VF x E	2	1.67	1.05
VF x E x Ss wg	20	1.59	
VC x E	4	2.41	1.20
H x VC x E	4	2.09	1.04
VC x E x Ss wg	40	2.00	
VF x VC x E	4	1.46	<1
H x VF x VC x E	4	0.90	<1
VF x VC x E x Ss wg	40	2.16	

** $p < .01$

Table VII.2

Distribution of significant main effects

(percentage correct)

Viewing Condition:	
Binocular	57.2
Left eye	53.3
Right eye	46.1
Exposure:	
80 ms.	65.6
40 ms.	56.3
20 ms.	34.7

Interaction of visual field x viewing condition

	LVF	RVF	D*
Binocular	52.4	61.8	+9.4
Left eye	49.6	57.1	+7.5
Right eye	50.3	41.9	-8.4

Interaction of handedness x visual field

	LVF	RVF	D*
Left-handed	53.1	53.8	+0.7
Right-handed	48.6	53.5	+5.9

* D+ = RVF superiority; D- = LVF superiority

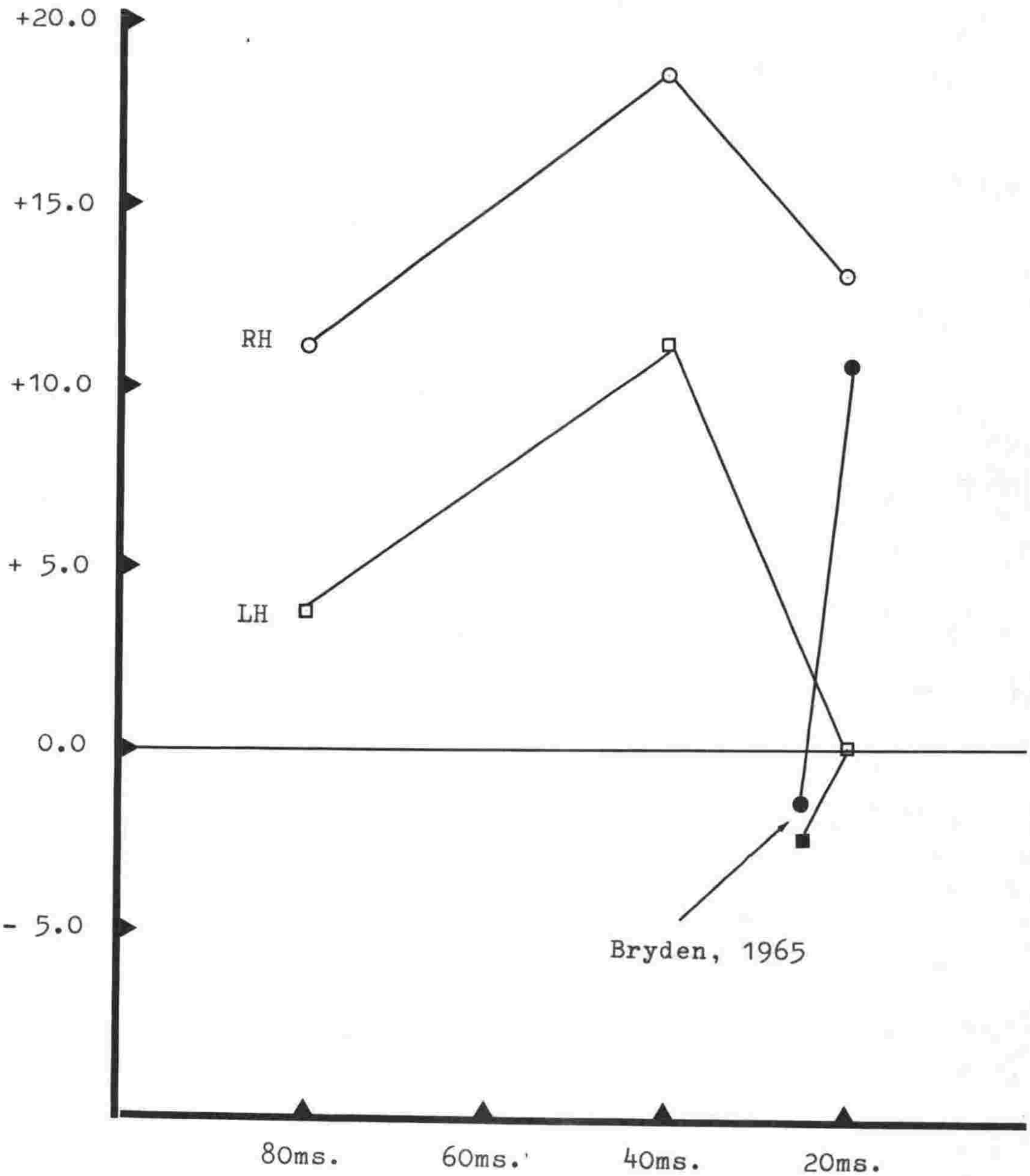


Fig. VII :1. Mean percentage visual field differences by handedness and exposure.

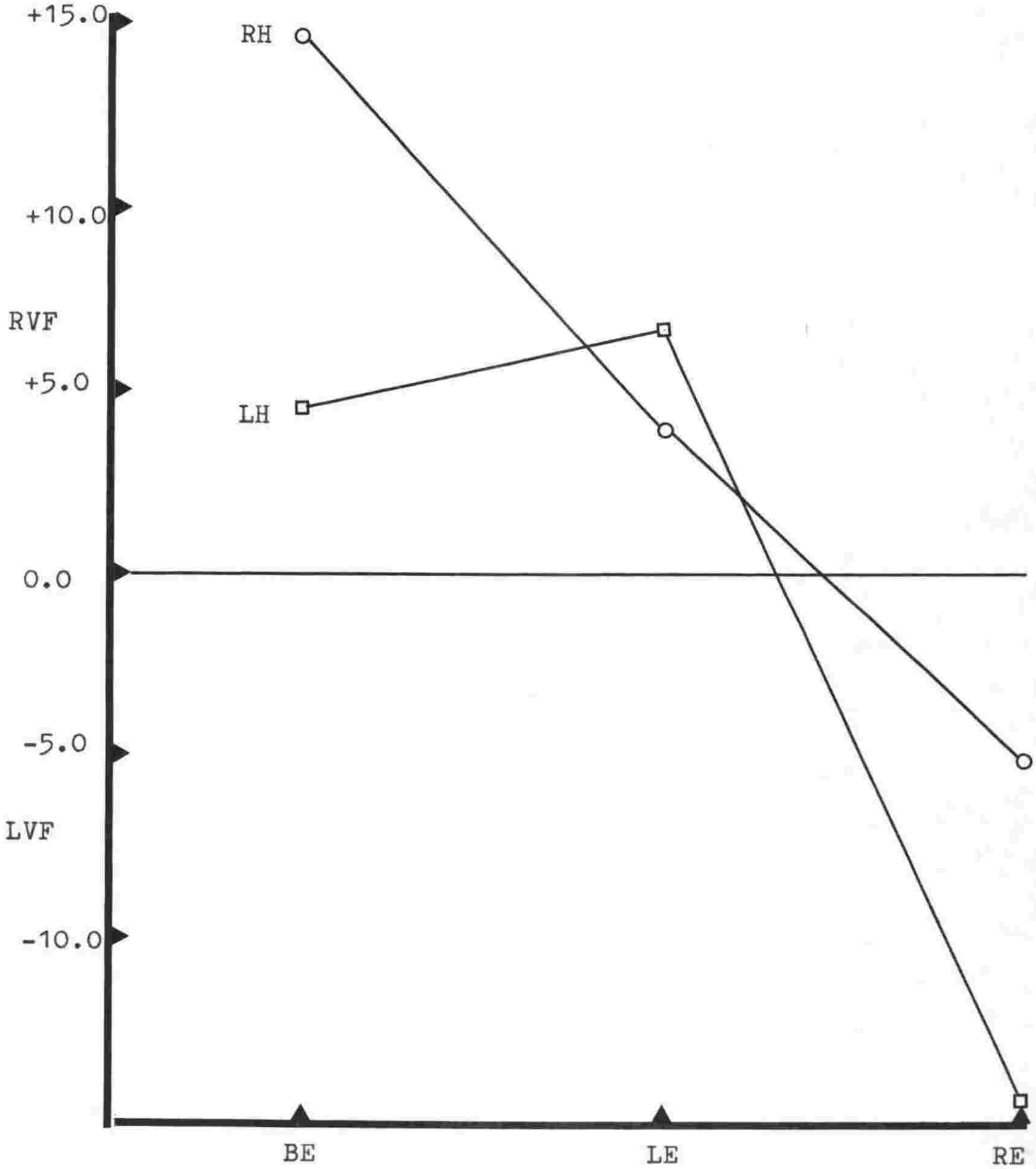


Fig.VII.2. Mean percentage visual field differences by viewing condition and handedness.

clear that right-handers displayed greater left-right differences than left-handers at all exposures. Averaging across exposures it was found that the magnitude of the visual field difference (in the RVF direction) for right-handers was twice that for left-handers. Again, five of the six right-handed Ss showed RVF superiorities while only three of the six left-handed Ss so did. This suggests that cerebral dominance may be a determinant of laterality differences. A group of strong left-handers is likely to include more right hemisphere dominants or ambilaterals than is a group of strong right-handers (Milner, Branch, & Rasmussen, 1964).

The absence of any significant handedness x visual field interaction may have been due to the effects of monocular viewing. Fig.VII.2 indicates that viewing with either eye alone reduced the degree of differential visual field superiority. It might be that handedness effects are observable only under binocular viewing conditions or under monocular conditions only if stimuli are presented dichoptically.

Three points need considering in relation to viewing condition: (a) the superiority of either eye, (b) the direction and degree of left-right differences associated with each eye, and (c) the interaction observed between

Table VII.3

Comparison of present (binocular) results, P, with those from Bryden (1965), B, showing mean percentage differences.

	P	P	B	P	B
	80 ms.	40 ms.	25 ms.	20 ms.	20 ms.
Left-handers	+ 3.7	+11.1	- 2.5	0.0	0.0
Right-handers	+11.1	+18.5	- 1.6	+13.0	+10.6

visual field and viewing condition. Table VII.2 shows the left eye to be better than the right eye for the recognition of letters and Table VII.4 shows results from three comparable experiments. With the exception of the Markowitz and Weitzman (1969) study, there is a general consensus that the left eye is superior. This difference may be explicable in terms of differential acuity. Crovitz (1961) has reported that the ratio of left acuity to right acuity dominant people is roughly 4:3. Thus, a subject sample biased in the direction of right acuity people may give artifactual results showing the left eye dominating the right. In the present experiment, where

Table VII.4

Comparison of present (monocular) results, P, with those from Barton, Goodglass, and Shai (1965), BGS; Overton and Wiener (1966), OW; and Markowitz and Weitzman (1969), MW. (percentage correct)

	Eye	LVF	RVF	D	TR	NR
P	Left	48.0	53.2	+ 5.2	50.7	43.8
	Right	48.2	39.7	- 8.5		
BGS	Left	49.3	63.8	+14.5	52.6	51.6
	Right	41.5	54.0	+12.5		
OW	Left	19.5	37.5	+18.0	32.7	21.7
	Right	28.0	24.0	- 4.0		
MW	Left	40.0	57.0	+17.0	56.5	49.0
	Right	56.0	58.0	+ 2.0		

Exposures: P: geometric mean of 3

BGS: threshold + 10 ms.

OW: 8.5 to 12 ms.

MW: 7.5 to 40 ms.

TR: temporal hemiretinae

NR: nasal hemiretinae

Ss were judged as being of equal acuity in both eyes, some form of acuity difference not apparent under normal testing conditions might have become operative under the conditions of limited exposure, luminance, and peripheral vision.

Table VII.4 also shows the left eye to be generally responsible for an RVF differential accuracy, and the right eye to be responsible for an LVF differential accuracy. Comparison results generally indicate the left eye to be associated with larger left-right differences than the right eye. The present results agree with these to the extent that an RVF superiority was associated with left eye effects. The change of direction of the differences for each eye might be attributed to the stimulus materials employed. The mean difference of the left eye-right eye differences was -1.6% for the present results; +13.5%, +7.0%, and +9.5% for the three comparison experiments' results. In other words, in the present experiment there was no consistent RVF superiority. The stimulus materials used in the comparison experiments consisted of vertically-mounted asymmetrical letters, horizontally-mounted words, and nonsense words. It is thought that asymmetrical letters and horizontal mountings are conducive to greater left-right differences and RVF superiorities than are symmetrical letters and vertical mountings (Bryden, 1966a).

The most interesting aspect of the viewing condition data was the visual field x viewing condition interaction. The left eye was associated with superiority in the RVF and the right eye with superiority in the LVF. The interaction indicated that the stimulus information impinging on the temporal hemiretinae was better reported than that impinging on the nasal hemiretinae. The temporal may have superior acuity to the nasal hemiretinae under conditions such as these, even though peripheral acuity is normally (fairly) symmetrical. This may account for the interaction with the effects cancelling under binocular viewing. Markowitz and Weitzman (1969), using conditions similar to those employed here, have found that horizontal rows of three letters were better recognized from the LVF by the right eye than by the left eye. They also found on a tachistoscopic acuity test that the temporal has superior acuity to the nasal hemiretinae. Such results are in agreement with those cited here.

It was thought that part of the pattern of eye-superiority might be due to differential sighting dominance and Ss were thus broken into groups according to this factor. Only two right-handed Ss and 2 left-handed Ss were unequivocally left sighting dominant, the remaining four right-handed and three of the left-handed Ss being strongly right sighting dominant.

Two interesting points emerged from an analysis of these data (Table VII.5). For both left and right sighting dominant groups the left eye was associated with an RVF differential accuracy and the right eye with an LVF differential accuracy. The degree of these left-right differences was more pronounced for the dominant eye than for the non-dominant eye. It may be that the visual field x viewing condition interaction was jointly determined by the dominant sighting eye and the superiority of the temporal hemiretinae. In other words, for the left sighting dominant group, the superiority of the left temporal hemiretinae created the direction and degree of large left-right differences (+12.4), while for the right sighting dominant group, the superiority of the right temporal hemiretinae created the direction and degree (-9.0).

Two further points arise from these results. For the right sighting dominant group the left eye showed an overall superiority. The degree of left-right difference

Table VII.5

Effects of differential sighting dominance. (percentage correct)

		LVF	RVF	D
Left	Binocular	43.8	69.2	+25.4
Sighting	Left eye	39.2	51.6	+12.4
Dominant	Right eye	44.2	36.7	- 7.5
Right	Binocular	54.8	56.2	+ 1.4
Sighting	Left eye	51.6	56.2	+ 4.6
Dominant	Right eye	50.4	41.4	- 9.0

under the binocular condition was much more marked for the left sighting dominant group than for the right sighting dominant group. No explanations are suggested to account for these results.

EXPERIMENT VIII

This experiment extended Experiment VII which evaluated the effects of viewing condition and handedness upon laterality differences. Here, stimuli were mounted at two spacings from center and were presented unilaterally and bilaterally. Viewing was monocular.

Procedure

Forty-eight cards were prepared: (a) eight cards had three letters mounted 2.20° to the left and three letters 2.20° to the right of center, (b) eight had three letters 1.10° to the left and three letters 1.10° to the right, (c) eight had three letters 2.20° to the left, (d) eight had three letters 1.10° to the left, (e) eight had three letters 1.10° to the right, and (f) eight had three letters 2.20° to the right of center. The letters were mounted vertically through the spacing points. The 48 cards were broken into two sets of 24, each set comprising four each of the above (a-f) arrangements. The sets were presented successively in the order left eye-right eye to half the _S_s and right eye-left eye to half the _S_s. Within each set the cards were randomized for presentation. Half of the stimulus displays consisted of random arrangements from the bilaterally symmetrical letters, A, H, M, O, T, U, V, X, and Y, and half from the asymmetrical letters, E, G, K, L, N, P, R, S, and Z.

Subjects were four right- and four left-handed persons who had served in Experiment VII. (Two Ss from Experiment VII, one with ambiguously dominant sight and one whose recall was exceedingly poor, were not run in this experiment). Exposure was 80 ms.

Results and Discussion

Overall, bilaterally symmetrical letters were better recalled than asymmetrical letters. The mean percentages correct were 59.8 and 46.8 respectively. This may have been due to higher visual confusability for asymmetrical letters (B, E, F, P, R) or to a frequency bias favouring asymmetrical letters. Subjects were also more aware of the symmetrical letter population as it was used in the preceding experiment.

Over all conditions the asymmetrical letters were better reported when appearing in the RVF (Table VIII.1). An unusual feature was that in the 1-space (1.10°) condition symmetrical letters were better recognized in the LVF while asymmetrical letters were better recognized in the RVF. This may imply that laterality effects due to letter structure are minimized at far spacings. Bryden

Table VIII.1

Mean percentage visual field difference for symmetrical and asymmetrical letters.

	Unilateral		Bilateral	
	1-space	2-space	1-space	2-space
Symmetrical	- 2.1	+ 3.0	- 8.3	+ 3.1
Asymmetrical	+ 2.1	+ 1.0	+14.6	+ 5.2

(1968) has argued that recognition differences observed between symmetrical and asymmetrical letters can be interpreted in terms of the former being more readily spatially masked. His stimuli consisted of horizontal rows of letters. The present results, based on vertical arrangements, suggest that something more than simple masking is responsible for the superior recall of symmetrical letters (cf. Table V.2).

An analysis of variance of correctly identified letters is given in Table VIII.2. The letter data were combined for this analysis. Right-handers were superior in letter identification (61.7%) to left-handers (45.6%).

Table VIII.2

Analysis of variance of correctly identified letters

Source	df	MS	F
Between Ss	7		
Handedness (H)	1	128.00	8.81*
Ss within groups	6	14.52	
Within Ss	120		
Presentation (P)	1	180.50	43.08***
H x P	1	0.13	<1
Visual Field (VF)	1	2.54	1.62
H x VF	1	7.03	4.48
Viewing Condition (VC)	1	12.50	4.28
H x VC	1	18.00	6.14*
Spacing (S)	1	162.00	62.99***
H x S	1	2.00	<1
P x VF	1	0.78	<1
H x P x VF	1	3.78	2.41
P x VC	1	6.13	4.47
H x P x VC	1	0.12	<1
P x S	1	10.13	7.13*
H x P x S	1	1.12	<1
VF x VC	1	0.03	<1
H x VF x VC	1	0.03	<1
VF x S	1	0.28	<1
H x VF x S	1	13.78	3.86
VC x S	1	1.13	<1
H x VC x S	1	2.00	<1
P x VF x VC	1	2.28	<1
H x P x VF x VC	1	0.28	<1
P x VF x S	1	0.03	<1
H x P x VF x S	1	2.53	<1
P x VC x S	1	1.99	1.73
H x P x VC x S	1	1.13	<1
VF x VC x S	1	33.65	10.14**
H x VF x VC x S	1	1.16	<1
P x VF x VC x S	1	1.16	<1
H x P x VF x VC x S	1	1.16	<1

*** $p<.001$ ** $p<.025$ * $p<.05$

Of the letters shown in the unilateral presentation condition 63.2% were correctly identified while 43.4% of the letters in the bilateral condition were correctly identified. For the 1-space condition, 62.6% of letters were correctly identified and for the 2-space condition (2.20^{o}), 44.0% were correctly identified.

No marked interaction between visual field and handedness was observed, verifying the previous experiment's conclusions that handedness or cerebral lateralization is a subordinate determinate of laterality differences when viewing is monocular. There was, however, a tendency for handedness and visual field to be associated for the combined spacing conditions. For right-handers, the mean visual field differences were, left eye: +5.7%, right eye: +6.7%, and for left-handers, left eye: -1.5%, right eye: -1.6%. Once again, a tendency for right-handers to show greater and more consistent RVF superiorities was manifested. This agrees with Experiment VII's results. The absence of a general visual field x viewing condition does not, however, accord with the previous results. Two explanations are advanced to account for this. First, a slight interaction existed between handedness and viewing condition favouring the eye associated with the dominant hand. Second, the results were based on the pooled spacing data. A breakdown of the pooled spacing data showed the following: For the 2-space condition, the percentages were for right-handers, left eye: +8.3, right eye: -5.2, and for left-handers, left eye: +14.6, right eye: -5.2. It would seem that whatever determines the visual field x viewing condition interaction is independent of presentation condition and letter structure but is dependent on visual field stimulus position.

The most important feature of the present data was the significant interaction between visual field, viewing condition, and spacing. This interaction is shown in Table VIII.3 and is plotted in Fig.VIII.1. As in Experiment VII, at spacings of 2.20^{o} the left eye was associated with the RVF and the right eye with the LVF. In the 1-space condition, however, the left eye was associated with the LVF and the right eye with the RVF.

Sighting dominance effects may have contributed to this unusual interaction. Subjects were thus broken into sighting groups as in Experiment VII. Here, three Ss were clearly left sighting dominant and five Ss were

Table VIII.3

Interaction of visual field x viewing condition x spacing, by presentation condition. (mean percentage visual-field difference)

	Eye	1-space	2-space
Unilateral	Left	-12.5	+12.7
	Right	+12;5	- 8.3
Bilateral	Left	- 2.1	+10.4
	Right	+ 8.4	- 2.1

Table VIII.4

Interaction of visual field x viewing condition x spacing, by sighting dominance. (mean percentage visual-field diff.)

	1-space		2-space	
Eye	Left Sight.	Right Sight.	Left Sight.	Right S.
Left	-23.6	+ 2.5	+ 9.8	+12.5
Right	+ 5.5	+13.3	0.0	- 8.3

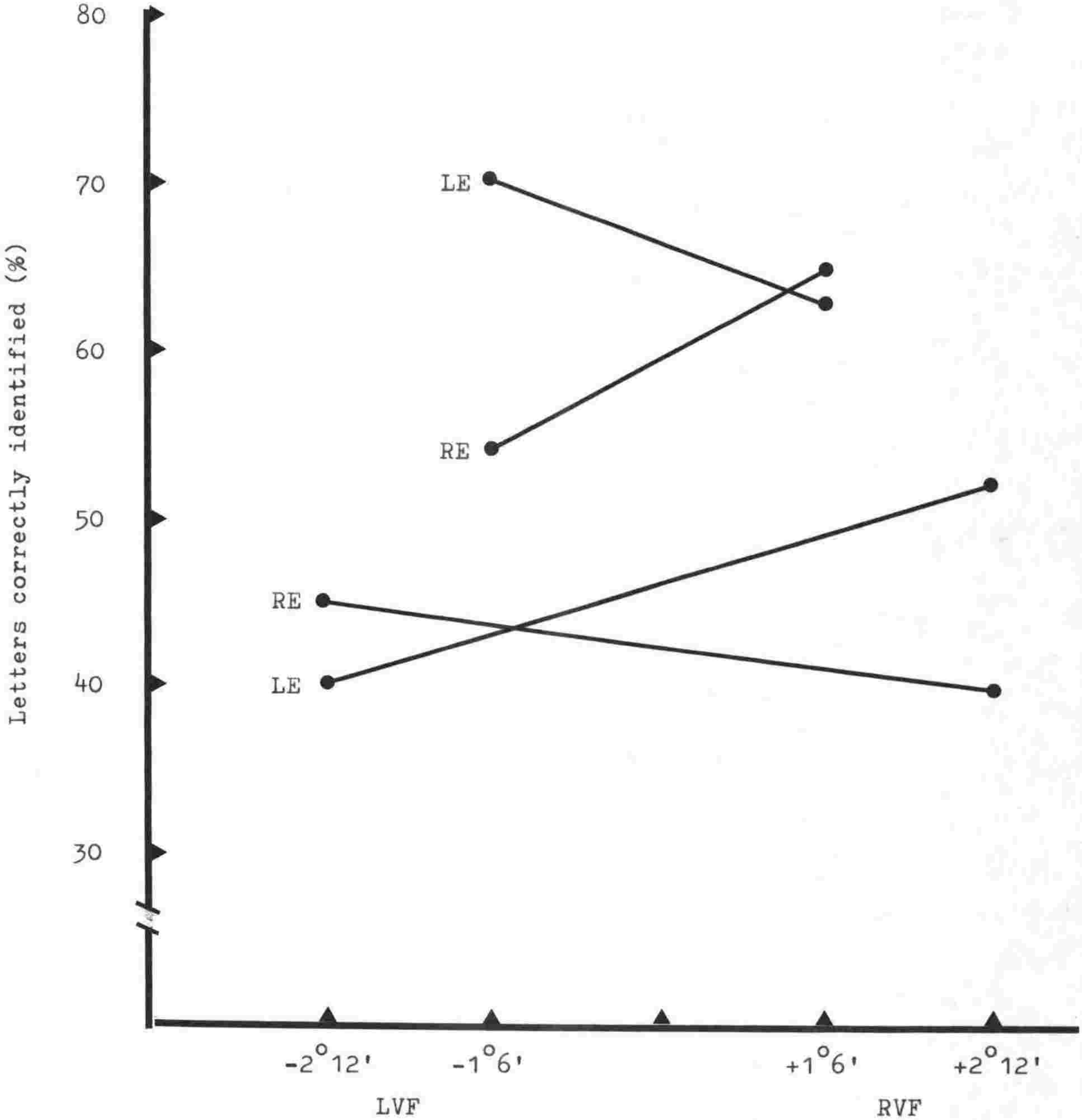


Fig.VIII.1. Interaction of VF x VC x S

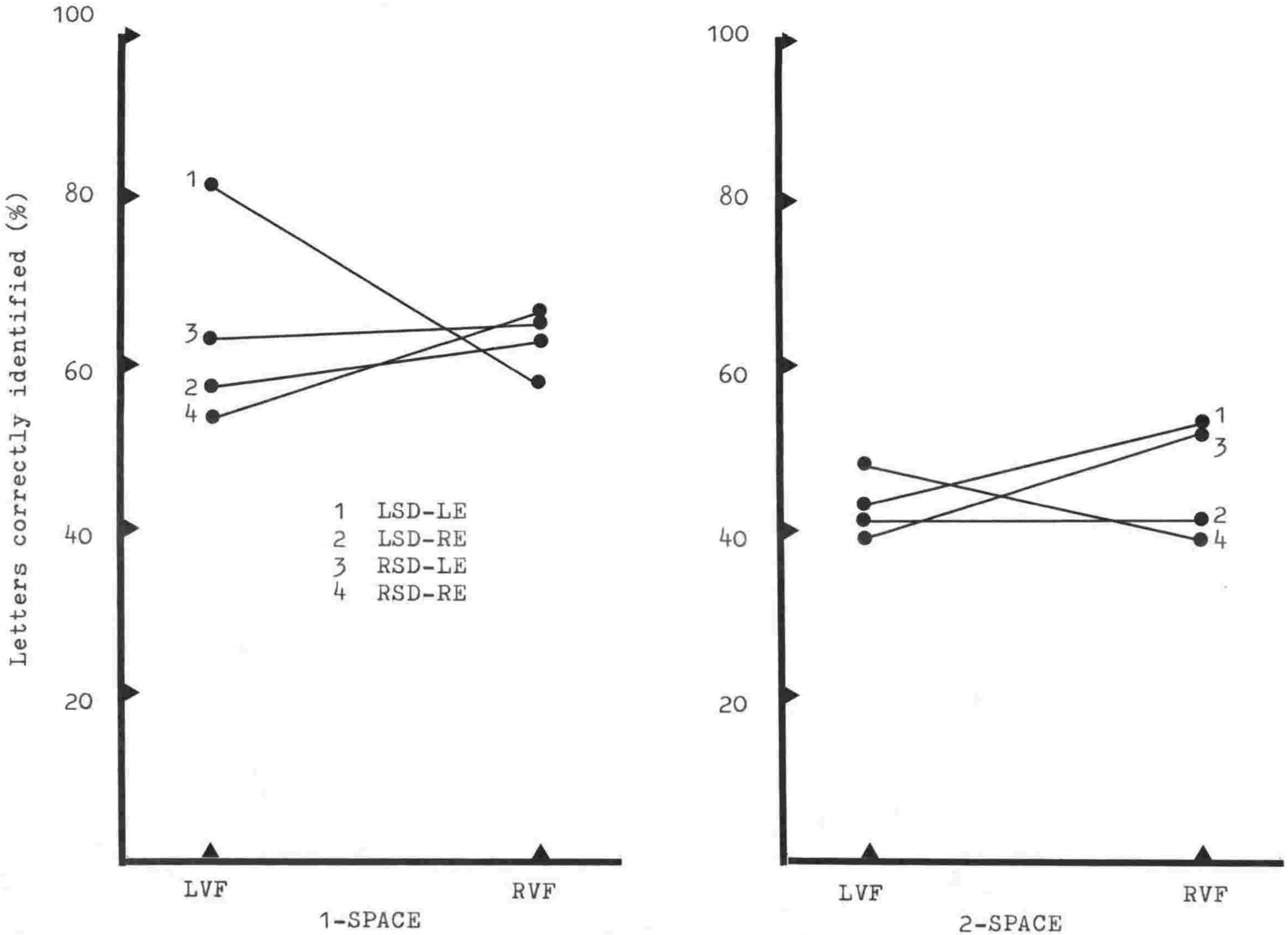


Fig. VIII.2. Interaction of VF x VC x S by sighting dominance clearly right sighting dominant. The relevant data are shown in Table VIII.4 and in Fig.VIII.2. It was apparent that differential sighting dominance contributed to left-right differences observed in the 1-space condition and less so in the 2-space condition. In the 1-space condition, for the left eye, there was an LVF superiority of 23.6% displayed by the left sighting Ss but an RVF superiority of only 2.5% by the right sighting Ss. For the right eye, the major contribution to the left-right differential came from the right sighting Ss.

In Experiment VII, the observed visual field x viewing condition interaction was explained for the left sighting dominant group by the superiority of the left temporal hemiretinae creating the direction and degree of large laterality differences, while for the right sighting dominant group, the superiority of the right temporal hemiretina created the direction and degree. The present results support this interpretation. It may be argued that the visual field x viewing condition interaction for the 1-space condition in the present experiment is largely a function of the dominant eye. The principal contribution to the left eye-LVF, right eye-RVF interaction came respectively from the left eye-left sighting dominant group and the right eye-right sighting dominant group. An implication is that peripheral acuity effects are minimized in the 1-space condition when stimulus exposure is well above "threshold".

SUMMARY OF RESULTS

1. Presentation condition

In Experiments I-V, unilateral and bilateral arrangements of stimuli were presented about a fixation point in the visual field. Unilateral arrangements consisted of four elements spaced either to the left or to the right of the center of the visual field, while bilateral arrangements consisted of eight elements spaced across the visual field. The visual angle subtended by a bilateral arrangement was 5.73°. The randomizing of presentation conditions within trial blocks was done so that effects due to pre-exposure set might be minimized. Previous researchers have tended to present all unilateral or all bilateral presentations within one block of trials. Where Ss are aware that each trial is going to be a bilateral trial, they may unwittingly shift their pre-exposure attention to the left periphery of the visual field in order to accomplish rapid left-to-right "reading" of the stimulus string. Laterality effects observed under these conditions may be attributable to nothing more than a differential foveal sharpening. Randomizing presentation conditions reduces the probability of elements occurring in the LVF from 1.00 to 0.67 and may serve to reduce Ss' pre-exposure attention strategies. In Experiment I an LVF superiority was observed under the bilateral condition and an RVF superiority under the unilateral condition (Table I.1). Throughout Experiments I-V slightly more elements were correctly reported from the unilateral (60.0%) than from the bilateral condition (29.6%). These percentages correspond to mean numbers of elements per display of 2.40 (unilateral) and 2.37 (bilateral).

2. Locus of fixation

The design of Experiment II required Ss to vary their fixation over three points in the visual field (left, center, right). This was done to further investigate the effects of "attentional set". When fixation was demanded at the center of the visual field, elements in the LVF were better reported than those in the RVF with bilateral presentations, while elements in the RVF were better reported than those in the LVF with unilateral presentations. The shapes of the error functions matched those observed in Experiment I (Fig.II.2). The most notable feature of Experiment II's data was that overall, letters appearing to the right of fixation were better reported than letters appearing to the left of fixation.

3. Exposure

In Experiment I, stimuli were exposed at four durations of 100 ms., 75 ms., 50 ms., and 25 ms. No laterality effects due to exposure were observed. The effects of exposure were, however, apparent in two ways. First, reducing exposure seemed to narrow the effective tachistoscopic field to the more foveally-centered stimuli. The shape of the errors functions plotted by element position showed that a marked decrease in correctly reported elements occurred at a 25 ms. exposure, relative to that observed at 50 ms., 75 ms., and 100 ms. (Figs.I.2,3). There may be a critical time span within the limit 25 to 50 ms. where a gross change in information processing occurs (cf. Chaikin, Corbin, & Volkmann, 1962). Second, increasing exposure was related to the starting position of the first correctly reported element. As exposure increased, the report sequence commenced further to the left periphery of the visual field (Fig.I.4). Increasing exposure also allowed for more consistent left-to-right reporting of elements (Table I.3). In all experiments, no exposure above 100 ms. was employed. Effects due to the "artifact" of eye-movement occurring during stimulus exposure were thus obviated.

4. Letters and digits

In Experiments I and III, unilateral and bilateral arrangements of letters or digits were presented about a central fixation point. No laterality effects due to differences in stimulus material were observed. Digits were slightly better reported than letters and this was attributed to digits being better remembered or "stored" for recall than random letters. Digits tended to have lower left-to-right report scores than letters (Table I.3), indicating that the former are less bound by a left-to-right ordering system (cf. Bryden, Dick, & Mewhort, 1968).

5. Partial report

In Experiments III and IV, Ss were presented with unilateral and bilateral arrangements of stimuli and required to report only the LVF or the RVF stimuli. These partial report experiments showed that stimuli from the RVF were consistently better reported than stimuli from the LVF (Table III.1). Contrary to Heron's (1957) proposal, it was observed that when bilateral arrangements of letters or digits were presented across Ss' visual fields, accuracy of report was not necessarily greater for LVF stimuli. Ss were capable of utilizing cues shown with the stimulus exposure, to report half-field information. With half-field report, RVF stimuli were better reported. When the report-cue was delayed by exposures ranging up to 500 ms., the RVF stimuli were still better reported, though there was a tendency for RVF stimuli to be less well reported the longer the cue delay. The reporting of half-field LVF stimuli was not improved by the presence of half-field report cues (Fig. IV.2). In both experiments the shapes of the error functions closely matched those observed under the conditions of Experiments I and II.

6. Order-of-report

Throughout Experiments I-IV, Ss were given a "free strategy" as to the order in which the stimulus elements were to be reported. Nevertheless, a consistent left-to-right reporting strategy was adopted by all Ss (Table I.3). In Experiment I, digits were less consistently reported from left-to-right than letters. In Experiment II, letters were more consistently reported from left-to-right when fixation was to the left of the visual field than when it was to the right.

Experiment V required Ss to report unilateral and bilateral arrangements of letters from left-to-right or from right-to-left. The stimuli consisted of bilaterally symmetrical letters, asymmetrical letters, and reversed asymmetrical letters. Symmetrical and asymmetrical letters were readily reported from left-to-right but were not well reported from right-to-left. Reversed asymmetrical letters were readily reported from right-to-left (Table V.2). For unilateral displays of symmetrical and asymmetrical letters, accuracy of report was better for the RVF stimuli than for the LVF stimuli; for reversed asymmetrical letters negligible laterality effects were observed. For bilateral displays of symmetrical and asymmetrical letters, report was better for the LVF stimuli than for the RVF stimuli while for reversed asymmetrical letters report was much better for the RVF stimuli.

Elements reported first were not necessarily reported more accurately than elements reported late (Fig.I.5). There was a tendency for accuracy of report to be related to position within the response sequence, but laterality effects and error functions were not explainable simply in terms of report order (Experiments I and IV).

7. Response criterion

Experiments I-V used the correct localization of an element as the response criterion. In these experiments, Ss were required to recall the total stimulus information from a display (Experiments I, II, and V) or half-field stimulus information (Experiments III and IV). In Experiment VI, unilateral arrangements of bilaterally symmetrical letters were presented about a central fixation point and Ss were required to detect whether or not a target letter (A) was present in the display. A recognition measure was substituted for a recall task in this experiment. An analysis in terms of signal detectability failed to show any appreciable laterality effects. The signal letter was recognized with equal facility whether presented in the LVF or in the RVF.

8. Handedness, viewing condition, and sighting dominance

The Ss serving in Experiments I-VI were all right-handed and viewing was binocular. In Experiments VII and VIII, Ss were classified into groups of strongly left-handed and strongly right-handed persons. Stimulus displays consisted of arrangements of three bilaterally symmetrical letters mounted vertically in the left or right visual hemifields (Experiment VII) and of three bilaterally symmetrical or asymmetrical letters mounted vertically at two spacings in the left or right, or in both hemifields (Experiment VIII). In Experiment VII viewing was both monocular and binocular and in Experiment VIII only monocular. Effects due to handedness were not significant but a trend was observed in the binocular data showing right-handers to have greater and more consistent laterality differences than left-handers (Fig.VII.1). This trend was observed at exposures of 80 ms., 40 ms., and 20 ms. In Experiment VII, the left eye was observed to be associated with an RVF superiority and the right eye with an LVF superiority. Stimuli impinging on the temporal hemiretinae were better identified than stimuli impinging on the nasal hemiretinae (Table VII.4). These results were confirmed by Experiment VIII. In Experiment VIII, where stimuli were spaced at two positions in the visual field, an interaction was observed between visual field, viewing condition, and spacing (Table VIII.3, Fig.VIII.1). In the closely spaced condition, the left eye was associated with an LVF superiority and the right eye with an RVF superiority. A breakdown of Ss into left and right sighting dominance showed that sighting dominance was related to laterality effects more in the close-space condition (1.10^{o} from fixation) than in the far-space condition (2.20^{o} from fixation) (Table

VIII.4, Fig.VIII.2). The exposure in Experiment VIII was 80 ms.

DISCUSSION AND CONCLUSIONS

When subjects' reporting strategies are not fixed by the experimenter, laterality differences are observed in two ways. Letters and digits are better reported from the LVF when stimuli are presented bilaterally across the visual field, while letters and digits are better reported from the RVF when stimuli are presented unilaterally in the left and right visual hemifields (Experiment I). This effect is independent of exposure. Subjects also consistently report lines of letters and digits from left-to-right. This effect is related to exposure in that decreasing exposure reduces the report consistency.

Heron (1957) advanced the notion of a directional trace-scanning mechanism to help explain these visual field asymmetries. Essentially, his idea was that stimulus elements activate a trace system and that this trace system is "scanned" post-exposurally in an order dictated by learned reading habits or by induced experimental sets. The reporting of stimulus elements is assumed to parallel this trace-scanning process. The traces of letters presented across the visual field are scanned from left-to-right, sequentially. Where the traces are not well-established, as in the case of stimuli presented tachistoscopically, the traces scanned first will be reported more accurately than traces scanned late which may fall below a threshold, before they can be reported. The scanning of traces set up by letters presented in the RVF is accomplished relatively faster than that of traces set up by letters presented separately in the LVF. In the first case, the scan proceeds directly across the traces from left-to-right; in the second, it must sweep to the left-most trace and subsequently back across the traces from left-to-right.

Recently, Bryden (1967) has made a formal statement of Heron's idea in developing a model for serial order in behaviour. The empirical basis for this model resides in the consistent findings from tachistoscopic recognition and dichotic listening experiments that tachistoscopically presented verbal stimuli are reported from left-to-right while non-verbal stimuli are as readily reported from right-to-left as from left-to-right, and that increasing the spacing between verbal stimuli disrupts the normal left-to-right reporting sequence. This left-to-right reporting of stimuli is apparently learned. (Bryden's model is schematized in the Introduction).

English readers scan alphabetic, and to a lesser extent, numeric material, in a left-to-right direction. There is a strong developmental component to this phenomenon since young children do not report stimuli from left-to-right as consistently as do young adults (Gottschalk, 1965; Gottschalk, Bryden, & Rabinovitch, 1964). In adulthood, a very strong left-to-right ordering system has been imposed on this information processing system. The learned aspect of this ordering system has been demonstrated in experiments studying serial order in children and in experiments using Yiddish readers as subjects (Harcum & Friedman, 1963; Orbach, 1952, 1967). There is a strong tendency for native Yiddish readers to recognise Yiddish alphabetic stimuli better in the LVF than in the RVF under unilateral presentation conditions. Some data also suggest that learned Japanese reading habits influence the direction of laterality differences (Hirata & Osaka, 1967).

The learned system which orders our reading and serial behaviour operates in the tachistoscopic recognition situation (cf. Bryden, 1967; Lashley, 1951). Alphabetic stimuli are reported from left-to-right, digits are reported less consistently in this direction, while geometric or binary forms are as easily reported from right-to-left as from left-to-right (Ayres, 1966; Bryden, 1960).

Two broad classes of explanation have been developed to account for laterality differences. One postulates a hypothetical post-exposural scanning mechanism and the other depends on the superior functioning of some physiological structure such as eye sensitivity or cerebral dominance. The latter types of explanation are more task-specific than the former. They cannot, for example, account for the laterality differences observed under the conditions used in Experiments I-VI where control was exercised over these structural factors. Subjects were all right-handed and of reasonably strong right sighting dominance. No subject was used if he showed a visual acuity superiority of more than 20% for one eye over the other. Viewing was binocular. An absolute RVF superiority of the sort that would be expected from a consistent "dominance" hypothesis was not found.

The results of Experiments I-VI are however, generally congruent with what would be expected or predicted from a trace-scanning model of the type developed by Heron (1957), Harcum and Finkel (1963), and Bryden (1967). These results are worth considering in more detail.

The reporting of letters in a left-to-right direction persists even when the locus of fixation is to the extreme right (Experiment II). Letters are not as well reported however, as when fixation is to the extreme left of the visual field. These results confirm the stability of a left-to-right ordering system for English letters. They also support a post-exposural scanning mechanism in that the traces of letters appearing to the right of fixation are more rapidly scanned than are the traces of letters appearing to the left of fixation, before the traces decay.

The direction of laterality differences giving a particular hemifield superiority may fluctuate according to induced sets and experimental instructions (Experiments III and IV). Heron's suggestion that bilateral displays of letters must be scanned from left-to-right is not substantiated. When subjects are required to report half-field information from bilateral displays, the stimuli in the RVF are better reported than are those in the LVF provided the report-cue is not long delayed. If the report-cue is delayed by 500 ms., there is a tendency for subjects to show an LVF superiority. This suggests that the trace-scanning mechanism is capable of commencing in the middle of a trace system provided the report-cue is almost immediate. If the report-cue is delayed the traces are scanned from left-to-right (the usual way) before the cue has registered, thus giving the typical LVF superiority. Considerable variability was found with a partial report, cue-delay technique. Some subjects were capable of "holding" the stimulus information before cue reception for longer periods than other subjects. Nevertheless, report accuracy is not as great from partial report as from unilateral whole report situations suggesting that the trace-scanning mechanism is somehow disrupted or inhibited by the presence of the non-cued (redundant) half-field stimuli.

The importance of the left-to-right ordering system is supported by manipulating order-of-report (Experiment V). Asymmetrical letters are readily reported from left-to-right but not as easily from right-to-left, The mirror-images of asymmetrical letters are, however, quite easily reported from right-to-left. Mirror-image traces presumably set up a strong right-to-left ordering system. Under both left-to-right and right-to-left report instructions, asymmetrical and symmetrical letters are better reported from the RVF than from the LVF with unilateral displays, and from the LVF than from the RVF with bilateral displays. These results, together with the observation that subjects tend sub-vocally to rehearse letter stimuli from left-to-right when reporting them from right-to-left, indicate that it is the order in which the traces are scanned and not the order in which the stimuli are reported which is the critical determinant of laterality differences.

A post-exposural scanning explanation depends on the postulation of a rapidly fading memory trace which is scanned in an over-learned or set-induced sequence. Where the subject is not required sequentially to report a stimulus string but is simply asked to detect the presence of a letter in a string, laterality effects are not observed (Experiment VI). This finding also supports the principle of a trace-scanning hypothesis. The memory component inherent in the sequential report situation is apparently absent from the detection situation. Where a subject is not required to report sequentially a string of information, stimuli in the LVF are reported as accurately as stimuli in the RVF (cf. Winnick, Luria, & Zukor, 1967).

In Experiments VII and VIII, the relationships of handedness and viewing condition to laterality differences were investigated. Some previous results have suggested that right-handed subjects tend to display greater left-right differences than do left-handers. Right-handers have also been found to be superior in recalling letter stimuli from the RVF (Bryden, 1965). These observations are not unequivocal. Bryden (ibid) found a small but significant association between handedness and laterality differences for letters presented at 20 ms., but not at 25 ms. Goodglass and Barton (1963) found no relationship between handedness and laterality differences. The present experiments showed a non-significant trend between handedness and laterality differences. Right-handers had larger laterality differences than left-handers.

The way in which handedness is related to visual field asymmetries of recognition is not clear. The usual interpretation is that right-handers are more left speech dominant than left-handers and so stimuli from the RVF which are transmitted to the left hemisphere are more accurately recognized or recalled by right- than by left-handers (Kimura, 1961). This interpretation is too gross. It is now known that the majority of people are "left brained" for speech, regardless of handedness. It is difficult, however, to determine other relationships between handedness and laterality differences. Handedness is not generally related to visual acuity (Merrell, 1957), and in the present experiments it was not related to sighting dominance.

It is possible that in the present samples more right-handers than left-handers were strongly left speech dominant and this may have determined a slightly larger laterality difference in right- than in left-handers. A further problem arises since this tendency was observed at exposures of 80 ms., 40 ms., and 20 ms., which suggests that handedness and laterality differences are not related only at some critical "threshold" exposure (cf. Bryden, 1965). Dichotic listening experiments have found such a relationship when stimuli are presented for periods up to 3 sec. Handedness and cerebral dominance may be highly related to both visual field differences and to audio asymmetry of recognition when competing stimuli are presented to the hemiretinae or to both ears, or when the task involves the sequential recall of sequentially presented stimuli. It is thought that cerebral dominance is in some way related to the memory organization of sequentially presented stimuli. The role of cerebral dominance in recall situations is much clearer than it is in recognition situations of which the tachistoscopic situation is an example.

The relationship between viewing condition and laterality differences is such that stimuli presented to the temporal hemiretinae are better reported than stimuli presented to the nasal hemiretinae (Experiments VII and VIII). At spacings close to foveal fixation, stimuli from the LVF are better reported when presented to the left than to the right eye, while stimuli from the RVF are better reported when presented to the right than to the left eye. When the stimuli are positioned in the periphery of the visual field, the association between eye and superior visual field is reversed. A complex relationship between sighting dominance, superiority of the temporal hemiretinae and the positioning of stimuli from fixation is therefore apparent. At far positions, the recognition of stimuli is expectedly related to peripheral acuity; at near spacings, recognition is less meaningfully related to differential sighting dominance. Sighting dominance itself is equivocally related to laterality differences (cf. Hayashi & Bryden, 1967; Mangan, 1967). Effects observed under tachistoscopic recognition conditions are not as clearly demonstrated as they are under serial recall conditions (Sampson & Spong, 1961). In these latter situations, stimuli are presented sequentially and are shown more in the center of the visual field at slow exposures.

The experiments reported in this thesis have been concerned with the tachistoscopic recognition of stimuli, where the stimulus exposures have not exceeded 100 ms. In two of these experiments, an attempt was made to assess the roles of handedness, cerebral dominance, and viewing condition to laterality differences but the results of these experiments were inconclusive with respect to the two first variables. Comparable experiments which have been reported in the literature offer results which are also rather inconclusive about the roles of these structural factors. Results from dichotic listening and dichoptic stimulation experiments do, however, show definite relationships. This perhaps suggests that relationships have been sought where in fact none, or only minimal relationships exist. The extensive but equivocal research which has investigated the roles of structural factors in tachistoscopic laterality differences in the past eight years, had its impetus in a suggestion offered by Kimura (1961b) who wrote, "If the relation suggested here between the identification of verbal stimuli and the hemisphere at which they arrive is correct, one might expect a similar effect with visually presented verbal material. That is, since material in the right field first excites the left hemisphere, it should perhaps be perceived more accurately than the same material in the left field (1961b, p.170)." It is now clear that such an "expectation" is over-simplified. One idea which does warrant experimenting, is the role of cerebral dominance to laterality differences when tachistoscopic stimuli are presented sequentially to the same hemiretina .

As mentioned above, the results of the experiments reported in this thesis are congruent with what should be expected from a post-exposural scanning hypothesis. One or two lines for further research are indicated. An interesting finding was the stability of the element position error function. A common bow-shaped function was found in all experiments, excepting in Experiment VI where a signal-detection task was used. The present research was not specifically designed to investigate letter span errors, and it is clear that more work needs doing in this area. Why the error functions are bow-shaped, why stimuli in the middle of displays should be less accurately reported than stimuli at the ends of displays, what role order-of-report has on the letter span error function, are questions for future study. It is also clear that further work needs doing on the developmental aspect of the left-to-right response ordering system. This matter, which is critically related to the mechanism for serial order previously outlined, has received scant attention. Finally, it would be desirable to investigate the spatio-temporal aspects of information processing and serial order. Tachistoscopic recognition and dichotic listening experiments have separately shown the importance of spatial and temporal characteristics on report-sequence and errors of recognition. By adapting the tachistoscopic situation so that stimuli could be presented sequentially as well as in fixed spatial order, more could be learned about the processes underlying visual laterality differences and serial order in behaviour.

APPENDIX I: HANDEDNESS TEST

The form of the handedness questionnaire was as follows (adapted from Crovitz & Zener, 1962):

Hand-Preference Questionnaire

Name:

As part of a study investigating hand-preference and eye-preference you are asked to carefully consider the following questions. Imagine you are performing the activity described, before answering each question. Answer by drawing a circle around the appropriate set of letters appearing to the left of each question, whose meaning is:

Ra = right hand always
Rm = right hand most of time
E = both hands equally often
Lm = left hand most of time
La = left hand always
X = do not know which hand

1	Ra	Rm	E	Lm	La	X:	is used to write with
2	"	"	"	"	"	"	to hold nail when hammering
3							to throw a ball
4							to hold bottle when removing top
5							is used to draw with
6							to hold potato when peeling

7	to hold jug when pouring out of it
8	to hold scissors when cutting
9	to hold knife when cutting food
10	to hold needle when threading
11	to hold drinking glass when drinking
12	to hold toothbrush when brushing teeth
13	to hold dish when wiping
14	holds tennis racket when playing

Is (or was)	your father	left-handed	right-handed
	your mother	left-handed	right-handed
	your sister(s)	left-handed	right-handed
	your brother(s)	left-handed	right-handed

* * * * * * * * * * * *

Every item is scored on a 5-point scale. On items 1, 3, 5, 7, 8, 9, 11, 12, and 14, Ra=1; Rm=2; E=3; Lm=4; and La=5. All other items (2, 4, 6, 10, 13) are scored in the reverse fashion. Items marked X are prorated.

<u>percentage with handedness scores (self-report)</u>
(from Crovitz & Zener; 1059 *Ss*)

	R.	L.		R.	L.
14 - 20	67	0	41 - 50	0	15
21 - 30	31	2	51 - 60	0	35
31 - 40	2	8	61 - 70	0	40

APPENDIX II: SIGHTING TESTS

The Crovitz and Zener (1962) group-sighting test required the following procedure:

S was instructed to sit erect and fixate a point placed upon the blackboard before him. While fixating this point, he was instructed to bring a pencil, which until then had been held vertically with his right (left) hand at his nose into line with the fixation-point. He was then told to close his right (left) eye and to note whether the pencil was still in line with the fixation-point or had shifted to the right or to the left of it.

Twelve trials are given every S in the group test; three each with a specified eye covered and with the pencil in a specified hand. When the right eye is closed, a report of the pencil remaining in line is classed as a left-eyedness report, while a report of the pencil jumping to the right is classed as a right-eyedness report. When the left eye is closed, a report of the pencil remaining in line is classed as a right-eyedness report, while a report of the pencil jumping to the left is classed as a left-eyedness report.

The Miles A-B-C Vision Test (Miles, 1929) required the following procedure:

S was required to sight through a funnel apparatus onto a stimulus display situated approximately six feet from the eyes. The funnel was devised so that it needed to be held in both hands in order both eyes might be covered by the large opening of the funnel. The stimulus displays consisted of arrangements of two separated circles of varying diameter and brightness. S was told the test was relevant to a study on size and brightness constancy. By judicious examination of the visual angle subtended by the horizontal axis of the funnel, E was able to gauge which eye, left or right, S was (unconsciously) using to sight the test objects.

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