INVESTIGATIONS OF VISUAL FIELD ASYMMETRIES

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Chapter One

Introduction to the Field

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If a subject is required to fixate a specific point in a tachistoscope field, prior to and during a stimulus exposure, it is found that his perception of that stimulus, or stimuli, is dependent upon its position within the visual field relative to fixation. The visual field may be divided into sections above and below the fixation point (upper and lower visual fields) and sections to the left and right of fixation (left and right visual fields). The experimental work of Mishkin and Forgays (1952) stimulated the current interest in the left-right visual field asymmetries, although there are earlier reports of work in the field (for example, Anderson, 1946). Mishkin and Forgays (1952) exposed eight-letter English words to either the left or right of a central fixation point for a duration of 150 msecs. They found that words presented in the right visual field (RVF) were recognised more accurately than the words which had been presented in the left visual field (LVF).

Following Mishkin and Forgays (1952) study there has been a proliferation of experiments using a wide variety of methodologies. Mishkin and Forgays presented stimuli in either visual field on any single trial. This has been termed "successive" presentation by some writers. The term, "unilateral" presentation will be used in preference, following White's (1969a) definitive review of the field. A second type of presentation has been called "simultaneous" or, currently, "bilateral" presentation (White, 1969a).

This involves the simultaneous presentation of stimuli in both the left and right visual fields. It typically results in findings different from those obtained under conditions of unilateral presentation. In addition to these two types of stimulus presentation, investigators have used a wide variety of stimuli and required that subjects perform a wide variety of tasks. There have been many explanations of the necessarily diverse findings. Early investigators emphasised the importance of reading habits. Mishkin and Forgays (1952) sought to support the now outdated Hebbian (Hebb, 1949) view of neurological development. In contrast, however, other early investigators, notably Heron (1957) put forward views, which are still worthy of consideration. Heron (1957) argued that the scanning habits, which are acquired in the development of reading, influence the perceptual asymmetries observed in tachistoscopic perception. More recently, as research on human brain functioning has proceeded, it has been suggested that the perceptual asymmetries observed in tachistoscopic situations are related to cerebral lateralisation of function. There is now much evidence to support this view. Although the scanning model of perceptual asymmetries cannot be totally discarded, it has apparently been forgotten.

There would clearly be profound consequences for brain research if such a simple technique does produce results that are clearly related to the functional asymmetry of the brain. Firstly it would permit the study of the "normal" brain. Although much has been gained from work on brain damaged patients, each case is virtually unique and there are problems with the generalisation of findings to other brain damaged and normal individuals. There is the possibility that the normal brain may differ from the damaged brain in some ways. It may, for example, be the case that one hemisphere inhibits the functioning of the other under some conditions in the normal brain. After damage, such inhibition may be released. There may also be a different pattern of load-sharing in the normal brain. Therefore it is useful to study normal subjects.

If the normal brain does differ from the damaged brain, there may be some difficulties in validating visual field asymmetries as a measure of brain function. It would be useful to test brain damaged patients, in whom the site of damage has been well established by other techniques.

Secondly, this testing procedure may be a useful and safe means of assessing brain damage. Thirdly, it may be useful in educational testing. It has been argued that the lack of lateralisation of function in the brain may lead to deficiencies in a child's intellectual development. This subject is, however, still subject to debate.

Before this technique may be used for the testing of individual cases it must be more fully understood than it is now. As yet, there are several problems. The mechanisms, which cause the relationship between functional asymmetry within the brain and perceptual asymmetry in tachistoscopic tasks are unclear. There are two major types of interpretation. These are the direct access and attentional theories, which will be discussed in detail in the following chapter. As cognitive psychology has developed, there has been a move towards the explanation of data obtained from lateralised visual tasks in terms of information processing models. Earlier papers show a lack of precision in the specification of the information processing stages, which may be involved in the processing of the stimulus material used. However, investigators are now becoming more sophisticated. Unfortunately, however, some of this model building has been carried rather too far. Models have been based on data which is not statistically significant (Davis and Schmit, 1973). In some cases its appears that the investigator was so eager to relate hemispheric asymmetry of function to perceptual asymmetry that the data have been explained in a seemingly ad hoc manner in order to make it fit in with some model of differential hemispheric functioning, if not the one originally proposed (Neville, 1976). One of the problems, which information processing theorists have failed to solve, is that of the hemisphere in which a particular type of material is processed. It is rarely possible to determine whether a single hemisphere is involved in the processing of the stimuli or whether both contribute. This consideration may become particularly important if one were to consider the use of lateralised tachistoscopic presentation in a clinical or educational testing situation.

It is of course likely that several factors may contribute within any given experimental situation, to a particular pattern of results. The processes under study are very complex and one would not expect every experiment to give rise to the predicted results. However, it does appear that even relatively minor changes in methodology used in different laboratories can give rise to large differences in results. These differences are often difficult to explain. This would not be a worrying situation if investigators frequently replicated or partially replicated experiments. This unfortunately is not the case. The literature in the field is growing rapidly and although patterns of results do emerge there are few interpretations of the findings in which one can have confidence. A good description of the current situation was given by Neville (1976), who noted that the majority of experiments were designed to investigate which hemisphere is specialised for the processing of the experimenter's particular choice of stimulus material.

Visual field asymmetries are generally very small. They are only observable after the administration of a large number of trials to a group of subjects. This does not constitute a problem for the cognitive psychologist with his stock of statistical procedures. It must, however, be overcome if the divided visual field technique is to be used in the study and assessment of individual cases. It would be undesirable for individual patients to have to suffer a protracted testing session or sessions. A related factor to be considered is that the results of such testing should be reliable. There should not be inter-session fluctuations in the visual field asymmetries observed. There is, to date, very little information available concerning the reliability of visual field asymmetries.

In summary, therefore, it has been suggested that there may be practical applications of what is still a research technique. If the technique is well understood, it may provide a safe and yet effective method of establishing a person's laterality and may be useful in assessing the extent of brain damage. As a research instrument, it would have even greater potential, than has yet been realised, were the underlying mechanisms more fully explained.

This thesis investigates the three major interpretations of visual field asymmetries. In this series of studies a variety of stimulus materials has been presented to normal subjects in several types of experimental situation. The influence of changes in methodology and stimulus materials upon results obtained is discussed. The experiments were performed with the aim of furthering the understanding of the testing technique. The aim was not to describe differences in hemispheric functioning, which may be peculiar to the specific stimuli and methodology used in these experiments.

Chapter Two

A Review of the Literature

A Review of the Literature

The first section of the review will consider studies which have been primarily concerned with the question of the relationship between reading habits and visual field asymmetries. This will be followed by a discussion of clinical studies demonstrating cerebral lateralisation of function, which stimulated cognitive psychologists to consider visual field asymmetries and auditory asymmetries and their relationship to cerebral asymmetry. Studies of auditory asymmetries will be briefly discussed and their relation to studies of visual asymmetries. Finally attention will be turned towards the work on visual field asymmetries, which demonstrate lateralisation of cerebral function.

Reading Habits Theories

There have been several approaches to the problem of the influence of reading habits on visual field asymmetries. Mishkin and Forgays (1952) based their discussion on the findings obtained when words were presented unilaterally. Heron (1957) however, presented stimuli both unilaterally and bilaterally and obtained different results in the two situations. Unilateral presentation of four letters arranged horizontally conferred an advantage on the RVF. Bilaterally presented groups of letters closely spaced and well separated from the fixation point and therefore appearing as two groups of letters produced no visual field asymmetry. When bilateral four-letter groups, which had a wider interletter spacing and therefore appeared as a single eight-letter sequence were presented, a LVF advantage was found, in agreement with Crosland (1931). Heron's (1957) findings led to much research on the use of different types of stimulus materials, the effect of relative stimulus positions and the effects of the order of report of stimuli. These factors will be discussed in turn.

The Effect of Manipulation of Stimulus Materials

There are several ways in which stimulus materials may be manipulated (White, 1969a). Firstly one may consider the comparison of the perception of English and Hebrew words. In contrast to English, Hebrew is read from right to left. Letter strings of different types have been used in order to assess the effect of familiarity and pronouncability of higher order approximations to English. The effect on performance of the introduction of non-letter stimuli into letter sequences has also been studied.

Studies Contrasting the Perception of Different Languages

Mishkin and Forgays (1952) followed their experiment in which they exposed English words unilaterally to the left and right of fixation with one concerned with the perception of English and Hebrew. The subjects in their experiment were said to be "bilingual".

However, their native language was English. Five-letter English words were better recognised when they were presented in the RVF, replicating their previous result. There was no visual field asymmetry in the perception of three- to five-letter Hebrew words. The conclusion drawn was that "anisotropy of visual space" resulting in greater clarity of patterns in the RVF, dominance of the left occipital cortex for vision, selective attention and the disproportionate significance of parts of a word could not account for the data. They concluded by supporting Hebb (1949),arguing that "it appears that a more effective neural organisation is developed in the corresponding hemisphere (left for English, right for Yiddish) as a result of training processes that are specific to the reading of those languages" (p 47). This is a strong interpretation to place on the results of a single experiment, which failed to reject the null hypothesis in the case of Hebrew.

Orbach (1952) adopted the same strategy, using more fluent Hebrew speaking subjects than those who participated in Mishkin and Forgays' study. He also used eight-letter rather than three- to five-letter words, which he presented unilaterally. He found a RVF advantage for the recognition of English words and no difference between visual fields for the recognition of Hebrew words. Orbach (1952) interpreted Mishkin and Forgays' nonsignificant difference between visual fields for the recognition of Hebrew words as a real difference (as did Heron, 1957) and argued incorrectly that his data were in conflict with their data. However, this led him to analyse his data in greater detail and an interesting finding emerged. He divided his subjects into those who had learned English as their first language and those who had learned Hebrew before English. In order to increase the number of subjects in this latter group to allow statistical analysis he included subjects who had learned both languages simultaneously. He found that all subjects recognised English words better when they were presented in the RVF. The subjects, who had learned English as their first language also recognised more Hebrew words from the RVF than from the LVF. However, the other group of subjects recognised Hebrew words in the LVF better than those in the RVF. An unpublished study by Anderson and Crosland (see Anderson, 1946) also found that when English and Hebrew words were presented bilaterally there was an interaction between language and visual field superiority. Unfortunately no statistical evidence was presented in support of the data.

A later study by Orbach (1967) may be considered in this context, although it was influenced by later views regarding the influence of cerebral asymmetry on visual field asymmetries. He reported a study performed in Jerusalem on Israeli subjects. He again found a RVF advantage for the perception of English words when he tested both left and right handed subjects. Right handed subjects recognised more Hebrew words from the

RVF than from the LVF. Left handers showed no such visual field asymmetry for the recognition of Hebrew. Orbach (1967) concluded that both directional scanning and cerebral dominance for language influenced his results. In addition he noted that although English and Hebrew have been treated as though they are different only in terms of the direction in which they are read (Braine, cited in Kimura, 1966, also noted that the letters have opposite directionality) there are other differences between them, in for example, sequential redundancy.

The Effect of the Relative Positions of Stimuli

Heron (1957) explained the phenomena, that he observed, in terms of a post-exposural attentional process related to eye movements, or tendencies toward them. He argued that in reading English there are two opposing tendencies. Firstly there is a scan from left to right in reading a line of text and secondly there is the movement from right to left in order to begin a new line. When alphabetical material is exposed unilaterally in the RVF the tendencies will be acting together in contrast to the conflict that occurs when the material is exposed in the LVF. Under conditions of bilateral presentation the dominant tendency is to move to the beginning of the line and this leads to a LVF advantage.

White (1969b) supported Heron's (1957) hypothetical formulation insofar as it gave, in his view, the best account of his data. White (1969b) mixed unilateral and bilateral trials (as did Heron), which should have controlled for pre-exposure attentional biases. When the subject's task was to identify letters and digits there was no interaction between unilateral and bilateral presentation and visual field. However, on trials where the subjects had correctly identified and localised the letter or digit, the LVF was superior to the RVF in the bilateral condition and the RVF was superior to the LVF in the unilateral condition. Therefore he argued that "(a) elements in the LVF in the symmetrical (bilateral) trials are better localised because their traces are stronger than those in the RVF and by the time the scan reaches the end (RVF) elements, the decaying trace allows for some identification but little localisation; and (b) elements in the RVF in asymmetrical (unilateral) trials are better localised than those in the LVF, for the same reason, and similarly, the decaying trace allows for little localisation relative to identification" (p136).

Heron's (1957) theory requires a further postulation of a top to bottom scanning tendency in order to account for his findings in his experiment three, where he presented groups of four letters arranged in a square in either the LVF or the RVF. He found that stimulus squares in the RVF were recognised better than the LVF squares when they were presented at certain visual angles and under certain instructional conditions. Kimura (1959) found that RVF squares were recognised better than LVF squares when they were exposed for 40 msecs but not when the exposure was only 20 msecs. Unfortunately her significant finding here is statistically suspect as she substituted a Wilcoxon test for a t-test when the latter failed to show a significant difference between the visual fields. The accuracy of report of the letters in the stimulus square went from greatest in the upper left, through upper right, lower left, to poorest in the lower right when the fixation point was placed outside (Heron, 1957) or in the centre (Cohen, R., cited in Heron, 1957; Kimura, 1959) of the square. Kimura (1959) extended the above experiment by placing the four stimuli in the form of a rectangle. This placed the LVF and RVF stimuli further apart than the upper and lower stimuli. In this case the recognition score order was upper right, upper left, lower right and lower left.

The Effect of the Order of Report of the Stimuli

It is possible that results, which have been attributed to a post-exposural attentional scan, may be due instead to the order in which the stimuli are reported. Many of the early experiments failed to consider the effect of report order as distinct from scanning order (Heron, 1957; Kimura, 1959; White, 1969b). It has generally been found that accuracy is greatest for the earliest reported elements in the sequence (Ayres, 1966; Kimura, 1959; Mewhort and Cornett, 1972; Rosen, Curcio, MacKavey and Hebert, 1975) with few exceptions (White, 1969a). In addition one may postulate that subjects scan the material in the order in which they intend to report it and that it is this which determines the scanning sequence rather than reading habits. However, as subjects tend to report material in the order in which they would read it (Ayres and Harcum, 1962; Bryden, 1960; Corballis, 1964; Harcum, Hartman and Smith, 1963; Heron, 1957; Hirata and Osaka, 1967; Kimura, 1959) one would expect that the two alternative mechanisms would produce the same pattern of results in many experiments.

Subjects are more accurate and more consistent in their report order when reporting from left to right rather than from right to left (Mewhort and Cornett, 1972). It is easier for subjects to alter the left to right report order when the stimuli are geometric forms rather than letters (Bryden, 1960), although forms are reported in the same order as letters when the subject is free to choose the order of report (Kimura, 1959). Harcum (1964) found that the left to right order of report is more pronounced with a row of asymmetrical than symmetrical letters. White (1969c) found that the report order made no difference to the accuracy of report of symmetrical letters. Asymmetrical letters were more accurately reported from the left to the right when they were presented in their usual orientation and from right to left when they were presented in the reversed orientation. Subjects always choose to report mirrored words from right to left (Kaufer, Morais and Bertelson, 1975; White, 1969c) if they realise that the words are being presented in this form. When the subjects are unaware that the stimuli are in fact mirrored words, the words are reported letter by letter from left to right (Davies, unpublished finding). Harcum (1966) and Harcum and Finkel (1963) have shown that unilaterally presented English words are better recognised from the RVF but their mirror images are better recognised from the LVF. Naive subjects, however, recognise more LVF words in the usual and mirrored orientations under conditions of bilateral presentation (Davies, unpublished finding). The influence of letter and word orientation on laterality differences is not easily explained by a cerebral asymmetry theory (White, 1973). One could argue that mirrored words and letters are not verbal material and therefore a cerebral asymmetry explanation of the data may be possible (see later section). However, in view of the effects of mirrored material on report order, this latter view appears to be incorrect. It is possible that subjects adopt a deliberate scanning strategy when faced with mirrored words in order to make as few errors as possible, as mirrored words are more difficult stimuli than words presented in the normal orientation. When subjects are presented with mirrored and normally orientated words in a randomised sequence the task of recognition becomes extremely difficult (Isseroff, Carmon and Nachson, 1974).

Increasing the spacing between stimulus elements has been argued to increase the difficulty of scanning the material (Mewhort, 1966). It also leads to a less consistent ordering of report (Bryden, 1966). Crosland (1931) pointed out that good readers show a stronger left to right ordering of recall than poor readers when they are viewing bilaterally presented material. This finding was extended by Kimura (1959) who found that when she introduced gaps and geometric forms into arrangements of letters it had a more disruptive effect on the performance of subjects with little reading experience than on the performance of good readers. Increasing the spacing between bilaterally presented stimulus elements also increases the probability that the fifth letter of an eight-letter horizontal sequence (that is the first letter in the RVF) will be reported and the frequency with which the first letter is chosen as the beginning of the report sequence diminishes (Mewhort, 1966).

Several experiments, using different techniques, have been designed to distinguish between the effects of scanning and those of report order. Mewhort, Merikle and Bryden (1969) used a partial masking technique. Eight-letter pseudowords of zero-order and fourth-order approximations to English were presented tachistoscopically and were masked in either the left or right visual field after various delays. Delaying the mask on the left improved recall of the letters from both sides, in particular it increased the superiority of the recall of the fourth-order pseudowords on the right. Delaying the mask on the right improved recall from the right but had little effect on recall from the left. They argued that the left to right transfer of letters from iconic store to short term memory is obligatory and that it proceeds more rapidly for familiar sequences than for random ones.

Another means of attacking the problem has been to manipulate the order of report. Ayres (1966) controlled the order of report and equalised the pre-exposure set by giving report order instructions before each target exposure. He virtually eliminated the superiority of the LVF under conditions of bilateral presentation. However, this method of controlling report order may merely cancel out the effect of report order so that it is no longer unidirectional. It does not rule out the possibility that scanning of the icon occurs. Mewhort and Cornett (1972) took the approach of signalling the order of report after stimulus exposure by means of a tone. They presented eight-letter pseudowords of first- and fourth-order approximations to English in normal and reversed orientations. They found that the fourth-order sequences were reported more accurately than the first-order sequences, confirming earlier studies. Although the subjects could use the familiarity of the normally orientated sequences when reporting in either direction, the familiarity of the reversed sequences was effectively lost regardless of report order. Therefore, they argued, one could conclude that the materials are scanned in left to right order. A point worth noting in connection with Mewhort and Cornett's (1972) experiment is that their subjects were not told that the pseudowords were sometimes to be reversed. They were simply informed that "some of the sequences might look more like English than others" (p184). The subjects would probably not consider reversal as a possibility and would expect any directionality to be from left to right.

Sequences of letters commonly occurring together in English may be processed as a "chunk" (see for example, Baron and Thurston, 1973). Mewhort (1966) presented evidence for "chunking". He presented pseudowords in which the first four letters were zero-order and the remaining four letters were fourth-order approximations to English. He argued that if the subject guessed letters on the basis of redundancy, his accuracy in reporting the fifth letter of these hybrid pseudowords should be less than in reporting entirely fourth-order sequences. Letters in the fifth position were in fact reported equally well in the two conditions and therefore he suggested that subjects "chunk" the high redundancy segment. In further support of his "chunking" hypothesis he found that the accuracy of report of zero-order pseudowords decreased from position one to position eight, whereas the accuracy of identification of fourth-order pseudowords remained high for five letters in a narrow spacing condition but paralleled zero-order pseudowords in a maximum spacing condition. This may have been thought to explain Mewhort and Cornett's finding. However, Kreuger (1976) argued that the visual familiarity of words persists in the reverse orientation, as he discovered that he obtained superior performance in word recognition in the normal and reversed orientations. He argued that this performance was not due simply to visual familiarity with word and letter gestalts, but also to a higher order, more abstract familiarity at the verbal or nominal level.

A variety of partial report techniques has been used to investigate the influence of report order. Merikle, Lowe and Coltheart (1971) displayed pseudowords tachistoscopically and required report of a single letter. The cue indicating the letter to report was a bar marker presented immediately after the stimulus display and accompanied by a visual noise field. They argued that a scanning model would predict an accuracy curve which decreased from left to right. Their accuracy function was W-shaped. A probe experiment like that of Merikle et al's (1971) may not, however, be an appropriate means of testing a scanning model (Mewhort and Cornett, 1972). To be successful in a probe experiment the subject must code the information spatially and avoid any strategy which would lead to its conversion to temporal information. Secondly, the scanning model concerns the transfer of information from iconic storage to short term memory. It is unlikely that the probe task taps the short term memory store. It is, in fact, more likely to be tapping the iconic store. Coltheart and Arthur (1971) also found a W-shaped accuracy function when they cued subjects post-exposurally to report either the LVF or the RVF of an eight-letter sequence. The shape, they argued, was governed by two factors, 1) visual acuity: in an eight-letter sequence letters four and five are favoured, 2) spatial masking: that is interference produced by adjacent contours, which favours letters one and eight. However, such a report accuracy curve may also be influenced by report order within each visual field.

Fitzgerald and Marshall (1967) presented a row of eight letters for 300 msecs, the subjects having been instructed to fixate at the centre of the row. At the offset of the letter row a tone indicating the visual field to be reported was presented. A full report group with instructions to report all of a row of four letters, which was presented bilaterally, was also tested. They found that although the full report group showed typical LVF superiority consistent with Heron's postulation of a left to right scan, those in the partial report group showed a RVF superiority. This, as they pointed out, is inconsistent with Heron's theory. Fitzgerald and Marshall proposed two explanations. Firstly, the point at which the left to right scan begins may have been under the control of their post-exposure cue, so that their subjects were only shifting attention to the left of the row when cued to report the left four letters. When cued to report the right field letters the scan could begin immediately. It is unclear as to what the subject is doing during the stimulus presentation if this is the case. Their alternative explanation is also, as Coltheart and Arthur (1971) point out, rather strange. Fitzgerald and Marshall (1967) suggest that the scan always begins at the leftmost letter but it has reached the right hand letters at the time of the cue. Therefore this favours the RVF. However the earlier scan of the LVF letters and presumably commitment to short term memory should favour the LVF unless Fitzgerald and Marshall are suggesting that the subject has to rescan them, if the cue requires a LVF report. This interpretation also conflicts with their interpretation of the data from the whole report group. Here they obtained a LVF superiority presumably because the LVF was the first to be scanned. However Coltheart and Arthur (1971) may not be correct in their argument. The post-exposure cue may interfere with the rehearsal of information in short term memory and therefore necessitate a rescanning of information in the LVF when subjects are cued to report LVF material. One important criticism of Fitzgerald and Marshall's latter explanation of their data was made by Coltheart and Arthur (1971) when they drew attention to the fact that if it takes 300 msecs for a scan to reach the RVF letters, then one would not expect increases in exposure duration beyond 50 msecs to have almost no effect on the amount of information reported (Sperling, 1967).

The feature of Fitzgerald and Marshall's (1967) experiment which must lead to its being discarded as serious evidence against Heron's hypothesis is the exposure duration of 300 msecs. This duration would allow subjects to take two fixations of the stimulus. If subjects move their eyes they are also likely to move their eyes to the right than towards the left (Kinsbourne, 1970a; Terrace, 1959). The results of Winnick and

Dornbush (1965), who used an exposure duration of 150 msecs are consistent with the argument that the asymmetry observed by Fitzgerald and Marshall was due to eye movements. Winnick and Dornbush, however, used a spoken post-exposure cue and therefore iconic store would have been lost in the delay in their study.

Smith and Ramunas (1971) presented six letters spaced across the visual field from 1° 31' left to 1° 30' right. The partial report group (that is those reporting one letter signalled after exposure by pressure on the fingers) recalled more than the total report group, in accordance with Sperling's (1960) finding. The total report group showed a LVF advantage while the partial report group showed greatest accuracy for items around the fovea. The total report group's accuracy function declined from left to right. These results are similar to those obtained by Bryden (1966) for single and multiple letter presentations. Smith and Ramunas argued that their findings did not support an obligatory left to right scan unless one were to postulate a scan so rapid that there is no significant decay of the RVF letters before they have been scanned. They argued that the decay appears to occur in the response process. The cueing procedure may however have eliminated perceptual as well as response factors. Kreuger (1976) studied directional scanning using a letter detection procedure. Subjects had to compare a central target letter with the display letters. The display was either unilateral or bilateral. There was a

LVF advantage in bilateral displays and a RVF advantage for the perception of letters in unilateral displays. When subjects were presented with mirrored words, the direction of scan tended to reverse.

The last experiments to be discussed in this section are those in which the stimuli have been presented vertically. This type of stimulus presentation has been used to eliminate left to right scanning tendencies (Bryden, 1970; McKeever and Gill, 1972a). However, there are top to bottom accuracy functions evident when subjects are presented with vertical stimuli. Ayres (1966) presented non-verbal stimuli vertically through fixation and found that subjects report top to bottom on 80% of the trials if they are given the choice. Rosen et al, 1975) presented subjects with two columns of four letters, one in each visual field. The subjects' predominant report order was from top to bottom when they were required to report either the LVF or the RVF stimuli.

Summary of the Research

1) Unilateral and bilateral presentation of stimuli gives rise to different results. The usual finding is that unilateral presentation of verbal stimuli yields a RVF advantage and bilateral presentation yields a LVF advantage.

2) The findings have been argued to arise due to the scanning habits relevant to reading. However, although Hebrew speakers and readers tend to show the reverse

pattern of results to those shown by English speakers and readers when each language is displayed tachistoscopically, this effect is modified by the handedness of the subject. Therefore it appears that cerebral lateralisation of function may be involved in producing different results in left and right handers.

3) It has been postulated that the results obtained which suggest the applicability of a scanning theory may also be due to the effect of report order. The first reported items are the most accurately reported. However, subjects may scan the material in the order in which they are going to report it and therefore the two factors are very much interlinked. Directional scanning of stimulus material may be more necessary when nonword, or mirrored word stimuli are presented as subjects are less able to "chunk" this type of material. The use of partial report techniques to determine which is the important factor in producing accuracy functions has not been very successful, partly because many studies have been methodologically inadequate. It may also be argued that the different accuracy functions obtained under conditions of full and partial report may be due to the different demands of the two types of task. When a subject knows that a full report of the stimulus information is required he may use a scanning strategy, which may help to organise the report of the material. When a partial report is required a scanning strategy would not be necessary in order to organise the material for report.

It does appear that a scanning model, such as that advanced by Heron (1957), may account for most of the data reviewed so far. However it has been suggested that a directional scanning model may only apply to multiple element unilateral and bilateral displays (White, 1969a).

Evidence for Functional Asymmetry of the Brain from Clinical Studies

Many workers in the field of visual field asymmetries have favoured explanations based on the functional asymmetry of the brain. There are two major types of clinical evidence for hemispheric functional asymmetry. The first will be termed lesion studies. These are studies of patients, who have sustained injury to brain tissue either through accident or disease. Some patients have undergone clinical lesioning for a variety of reasons, such as the removal of tumours. Clinical lesions may be relatively small or may extend to the removal of an entire hemisphere. The second area of research will be referred to as the split brain studies. This research has been concerned with patients who have undergone surgical sectioning of the corpus callosum and other neocortical commissures. There are in addition some patients suffering from congenital absence of the corpus callosum and others who have naturally occurring callosal sectioning due to disease processes. The literature in these fields is extensive and therefore only some of the findings which are relevant to a consideration of visual field asymmetries will be reviewed briefly.

Lesion Studies

First to realise in modern times, that as far as language is concerned, the two hemispheres are not equipotential, was Marc Dax, who presented a paper in 1836 before the Congres Meridional. In addition there was an early observation that many aphasic patients showed intellectual impairment more extensive than a simple language disability (Trousseau, 1864, cited in Benton, 1972). This additional disability is principally in abstract reasoning and symbolic thought. Hughlings Jackson in a paper published in 1874 "On the Nature of the Duality of the Brain" (in Taylor, 1958) argued against the strict localisation of language, although he did not deny that a speechless patient most commonly suffered damage to the left hemisphere and in particular to the third frontal convolution, considered by Broca (1865) to be of the utmost importance. The most important point, Jackson considered, was that damage to one hemisphere alone could render a person speechless, thus refuting any ideas of one hemisphere being a mere duplicate of the other. His clinical studies led him to making one of his major contributions, that is, stressing the distinction between the "propositional" and "automatic" use of words. He noted that a speechless person may still possess the automatic use of words and may thus reply to a question with the word "no" or say "no, no, no" in varying tones of voice in order to express emotions. The patient, however, would be incapable of saying the word "no" if requested to do so. Similarly, the speechless patient is unable to formulate simple sentences for himself, although he is able to understand them. As a consequence of these studies, Jackson insisted that aphasia should not only be regarded as a disorder of speech but as a failure of the basis of intellectual processes that underly propositional thought.

Jackson further considered, that in addition to being capable of the automatic use of words, the minor hemisphere (in terms of language ability) may be concerned with perception, the opposite of expression. He subsequently supported this proposal by observations of a patient with a right hemisphere tumour who did not recognise objects, persons or places.

Jackson's views as to the modest role of the right hemisphere in the physiology of speech did not attract much sympathetic attention. The more striking phenomenon of the correlation of language loss with left hemisphere damage usurped the attention of all interested in aphasia. As most neurophysiologists were preoccupied with localisation, or lack of it, of the various functions of the left hemisphere, the right hemisphere was not credited with much importance (Smith, 1974). The left hemisphere was judged to be the "major" or "dominant" hemisphere, implying that the right hemisphere was thought to be "minor" or "subordinate". The right hemisphere was thought to be the equivalent of the left in that it mediated sensation and movement of the contralateral side of the body, but as it played no role in language production or reception (it was thought) it was assumed that it had no distinctive functions. Early reports to the contrary had little effect on the prevailing conceptions of hemispheric dominance (Benton, 1972).

During the 1930's the right side of the brain began to receive attention. New information arose as psychologists began to use tests standardised on "normal" people in studies of neurological patients. These tests included subtests concerned with non-verbal intelligence, unlike earlier testing procedures, which had been solely concerned with language. Greater sophistication was accompanied by numerous data as the reporting of individual cases gave way to the testing of larger populations. Weisenberg and McBride (1935) published the results of an extensive study using a wide variety of standardised tests on over two hundred aphasic and non-aphasic patients. Their results are particularly significant because they found evidence of the segregation of function between the two hemispheres. Patients with right-sided lesions performed poorly on tests involving manipulation and appreciation of forms and spatial relationships, in contrast to patients with left-sided lesions, who suffered language disabilities.

Constructional apraxia was first described among the symptoms arising from left hemisphere lesions, but it was later found to be more frequent in cases where there were lesions of the right hemisphere (Paterson and Zangwill, 1944). When there was a lesion of the left hemisphere patients made drawings carefully but they were poor in content, although those done in the presence of a model were more elaborate. Lesions of the right hemisphere led to a more severe disturbance, drawings being made hastily and without care. The presence of a model in this case was of no assistance (Piercy, Hecaen and De Ajuriaguerra, 1960). Piercy et al (1960) carried out a systematic review of the incidence of constructional apraxia and found that 22.3% of the right-sided lesioned patients and 11.6% of the left-sided lesioned patients exhibited the disorder. An analysis of patients with postrolandic lesions gave a greater difference (37.8% and 16.1% respectively). Piercy and Smyth (1962) reported an experimental study in which all patients with unilateral lesions were given a variety of constructional tasks to perform. Seven out of eighteen left-sided cases and thirteen out of nineteen right-sided cases showed the syndrome. Again the right-sided lesions were associated with more severe disturbance than the left-sided lesions (see Warrington, 1969, for a review of this field).

Despite the usefulness of studying patients with naturally occurring lesions, surgical lesions give clearer information because the investigator has a more precise knowledge of the area damaged by surgery. In 1958, Milner reported her conclusions, which are often quoted, that she reached after a study of over one hundred patients suffering from temporal lobe seizures. Those with left temporal lobe epileptogenic lesions tended to do poorly on all verbal memory tasks, the deficit showing up most clearly and characteristically when they were asked to recall simple prose passages. After left temporal lobectomy the verbal memory deficit persisted and there was considerable impairment even in the initial comprehension of stories. Patients with right temporal lesions had none of these verbal difficulties, but she found that they showed a reliable impairment on a pictorial test (McGill Picture Anomaly Series). They had difficulty in identifying various parts of a drawing. Patients with right parietal lesions did not show impairment on this test but they had difficulty with tests such as Koh's blocks, which are primarily dependent on spatial ability. These specific deficits persisted after lobectomy. Thus it was suggested that the left temporal lobe contributes to the understanding and retention of verbally expressed ideas, while the right temporal lobe aids rapid visual identification.

Removal of a left or right hemisphere, that has matured normally, reveals similar differences between the two hemispheres. After left hemispherectomy all non-language functions remain but language is profoundly impaired and only comprehension reaches normal levels one year after operation. Following right hemispherectomy non-verbal visual reasoning and constructive and spatial capacities are impaired. It has been suggested that there is little evidence for improvement in these functions with time (Smith, 1972).

There are many reviews of clinical work (Goldstein, 1974; Hecaen and Albert, 1978; Joynt and Goldstein, 1975; Oxbury, 1975; Walsh, 1978). While these demonstrate that in the majority of right handed adults the left hemisphere is concerned with language while the right hemisphere is concerned with spatial and visual processes (De Renzi, Faglioni and Villa, 1977; Franco and Sperry, 1977), recent work shows that the distinction between the two hemispheres is not as clearcut as was once believed. There is evidence that patients with left hemisphere damage may be more impaired than a right hemisphere lesioned group on tests requiring discrimination of complex random shapes, which are not readily verbally encodable (Bisiach and Faglioni, 1974). This would previously have been thought to be the type of task performed by the right hemisphere. The right hemisphere correspondingly, is not lacking in linguistic capacity and Moore and Weidner (1974) have suggested that when the left hemisphere is lesioned, the linguistic capacity of the right hemisphere in perception and comprehension is intensified.

Split Brain Studies

The pioneers in this field were Akelaitis and his colleagues, who reported on a series of twenty-six patients who had undergone surgical section of the corpus callosum in an attempt to prevent the interhemispheric spread of epileptic seizures (Van Wagenen and Herren, 1940). These patients, with complete and partial section of the corpus callosum, were subjected to a series of tests (Akelaitis, 1943; 1944; Akelaitis, Risteen, Herren and Van Wagenen, 1942). Their ability to handle objects and the execution of spontaneous, imitative and repetitive movements both unilaterally and bilaterally were tested. Other tests included the writing of dictated and spontaneous sentences with both hands, recognising letters, numerals and sentences by tactile cues alone with both hands and recognising wooden letters presented in both visual fields. There was an almost total lack of symptomatology attributable to callosal damage. Akelaitis (1943) concluded:

"These findings suggest that commissural systems other than the corpus callosum are utilized for the activities tested in the interhemispheric connections between dominant and subordinate hemispheres."

It is surprising that a large neural feature such as the corpus callosum had no demonstrable function. There was no evidence that the subjects showed a greater degree of mixed handedness than the general population and therefore bilateral representation of linguistic functions was thought to be unlikely. As all cases except one were over the age of twelve years, the transfer of information postoperatively was not considered to be a serious possibility. However, not all the callosal sections were performed in a single operation. In many cases the patient suffered a recurrence of epileptic fits after partial section of the commissure and was then subjected to further section. This may have led to a lessening of the symptomatology (Gazzaniga, 1966). Secondly, many of the patients had only partial sectioning of the neocortical commissures when they were tested and therefore they may have had pathways available for the transfer of information between the hemispheres. Thirdly, the testing techniques were fairly crude and patients may have been able to develop strategies for coping with the lessened ability to transfer information between the hemispheres.

Although a syndrome associated with hemispheric disconnection had been identified (Alpers and Grant, 1931; Geschwind and Kaplan, 1962; Sweet, 1941) in non-surgically sectioned patients, the belief that the corpus callosum was not of major importance went largely unchallenged until a series of animal experiments in the early 1960's (Myers, 1961; Sperry, 1961). Utilising more sophisticated methods, they showed that the commissures of the neocortex are necessary for the interhemispheric transfer of learning and memory and for the inter-hemispheric integration of sensory and motor functions involving the bilateral use of hands and paws and the left and right visual fields.

There is more recent human evidence from the study of patients who underwent surgical section of the commissures by Dr. P. Vogel, again for the relief of intractable seizures (Bogen, Fisher and Vogel, 1965; Bogen and Vogel, 1962). The early patients in this series had complete section of the corpus callosum and anterior commissure. The hippocampal commissure is presumed to have been divided along with the corpus callosum and the massa intermedia was also divided in some cases (Bogen, 1969a; 1969b). It is most likely that the operations also damaged the fornix system (Oxbury, 1975). Later patients in this series did not have complete section of the commissures (Gordon, Bogen and Sperry, 1971). The anterior commissure and a major portion of the corpus callosum were divided but the splenium of the callosum was spared. The two patients (NF and DM) described by Gordon et al (1971) were roughly comparable in terms of the spared region of the commissures with the naturally occurring cases described by Sweet (1941) and Geschwind and Kaplan (1962). There is now another series of patients with partial disconnection operated upon by Dr Wilson (Gazzaniga, 1977; Gazzaniga and Le Doux, 1978; Le Doux, Wilson and Gazzaniga, 1977; Risse, Le Doux, Springer, Wilson and Gazzaniga, 1978). The experimental study of the earlier Vogel patients showed that there are few readily noticeable symptoms of callosectomy (Sperry, Gazzaniga and Bogen, 1969). Highly practised daily activities involving integrated bilateral actions such as tying shoelaces and bicycling show little, if any, impairment after surgery. However, appropriate testing techniques can reveal measurable deficits (Gazzaniga, Bogen and Sperry, 1963; Zaidel and Sperry, 1977). Sperry and his colleagues used a divided visual field technique to present information selectively to each hemisphere. Under these conditions they found that patients are able to verbalise material presented in the RVF (to the left hemisphere) but are unable to verbalise information presented in the LVF (to the right hemisphere). The numerous cross integration deficits of patients with complete commissurotomy have been reviewed by several authors (Bogen, 1969a; 1969b; Gazzaniga, 1967; 1970; Sperry, Gazzaniga and Bogen, 1969). Patients with complete section have provided no opportunity for studying modality specific aspects of the transfer mechanism. Neuropsychological testing of patients with only partial section of the commissures has enable more specific localisation of some modality specific information traversing the corpus callosum and anterior commissure (Gazzaniga, 1978). Fibres of specific portions of the system transfer particular types of information, although the anterior commissure appears to be capable of mediating multi-modal interhemispheric transfer, that is, visual, auditory and olfactory information (Risse et al, 1978). A patient with only fibres of the splenium intact however, can transfer visual information but not tactile information (Gazzaniga, Risse, Springer, Clark and Wilson, 1975). Interhemispheric visual communication is severely disrupted with section of the splenium and partial section slows transfer of visual information (Gazzaniga and Freedman, 1973). The Wilson series of patients does show, however, that a particular neural structure can vary greatly from patient to patient in terms of what it transfers (Gazzaniga, 1977).

Interestingly, congenital agenesis of the corpus callosum (Jeeves, 1965) does not result in the same symptoms as those of patients with complete surgical section of the commissure. These subjects show normal test scores on performances involving cross integration of processes lateralised to the left and right hemispheres (Saul and Sperry, 1968). They may, however, be slower (Jeeves, 1969) than normal subjects when a transfer from one hemisphere to the other is required. It has been suggested that there is an elaboration of ipsilateral sensory and motor pathways as a compensation (Dennis, 1976). This gives both hemispheres access to information in each hand but restricts fine sensation and movement.

The extent to which performance efficiency of one hemisphere is affected by simultaneous activities in the other has varied according to task requirements. There is improved parallel performance by the two hemispheres after commissurotomy (Gazzaniga, 1968; Gazzaniga and Hillyard, 1973; Gazzaniga and Sperry, 1966). There is less interference between hemispheres than within a hemisphere (Kreuter, Kinsbourne and Trevarthen, 1972). The interhemispheric interference that is observable does not appear to be present in all stages of the processing chain but takes the form of an all-or-none rivalry in some gating mechanism (Teng and Sperry, 1973; 1974).

The functional specialisation of the two hemispheres have been demonstrated (Levy, 1974) in many studies. The right hemisphere of these patients is able to decode linguistic information (Gazzaniga and Sperry, 1967; Sperry and Gazzaniga, 1967), although the patient can not verbally respond with his right hemisphere. Kinsbourne (1974) argued that the right hemisphere is unable to control speech not because it lacks the necessary neural organisation but because the left hemisphere inhibits its utilisation of the speech motor facilities. Evidence for the right hemisphere's specific linguistic abilities is conflicting. It has been reported by Gazzaniga (1970) that the right hemisphere can respond to some nouns flashed in the LVF but not all nouns are responded to equally well. Gazzaniga (1967) found no evidence to show that the right hemisphere can respond to printed verbal commands and he found that it was unable to relate subject to object via a verb, or to comprehend the semantic aspects of verbs (Gazzaniga and Hillyard, 1971). The right hemisphere is able to recognise the negative but it has been reported that it can not form plurals or recognise the difference between active and passive constructions (Gazzaniga, 1971). Although the right hemisphere vocabulary is inferior to the left hemisphere's vocabulary in adult life, both "dictionaries" show a similar dependence on word frequency which Zaidel (1976) suggested may reflect similar or shared lexical structures. It is possible, he argued, that they have access to a common dictionary but that the right hemisphere has a higher threshold for retrieving meanings. Unlike other studies of right hemisphere language, in these patients, Zaidel (1976) found that there was no difference between the right hemisphere's comprehension of nouns and its comprehension of verbs. Zaidel (1977) extended his research to show that the right hemisphere can comprehend size adjectives, colour adjectives and shape nouns in the Token test, but makes consistent errors when the words are combined. He suggested that this reflects a deficit in short term sequential verbal memory.

The right hemisphere of split brain patients has been shown to predominate in visuo-spatial processing, confirming the work on unilaterally lesioned patients. Nebes (1971; 1974) showed that the right hemisphere is superior in generating a concept of the whole stimulus from the partial information given. It is also superior at matching visual information (Gazzaniga, Bogen and Sperry, 1965), responding to visuo-constructive problems (Bogen and Gazzaniga, 1965) and processing geometry (Franco and Sperry, 1977). Recently however, it has been suggested that the superior performance of the right hemisphere in these patients on a variety of manipulo-spatial tasks may reflect not the overall cognitive style and specialisation of the right hemisphere but may represent localised processing inefficiencies in the left parieto-temporal junction due to the left hemisphere's pre-occupation with language. Therefore the right hemisphere's superiority may be due to the involvement of manual activities (LeDoux, Wilson and Gazzaniga, 1977). It has also been suggested that the left hemisphere must have some musical ability and that it is able to recognise facial expression, two abilities which have often been regarded as the province of the right hemisphere

(Gazzaniga et al, 1975).

In summary therefore, it may be said that,

1) These clinical studies on adult patients have shown that the left hemisphere is specialised for language and in particular, speech processes. Although the right hemisphere is now believed to have a greater capacity for language than was thought previously, its ability is nevertheless lower than that of the left hemisphere. It appears to have little capacity for speech.

2) The right hemisphere is specialised for visuo-spatial processing, although it is possible that some of this apparent specialisation is due to the procedures used in testing patients. The right hemisphere specialisation for these functions may arise simply because it has little linguistic capacity and that the left hemisphere as a consequence has insufficient space for the full functioning of visuo-spatial abilities.

3) Transfer of information between the hemispheres is by means of the neocortical commissures, although congenital acallosals may use subcortical pathways to a greater extent than individuals who have developed normally. Information traverses specific regions of the commissures, although there do appear to be individual differences between patients. After damage to one region of the commissures another region may take over the transfer of information previously transferred by that region.

4) It is difficult to extrapolate from brain damaged patients to normal individuals (Selnes, 1976). Many

of the patients, who underwent unilateral surgery or commissurotomy, had long standing natural lesions, which may have caused changes in the functional regions of the brain.

The Development of Lateralisation

The previous section has dealt with the lateralisation of function in adult subjects suffering from brain damage. It has been discovered that when damage occurs early in life, functions which would normally have developed in the damaged region of the brain develop in other regions. Thus after early damage to the left hemisphere, language may develop in the right hemisphere. Correspondingly, damage early in life to the right hemisphere usually results in the transfer of visuo-spatial functioning to the left hemisphere. This is not the case when damage occurs after puberty. Therefore two major questions must be asked. Firstly, why does lateralisation of function develop and secondly, how does it develop?

Why Does Lateralisation of Function Develop?

Lateralisation of function was thought to be peculiar to humans, however, there is now evidence which suggests that there may be asymmetry of cognitive functioning in non-human primates (Warren, 1977). As primates show no hand preference, Warren suggested that asymmetry of cognitive functioning may have arisen before handedness in evolution. Levy (1977) has argued that cerebral lateralisation of function has almost doubled the human cognitive capacity as visuo-spatial and verbal processing are incompatible and therefore would not reside well together in a single hemisphere (Levy-Agresti and Sperry, 1968). She suggests that although lateral specialisation does not maximise either verbal or visual processing, it provides for a fairly high level of both. There is however no evidence to support Levy's interesting suggestion.

How Does Lateralisation Develop?

There is evidence for structural asymmetry in the neonate brain (Levy, 1976; Witelson and Pallie, 1973). The question of how and when functional asymmetry develops has led, however, to opposing views. It was thought that both hemispheres develop functionally in parallel until a critical age is reached. At this point the two hemispheres diverge in development. The specialised functions are then confined to a single hemisphere. The brain remains plastic until puberty (Witelson, 1978) allowing relocation of functions within the brain, should damage occur before this age (Gazzaniga, 1971; Lenneberg, 1967). Numerous hemispherectomy studies (Smith, 1974) can demonstrate that the right hemisphere can support linguistic functions. Searleman (1977) stated that if a hemispherectomy is performed in the first few years of life, normal linguistic development results in 99% of the cases, irrespective of the person's handedness or the hemisphere involved. Left hemisphere specialisation for speech may not always be fully compensated for in the event of an early left-sided lesion however. Annett (1973) argued that in these cases the deficit is in the motor production of speech but not in higher linguistic functions. Searleman (1977) differs on this point. He suggested that there may be subtle deficiencies in abstract linguistic functioning following left hemispherectomy for infantile hemisplegia. The left hemisphere is capable of supporting visuo-spatial activity, although there appears to be a developmental hierarchy in which language degelopment takes precedence over non-linguistic functions when the brain is drastically reduced in size by hemispherectomy (Smith, 1974).

Krashen (1972) did not take the view that lateralisation is not complete until puberty. In his review of hemispherectomy case histories he showed that language skills were recovered only if the onset of malfunction occurred before the age of five years, rather than puberty. Zaidel (1977) has further complicated the issue by demonstrating that the view of a sudden shift of language dominance at a critical age (Zaidel, 1976) may not be tenable. His data suggest that after the age of four years, when lateralisation of language has been argued to be complete (and in Krashen's view irreversible), some aspects of language may continue to develop in the right hemisphere. Finally, Kinsbourne's (1976) theory of functional lateralisation development must be mentioned. He suggested that functional lateralisation is present from the earliest stages of linguistic development (Kinsbourne, 1975a; Kinsbourne and Hiscock, 1977). He argued that it is not a slowly emerging function, although language may be relocated in the brain as a result of early insult because the young brain is extremely plastic (Witelson, 1978).

It is therefore not clear at present, how lateralisation of function develops in the human brain (Moscovitch, 1976). It may be a slowly emerging phenomenon, with the parallel development of the two hemispheres having virtually ceased by the age of four or five years. Alternatively, lateralisation of function may accompany, or even precede, language development. It was believed that the major distinction between an adult and a young brain was that the young brain is far more flexible in its assignment of function to structure than the adult brain, should damage occur. This is now open to debate as recent work has revealed the issue to be more complex than it was once thought to be.

Evidence for Functional Asymmetry of the Brain from other Types of Study

Several other types of experimental study have provided evidence for functional brain asymmetry. These will be discussed briefly in the following section. The first type of evidence comes from studies using the electroencephalogram (EEG). There is also some evidence from studies of patients who have undergone electro-convulsive therapy (ECT). Dichotic listening studies, which have provided evidence of auditory asymmetries will then be considered. After a brief discussion of ocular asymmetries, the relationship between auditory and visual field asymmetries will be discussed.

Evidence for Functional Asymmetry of the Brain from EEG Studies

Several EEG measures have shown lateral asymmetry of the brain in intact normal subjects. These include the contingent negative variation (CNV) (Tecce, 1972), which has been shown to be asymmetrical prior to numerical tasks (Dumas and Morgan, 1975), evoked potentials and alpha activity. The findings from this type of study have been reviewed by Marsh (1978) and will only receive brief attention here.

There is asymmetry in the visual (Buchsbaum and Fedio, 1969; Galin and Ellis, 1975) and auditory evoked potential. Buchsbaum and Fedio (1969) found maximum occipital responses to tachistoscopic presentation of verbal stimuli on the left hemisphere of right handed subjects. Davis and Wada (1974) showed a dominance of the speech controlling hemisphere for auditory click perception and a superiority of the non-speech hemisphere for visual perception in adults and infants (Davis and Wada, 1977). Friedman, Simson, Ritter and Rapin (1975) however, suggested that the literature concerning evoked potential correlates of functional hemispheric asymmetry shows many flaws in experimental design and statistical treatments and that evoked potentials rarely reflect hemispheric differences in cognitive abilities.

There is also hemispheric asymmetry in the amount of alpha recorded from each hemisphere during cognitive processing (Doyle, Ornstein and Galin, 1974; Dumas and Morgan, 1975; Galin and Ellis, 1975; Galin and Ornstein, 1972). The alpha rhythm (8 - 13 Hz) is associated with a relaxed state of mind and characteristically disappears when the subject closes his eyes, is presented with a stimulus, or performs higher levels of cognitive activity. There is a suppression of alpha activity, relative to the total amount of alpha, in the hemisphere dominant for a particular task. Butler and Glass (1974) showed that although the alpha component of the EEG was symmetrically distributed while the subjects were relaxed it was suppressed more over the left hemisphere than the right hemisphere when right handed subjects were engaged in mental arithmetic. This effect was absent in left handed subjects. Galin and Ellis (1975) showed that changes in alpha power were correlated with the visual evoked potential in temporal leads.

Evidence for Functional Asymmetry of the Brain from the Use of Lateralised Electroconvulsive Therapy

When applied unilaterally ECT produces a temporary malfunction of the hemisphere to which it is directed. Differential effects of left and right-sided placement of electrodes has been reported. Fleminger, Horne and

Nott (1970) found that verbal paired associate learning was more impaired by the application of left-sided ECT in right handed patients than right-sided ECT. Miller (1974, cited in Cohen, 1977) found that the recognition of geometrical and nonsense figures was relatively more impaired when ECT was administered to the right hemisphere than when it was administered to the left hemisphere. Berent (1977) suggested that facial recognition may be mediated by structures in either hemisphere. This is in agreement with Gazzaniga et al (1975). The factor determining where facial recognition takes place in the brain may depend on the functional demands imposed by the task. When Berent's (1977) subjects had to pick a face with a similar facial expression to a previously presented face (that is "smiling" for example), left ECT led to a lowering of performance. When the task was to identify the actual face seen previously, right ECT led to a performance decrement. It is possible that the verbal component in the former task was important.

Evidence for Functional Asymmetry of the Brain from Studies of Dichotic Listening

Dichotic listening tasks involve the simultaneous presentation of different stimuli to both ears (Cherry, 1953) with the result that stimuli presented to each ear are not perceived equally well (Broadbent, 1954; Darwin, 1971; 1974). There are two major routes from each ear to the cortex, the ipsilateral and the contralateral pathways. It has been suggested by Sparks and Geschwind

(1968) as a result of a study of a commissurotomy patient that material from one ear has in fact two pathways by which to reach the ipsilateral temporal lobe. One route is the direct one via the ipsilateral auditory pathway. The other route follows the stronger contralateral pathway to the opposite temporal lobe and then travels via the corpus callosum to the ipsilateral temporal lobe.

Kimura (1961) found that subjects in whom speech was represented in the right hemisphere, as determined by the sodium amytal technique (Wada and Rasmussen, 1960), reported more digits that were presented to the left ear than those which were presented to the right ear. The large majority of subjects with left hemisphere representation of language reported more digits from right ear presentations than from left ear presentations*. Kimura (1967) argued that this was due to the greater effectiveness of the contralateral pathways, and that when there is competitive stimulation of the two ears the impulses along the ipsilateral pathways are partially occluded. There is evidence from work on split brain patients to support this view. It has been demonstrated that while these patients perform equally well with the

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* It should be noted in this context that it is not possible to make the reverse inference that subjects who show a right ear advantage in dichotic listening tasks are left hemisphere dominant for language (Satz, 1977).

left and right ears in the monaural identification of digits and nonsense syllables, their dichotic performance reveals a massive left ear loss (Springer and Gazzaniga, 1975).

The right ear advantage in the perception of verbal material has received support from many studies. There are, however, differences in the ear advantage across phonetic classes (Shankweiler and Studdert-Kennedy, 1967; Studdert-Kennedy and Shankweiler, 1970), which Studdert-Kennedy (1975) has suggested may be viewed as reflecting differences in the degree to which different stimuli are liable to callosal degradation.

Lateralisation of music function has not been as consistently demonstrated as the lateralisation of speech. Kimura (1967) found that the majority of subjects were more able to hum melodies presented to the left ear than to the right ear. A left ear superiority has also been found for the recognition of hummed melodies (Bartholomeus, 1974) and melodies sung to letter names (Bartholomeus, 1974) or consonant vowel syllables (Spellacy and Blumstein, 1970). Heilman et al (1977) have shown that the relative specialisations of the two hemispheres may be demonstrated using a masking technique. They showed that the ear/hemisphere which usually processes a particular type of stimuli has greater difficulty in filtering out relevant stimuli from a masking stimulus than does the non-specialised ear/hemisphere. They found that although the relevant stimuli remained the same in their two experiments (tonal patterns) the predominant shift of ear effect changed with the masker, which was either music or language.

Several dichotic listening studies have, however, shown no ear differences in the recognition of melodies and the same melodic stimuli have at different times and under different dondition yielded varying results. Gates and Bradshaw (1977), in their review of this field, suggested that the perception of music depends on the synthesis of pitches and rhythms and that both hemispheres interact, each operating according to its own specialisations.

Right-left differences in dichotic listening tasks tend to be very small and much of the evidence suggests that they are not very stable (Friedes, 1977). It has been suggested that subjects' response strategies influence the results to a greater extent than has previously been acknowledged. Friedes (1977) evaluated spontaneous response strategies under conditions of free recall and found that ear asymmetry was dependent upon the response strategy. Subjects most often reported the right ear stimuli first and showed a strong right ear advantage. When the left ear stimuli were reported first, however, there was no difference between the ears. When Friedes (1977) manipulated subjects' response orders he again found that the dominance relationship of the ears clearly related to report order. Therefore it may be the case that there is a right ear advantage during the presentation of verbal material, which is enhanced by the effect of the predominant report order. Future studies should take this into account.

Evidence for Functional Asymmetry of the Brain from Studies of Visual Field Asymmetry

It has been suggested that the same type of information that has been gained from the study of commissurotomy patients may be obtained using a divided visual field technique with normal subjects. There is some disagreement as to the degree of separation of the visual fields required in order to ensure that LVF information is received solely in the right hemisphere and the RVF information is received solely in the left hemisphere. It has been considered that the separation should be 2.5° to 5° (McKeever and Huling, 1971a; Van Der Staak, 1975; White, 1972). Bouma (1973) suggested that acuity falls off markedly at distances greater than 5° off centre, however. Therefore it would be desirable to present information as near to the midline as possible in order to ensure a reasonable level of acuity. Studies of split brain patients have shown that a large separation of the LVF and RVF stimuli is unnecessary and that the midline effectively demarcates the receptive fields of the left and right hemispheres. The temporal retinae transmit information to the ipsilateral hemispheres and the nasal retinae transmit information to the contralateral hemispheres via the optic chiasma.

The Influence of Ocular Asymmetries

Unfortunately the technique is marred to some extent by the possibility that there may be ocular asymmetries.

There is in fact some evidence for asymmetries in the peripheral visual system, which may affect visual field asymmetries. Schaller and Dziadosz (1975) presented a bilateral 7 x 5 matrix of circles, one of which had a horizontal or vertical bar present. They found a decrease in accuracy with distance from fixation and an upper visual field superiority. A detailed analysis showed that two-thirds of the subjects were left-superior and one-third were right-superior. This bimodal distribution may explain some of the discrepant results of past experiments on visual field asymmetries (for example, Ayres, 1966; Harcum et al, 1963; Smith and Ramunas, 1971). It indicated the importance of individual differences. As Schaller and Dziadosz (1975) pointed out, although the left superiority of detection of stimuli in a bilateral display is in the same direction as that found in many previous studies, the shape of the accuracy function obtained by them differs from those in previous studies. Most earlier experiments showed W- or U-shaped functions indicating rehearsal or reporting artifacts or lateral "unmasking" (Bouma, 1970; 1973). They considered that it is difficult to reconcile their results with a left to right scan because not all of the subjects showed the same pattern of results. Although left to right scanning habits predominate over top to bottom scanning even for poor readers (Alpern, 1971), Schaller and Dziadosz (1975) found that there was a top superiority. In addition the top left hand corner of the display was not the most accurately perceived. They therefore suggested that asymmetries in the peripheral visual system, for example, greater acuity in one eye interacting with the greater number of fibres in nasal projections may be responsible for their data. This would produce a LVF advantage for the 42% of the population who are left acuity superior (Crovitz, 1961) and a RVF advantage for the 31% who are right acuity superior. As they pointed out, this does not offer an explanation for the top superiority as there is no indication that there is any difference between upper and lower hemiretinae in terms of the number of fibres, or accuracy of focussing.

As several investigators have used monocular viewing of stimulus fields, it is worth noting that visual field asymmetries may vary according to the viewing eye. Neill, Sampson and Gribben (1971) found that monocular viewing of unilateral displays led to RVF superiority only for left eye viewing. That is, the left eye's temporal retina was superior to the nasal retina. With monocular viewing of bilateral displays both eyes showed a LVF superiority but there was a larger asymmetry with right eye viewing. Neill et al (1971) pointed out that these results are, contrary to Schaller and Dziadosz's (1975) statement, consistent with temporal retinal superiority. However in this case, report order may have been an important factor in producing their results as the subjects reported verbally from left to right and one would therefore expect a LVF superiority with a bilateral display. A further series of trials requiring partial report led to RVF superiority in unilateral and bilateral conditions. A recent study by Parker, Satz and Horne (1976) further complicated the issue, as they found no difference between nasal and temporal pathways.

Therefore, although few investigators have considered the effect of acuity differences and the effects of monocular and binocular viewing, they may exert an influence on the data. However, the evidence is conflicting and it may be premature to attach too great an importance to one particular finding.

The Influence of Unilateral Versus Bilateral Presentation

There has been some disagreement as to whether both unilateral and bilateral presentation of stimuli yielded results dependent on hemispheric asymmetry. Kimura (1966) argued that as bilateral presentation yields a LVF advantage not only for letters but also for geometric forms (Bryden, 1960) and sequences of filled and unfilled circles (Harcum et al, 1963) it appears that it is more dependent on a general scanning mechanism, which always proceeds from left to right irrespective of the type of material. However many studies have contradicted such a mechanism (for example, White, 1969c). Unilateral presentation on the other hand, argued Kimura (1966), produces visual field asymmetry dependent on the type of material presented. Words and letters give rise to a RVF advantage (Kimura, 1966; White, 1971a) but geometric forms (Orbach, 1952; Terrace, 1959), single nonsense forms (Heron, 1957) and figures (Kimura, 1966) do not. Kimura (1966) found that unilateral dot detection tasks and form enumeration led to fewer errors in the LVF. White (1971b) however, found that both forms and Greek letters, which he believed to be on the verbal-nonverbal borderline, were equally well enumerated in both visual fields.

McKeever and Huling (1970a) and McKeever (1976) adopted a contrasting position to Kimura (1966). They argued that a major problem with many of the earlier studies supporting a scanning theory of visual field asymmetry was the lack of control of eye movements and the lack of positive fixation control. They criticised Heron (1957) and Crosland (1931) for using exposures of too long a duration. They quoted Heron (1957) as using an exposure duration of 150 msecs. This error, although noted by White (1972) was repeated by Rosen et al (1975). McKeever and Huling's (1971a) exposure durations were 15 msecs, producing an extremely high error rate. It is unlikely that such a short duration is necessary simply in order to control eye movements (White, 1972) as eye movement latencies are in the region of 120 to 240 msecs, with a mean latency of 200 msec (Saslow, 1967; Woodworth and Schlosberg, 1955). In order to control fixation, McKeever and Huling (1970a) presented a digit between 2 and 9 at the central point of the stimulus field. The subject was required to report this fixation digit prior to the lateralised stimulus. Using this procedure they found that both unilateral and bilateral (McKeever and Huling, 1970a; 1971a) presentation of words resulted in a RVF advantage. White (1973) has argued that randomly mixing unilateral and bilateral trials would control pre-exposure fixation biases and that a central fixation digit may adversely affect visual field asymmetry if the digit has to be reported prior to the lateralised stimuli. However, although subjects do report fewer lateralised stimuli when they are required to report a central digit (Rosen et al, 1975) there is no direct evidence that digit report per se affects visual field asymmetry. It could be suggested that a fixation digit alters the subjects' attentional bias (Kinsbourne, 1970) although there is no evidence for this.

McKeever and Huling found that bilateral presentation of stimuli in the presence of a fixation digit results in a greater visual field asymmetry than does unilateral presentation. RVF recognitions outnumbered LVF recognitions by 5.5 : 1 (McKeever and Huling, 1971a) and 4 : 1 (McKeever, 1971) when stimulus words were presented bilaterally. This compared with visual field ratios of 1.7 : 1 (McKeever and Huling, 1970a), 1.5 : 1 (McKeever and Huling, 1970b) and 1.6 : 1 (McKeever, 1971) in unilateral presentation conditions. They found that very few LVF words were recognised, particularly early in the experimental sequence when the procedure was still relatively unfamiliar to the subjects. When McKeever and Huling (1971b) presented the LVF earlier than the RVF word by six or twenty msecs they found that the RVF was still superior. Therefore the time of arrival of the words at the visual cortex was not important. They argued that when words are presented bilaterally the direct input of word stimuli to the left hemisphere assumes priority over the indirect input arriving from the LVF.

More recently however, Fudin (1976) has advanced an alternative explanation of the large RVF superiority in McKeever and Huling's tasks. He argued that it seems likely that their subjects reacted to the difficult perceptual task by attempting to process the word in the right rather than the word in the left visual field, as it would be unlikely that they would be able to process both in the time available. The RVF words would be favoured because the first two letters in the word in the RVF fall on an area of greater visual acuity than their counterparts in the LVF. Therefore prior to the commencement of decay of the stimulus information there is more information in the iconic store concerning the RVF elements. The beginning of a word is far more important than the ending for overall recognition (MacKavey et al, 1975) and therefore this word is more likely to be recognised. It is also easier, given central fixation, to shift attention to the first two important letters of the RVF word than it is to attend to the first two elements of the LVF word. The scanned information from the RVF will then be transmitted to the left hemisphere for rehearsal with less decay than any scanned information which may reach the right hemisphere. Since scanned information is held in a very temporary store, there should be less loss of scanned information initially received in the left hemisphere.

Therefore it appears that both unilateral and bilateral presentation results in visual field asymmetry which is to some degree dependent on hemispheric asymmetry. More striking visual field asymmetry is likely to occur with bilateral presentations if the subjects' fixation is well controlled and the exposure duration is short. A short exposure will ensure that no eye movements can occur during the exposure and if of the order of 20 msecs it may also limit the information which may be scanned.

Visual field asymmetries will be reviewed in greater detail later in this chapter. We will now turn to a consideration of the relationship between the asymmetries found in dichotic listening and those found in visual studies.

Relationship Between Dichotic Listening and Visual Studies

If both dichotic listening asymmetry and visual field asymmetry may be used as measures of hemispheric specialisation one would anticipate that there would be a high correlation between the asymmetries observed in the two situations. This is not the case. Bryden (1973) found that there was no relationship between subjects' performance on a unilateral visual form perception task and a dichotic listening task. Dot localisation, another visual task which utilises non-verbal rather than verbal processing did show a relationship with dichotic performance. A significant percentage of right ear dominant subjects on a verbal dichotic task also showed a

RVF advantage in the dot localisation task. This is in fact the reverse of the finding which one might expect. Bryden also found that subjects, who showed a left ear advantage on the dichotic task, showed a RVF advantage in letter perception. Again, this finding is the reverse of expectation, particularly as dichotic listening performance has been thought to be a superior index of lateralisation of function (Kimura, 1967). Hines and Satz (1974) found a significant correlation between asymmetry in a unilateral visual digit perception task and a dichotic listening task, when they used right handed subjects. A more recent study by Fennell, Bowers and Satz (1977) obtained a significant right ear and RVF advantage in verbal tasks for right handed subjects over four test sessions. However there was not a significant correlation between RVF and right ear scores and LVF and left ear scores. When directional asymmetries in recall were examined for concordance across modalities it was found, however, that for later testing sessions, subjects who showed a superior RVF were very likely to show a right ear advantage also. It may therefore be the case that in early testing sessions the lack of practice strongly influences the data and that it may have a slightly different effect on the two measures of functional specialisation.

Individual Differences in the Lateralisation of Cerebral Function

Several factors are believed to affect the lateralisation of function within the brain. These will be discussed in terms of their effect on data obtained in visual field and dichotic listening studies. The factor most strongly supported by evidence from clinical studies is that of handedness. The development of lateralisation has been discussed in a previous section. In this section of the review the effects of age, deafness and blindness on the results of studies of normal subjects will be considered. The final factor to come under scrutiny is that of sex. There is little evidence from studies of clinical populations that sex influences the lateralisation of function, although it will be shown that many studies of normals suggest a sex difference.

The Effect of Handedness

Handedness (Annett, 1967; 1972) has been used as a criterion of cerebral dominance for language despite the lack of a clearcut relationship between them (Annett, 1975; Hicks and Kinsbourne, 1978; Roberts, 1969). The majority of right handed and left handed people have left hemisphere representation of language, although more of the latter show mixed or right hemisphere dominance (Hardyck, 1977; Milner, Branch and Rasmussen, 1964; Penfield and Roberts, 1959; White, 1969a). Organisation of the left handers brain appears to be more diffuse (Beaumont, 1974). Selection of right handed subjects on the basis of a handedness test does increase the probability that those subjects will be left hemisphere dominant for language. Several pencil and paper tests of handedness have been devised (Annett, 1970; Crovitz and

Zener, 1962; Oldfield, 1971).

It has been argued (Bryden, 1965) that handedness may be more clearly related to visual field asymmetries in the perception of single rather than multiple letter stimuli (Goodglass and Barton, 1965). The influence of directional scanning may be stronger in experiments involving multiple letter stimuli without adequate fixation control. Bryden (1965) found that right handed subjects find it easier to identify single letters in the RVF at an exposure of 20 msecs whereas left handed subjects show no such asymmetry. Hines (1972a) quoted this finding with no reference to the methodological flaws of the experiment. At an exposure of 25 msecs there were no consistent differences betwaen left and right handers. The bias, if any, was toward superior recognition of letters presented in the LVF. Bryden suggested that this difference may be due to the higher accuracy level at the 25 msec exposure. The difference in accuracy between the two conditions was in fact extremely slight. He further suggested that there may be a critical exposure duration above which a RVF advantage will not occur. He noted that Bryden and Rainey (1963) and Heron (1957) used a 10 msec exposure duration when they obtained a RVF advantage for the recognition of unilaterally presented stimuli. In fact Heron (1957) used a 100 msec exposure. The most likely explanation of Bryden's data appears to be that the 20 msec exposure condition was always presented after the 25 msec condition. Any visual field asymmetry in the 25 msec condition may have been swamped by variance due to the lack of practice. A sampling artifact in Bryden's experiment is also suggested as left handed men and right handed women produced the most accurate results. Bryden (1965) also found no correlation between dichotic listening and handedness. Dichotic listening has in fact been thought to be more highly correlated with language lateralisation than with handedness (Curry, 1967). Bryden (1975) again using unilateral presentation of letter stimuli found that accuracy of perception of RVF stimuli was greatest in right handers. This superiority was most evident in the second half of the testing session, which supports the interpretation of the earlier Bryden experiment. It strongly suggests that subjects should be given practice trials prior to experimental trials.

It has been considered that familial sinistrality (left handedness) is associated with less dependence on the left hemisphere for language functioning (Annett, 1973 ; Bryden, 1970:.Hines and Satz, 1971; McKeever, VanDeventer and Suberi, 1973; Zurif and Bryden, 1969). Several studies have reported smaller visual field differences in right handed subjects with familial sinistrality, suggesting a less lateralised language function (Hines and Satz,1971; McKeever, VanDeventer and Suberi, 1973; Zurif and Bryden, 1969), although other studies have not found it to be a relevant factor (Bryden, 1973). If one is interested in the visual field asymmetry shown by right handed subjects, in the majority of whom language is lateralised in the left hemisphere, it is probably adequate to select the right from the left handed subjects and collect information on familial handedness, which may under some circumstances be an explanation of a lack of visual field asymmetry.

The Effect of Age

Adults and children have been demonstrated to show different ear and visual field asymmetries in dichotic listening and visual tasks. It has been argued that young children, particularly those below what was thought to be the critical age at which lateralisation of function develops, should show no lateralisation in dichotic and visual tasks. It is very difficult to test young children under the same conditions as those which one can apply to adults. Children have difficulty in understanding intructions and complying with them, particularly in maintaining fixation during stimulus exposure. Stimulus exposures have frequently been greater in studies of children, allowing the criticism that eye movements may have occurred during the stimulus exposure. Children, who are unable to read, require modified tasks.

The right ear advantage in dichotic listening has been shown to vary as a function of age (Bryden and Allard, 1974; Kimura, 1963; 1967). In addition Kimura (1963; 1967) found that children from low socio-economic backgrounds did not show a right ear advantage until a later age than middle class children. However Dorman and Geffner (1973) showed that these findings were largely due to the fact that more of the lower class subjects were black and that the experimenter was white. When they matched the subject's and experimenter's race, they found that all six year old children showed a right ear dominance. Knox and Kimura (1970) have shown that there is a right ear advantage for verbal material at the age of five years. They also demonstrated that children of this age show a left ear advantage for the perception of non-verbal environmental sounds. Kinsbourne (1976) argued that the idea that young subjects should show a smaller right ear advantage than that shown by adults for verbal perception is, however, based on the unconfirmed belief that a stronger right ear advantage reflects a greater degree of language lateralisation. He suggested that the ear advantage is more likely to reflect the extent to which the subject found it necessary to enlist his verbal capacities to solve the problem. He argued that this is not merely a function of lateralisation but of the extent to which the subject tries to perform on the task and uses a specific verbal strategy to do so. It is likely that young children will be less concerned with their task performance than will adults and less consistent in the strategies which they apply. This criticism also applies to studies in the visual modality which will be discussed below.

There have been conflicting results obtained in studies of visual perceptual laterality in young children. Carmon, Nachson and Starinsky (1976) showed a developmental aquisition of visual field asymmetry in the perception of verbal material. They showed that single letters are better perceived by young children when they are presented in the LVF. This, they argued, shows that they are processed as simple non-verbal material. Older children showed no visual field asymmetry for single letter stimuli. Although these results indicate that their experiment was not tapping lateralisation of language, they did, however, show a RVF advantage for the perception of Hebrew words, which argues for a dominance interpretation rather than a scanning interpretation of the data. When Barroso (1976) required children to compare simple pictorial stimuli in a verbal mode (by naming the pictures) he found a RVF advantage in ten and twelve year old children. Six, eight and nine year olds showed no visual field asymmetry.

Reading ability has been shown to affect visual field asymmetry in children. One theory of dyslexia is that there is a failure to establish cerebral dominance. Therefore one would anticipate a lack of RVF superiority for the perception of verbal material in dyslexic children, although it should appear in normal children of a comparable age. Marcel, Katz and Smith (1974) showed that reading ability in eight year old children is correlated with the degree of visual field asymmetry in a unilateral visual task. They interpreted this as demonstrating that cerebral asymmetry in verbal processing is more highly developed in good than in poor readers. However, it may be that good readers have a more highly developed scanning strategy. Marcel and Rajan (1975) studies seven to nine year old children and found that higher reading ability was related to RVF superiority for word recognition only in the case of boys. However, they used different exposure times for girls and boys and good and poor readers. They discounted scanning as a possible explanation of the observed visual field asymmetry as there was no effect of position within the word on individual letter recognition. An early study by Forgays (1953), which he interpreted as favouring a Hebbian view of development, showed that there was no visual field difference in the perception of three and four letter words when subjects were below educational grade seven. A RVF advantage developed in late adolescence and adulthood. This is rather later than the age at which other workers have found a change in asymmetry. It could be argued that this finding favours either a lateralisation of function or a scanning theory. The latter is more likely as the age at which the change occurred is so late. Scanning habits probably become more ingrained in the later stages of reading development.

McKeever and VanDeventer (1975) selected a group of dyslexics on the basis of stringent criteria, rather than merely using poor readers. The dyslexic subjects showed lower recognition levels overall and a different pattern of visual field asymmetry from "normal" subjects. However, the results showed that dyslexic subjects recognise more words from the RVF and therefore they are as likely as "normals" to have left-sided lateralisation of language functions.

There have been corresponding studies of non-verbal perceptual asymmetries in children. There is a LVF superiority for the recognition of faces at five, seven and eleven years of age (Young and Ellis, 1976) showing no increase in the degree of lateralisation with age. However it should be noted that they used a different stimulus exposure duration for each age group so that the degree of visual field asymmetry for each group is not strictly comparable. Similarly Marcel and Rajan (1975) using non-verbal material found no support for the view that the degree of specialisation for language is linked with that of spatial functions (Buffery and Gray, 1972).

Therefore the data obtained from studies of children is conflicting and possibly based upon unsound assumptions of progressive lateralisation of language and non-verbal functions in the brain and that the degree of visual field asymmetry and ear asymmetry reflects the degree of lateralisation of cognitive functioning within the brain.

The Effect of Deafness

As it has been suggested that the left hemisphere is more specialised than the right for the processing of auditory stimuli and that this plays a large part in the development of the left hemisphere's dominance for linguistic processing, it is interesting that congenitally deaf subjects do not show left hemisphere dominance for language to the same extent as normal subjects. There are no observable visual field asymmetries for deaf subjects, whose communication is manual (Manning, Goble, Markman and LaBreche, 1977; McKeever, Hoemann, Florian and VanDeventer, 1976; Phippard, 1977). In fact, subjects whose communication is oral, show a LVF advantage for verbal and non-verbal material suggesting that they use a visual memory code (Phippard, 1977). There is also better LVF recognition of American Sign Language (Manning et al, 1977).

The Effect of Blindness

As blindness is another major sensory disability it is worthy of consideration in terms of its effect on the lateralisation of function within the brain. There has been little research upon blind subjects. As far as reading is concerned, blind people are dependent upon braille. As this form of reading requires haptic rather than visual discrimination it is possible that it has some influence on the lateralisation of function in the brain, at least in congenitally blind people.

Investigations have shown that haptic discrimination in right handed subjects, both blind and sighted, is more accurate for the left than for the right hand. This is true for the naming of braille symbols or letters of the alphabet (Smith, Chu and Edmonston, 1977). Smith et al (1977) suggested that the left hemisphere has full haptic perceptual capacity but that it is subject to interference from the right hemisphere unless the right hemisphere is involved in other processing. Further research needs to be done regarding the exchange of information between the hemispheres when blind subjects are performing linguistic tasks. However, as visual research can not be performed on blind subjects, this field will not be further discussed here.

The Effect of Sex

It has been proposed that cerebral lateralisation of function develops earlier in girls than in boys and that girls, therefore, develop a more left-sided dominance for linguistic functions than do boys (Buffery and Gray, 1972), which leads to the well documented (Harris, 1978; Hutt, 1972) female superiority in verbal skills. As boys' left and right hemispheres are not as functionally distinct, if this argument is correct, boys have a more bilateral representation of language and spatial skills. Boys are argued to be superior in spatial tasks because spatial skills are better served by more bilateral representation. This rather strange argument has not gone unchallenged (Marshall, 1973). Several authors have suggested that, on the contrary, both visuo-spatial (Bakan and Putnam, 1974; Davidoff, 1977; Kimura, 1969; Knox and Kimura, 1970; Metzger and Antes, 1976; Metzger and Kertesz, 1973; McGlone and Davidson, 1973) and verbal (Bradshaw and Gates, 1970; Gates, Bradshaw and Nettleton, 1977; Hannay, 1976; Hannay and Malone, 1976; Lake and Bryden, 1976; Metzger and Antes, 1976) processes may be more lateralised in men than in women. It has even been proposed that there may be sex differences within the hemispheres in regional specialisation (Tucker, 1976), although this is based upon an analysis of EEG differences, the interpretation of which is unclear. There has been speculation that female verbal superiority may stem from the invasion of right hemisphere space, which is reserved in males for spatial processes. The right hemisphere speech centre, it has been suggested, is called into action when the processing of more difficult, unfamiliar material is required (Bradshaw and Gates, 1978).

Other researchers have, however, reported no sex differences in the degree of lateralisation of function (Borowy and Goebel, 1976; Bryden, 1965; Kimura, 1969). The majority of this research has been performed on normal subjects and the findings are not well substantiated by the clinical literature (Rizzolatti and Buchtel, 1977). A recent finding, which possibly throws some light on the discrepancies apparent in the normal literature, is that of Rizzolatti and Buchtel (1977), who showed that the exposure duration may be a very important factor in determining whether or not sex differences are found in studies of visual field asymmetry. They suggested that the lack of visual field asymmetry in female subjects for the perception of faces, contrasting with the LVF advantage in male subjects, was due to the lateralised mechanism in women not being activated with the brief exposure of 100 msecs. Exactly why the lateralised mechanism was not activated is unclear. However, they suggested that the visual field difference in males may be amplified by the use of an even shorter exposure duration. This implies that the sex difference may be at a very early stage in processing.

As more of the literature appears to support the view of greater lateralisation of cognitive function in males than in females, it is possible that experiments in visual field asymmetry may give rise to less or no asymmetry if a predominantly female subject pool is used.

However, it must be remembered that the degree of visual field asymmetry has not been shown to be correlated with the degree of functional lateralisation within the brain. Therefore the above data should be viewed with some reservations.

Theories of Visual Field Asymmetry Related to Functional Lateralisation within the Brain

There has been a variety of approaches to the study of hemispheric asymmetry of function in normal subjects, using the divided visual field technique. Until the work of Kinsbourne in the early 1970's drew attention to the possible influences of attentional biases on visual field asymmetries, the results of studies were interpreted in terms of the direct access theory of visual field asymmetry. The studies will be reviewed under the two headings of "direct access" and "attentional" theories.

Direct Access Theory

This type of explanation relates visual field asymmetry to the ease with which a particular stimulus can gain access to the hemisphere involved in the processing of that type of stimulus and the accuracy and speed of the processing within a hemisphere. A stimulus presented in the RVF arrives initially in the left hemisphere. If it requires processing by the right hemisphere mechanisms a callosal transfer of the stimulus information is necessary. The converse is true when a stimulus, which requires processing in the left hemisphere, is presented in the LVF.

There have been two alternative hypotheses advanced in the class of direct access explanation (Gross, 1972). The first hypothesis is that all processing of a particular stimulus is performed in the hemisphere dominant for that type of information processing. If this is the case, then visual field asymmetry measured in terms of errors reflects the decay of stimulus information during transfer across the corpus callosum when material is presented to the non-dominant hemisphere (Dimond, Gibson and Gazzaniga, 1972; Kimura, 1966). Reaction time differences reflect the time taken to transfer information across the corpus callosum when necessary. The second alternative is that both hemispheres are capable of processing all types of information. The subordinate hemisphere, however, processed information more slowly and less accurately than the dominant hemisphere and this is reflected in reaction time and error asymmetries.

Earlier investigators were concerned with the transfer of information between the two hemispheres, in particular, they were interested in the interhemispheric transfer time (ITT). This approach then gave way to studies which paid more attention to the different modes of processing information in the two hemispheres. Investigators became less concerned with distinguishing between the two alternative mechanisms underlying the direct access view of visual field asymmetries, having come to realise that both are probably involved to some degree in most experimental studies.

The research in this section will be discussed under the two major headings of studies dealing with interhemispheric transfer and those concerned with the different modes of processing information.

Interhemispheric Transfer

Many experiments have been designed to discover how long it takes information to be transferred from one hemisphere to the other. One method has been to ask subjects to judge when two stimuli, one presented to each hemisphere, have been displayed simultaneously (Efron, 1963, Umilta et al, 1973). The theory is that when two stimuli are to be judged as simultaneous, information from one of the stimuli must cross the corpus callosum in order for the comparison to be made. As the system does not compensate for the time lag (Efron, 1963) when the stimuli are judged as arriving simultaneously, the stimulus, from which information must cross the corpus callosum, must have been presented earlier than the other stimulus by the amount of time that it takes to transfer the information across the corpus callosum. Efron (1963) using light stimuli of 1 msec duration presented at 26° from fixation in the left and right visual fields, obtained an ITT of 3.81 msecs and showed that the language dominant hemisphere is responsible for the comparison of simultaneity.

Another method of investigating ITT is to present a stimulus to one hemisphere and to require a response from the other. The response may be verbal, which would usually necessitate the sole involvement of the left hemisphere in producing speech. It is possible, however, that the right hemisphere may process a meaningless vocal response (Geffen, Bradshaw and Nettleton, 1973). Alternatively a manual response may be required. A single finger response is controlled by the hemisphere contra-lateral to the hand making the response. A whole hand response, however, such as that used by Filbey and Gazzaniga (1969) may be ipsilaterally controlled (Gazzaniga, 1967).

Poffenberger (1912) was an early investigator, who reasoned that he could calculate the time taken for information to cross the corpus callosum by presenting a stimulus to one hemisphere and requiring a response from the other in this manner. He used a control condition in which he required the response from the receiving hemisphere. He showed that there was an ITT of 5.6 and 6.0 msecs in his two highly trained subjects. Although Efron (1963) thought that his findings were clearly significant, Davis and Schmit (1971) did not. One must be sceptical of a finding using only two subjects, particularly when there is no statistical analysis presented.

Continuing the work which has used simple lateral-ised stimuli, Berlucchi, Heron, Hyman, Rizzolatti and Umilta, (1971) used a square patch of light as the stimulus.

They found that reaction time increased the further toward the periphery that a stimulus was presented, regardless of the visual field of presentation and the hand used in making the response. Crossed reaction times (that is, LVF input/ right hand output and RVF input/ left hand output) were slower than the uncrossed reaction times (that is LVF input/left hand output and RVF input/right hand output), irrespective of the degree of eccentricity of the stimulus. There is some evidence that the width of the central vertical strip projecting to the visual cortical area via the corpus callosum is approximately 20° on each side of the vertical meridian. If these connections are crucial one would expect that the delay between crossed and uncrossed reaction times would increase greatly when the stimulus was outside this region. It did not. Therefore Berlucchi et al (1971) suggested that the callosal connections of the visual cortex are not a major component of this type of interhemispheric coordination. Presumably the information must be transferred either through a different region of the corpus callosum (for example, between motor regions) or subcallosally. Meikle and Sechzer (1960) showed that split brain cats are able to transfer brightness discriminations from one hemisphere to the other although they are unable to transfer pattern discriminations. This suggests that subcallosal transfer of brightness discriminations, for which the striate cortex is unnecessary (Smith, 1947) may occur, although near threshold brightness discriminations requiring the involvement of the striate cortex (Bridgman and Smith,

1942) do not transfer subcallosally (Meikle and Sechzer, 1960). Electrophysiological studies show that when the cortex of one hemisphere is stimulated and the response on the other studied, there is a second response following the callosal response, between homologous points on the cortex. This second response survives section of the corpus callosum, supporting the finding of Meikle and Sechzer (1960). The second response has a longer latency and is weaker and less stable than the callosal response and is not readily obtainable between sensory projection areas (Rutledge and Kennedy, 1960). Jeeves (1969) found that congenital acallosal patients, transferring information between the two hemispheres subcallosally, took longer than normal subjects when they had to perform a brightness discrimination and vibration detection task. Therefore it is unlikely, though possible, that Berlucchi et al's (1971) data demonstrate subcallosal transfer of information as the ITT derived from their experiment was in the region of 1.2 msecs. Unfortunately, Berlucchi et al (1971) gave their subjects four blocks of fifteen trials consecutively to one side of the fixation point at a particular visual angle. Therefore it is extremely likely that pre-exposure biases played an important role in their findings, which can not therefore be taken seriously.

From studies using very simple visual stimuli, investigators progressed to the use of more complex stimuli. This was perhaps premature as a clear ITT for simple stimuli has not been established. It would have been useful to replicate Efron and Poffenberger's findings and repeat Berlucchi et al's study with methodological corrections. There have been two approaches used in the following type of study. Some workers have provided subjects with situations which have been thought to require an interhemispheric transfer due to the nature of the response. Others have altered the type of processing involved in the task so as to involve one hemisphere or the other. The latter approach presents many difficulties as it is very hard to say that any task requires the sole involvement of one hemisphere.

Moscovitch and Catlin (1970) found that the vocal response to single letter stimuli unilaterally presented to the LVF or the RVF favoured the latter by 10 msecs. They argued that this was the time taken to transfer information from the right hemisphere to the left in order that the left hemisphere could make the verbal response. Davis and Schmit (1971) however, suggested that the left hemisphere may also have been involved in the processing of both LVF and RVF stimuli and that therefore the reaction time difference may have reflected the inter-hemispheric transfer of the raw stimulus information from the right hemisphere to the left prior to processing by the left hemisphere. One unfortunate feature of Moscovitch and Catlin's experiment was that they presented stimuli in thirty-trial blocks. All stimuli within a block were presented to the same visual field. Therefore the subjects could have altered their fixation or pre-exposure biases in the direction of the stimulus field. Although visual field asymmetry was observed in their experiment, this factor casts doubt on its origin.

Rizzolatti et al (1971) obtained evidence in support of Davis and Schmit's (1971) view that the left hemisphere was involved in the processing of all the stimuli in Moscovitch and Catlin's experiment. They showed that the reaction times to letter stimuli favoured the RVF over the LVF and that there was no interaction with the hand used in making the response. This implies that the information reaching the right hemisphere is transferred to the left hemisphere for processing. When information is processed by the left hemisphere a right hand response is faster than a left hand response. An alternative explanation however, would be that the response time difference between the visual fields reflects the difference between the hemispheres in processing time.

Moscovitch (1972) made a further investigation of the processing of letter stimuli. He found that manual response times to LVF stimuli were 2.2 msecs less than response times to RVF stimuli, when subjects made "same" responses. The task was to match a visually presented letter to a letter presented in the auditory mode two seconds earlier. All responses were made with the left hand, thus increasing the probability that the responses to LVF stimuli would be faster than responses to RVF stimuli. As it may be argued that an auditory letter may evoke a visual code and therefore the right hemisphere may be performing a visual matching rather than a linguistic task, if indeed it is capable of processing letter stimuli, Moscovitch (1972) increased the auditory memory set to six letters. He argued that it is more difficult to transfer six letters to a visual code in the available two seconds than it is to transfer one letter from an auditory to a visual coding. In this case (again requiring a left hand response) Moscovitch found that responses to RVF stimuli were faster than responses to LVF stimuli by 14 msecs when subjects made "same" responses. Again there was no difference in response times to left and right visual field stimuli when subjects made "different" responses.

Similar studies have been performed using non-verbal stimuli. Rizzolatti et al (1971) found that reaction times favoured the LVF for the recognition of faces, with no interaction with the hand of response. In a unimanual two-finger choice reaction time task requiring subjects to identify faces, Geffen, Bradshaw and Wallace (1971) found a LVF advantage of 25 msecs, but no significant hand effects. They argued that the responses may have been ipsilaterally controlled. Two details pertinent to the analysis of this lack of hand effect are 1) that the subjects were given a mnemonic to aid response selection. Thus the left hemisphere may have performed the response selection irrespective of the hand making the response. 2) Only forty trials per hand were run. This is considerably less than other investigators such as Moscovitch (1972). A final criticism of Geffen et al's (1971) experiment is that although they regarded the identikit faces as being difficult to encode verbally, this is open to question. They gave each subject one of five dissimilar faces to memorise for ten minutes prior to the experimental trials. Before the onset of each trial the subject viewed the memory stimulus for one second at the fixation point. It is probable that with this degree of exposure, the subject would attach a verbal label to the memory face. This labelling may have aided discrimination with the left hemisphere.

Several difficulties have arisen in attempting to measure ITT. There is difficulty in equating studies using simple stimuli with those involving more complex stimuli. Simple brightness discriminations may be performed by either hemisphere. When complex stimuli are used, it is not possible, given our present knowledge, to argue that the stimuli are processed solely in one hemisphere, or that both hemispheres contribute equally to the stimulus processing. It is also unlikely that there is a single interhemispheric transfer of information when subjects are processing complex stimuli.

Measures of ITT have been extremely variable. More than one explanation has been advanced to account for this . McKeever and Gill (1972b) showed that ITT varied according to the degree of stimulus lateralisation. They found that stimulus letters projected 1.6° into each visual field yielded an ITT of 41.4 msecs. A visual angle of 3.9° gave rise to an ITT of only 17 msecs. This, they considered, could account for the difference between the findings of Filbey and Gazzaniga (1969) and Moscovitch and

Catlin (1970). As previously noted, however, both of these studies suffered from methodological flaws, which could account for the difference between them. It is worth noting in this context that Heron (1957) found an effect of visual angle. Under conditions of unilateral presentation he found that there was a RVF superiority only when letters were presented 5^{o} from fixation and not at 4^{o}, 6^{o} or 7^{o}. The mechanism causing these effects of visual angle is unclear and could be usefully investigated.

Finally it has generally been found that uncrossed reactions are faster than crossed reactions. This, as suggested earlier, may be due to the greater directness of the route for ipsilateral reactions. Broadbent (1974) however, challenged this hypothesis and argued that laterality effects could best be understood in terms of the relationships between stimuli and response device (Rabbitt, 1971). There is a greater stimulus-response compatability between a LVF stimulus-left hand response and a RVF stimulus-right hand response than between crossed reactions. One method of testing between these two hypotheses is to perform experiments in which subjects respond with their hands crossed over. This will change the stimulus-response device relationship but not the anatomical relationship. It has been found that in a simple reaction time paradigm the main factor determining which hand is faster in responding to lateralised stimuli is the directness of the anatomical connections between the receiving hemisphere and the responding hand (Anzola, et al, 1977; Berlucchi et al, 1977). In choice reaction time studies where the subject has to make a decision regarding his response, the spatial contiguity of the responding hand and the stimulated visual field is the important factor in determining the speed of response.

Modes of Processing

Neisser (1967) pointed out that Psychology has recognised the existence of two forms of mental organisation for a long time, the distinction having been given many names. Table 2-1 presents a list of dichotomies, which may be classified in terms of their association with the right and left hemispheres (Bogen, 1969b; Ornstein, 1972). It has been suggested that a common thread runs through all the dichotomies (Neisser, 1967). This is the distinction between "deliberate, efficient and obviously goal directed.. usually experimenced as self-controlled.." and "rich, chaotic and inefficient; it tends to be experienced as involuntary..." (p297). He further suggested that this is reminiscent of the parallel-sequential processing distinction. The most important dichotomy for consideration here is the verbal-visual distinction. Although some writers have associated many factors with the left and right hemispheres many of these are rather far fetched and based on no evidence.

Sperling (1960) demonstrated that subjects have a large capacity visual memory (iconic memory) that decays rapidly over intervals of up to one second. Posner and Mitchell (1967) found that "same" response times were longer for different-case letter comparisons than for

Table 2-1

A List of Dichotomies Associated with the Left and Right Hemispheres

Left hemisphere	Right hemisphere
expression	perception
propositionising	visual imagery
linguistic	visual or kinaesthetic
verbal	perceptual or nonverbal
discrete	diffuse
symbolic	visuospatial
linguistic	preverbal
logical or analytic	synthetic perceptual
propositional	appositional
sequential	simultaneous
analytic	gestalt
intellectual	intuitive
active	receptive

From: Bogen (1969b) and Ornstein (1972).

same-case comparisons presented at interstimulus intervals of up to 1.5 seconds, thus illustrating the influence of visual coding. At intervals of 1.5 to 2 seconds the advantage of same-case decisions was not apparent. Thus the iconic memory may be replaced by verbal encoding of the information (Posner, Boies, Eichelman and Taylor, 1969; Sperling, 1967). Information may be held for longer periods in a visual form as imagery (Kosslyn, 1975). It has been suggested that an acoustic-verbal encoding may not be a necessary stage in the transfer of the icon to a longer lasting form of coding.

Independent operation of the two codes (visual and verbal) has been supported by numerous experiments (for example, Brooks, 1968; Ellis and Daniel, 1972; Henderson, 1972; Paivio, 1971a; 1971b). Murray and Newman (1973) presented subjects with a matrix of twelve cells in three of which there was a readily verbally encodable shape. The stimulus field was presented for a duration of five seconds. A visual task during the retention interval (up to twenty seconds) led particularly to the forgetting of the location of the shapes. If the retention interval was filled with a verbal task, forgetting was of the shapes themselves. Tatum and Friden (1974) showed that words and pictures may be encoded in different forms. Response times of same-different judgements were directly related to the number of syllables in the words. There was no relationship between the response times and the number of syllables in the picture names.

Items that can be represented cognitively both verbally and as images can be searched and compared in either mode depending on the demands of the task (Burrows and Okada, 1974; Paivio and Begg, 1974; Posner, 1969; Posner et al, 1969; Tversky, 1969). Paivio and Begg (1974) required subjects to search through an array of pictures or words for a target item that had been presented as a picture or as a word. They found that the mode of representation actually used depended upon the search array. Comparisons of items takes place within a modality. If an intermodal transfer is required this results in an increased processing time (Arthur and Daniel, 1974) of approximately 150 msecs (Tversky, 1969; 1974). Pictures may more readily allow dual coding than words (Ellis, 1975; Goldstein and Chance, 1971). Paivio (1969) demonstrated that imagery-inducing concrete nouns can be more readily recalled than abstract nouns, thus illustrating the facilitating effect of imagery.

Visual and verbal memory have different characteristics. The duration of the stimulus itself is particularly important in visual memory. It has been demonstrated that pictures are processed only for the duration of the presentation (Loftus, 1974; Potter and Levy, 1969; Shaffer and Shiffrin, 1972). Recognition memory for a rapidly presented series of pictures is unaffected by the length of the interstimulus interval beyond one second (Shaffer and Shiffrin, 1972), though this is not always the case with complex non-verbal stimuli (Weaver, 1974). In contrast, the interstimulus interval is important to verbal retention as it allows time for the rehearsal of stimulus information. Pictures are less subject to retroactive and proactive interference than other stimulus material. Subjects are able to recognise large numbers of pictures after a single brief exposure (Nickerson, 1965). This is not the case with verbal material such as numbers, which is not surprising as each picture is unique and composed of unique units, which is not the case with verbal material.

It has been suggested that there is a sequentially organised verbal code and an imaginal code which involves parallel processing (Paivio, 1969; Tatum and Friden, 1974) although Arthur and Daniel (1974) found that both visual and verbal processing in their experiment were serial processes. Neisser and Beller (1970) showed that verbally mediated matching is necessarily serial and that parallel processing is confined to matching on the basis of physical characteristics (Beller, 1970). Levy-Agresti and Sperry (1968),as noted earlier, suggested that the two modes operate most efficiently when separated, each mode being confined to a hemisphere. There is however, no evidence for this view and it has recently been challenged (McKeever and VanDeventer, 1977).

Several researchers have investigated the possibility that there may be a distinction between the hemispheres in terms of parallel versus serial processing. Others have kept to the simple visual-verbal distinction. Attempts to define non-verbal material, which should give rise to a LVF (right hemisphere) advantage have led to a great amount of research using faces and shapes as stimuli. Verbal material has been studied in detail in an attempt to discover the limits of the right hemisphere's linguistic processing capacity. These approaches will be discussed in turn.

Experiments relating Hemispheric Asymmetry to Serial-Parallel Processing

It has been suggested (Cohen, 1973) that the right hemisphere is superior to the left hemisphere in the physical matching of stimuli, while the left hemisphere excels in name matching. In her 1973 paper, Cohen attempted to relate the method of processing of stimulus information to the hemisphere in which the information is processed. This had already been suggested as a possibility (De Renzi, Scotti and Spinnler, 1969; Levy-Agresti and Sperry, 1968). Cohen's experiment I involved the presentation of two, three or four letters in a cluster in either the left or right visual field. The subject had to judge whether all the letters were the same or whether one was different from the others, She found that when subjects responded "same" correctly, there was no difference in reaction time as a function of set size when the stimuli were presented in the LVF. However correct reaction times to "same" sets presented in the RVF were less than those to LVF stimuli and increased as a function of set size. The RVF stimuli may have had the advantage as "same" responses were made with the right hand and "different" responses were made with the left hand. There was no visual field asymmetry for correct "different" responses. Reaction time increased as a function of set size for correct "different" responses irrespective of the visual field of presentation. In her experiment II, Cohen (1973) used shapes as stimuli and found that for "same" responses the RVF was again superior in terms of response times. In her experiment III she balanced the hand used in response and the response and increased the number of items per set to two, three, four or five. When letters were presented in the RVF, correct "same" responses showed that an increase in set size produced an increase in reaction time. There was a decrease in reaction time when letters were presented in the "same" condition in the LVF. Correct "different" responses showed LVF presentations to be superior overall, but the interaction between hemisphere of presentation and set size is unclear. Correct "same" responses to shapes produced no significant differences while correct "different" responses produced faster reactions when the stimuli were presented in the LVF. In her experiment II, therefore, there was a bias in favour of the LVF on the "different" trials only. Therefore, although the exposure duration in this experiment was 200 msecs (that in experiments I and II was 100 msecs) it is unlikely that a pre-exposure bias can account for the LVF superiority. Cohen (1973) presented her stimuli monocularly to the right eye and argued that there would be no difference between the two visual pathways in favour of the faster contralateral pathway to the left hemisphere because it was not a competitive situation. Neill et al (1971) however, showed that the temporal pathway is superior and if they are correct the LVF bias obtained by Cohen (1973) may be due to this. Therefore, Cohen's results may be artifactual or they may show that the left hemisphere processes stimuli in a serial manner whereas it is not clear how the right hemisphere operates as the finding is contrary to expectations based on either a serial or parallel model.

Bradshaw and Wallace (1971) investigated the processing of faces. They presented subjects with identikit faces which were alike or differing in two to seven features. They argued that the processing was serial rather than a parallel search of the different features.

Thus attempts to assign a specific mode of processing to a particular type of stimulus and to a particular hemisphere have not been successful in producing the predicted results using the approach outlined above. It appears that most processing is in fact serial irrespective of the hemisphere of presentation and the type of stimulus material.

The next section therefore considers the experiments relating visual field asymmetries to the simple visual-verbal distinction. Firstly, however, the few experiments which have used extremely simple material, which is not readily classifiable as either visual or verbal material, will be considered.

Experiments Studying Visual Field Asymmetries Produced by Simple Stimuli

It has been found that the LVF is superior to the RVF in simple perceptual tasks, such as dot detection (Davidoff, 1977), discrimination of line orientation (Fontenot and Benton, 1972), curvature discrimination (Longden et al, 1976) and dot localisation (Kimura, 1969). However, the last type of task does not produce a consistent LVF advantage (Bryden, 1973; 1976). It has been suggested that the right hemisphere visual structures may be superior to those of the left hemisphere and that the locus of this superiority may be early in the system (Davidoff, 1977). As a result of this superiority at a very basic level, the right hemisphere may be concerned with the early visual processing of stimuli presented to both hemispheres (Bryden and Allard, 1976; Dorff, Mirsky and Mishkin, 1965). Short visual exposures may particularly favour the LVF due to this superiority.

Experiments Studying Visual Field Asymmetries Produced by Non-verbal Stimuli

The most commonly studied type of non-verbal material is faces, either as photographs, or as drawings of varying degrees of sophistication. Facial recognition appears to be a solely visual process in many instances, attempts to explore the role of verbal encoding being largely unsuccessful (Ellis, 1975), although the use of certain stimulus sets may allow subjects to encode verbally a limited number of faces.

Numerous studies have shown that faces presented in the LVF are recognised more rapidly and more accurately than those presented in the RVF (Berlucchi et al, 1974; Ellis and Shepherd, 1975; Geffen, Bradshaw and Wallace, 1971; Hilliard, 1973; Pirozzolo and Rayner, 1977; Rizzolatti et al, 1971). The LVF advantage in reaction time is increased when subjects have to discriminate emotional faces, which is consistent with the view that the right hemisphere is concerned with the processing and storage of affective material (Suberi and McKeever, 1977). Some recent studies have shown that the above findings do not generalise to familiar faces. Marzi and Berlucchi (1977) and Marzi et al (1974) have shown that there is a RVF superiority for the recognition of famous faces. This RVF advantage also applies when names are allocated to previously anonymous faces and the subjects learn the face-name combinations prior to the experiment (Marzi et al, 1974). These findings suggest that under certain conditions the discrimination of faces may rely on cognitive strategies which require left hemisphere involvement, possibly verbal processing. It has been suggested that in such instances the analysis of faces may rely on a single salient feature (Marzi and Berlucchi, 1977), which may be analysed by the left hemisphere (Paterson and Bradshaw, 1975).

Other tasks, which appear to involve primarily non-verbal processing are those requiring the recognition of different types of forms. These stimuli generally result in a LVF advantage if there is any visual field asymmetry produced. However the results are by no means clearcut. Fontenot (1973) reported that there was no visual field asymmetry for low complexity forms, but high complexity forms have been demonstrated to produce a LVF advantage (Dee and Fontenot, 1973). Hannay et al (1976) produced a contrary finding when they showed that there was a RVF superiority for low complexity four-point forms (Vanderplas and Garvin, 1959) and for higher complexity twelve-point forms. There was no visual field asymmetry obtained when eight-point forms were presented as lateralised stimuli. This type of stimulus material clearly requires more detailed study in order to assess its predominant processing mode.

Experiments Studying Visual Field Asymmetries Produced by Verbal Material

Although the left hemisphere is dominant for language processing, the right hemisphere is in possession of a reasonable linguistic capacity when it is isolated from the left hemisphere in split brain patients. The question of whether the linguistic skills of the isolated right hemisphere reflect normal right hemisphere function is now being investigated. It has been suggested that in the intact brain the left hemisphere may suppress the linguistic ability of the right hemisphere (Moscovitch, 1973; 1976) so that it is difficult to observe the right hemisphere's capacity in normal subjects.

There are several questions which may be posed in the investigation of the relative abilities of the two intact hemispheres. Words are composed of smaller units, that is, letters and groups of letters. A RVF superiority showing that the left hemisphere is generally better than the right at dealing with letters (Axelrod et al, 1977; Berlucchi et al, 1974) has often been found, particularly when subjects are required to make a name match rather than a physical match. Digits, which are a similar type of stimulus also give rise to a RVF superiority (Geffen et al, 1973). Letters may be combined in strings to form words or nonwords. The closeness of a letter string's approximation to a word is important in determining the visual field asymmetry which it will produce. Cohen and Freeman (1976) displayed letter strings in the left and right visual fields and required subjects to state whether the string was a word or a nonword. Nonwords, which were homophones of words, took longer to reject when they were presented to the left hemisphere than to the right hemisphere, indicating that the misleading phonological analysis occurred in the left hemisphere. It has been suggested previously that hemisphere dominance in speech perception may operate at this level (Shankweiler and Studdert-Kennedy, 1967). Words may be processed by the left hemisphere as "chunks" (Axelrod et al, 1977). There is a RVF advantage for high and low frequency words. This RVF advantage for bilaterally presented high frequency words increases as the word length increases and exposure duration decreases (Gill and McKeever, 1974). The RVF advantage also applies to pseudowords of high approximation to English when the subjects pronounce the pseudowords orally (Axelrod et al, 1977). This pronunciation, it has been argued, confers a unity upon the pseudowords allowing them to be processed as "chunks". Meaning may be an important factor when pseudowords are not pronounced orally (Leiber, 1976).

As the right hemisphere is more specialised for visual processing than the left hemisphere, it has been suggested that visual field asymmetry may vary as a function of the word's imagery-inducing capacity. The more concrete a word, the more imagery-inducing it generally is. Experiments investigating the visual field asymmetry as a function of the variations along the abstract-concrete dimension have produced conflicting results. Although Ellis and Shepherd (1974) showed a larger RVF superiority for familiar abstract words than for familiar concrete words under conditions of bilateral presentation, they could not reproduce this finding using unilateral presentation (Ellis, personal communication). Hines (1976) under conditions of unilateral and bilateral presentation used abstract-concreteness and word frequency as independent variables. He found that there was a larger RVF advantage for abstract noun recognition only when the words were familiar. There was no asymmetry in the perception of unfamiliar words. Again, under conditions of unilateral and bilateral presentation, Hines (1977) found that overall recognition varied positively with the degree of concreteness for high and moderate frequency words and that when abstract and concrete words were matched for RVF recognition, abstract words showed a larger RVF superiority. There were differences between these studies in terms of the methodology. Hines (1976) randomly paired words within the same dimension. Ellis and Shepherd (1974) paired abstract and concrete words. Orenstein and Meighan (1976) were unable to replicate Ellis and Shepherd's (1974) finding. They found a LVF superiority for both classes of words. Although Day (1977) found that reaction times obtained using abstract nouns as stimuli favoured the RVF supporting the view that abstract nouns, but not concrete nouns, are analysed necessarily by the left hemisphere, he argued that reports of differing visual field asymmetries for the identification of abstract and concrete nouns should be viewed with caution until they can be replicated.

As differential responsiveness of the two hemispheres to nouns and verbs has been suggested by the split brain research, some similar studies have been performed on normal individuals. Marshall (1973) found that nouns were more easily detected than verbs when they were presented in the RVF but there was no difference between the two word types when they were presented in the LVF. He argued that the right hemisphere does not organise its semantic memory according to a syntactic referencing system. Hines (1976) however, contradicted this study by finding a difference between the perception of nouns and verbs when they were presented in both the right and left visual fields. When investigating the visual field asymmetry produced by nouns, nouns derived from verbs (for example, worker) and words which may be used as either nouns or as verbs (for example, master), Caplan, Holmes and Marshall (1974) found no interaction between word class and visual field of presentation, contrary to the observations of split brain patients (Gazzaniga, 1970).

Another attempt to investigate a suggestion arising from clinical research was made by Ellis and Young (1977). They proposed that nouns acquired early in life and therefore bilaterally represented (which is itself an assumption that is open to question) would lead to less visual field asymmetry than later acquisitions. Later acquisitions, they argued, would give rise to a RVF advantage. In fact they found that all nouns gave rise to a RVF advantage.

In summary therefore, it may be said that the majority of verbal stimuli produce a RVF advantage. This appears to be due to the fact that the left hemisphere is specialised for language and in particular for the phonological processing of linguistic stimuli. Although it has been suggested that the left hemisphere's advantage may be particularly apparent when the processing of abstract words is required, the evidence for this is poor. Similarly, there is little evidence to date, arising from research on normal subjects, to suggest that there is a difference between the hemispheres in their relative abilities to process nouns and verbs. The right hemisphere appears to be generally poorer overall.

General Summary of the Direct Access Theory

The direct access view appears to be able to cope with much of the data generated in divided visual field experiments, although many may be partially explained by a scanning model. It is extremely striking, that verbal stimuli are usually better perceived when they are presented in the RVF, while non-verbal stimuli are frequently better perceived when they are presented in the LVF. This appears to provide the strongest support for the direct access theory. The basis of this visual-verbal distinction is not yet fully understood. It is doubtful that there is a clearcut serial-parallel processing distinction between the two hemispheres. Bryden and Allard (1976) suggested that the fundamental distinction between the two hemispheres may be their relative abilities to perform global and analytic processing. They suggested that the right hemisphere may be involved in global pre-processing of stimuli, while the left hemisphere is concerned with analytic-naming processing. If the stimulus requires extensive pre-processing there will be a visual field asymmetry produced which favours the LVF. If the stimulus requires only a small amount of pre-processing a more rapid identification will be possible when it is presented in the RVF.

Although the direct access theory can explain much of the data, it is often the case that findings are still relatively unpredictable and often difficult to replicate. This may be due to the complexities of the stimuli used.

It is possible that slight differences between apparently identical stimuli used in different laboratories may require slightly different processing. This alone, if Bryden and Allard (1976) are correct, could give rise to large differences in the observed visual field asymmetries. However, Kinsbourne's (1970) attentional theory of visual field asymmetries may also have something to offer in the explanation of the lack of consistency. It is to this theory which we shall now turn.

Attentional Theory of Visual Field Asymmetries

Kinsbourne (1970) proposed an attentional model of visual field asymmetries. He argued that even if fixation is controlled there are no means of controlling covert shifts of visual attention. Therefore, if attention is biassed to one side, the perceptual mechanisms will be more ready to respond to material presented on that side. He cited much evidence (Kinsbourne, 1974a,b,c) from both animal and human studies in support of his view that the cerebral hemispheres are in inhibitory balance with each other. He argued that when a stimulus display appears, there is a conflict between a tendency to orient towards the left side of the display (controlled by the right hemisphere) and to its right side (controlled by the left hemisphere). When hemispheric activity is in exact balance, gaze is directed towards the centre of the field. Thus attention is shifted towards the field contralateral to the more active hemisphere when one hemisphere is stimulated or depressed. The latter, he maintained, is the case with lesioned individuals. The visual field contralateral to the lesion may be neglected. Similarly when one hemisphere is suppressed with sodium amytal there is a sudden deviation of the gaze toward the side of anaesthesia.

Kinsbourne (1970; 1972; 1975b) argued that since man has asymmetrically lateralised higher cognitive functions, such as language, the activity of one hemisphere can be raised by such processing, so as to bias visual attention towards contralateral space. This would occur due to cross talk between the lateralised higher function and the orienting control mechanism on the same side. In support of this theory, Kinsbourne (1972) cited evidence from studies of gaze shifts during cognitive processing. Bakan (1969) speculated that left and right deviating subjects may differ in their cerebral organisation. Kinsbourne (1972) gave left and right handed subjects verbal, spatial and numerical questions and recorded their gaze deviation and change in head position. He found that head and eye movement were largely the same, supporting his view that they represent the same mechanism. Right handers oriented towards the right after verbal questioning, whereas some left handers looked left and some looked right. He showed in a further experiment that when subjects were required to repeat a sentence verbatim, they looked right if they were right handed. If they had to draw a representation of the sentence on paper, right handed subjects looked upward and left. Left handers looked either right or left in both tasks. This is in agreement with other indices of lateralisation and the suggestion that they are related to cognitive mode rather than to the mode of input (Seamon, 1974). Spatial questions led to upward and leftward orienting by right handers. Left handers who looked right with verbal questioning almost always did so with spatial questioning, whereas those who looked left with verbal questioning usually looked left with spatial questioning. Numerical questioning of left handers gave results less closely correlated with either of the other two conditions. Right handers looked upwards in this condition.

Kinsbourne's results, however, have proved difficult to replicate. Ehrlichman et al (1974), testing right handed subjects found that verbal questions elicited more downward shifts than did spatial questions. Spatial questions failed to produce gaze shifts more often than did verbal questions. These phenomena can not be dealt with adequately by Kinsbourne's theory, as these authors point out. Kinsbourne made no attempt to explain the vertical gaze shifts found in his experiments. In addition, Ehrlichman et al's (1974) data indicate that horizontal gaze shifts appear to be ipsilateral to the hemisphere presumably involved in the processing. As an explanation for the discrepancy between their data and that of Kinsbourne (1972) and Kocel et al (1972), Ehrlichman et al (1974) suggested that the subject populations may be different and that individual differences may moderate the effect. Another variable which appears to influence gaze shifts is that of experimenter position (Gur, 1975). Gur (1975) found that when the experimenter sat behind the subject (as was the case in Kinsbourne's study) verbal questions elicited gaze shifts towards the right, while spatial questions elicited shifts towards the left. When subjects were confronted by the experimenter, gaze deflections were in a consistent direction irrespective of the question asked. This latter finding is supported by Hiscock (1977), who found no difference between verbal and spatial questions in face to face or experimenter absent conditions. The findings from this study also suggested that the choice of questions is critical. Thus there is no really adequate support for Kinsbourne's hypothesised post-stimulus attentional biases from this source.

There is, however, evidence suggesting the influence of post-stimulus attentional biases of this type from studies of visual perception not involving tachistoscopic presentation. When subjects freely inspect photographs it appears that their attention is biassed towards the LVF, due to the greater right hemisphere involvement in the task. Gilbert and Bakan (1973) found that when subjects were given photographs of faces to inspect and asked to say whether the original or mirror-reversed photograph looked more like photographs constructed of two left or two right halves, right handed subjects almost always selected the construction composed of the half field which is on the subject's left in the inspection photograph. A similar finding is that right handers prefer slides with greater heaviness, or more important material, on the right (Levy, 1976). It was suggested that this balances the attentional bias towards the LVF when viewing non-verbal material.

Kinsbourne (1970; 1973; 1975b) demonstrated pre-stimulus effects of attentional biases. That is, he produced evidence which he claimed supported his theory of covert shifts in attention prior to stimulus exposure. These occur, he argued, because the contralateral hemisphere is already active prior to presentation of the stimulus. He performed several experiments in which outline squares were presented in the left, right (Kinsbourne, 1970; 1973) or central (Kinsbourne, 1975b) visual fields. On 50% of the trials a gap was present on one side of the square. In his 1970 paper, on 50% of the trials the gap was present on either the right, left, top or bottom of the square. However, Kinsbourne only presented data on gap detection when they were present on the left and right. In view of the conflicting evidence on post-stimulus effects this is unfortunate. Gap detection was compared under two conditions of tachistoscopic presentation. In one condition the subjects simply performed the visual gap detection task. In the alternative condition they were required to memorise a set of words, which they were to repeat after viewing the visual display. In the non-verbal condition, Kinsbourne found that there was no difference between left and right gap detection. In the verbal condition he found that gaps on the right were more frequently detected than those on the left of the square. Thus, given the same position in terms of visual angle from fixation, when a gap fell on the right of a square it was more likely to be detected than when it fell on the left of a square. Kinsbourne (1975b, experiment I) found more specifically that there was a trend towards greater efficiency of gap detection from left to right for gaps on the left of squares but not for gaps on the right of squares. In this experiment and in experiment II (Kinsbourne, 1975b) he showed that this right bias applied within as well as between visual fields. He explained his findings by arguing that verbally biassed attention will orient the perceptual analyser to the rightward extremity of the display. If the crucial feature is located there then it will have a high probability of being detected. If it happens to be elsewhere then it will not be detected until there is a further shift in attention leftwards, by which time the stimulus trace may have been lost. This attentional scan appears to operate in a very similar manner to the scan proposed by Heron (1957). Although the two hypothesised mechanisms should give rise to opposite results when verbal material is presented to the subject, it is possible that under some circumstances it may prove difficult to distinguish between them.

Kinsbourne's views have stimulated some recent research in the auditory and visual modes. The strongest support for his theory comes from the work of Morais and his colleagues. Morais (1974) has shown that the right side advantage in auditory unilateral recall can be obtained with presentation of the stimuli over loudspeakers.

This dismisses a purely structural view of lateral perceptual asymmetries. Work in the same laboratory (Morais and Landercy, 1977) has shown that a right ear advantage for the detection of consonants, which was present when the subjects had a verbal memory load, disappeared when the subjects had to retain a melody in memory.

There have been several studies in the visual modality. These have provided conflicting evidence, however. Davidoff (1977) found that a LVF advantage for dot detection was nullified in the condition in which subjects had a concurrent verbal task, hence supporting Kinsbourne's theory. Also providing support is the study of Hellige and Cox (1976). They found that a verbal memory load improved the RVF recognition accuracy of complex shape stimuli. Other studies, however, have failed to support Kinsbourne (Berlucchi et al, 1974; Gardner and Branski, 1976). In none of the experiments performed by Gardner and Branski (1976) was discriminability enhanced in either a concurrent verbal or music condition in the visual field in which Kinsbourne would have predicted. These studies have served to highlight several problems in this area of research. It is in practice difficult to distinguish between experimental situations in which a memory load will activate one of the hemispheres and produce a contralateral visual field superiority and situations in which a memory load will overload one hemisphere and lead to an ipsilateral visual field superiority (Geffen et al, 1973). Although a verbal memory load or verbal priming may cause a change in attentional bias in favour of the RVF, it may also lead to the subject's adoption of verbal strategies in the processing of all stimulus material irrespective of whether it is verbal or non-verbal. Thus, RVF superiority may in such cases be explained by the direct access theory. A further criticism of Kinsbourne's theory is that it can be manipulated to explain almost any data. If the anticipated results are not obtained it is possible to argue that the irrelevant mentation of the subject led to an attentional bias in the direction opposite to the direction anticipated.

General Summary

The three major types of explanation of visual field asymmetries have been considered. The first theory to be discussed was that advanced by Heron (1957). He argued that in reading English there are two opposing tendencies, which influence tachistoscopic recognition. There is the left to right scan involved in reading a line of text and the scan to the extreme left in order to begin a new line. It was suggested that these tendencies will act together to favour the RVF in conditions of unilateral presentation. When material is exposed bilaterally, the dominant tendency will be to scan to the extreme left, favouring the LVF.

Although much research supports Heron's theory, it has been shown more recently that when fixation is controlled and eye movements eliminated, a RVF advantage is obtained for verbal material presented bilaterally. The other important factor in producing these findings may be that these recent stimulus displays have not consisted of a series of discrete elements spread across the visual field. The left and right visual fields have been clearly separate. These later findings therefore, support a cerebral lateralisation view of visual field asymmetries. Further support for this type of explanation comes from studies which show that non-verbal material tends to produce a LVF perceptual advantage.

The two types of theory which relate cerebral lateralisation of function to visual field asymmetries have been discussed. The direct access theory is a structural theory. The important factor in determining visual field asymmetry is considered to be the hemisphere in which stimulus material is initially received. If verbal material is received in the left hemisphere by the most direct route (from the RVF) it will be processed more efficiently than if it is initially received in the right hemisphere (from the LVF). The converse is true of non-verbal material. It is not clear whether visual field asymmetries occur due to the differential processing efficiency of the two hemispheres or the callosal transfer of information. However, investigators have performed a large number of studies which have been interpreted as demonstrating each hemisphere's specialisations and capabilities.

The final theory to be discussed was Kinsbourne's attentional theory. He argued that visual field asymmetries arise neither from structural factors nor from cognitive factors such as scanning. The basis of his argument is that greater activation of one hemisphere leads to an attentional bias towards the space contralateral to that hemisphere. Hence the subject is more likely to perceive information presented in that visual field. Kinsbourne's theory appears to be well worthy of consideration although research has shown that it can not explain all the experimental data.

The following chapters contain a series of experiments in this area of visual field asymmetries. They are not intended as a study of the specialisations of the two hemispheres for particular tasks. Rather, they are investigations of the explanations of visual field asymmetries in an attempt to determine which is the most useful theory and how the theories are inter-related in explaining the observed results.

Chapter Three

Experiment One

Experiment One

Introduction

Although White (1969a), in his definitive review of the field, considered that a RVF superiority for the perception of unilaterally presented verbal stimuli had been fairly well established, he concluded that the corresponding LVF superiority for the perception of non-verbal-spatial stimuli was not so clearcut. Classification of stimuli, which are analysed predominantly by the right hemisphere, has proved rather difficult. As will have been noted from Chapter Two, stimuli producing a LVF advantage in a unilateral presentation paradigm have ranged from faces, through nonsense forms to dot localisation tasks. It is probably most convenient to adopt an operational definition of non-verbal stimuli. Such stimuli are those which can not be distinguished from other members of the stimulus set by means of readily applied verbal codes. Therefore one may present a group of nonsense stimuli which are not classifiable in terms of verbal concepts possessed by the subject. Vanderplas and Garvin's (1959) random shapes fall into this category. Alternatively one may present a set of highly similar stimuli which may be representations of well known and individually verbally classifiable objects. The latter type of stimuli were used in the following experiment. A series of outline drawings of people ("stickmen") were presented in a divided visual field apparatus.

As noted in the review, there are two major current measures taken of visual field asymmetry. One may use reaction time or response accuracy as the dependent variable. It has generally been assumed that the data obtained using these techniques reflects the same underlying mechanisms. Gross (1972) suggested that reaction time may be a more sensitive measure of hemispheric specialisation. The following experiment was analysed in terms of both of these measures in order to test the validity of this assumption.

In essence the subject was presented with a memory stimulus followed by a test stimulus,which was lateralised to one visual field. The task was to make the comparison between the two stimuli quickly and accurately. The aims of the study were therefore as follows. 1) To investigate whether or not there is a response time and accuracy difference between responses to stimuli presented in the two visual fields. 2) To discover whether "same" and "different" comparisons gave the same pattern of visual field asymmetry. Moscovitch (1972) found that although there was a visual field asymmetry in terms of response time favouring the LVF when the subjects made the response "same", there was no such asymmetry when the response was "different". 3) To investigate the effect of stimulus eccentricity. McKeever and Gill (1972b) found that response times to stimuli presented in different loci in the LVF were more consistent than the response times to stimuli presented at different RVF loci. Although response times favoured the RVF at a 1.5° locus by an average of 41.4 msecs, at a 3.9° locus the response times to RVF stimuli were on average only 17 msecs less than those recorded to LVF stimuli at 3.9° from fixation. Berlucchi et al (1971) found that although response time to stimuli increased as the stimuli were presented further from fixation, there was no interaction between stimulus eccentricity and visual field of stimulation.

Moscovitch (1972) presented subjects with verbal stimuli and argued that if they were required to respond with the left hand this would favour the right hemisphere if that hemisphere was capable of analysing the stimuli. In the experiment presented here, subjects were required to respond with their right hand. If one agrees with Moscovitch (1972) it may be argued that a right hand response would encourage the left hemisphere to analyse the stimuli if it is capable of analysing non-verbal stimuli as the left hemisphere is required to make the response. If the task processing and response are alternatively argued to be independent, as is more probable, one would expect that the left hemisphere would be at an advantage in producing the response in the following experiment.

Stimulus directionality may be related to the visual field asymmetry in tachistoscopic perception of words. Kimura (1966) suggested that directionality may also affect visual field asymmetry in the perception of non-verbal stimuli. Therefore in the following experiment stimuli of two types were presented. Some were in a left-facing orientation and some were right-facing.

Method

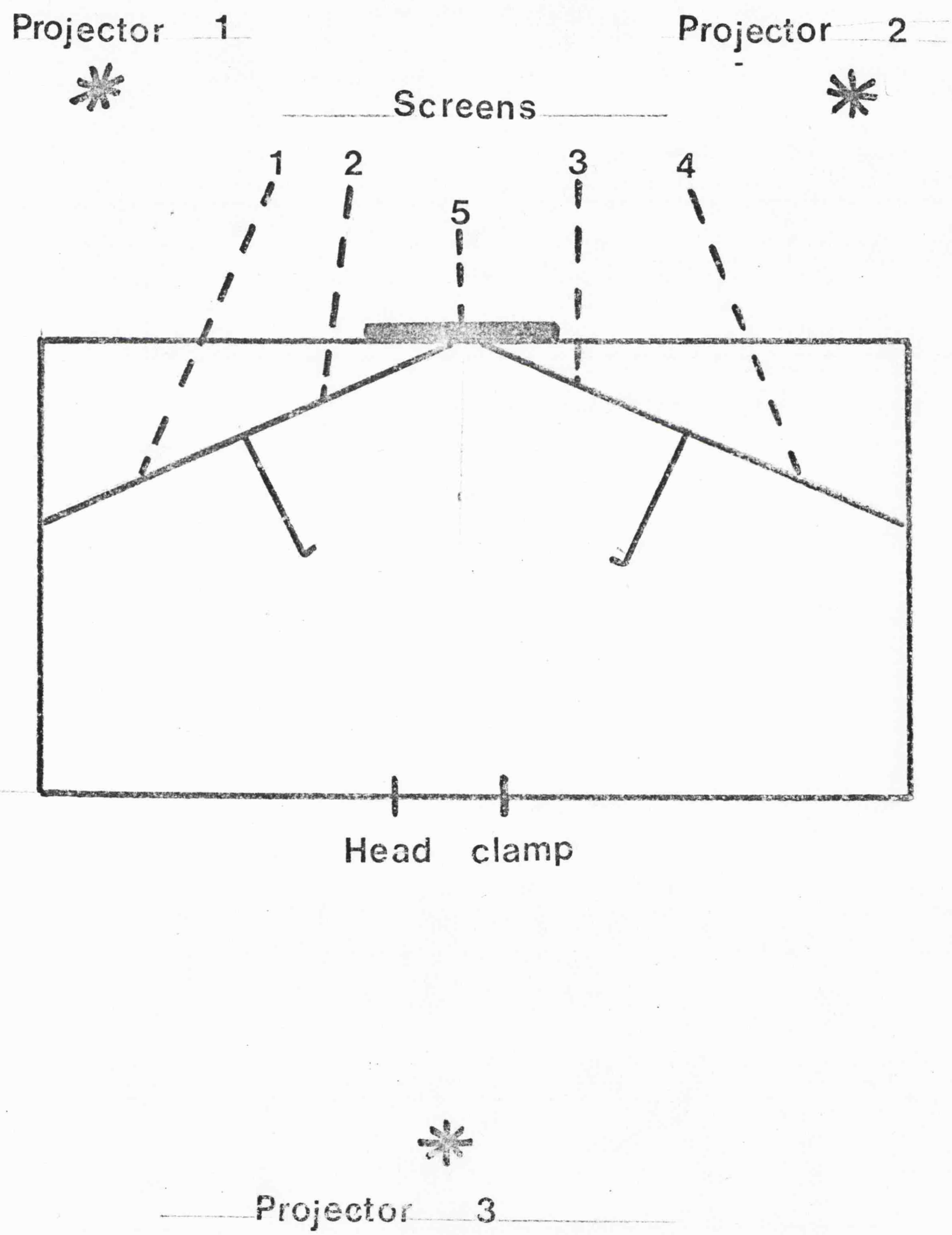
Apparatus and Stimulus Design

The divided visual field apparatus was taken from Dimond and Beaumont (1971). It consisted of four screens mounted as illustrated in Figure 3-1. The visual angles subtended by the screens were 20° and 50°. Two Hanimex Rondette projectors backprojected slides on to the four screens. A fifth screen was mounted above the central fixation point. Slides were projected on to this screen by a third projector. The stimulus exposure sequence was controlled by Behavioural Research and Development Ltd., logic modules. Stimulus exposure on the fifth screen was also controlled by this equipment. Stimulus exposure on screens 1,2,3 and 4 was controlled by means of electromagnetically operated shutters mounted on the projectors.

Screens 1 and 2 directed information to the RVF. Screens 3 and 4 directed information to the LVF. A red light mounted between screens 2 and 3 at the subject's eye level marked the fixation point. There was a small viewing hole above the fixation light in order that the experimenter could monitor the subject's fixation. The subject's head was held loosely in position by means of a head clamp. The subject's responses were made via two microswitches enclosed in a box, which was placed on a shelf in a convenient position below the table top of the divided visual field apparatus. The switches were connected to a Venner timer and a Kienzle printer.

Figure 3-1

Divided Visual Field Apparatus



Each trial began with a 2 second exposure of a slide, S1 on screen 5. This was followed by a 4 second interval after which the test stimulus, S2, was displayed for 125 msecs on one of the screens 1 to 4. Both the projectors A and B operated simultaneously giving equal illumination to the four screens. The subject was then given 3 seconds in which to respond, after which another trial sequence was initiated. Sixteen black outline drawings of "stickmen" were produced and from these a set of slides was prepared. In slide form each drawing was reproduced as "left-facing" and "right-facing" in terms of the direction in which the "stickman" appeared to be running. Figure 3-2 illustrates the "right-facing" set of stimuli.

Subjects

14 undergraduates of the University of Leicester acted as volunteer subjects. Half of the subjects were male. All the subjects scored eight or more right-handed responses on Annett's Handedness Questionnaire (Annett, 1970). All had normal, or corrected to normal vision. Their ages ranged from 18 to 21 years with a mean of 18.64 years.

Procedure

The subject was seated in front of the screens with his head in the head clamp. He was instructed to look at the screen 5 during the period that the slide S1 was being shown and then with as little movement as possible

Figure 3-2

Stimuli used in Experiments One and Two

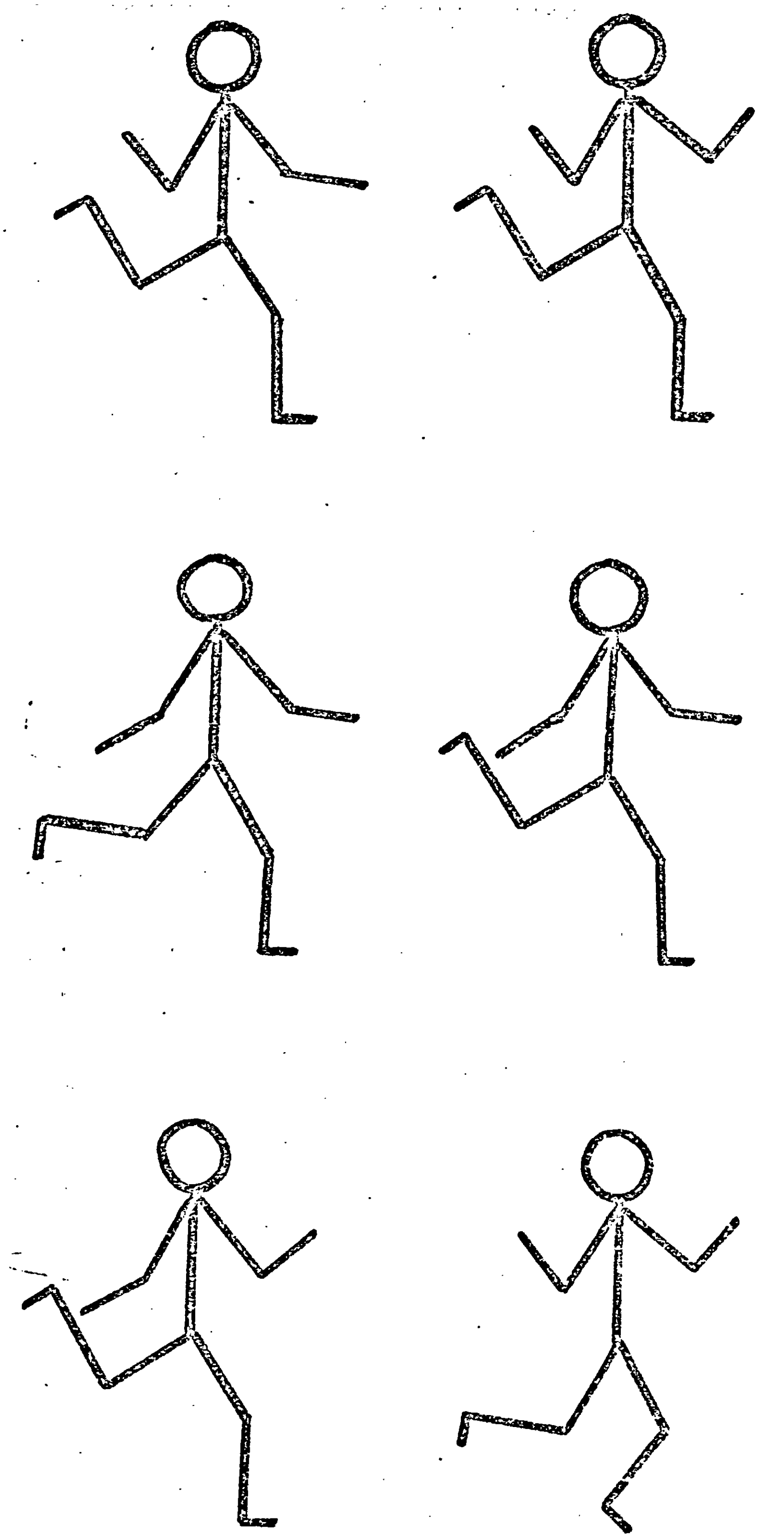


Figure 3-2 continued

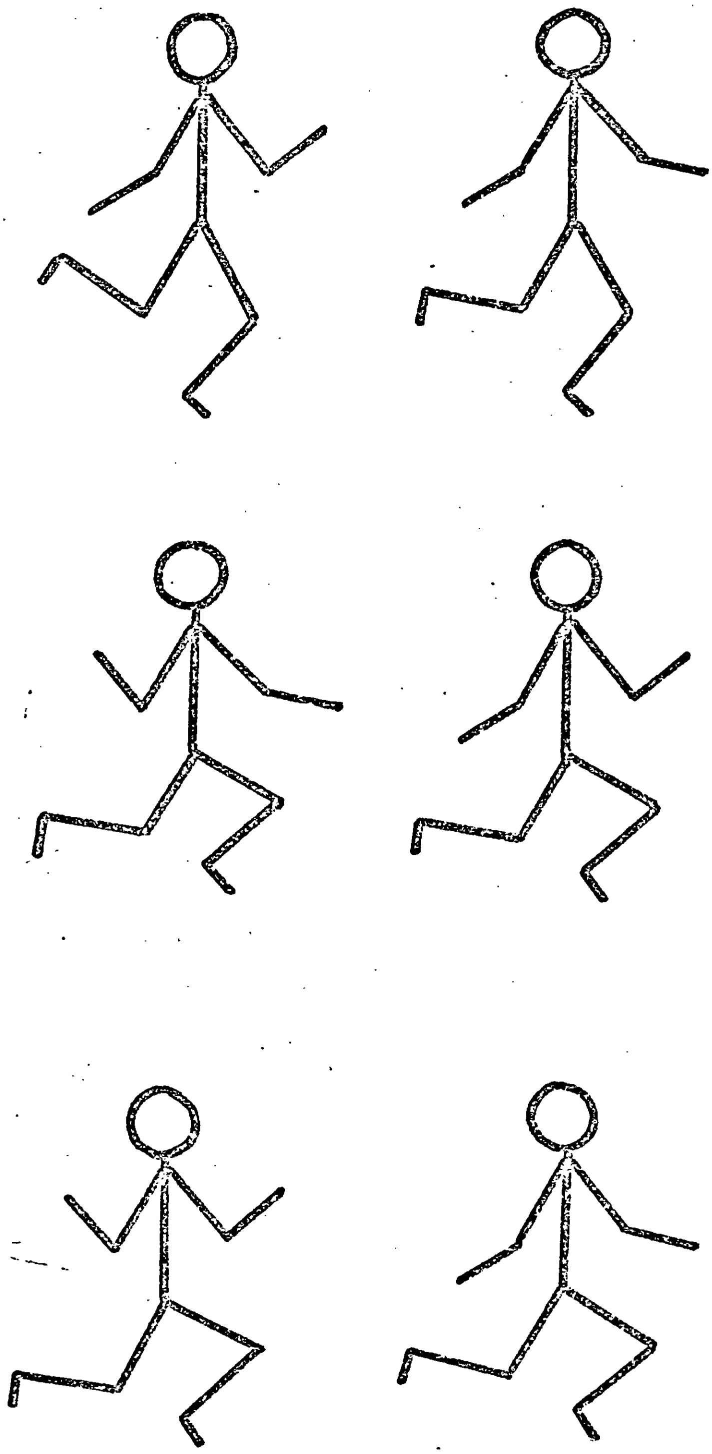
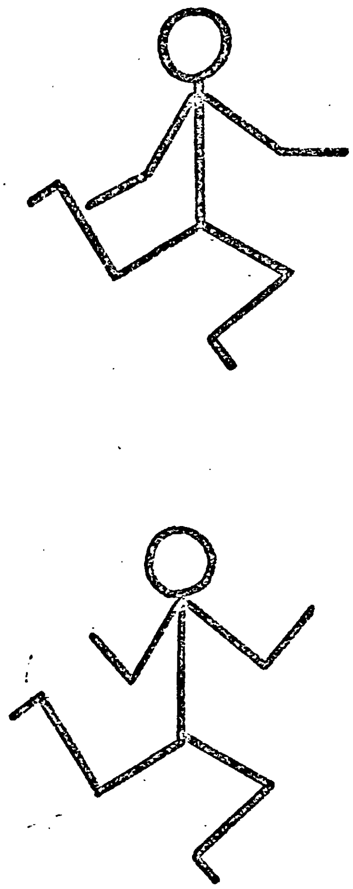


Figure 3-2 continued



to return his gaze to the fixation point. When the slide, S2, had flashed on to one of the screens 1 to 4 he was instructed to press the "same" or "different" response button, with his right hand, as quickly as possible, according to whether S1 and S2 were the same or different from each other. He was then to return his gaze to screen 5 in preparation for the next trial. Half of the subjects used their index finger for "different" responses and their third finger for "same" responses, this being reversed for the other half of the group.

Stimuli were presented in blocks of 16 trials. Blocks of stimuli facing left and right were alternated. Half of the subjects began with a block of right-facing stimuli and half began with a block of left-facing stimuli. Each subject began with four blocks of practice trials followed by four experimental blocks. The subjects were not informed of this distinction between trial blocks.

Within each block, memory stimuli (S1) were randomised and test stimuli (S2) were also randomised within the constraint that there was an equal number of "same" and "different" comparisons on each of the screens 1 to 4 within and block and that each stimulus appeared once as a memory stimulus. "Different" discriminations were not of equal difficulty. Sixteen blocks of trial sequences were prepared (eight right-facing and eight left-facing). Each subject was randomly allocated to a particular random combination of eight blocks (four right-facing and four left-facing).

Results

The data were first analysed in terms of errors. Table 3-1 presents the mean error scores in each condition and their standard deviations. A 5-way analysis of variance (Table 3-2) was performed. There were fewer errors to stimuli presented in the LVF than to stimuli presented in the RVF ($F=6.33$, df 1,13, $p<.05$). There were fewer errors when stimuli fell on one of the inner screens (2 and 3) than on the outer screens (1 and 4) ($F=7.411$, df 1,13, $p<.05$). The only significant influence on error scores of the type of comparison (that is, "same" or "different") and stimulus directionality was an interaction between the two factors ($F=7.944$, df 1,13, $p<.05$).

Table 3-3 shows the means and standard deviations of the correct response times. Table 3-4 is the 5-way analysis of variance summary. Subjects 2,13 and 14 were discarded from the analysis because they made no correct responses in some of the conditions. Subject 6 was randomly discarded in order to balance the finger used in response and the trial order. Responses to stimuli presented in the inner visual fields were faster than those to stimuli presented in the outer visual fields ($F=19.280$, df 1,9, $p<.01$). There were no other significant differences.

Table 3-1

Means and Standard Deviations of the Error Scores

			LVF		RVF	
			Same	Diff.	Same	Diff.
Inner	left-facing	$\bar{X}$	0.643	0.857	1.143	1.500
		s.d.	0.929	1.027	0.949	1.019
	right-facing	$\bar{X}$	0.929	0.786	1.500	1.500
		s.d.	1.141	0.802	1.019	1.160
Outer	left-facing	$\bar{X}$	1.214	1.286	1.429	1.500
		s.d.	1.251	0.994	0.852	0.760
	right-facing	$\bar{X}$	1.500	1.000	2.214	1.214
		s.d.	0.941	0.784	0.975	0.893

Table 3-2

Summary of the Analysis of Variance on the Error Data

Source	SS	df	MS	F
Subjects	20.522	13	1.579	
A (vis. field)	12.540	1	12.540	6.33*
A x subjects	25.772	13	1.982	
B (comparison)	0.754	1	0.754	
B x subjects	31.058	13	2.389	
C (inner/outer)	5.469	1	5.469	7.411*
C x subjects	9.594	13	0.738	
D (direction.)	1.004	1	1.004	
D x subjects	7.058	13	0.543	
AB	0.040	1	0.040	
AB x subjects	6.522	13	0.502	
AC	1.004	1	1.004	
AC x subjects	11.308	13	0.870	
AD	0.362	1	0.362	
AD x subjects	7.451	13	0.573	
BC	2.790	1	2.790	4.522
BC x subjects	8.022	13	0.617	
BD	4.862	1	4.862	7.944*
BD x subjects	7.951	13	0.612	
CD	0.004	1	0.004	
CD x subjects	15.058	13	1.158	
ABC	0.540	1	0.540	
ABC x subjects	4.022	13	0.309	
ABD	0.219	1	0.218	
ABD x subjects	20.844	13	1.603	
ACD	0.112	1	0.112	
ACD x subjects	11.701	13	0.900	
BCD	0.754	1	0.754	
BCD x subjects	12.058	13	0.928	
ABCD	0.219	1	0.219	
ABCD x subjects	7.844	13	0.603	
total	237.458	223	1.065	

* $p < .05$

Table 3-3

Means and Standard Deviations of the Correct Response Times

			LVF		RVF	
			Same	Diff.	Same	Diff.
Inner	left-facing	$\bar{X}$	1305.358	1234.375	1215.175	1214.091
		s.d.	332.998	228.314	340.153	191.983
	right-facing	$\bar{X}$	1252.092	1212.816	1300.916	1231.358
		s.d.	238.377	274.430	246.449	185.688
Outer	left-facing	$\bar{X}$	1412.191	1307.883	1346.857	1445.732
		s.d.	347.399	231.102	386.466	411.906
	right-facing	$\bar{X}$	1274.792	1333.925	1366.308	1403.275
		s.d.	316.303	225.835	306.755	374.302

Table 3-4

Summary of the Analysis of Variance on the Correct Response Times

Source	SS	df	MS	F
Subjects	8002595.994	9	889177.333	
A (vis. fld.)	22629.048	1	22629.048	0.548
A x subjects	371884.394	9	41320.488	
B (same/diff)	5088.859	1	5088.859	
B x subjects	498639.882	9	55404.431	
C (inner/outer)	534513.591	1	534513.591	19.280**
C x subjects	249512.691	9	27723.632	
D (direct.)	7046.37	1	7046.37	
D x subjects	189522.311	9	21058.035	
AB	30424.601	1	30424.601	
AB x subjects	365867.947	9	40651.994	
AC	47776.436	1	47776.436	
AC x subjects	325229.711	9	36136.635	
AD	44283.702	1	44283.702	2.132
AD x subjects	186896.089	9	20766.232	
BC	46093.238	1	46093.238	4.340
BC x subjects	95585.685	9	10620.632	
BD	2621.646	1	2621.646	
BD x subjects	309840.796	9	34426.755	
CD	16513.252	1	16513.252	
CD x subjects	727339.251	9	80815.472	
ABC	12496.224	1	12496.224	
ABC x subjects	540298.48	9	60033.164	
ABD	66231.113	1	66231.113	3.779
ABD x subjects	157722.069	9	17524.674	
ACD	5004.391	1	5004.391	
ACD x subjects	60324.685	9	6702.74	
BCD	11954.306	1	11954.306	
BCD x subjects	286856.660	9	31872.962	
ABCD	9791.892	1	9791.892	
ABCD x subjects	423546.130	9	47060.681	
Total	13654131.444	159	85875.037	

Discussion

The prediction of a visual field asymmetry in favour of the LVF was upheld when the number of errors was the dependent variable. It would therefore seem appropriate to discuss the results in terms of a cerebral lateralisation view. There was no visual field asymmetry in terms of response times, however, irrespective of the type of comparison. Several explanations of this discrepancy may be provided. There may be a trade-off between errors and response times. Subjects were required to respond within a certain time limit. It is therefore probable that they placed more emphasis on keeping their response times within acceptable limits, rather than keeping their error rates within limits. Therefore on trials in which an error occurred an increase in processing time may have eliminated the error.

An alternative explanation is that there may be a difference between the hemispheres in terms of processing time in favour of the right hemisphere, which would have been measurable, given suitable experimental conditions. If this processing time difference is comparable to the time taken for response information to transfer from the right hemisphere to the left hemisphere, any advantage gained by the right hemisphere/LVF stimuli in terms of faster processing, would be lost in the necessary callosal transfer to the left hemisphere for the right hand response.

In contrast to the preceding lack of correspondence between error data and response time data, there was a difference in terms of both errors and correct response times between the inner and outer screen presentations. The lower visual acuity of the peripheral visual fields was observable in terms of increased errors and response times. The findings discussed, taken together, may be said to suggest that response times and error scores do not measure the same mechanisms. It is arguable that only the error score provides an index of visual field asymmetry due to hemispheric lateralisation of function. The most parsimonious explanation of the limited data available is based on the fact that due to the large number of errors there was a correspondingly reduced pool of correct response times. The variance of the response time data may have swamped a small visual field asymmetry, which, given a larger sample of data may have been demonstrable.

The interaction between type of comparison and stimulus directionality is difficult to interpret. Subjects responded "different" to "same" comparisons more frequently when the "stickmen" were facing right than when they were facing left. Subjects may scan the stimuli in a particular direction or there may have been an attentional bias towards the left of the figure (Kinsbourne, 1970). Such a mechanism may be hypothesised to have an effect on the pattern of responses, dependent upon the directionality of the stimuli if there was more information available from this experiment. However, it may be that this finding is an artifact of the selection of comparisons in the "different" condition.

This experiment produced the anticipated visual field asymmetry in terms of errors. This supports both a direct access theory or an attentional theory of visual field asymmetries. Initially the former type of explanation will be considered. It is not possible to distinguish between the alternative mechanisms which underly a direct access model. It is possible that material presented in the RVF, initially arriving in the left hemisphere, may be analysed exclusively by that hemisphere. Thus the greater number of errors arising in response to RVF stimuli may be due to the poorer facilities in the left hemisphere for processing non-verbal information, relative to the right hemisphere's non-verbal processing facilities. However, the greater number of errors to stimuli arriving in the RVF may be due to their having to be transferred to the right hemisphere, across the corpus callosum with the consequent loss of fidelity. Experiment two attempts to distinguish between these two alternatives.

<u>Chapter Four</u>

<u>Experiment Two</u>

Experiment Two

Introduction

This experiment was designed to investigate the direct access model of visual field asymmetry in more detail. The two alternative mechanisms which may underly visual field asymmetry within a direct access interpretation are, as stated earlier, either that material of a particular type must be analysed by the hemisphere dominant for that type of material, or that material may be analysed by either of the hemispheres, though less efficiently by the hemisphere subordinate for the analysis of that type of material. It has been suggested that the two hemispheres may have different modes of processing, as discussed in Chapter Two. The left hemisphere may process material in a serial manner (assumed to be suitable for verbal material) while the right hemisphere may use parallel processing, which has been thought to be more suitable for non-verbal material.

Serial processing is the analysis of each feature in turn and may or may not be self-terminating. A self-terminating model of an experiment, such as experiment one, would predict that the subject would analyse each feature of S2 in turn until a feature, which distinguished it from S1, was located. The subject would then make the response "different". "Different" responses would tend to be faster than "same" responses, as in order to make a "same" response the subject would have to analyse all features of the stimulus. The greater the number of features differing between S1 and S2, the shorter the response time for "different" responses.

When all features of S2 are analysed simultaneously as in parallel processing there would be no difference in response times to "same" and "different" comparisons. There would also be no variation in response times as a function of the number of features differing between S1 and S2.

The following experiment is essentially a replication of experiment one. In experiment two, however, the "different" comparisons were graded in terms of the number of features varying between S1 and S2. Thus if both hemispheres are able to process non-verbal material, utilising their peculiar processing modes, which may be parallel and serial self-terminating, RVF and LVF presentations of S2 should give rise to different patterns of response time data when the "different" comparisons are considered. "Different" response times to RVF stimuli should be less than response times to "same" stimuli presented in the RVF if the left hemisphere uses a serial self-terminating mode. There should be no difference between "same" and "different" response times to LVF stimuli if the right hemisphere uses a parallel process.

Method

Apparatus and Stimulus Preparation

The apparatus was that used in experiment one. The stimuli used were those from experiment one, although the "different" comparisons were altered. There were three levels of "different" comparison in this experiment. Level 1 was that in which S2 differed from S1 by the position of one arm only. Level 2 was that in which S2 differed from S1 by two arms. In level 3 there were randomly more differences than at level 2. Thus level 3 S2 stimuli may have differed from S1 stimuli by one or both legs and both arms.

Subjects

18 subjects participated in this experiment, 16 were undergraduates of the University of Leicester and 2 were postgraduates. All subjects had normal, or corrected to normal, eyesight (spectacles if worn had unobtrusive frames) and gave 8 or more right handed responses on Annett's Handedness Questionnaire (Annett, 1970). There were 11 males. The age range was from 18 to 28 years with a mean age of 20 years.

Procedure

Stimulus presentation was divided into 8 blocks, each of which was composed of 16 trials. The subject performed 2 blocks of practice trials (this was considered sufficient as a consequence of experiment one pilot work).

One practice block of trials consisted of right-facing stimuli, the other was a set of left-facing stimuli. The order of presentation of these practice blocks was balanced across the group. The remaining 6 blocks of trials (3 right-facing and 3 left-facing) were then presented in random order as experimental trials.

Each trial begain with slide S1 presented on the screen 5 for a period of 2 seconds, following which there was an interval of 4 seconds during which the subject had to shift his gaze to the fixation point. Fixation was visually monitored by the experimenter and as subjects had no difficulty in fixating, no experimental trials had to be discarded. Slide S2 was randomly allocated to one of the screens 1 to 4, with the proviso that within a block of trials there were four slides per screen. On 50% of the trials in each block on each screen S2 was the same as S1. In the remaining 8 trials per block, S2 differed from S1 by one arm (level 1), two arms (level 2) or randomly more than two arms (level 3). The number of trials in each of these conditions was balanced across screens for the 6 experimental blocks. Within blocks the presentation of same and different S2's was randomised.

The subject was given 3,400 msecs in which to give a manual yes/no response to slide S2. Half of the group was instructed to press the index finger key when S2 was the same as S1 and the third finger key when S2 was different from S1. The other 9 subjects were given the reverse instructions. Both speed and accuracy were emphasised. After making the response the subject directed his gaze towards screen 5 in preparation for the next trial, which followed immediately after the 3,400 msec response interval. During the practice blocks the subjects were told whether or not they had made a correct response immediately after each response. No feedback was provided during the experimental trials because it tended to disrupt the performance of pilot subjects. There was an interval of approximately 2 minutes between blocks. Response times in excess of 3,400 msecs were not recorded, but as there were few (three for one subject in all) they were scored as errors with a response time of 3,400 msecs, for purposes of the analysis.

Results

The first analysis pooled all categories of "different" comparisons. A 4-way analysis of variance (Table 4-1) was performed on the number of errors (Table 4-2). There were more errors to stimuli presented in the RVF than in the LVF ($F=9.96$, df 1,17, $p<.01$). There were more errors when the subjects were required to respond "different" than when they were required to respond "same" ($F=6.15$, df 1,17, $p<.05$). There were more errors when stimuli were presented on the outer screens (1 and 4) than when they fell on the inner screens (2 and 3) ($F=13.99$, df 1,17, $p<.01$). There was a significant interaction between type of comparison and inner/outer screens ($F=17.93$, df 1,17, $p<.01$). Tukey (a) tests showed that the interaction was due to the "same" comparisons on the

Table 4-1

Means and Standard Deviations of the Error Scores

		LVF		RVF	
		Inner	Outer	Inner	Outer
"Same"	$\bar{X}$	2.78	4.83	3.44	5.67
comparisons	s.d.	2.13	2.28	2.83	2.70
"Different"	$\bar{X}$	6.00	4.83	6.28	6.39
comparisons	s.d.	1.97	1.58	1.96	1.75

$\bar{X}$ Outer Screens = 5.43

$\bar{X}$ Inner Screens = 4.63

$\bar{X}$ "Same" comparisons = 5.45

$\bar{X}$ "Different" comparisons = 4.63

Table 4-2

Summary of the Analysis of Variance on the Error Scores

Source	SS	df	MS	F
Subjects	127.14	17	7.48	
A (visual field)	25.00	1	25.00	9.96**
A x subjects	42.75	17	2.51	
B (type of comp)	103.36	1	103.36	6.51*
B x subjects	269.89	17	15.88	
C (inner/outer)	23.36	1	23.36	13.99**
C x subjects	28.39	17	1.67	
AB	0.25	1	0.25	0.11
AB x subjects	40.50	17	2.38	
AC	4.69	1	4.69	1.75
AC x subjects	45.56	17	2.68	
BC	64.00	17	64.00	17.93**
BC x subjects	60.75	17	60.75	
ABC	2.78	1	2.78	1.26
ABC x subjects	37.47	17	2.20	
Total	875.89	143	6.13	

* $p<.05$

** $p<.01$

inner screen giving rise to significantly fewer errors than "same" comparisons on the outer screens ($q_{4,17}=6.70$, $p<.01$) and "different" comparisons on inner ($q_{4,17}=9.61$, $p<.01$) and outer screens ($q_{4,17}=7.94$, $p<.01$).

Table 4-3 shows the means and standard deviations of the correct response times when all the "different" comparisons were pooled. Table 4-4 is the 4-way analysis of variance summary table of the data. There was no difference between visual fields ($F=1.92$, df 1,17, $p>.05$), type of comparison ($F=0.17$, df 1,17, $p>.05$) or inner/ outer screens ($F=1.37$, df 1,17, $p>.05$). There was a significant interaction between visual field and inner/ outer screens ($F=5.54$, df 1,17, $p<.05$). Tukey (a) tests showed that the response times to stimuli presented on the outer screen in the RVF were longer than the response times to stimuli presented on the inner screen in the RVF ($q_{4,17}=4.13$, $p<.05$) and the inner screen ($q_{4,17}=4.10$, $p<.05$) and outer screen ($q_{4,17}=4.68$, $p<.05$) of the LVF.

Analyses were then performed on the 3 levels of "different" comparisons. Table 4-5 shows the means and standard deviations of the error scores. Table 4-6 is the 4-way analysis of variance summary on the error data. There were more errors when the stimuli were presented in the RVF than in the LVF ($F=5.60$, df 1,17, $p<.05$). There was a significant difference between levels of "different" comparisons ($F=21.54$, df 2,34, $p<.01$). Tukey (a) tests showed that there were more errors when there was only one distinguishing feature between S1 and S2 ($q_{3,34}=6.97$, $p<.01$) or two distinguishing features ($q_{3,34}=9.06$, $p<.01$)

Table 4-3

Means and Standard Deviations of the Correct Response Times

		LVF		RVF	
		Inner	Outer	Inner	Outer
"Same"	$\bar{X}$	1535.08	1542.81	1564.60	1675.70
comparisons	s.d.	309.38	256.41	366.71	388.44
"Different"	$\bar{X}$	1564.03	1525.54	1532.93	1642.25
comparisons	s.d.	281.57	282.92	306.35	433.73

Table 4-4

Summary of the Analysis of Variance on the Correct Response Times

Source	SS	df	MS	F
Subjects	10300740.85	17	605925.93	
A (visual field)	138404.46	1	138404.46	1.92
A x subjects	1224270.56	17	72015.92	
B (type of comp)	6424.16	1	6424.16	0.17
B x subjects	639981.57	17	37645.97	
C (inner/outer)	80930.30	1	80930.30	1.37
C x subjects	1003698.15	17	59041.07	
AB	13268.16	1	13268.16	0.56
AB x subjects	399242.80	17	23484.87	
AC	141952.50	1	141952.50	5.54*
AC x subjects	435833.43	17	25637.26	
BC	5186.77	1	5186.77	0.14
BC x subjects	650778.06	17	38281.06	
ABC	4443.21	1	4443.21	0.17
ABC x subjects	443644.21	17	26096.72	
Total	15488799.18	143	108313.28	

* $P < .05$

Table 4-5

Means and Standard Deviations of the Error Scores for the Three Levels of Different Comparisons

		LVF		RVF	
		Inner	Outer	Inner	Outer
Level 1	$\bar{X}$	2.22	2.50	2.67	3.00
	s.d.	1.11	1.10	1.03	0.69
Level 2	$\bar{X}$	2.39	1.67	2.44	2.11
	s.d.	1.38	1.03	1.25	0.90
Level 3	$\bar{X}$	1.44	0.67	1.17	1.33
	s.d.	0.98	0.84	1.10	1.19

Table 4-6

Summary of the Analysis of Variance of the Error Scores For the Three Levels of Different Comparisons

Source	SS	df	MS	F
Subjects	34.86	17	2.05	
A (visual field)	5.04	1	5.04	5.60
A x subjects	15.37	17	0.90	
B (level)	78.81	2	39.41	21.54*
B x subjects	62.35	34	1.83	
C (inner/outer)	1.67	1	1.67	1.88
C x subjects	15.08	17	0.89	
AB	0.78	2	0.39	0.47
AB x subjects	28.06	34	0.83	
AC	2.89	1	2.89	5.78
AC x subjects	8.52	17	0.50	
BC	6.70	2	3.35	2.72
BC x subjects	41.80	34	1.23	
ABC	1.81	2	0.91	1.23
ABC x subjects	25.02	34	0.74	
Total	328.77	215	1.529	

* $p < .05$

than when there were more than two features in which the two stimuli differed. There was no difference in the number of errors to "different" comparisons with one or two distinguishing features ($q_{3,34}=2.09$, $p>.05$). There was no effect of inner versus outer screens ($F=1.88$, df 1,17, $p>.05$). There was, however, a significant interaction between visual field and inner/outer screens ($F=5.78$, df 1,17, $p<.05$). Tukey (a) tests showed that there were significantly fewer errors to stimuli presented in the outer LVF than the inner LVF ($q_{4,17}=4.23$, $p<.05$), inner RVF ($q_{4,17}=5.00$, $p<.05$) and outer RVF ($q_{4,17}=5.58$, $p<.05$).

Table 4-7 shows the means and standard deviations of the correct response times in the "different" comparisons analysis. Only 12 subjects were included in this analysis. Subjects 1,2 and 13 were eliminated as they did not produce sufficient correct response times. Subjects 8,19 and 11 were randomly discarded in order to balance the finger used in making the response across the remaining group of subjects. Inner and outer screens were pooled due to insufficient data. Table 4-8 shows the analysis of variance summary. There was a significant effect of the number of distinguishing features ($F=6.01$, df 2,22, $p<.05$). Tukey (a) tests showed that there were shorter response times when S1 and S2 had several distinguishing features rather than one difference ($q_{3,22}=4.56$, $p<.05$) or two differences ($q_{3,22}=3.84$, $p<.05$).

Table 4-7

Means and Standard Deviations of the Correct Response Times for the Three Levels of Different Comparisons

		LVF	RVF
Level 1	$\bar{X}$	1754.62	1663.79
	s.d.	353.34	354.39
Level 2	$\bar{X}$	1699.29	1651.58
	s.d.	477.67	491.04
Level 3	$\bar{X}$	1484.52	1503.94
	s.d.	324.20	339.52

Table 4-8

Summary of the Analysis of Variance on the Correct Response Times for the Three Levels of Different Comparisons

Source	SS	df	MS	F
Subjects	6639065.56	11	603551.41	
A (visual field)	28383.91	1	28383.91	0.22
A x subjects	1392925.31	11	126629.57	
B (level)	641534.13	2	320767.06	6.01*
B x subjects	1174952.91	22	53406.95	
AB	37045.41	2	18522.70	0.36
AB x subjects	1134222.32	22	51555.56	
Total	11048129.55	71	155607.47	

* $p < .05$

Discussion

Only the overall analysis of errors showed a visual field asymmetry in favour of the LVF. Thus there is no evidence of an interhemispheric transfer of information from the response time data. It is possible that the greater error rate to stimuli presented in the RVF is due to information received in the left hemisphere being transferred to the right hemisphere with a consequent loss of fidelity. Alternatively, the error score differential between the hemispheres may be due to a difference in processing efficiency. It is possible that the factors suggested in Chapter Three may be operating to eliminate the asymmetry, which would otherwise be measured, in terms of response times. It is also true that the response times obtained in experiments one and two were larger than those obtained by other workers in the field. This is presumably due to the more complex stimulus comparisons that the subjects in experiments one and two had to perform. It is likely that in a more complex task there will be a greater variance due to factors other than hemispheric differences in processing time and the simple transfer of information between the hemispheres. There may, for example, be several methods of structuring the complex information for transfer across the corpus callosum, if such a transfer is required. Therefore, any visual field asymmetry in terms of response times may be masked by this variance. It may be necessary to choose a simpler comparison task which will generate very few errors and shorter response times. This was attempted in experiment three.

There was no difference in response time to "same" or "different" comparisons. This suggests that a serial self-terminating process was not taking place in either of the hemispheres. However, response times to level 3 "different" comparisons were shorter than response times to level 1 and level 2 "different" comparisons. Therefore a serial self-terminating process can not be entirely ruled out. It may be that the small difference in processing time between level 1 and level 2 comparisons is indetectable with the limited amount of data available from this experiment. There is, however, no evidence that the two hemispheres analyse the information differently from each other and there was no interaction between visual field of presentation and level of "different" comparison. Therefore one must conclude, if a direct access model is appropriate, that in the situation observed in this experiment either all the information was analysed in the right hemisphere, that both hemispheres were analysing the information using the same processing mode, or that both hemispheres were analysing the stimuli using different modes which were indistinguishable given tha data collected in this experiment. Thus the left hemisphere may have been using a non-self-terminating serial mode, and the right hemisphere may have used a parallel mode. Any difference in favour of the right hemisphere may have been masked by the factors mentioned earlier.

Townsend (1971; 1972) made the point that it is in fact not possible to distinguish between certain forms of serial and parallel processing by means of response times. For example, a parallel process may take longer the more features there are to analyse, if the analyser has a limited capacity available. Thus such a system would produce the same data as a serial system.

One may postulate a system in which two modes of processing are possible given stimuli of a particular relationship. For example, if there are sufficient differences between S1 and S2 (as perhaps in level 3) the information may be processed holistically, the operation taking less processing time than either a serial or parallel process as previously postulated. There was a large difference in terms of response time and errors between level 3 comparisons and level 1 and level 2 comparisons. There may have been a qualitative difference between these conditions in their processing.

Subjects had a bias towards responding "same" to stimuli on the inner screens. This may have been due to the difficulty of some of the "different" comparisons. Level 1 and level 2 comparisons may have looked the "same". On the outer screens, however, there was an equal number of errors to "same" and "different" comparisons. In this case the subjects may have been responding rather more randomly as their acuity was poor. As in experiment one, there was no inner/outer screen effect on response times. In the present experiment, stimuli on the outer RVF screen produced longer response times than those on the inner RVF screen and LVF screens. This is interesting as McKeever and Gill (1972b) found that there was a greater fall off across the RVF than the LVF. Rizzolatti et al (1971), who used more comparable visual angles however, found no such interaction between visual angle and visual field. It is possible that this finding has emerged in experiment two either as a function of the more difficult "different" comparisons compared with those of experiment one, or the larger body of data.

There is a rather unusual finding resulting from the analysis of errors between the "different" conditions. That is, there were fewer errors to stimuli presented in the outer LVF than to stimuli presented in any of the other three positions. This finding is not in line with a direct access interpretation of the data because such a model would predict that information in both LVF positions would be more likely to be accurately identified than information presented in either RVF position allowing that stimuli in the inner visual fields will be more accurately identified than those in the outer visual fields due to differences in visual acuity. That stimuli presented in the outer LVF, where visual acuity would be expected to be poorer than in the inner LVF, give rise to fewer errors is therefore suggestive of an attentional bias towards the LVF or of a left to right scan of the information. There is, however, no comparable finding in the corresponding analysis of response times or in the preceding analyses of response times and errors in which all "different" comparisons were pooled.

It has been shown in this experiment and in experiment one that there is a LVF advantage for the processing of non-verbal stimuli when error scores are the dependent variable. There was no visual field asymmetry when response times were the dependent variable. This lack of asymmetry in terms of response times may be due to several factors. It may be that any LVF advantage was lost due to the requirement of a right hand response. It may be that subjects "traded" response time for errors in a manner, which kept response times constant across the visual field. A third explanation may be that visual field differences measured in terms of response times are so small that given a greater variance, due to a complex task, than other workers in the field, only a large acuity difference between inner and outer screens reached significance.

Most of the data may be explained by a direct access model of visual field asymmetry. The mechanism underlying the results, if a direct access model is implicated, is unclear. Experiment two failed to distinguish two separate processing modes operating in the two hemispheres. It is also not possible to argue, on the basis of the data collected, that there is a single processing mode used by either both or one of the hemispheres. Experiment three attempts to collect more data on the problem of whether a direct access model of visual field asymmetry is appropriate. As in experiments one and two it is an attempt to discover whether or not different processing modes are assigned to the two hemispheres. In the case of experiment three, however, the possibly more fruitful approach of concentrating on the visual-verbal distinction rather than the serial-parallel distinction is used.

It is not, on the basis of experiments one and two, possible to discount an attentional theory of visual field asymmetry. The asymmetry found could be interpreted by an attentional theory. In fact there is an indication in experiment two that an attentional process may be involved. The suggestion that the non-verbal material led to a LVF bias in attention has been advanced.

Chapter Five

Experiment Three

Experiment Three

Introduction

As was noted in Chapter Two, visual and verbal processing have been distinguished by several writers (Bower, 1972; Paivio, 1971a; Seamon, 1974). One difference between the two processing systems is that verbal processes are assumed to be less dependent on concreteness for their arousal and functioning than are imaginal processes. As was discussed earlier, it has been suggested that a distinction between the two hemispheres may be made in terms of the processing systems which they employ. This view is probably oversimplified, because Paivio (1971a) noted that many situations are likely to involve an interaction of verbal and imaginal processes. Herriot (1974) similarly argued that it is a mistake to regard the different forms of coding as mutually exclusive.

It is possible to distinguish between studies of laterality involving simultaneous comparison of two stimuli and those requiring retention of a memory set and comparison of a test stimulus occurring after an interval of half a second or more. The former type of methodology was employed by Davis and Schmit (1973). They found that when subjects were required to match stimuli on a visual basis, "same" signals (that is, two identical stimuli) were responded to faster when stimuli were presented in the LVF than when they were presentedin the RVF. The opposite was true for "different" signals. Their hypotheses explaining the underlying processes are outlined in Figure 5-1. Unfortunately the authors do not state whether or not the differences on which they base their model are significant. This particular type of study is tapping differences between the visual fields in sensory registration (Herriot, 1974; Sperling, 1960), which has been further examined by Cohen (1976). She used a partial report procedure and backward masking paradigm to explore iconic storage and encoding from store. The displays persisted longer in the LVF than in the RVF. However encoding of RVF information was more rapid than encoding of LVF information and selection of information from the RVF was superior in the precued conditions. Therefore, although White (1969a) suggested that functional asymmetries may be more related to the holding of information than its initial reception, recent findings suggest that there may be observable asymmetries at all stages of processing.

The experiment reported here is concerned with storage processes rather than with sensory registration or early encoding of the icon. Rather than requiring the subjects to code the information in a specific form (Seamon, 1974), they were told that they would be required to match stimuli on a physical basis. This should have encouraged imaginal coding. However, as the stimulus material consisted of letters of the alphabet, it is likely that the subjects would also automatically code the material verbally (Herriot, 1974). Although an

Figure 5-1

Visual Matching of Stimuli

Same signals

Right hemisphere

Visual comparison

same

Same response

(692 msec)

Left hemisphere

Visual comparison

same

Verbal comparison

same

Same response

(714 msec)

Different signals

Right hemisphere

Visual comparison

differ → to left hem.

Visual comp.

differ

Verbal comp.

same

decision

Differ response

(748 msec)

Left hemisphere

Visual comparison

differ

Verbal comparison

same

decision

Differ response

(725 msec)

From: Davis and Schmit (1973).

upper case and its lower case equivalent have the same verbal code, the verbal code alone can not distinguish between them. It was predicted that the automatic verbal coding of the stimulus material would increase the response time to stimuli presented in the RVF in conditions where the verbal code was not adequate for matching test to sample. In these conditions it was predicted that the responses to LVF stimuli should be faster if the right hemisphere uses visual coding more than the left hemisphere.

Method

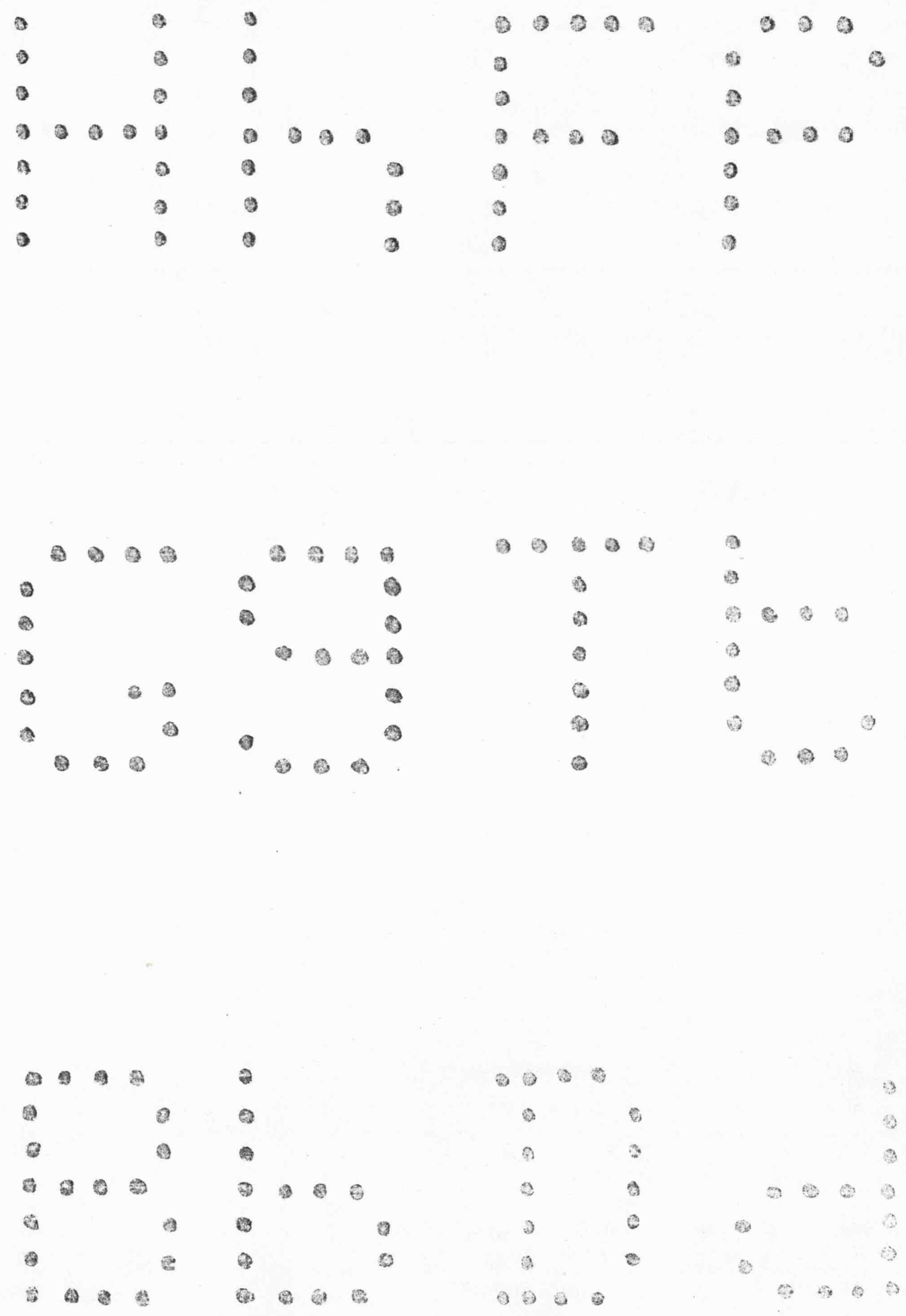
Apparatus and Stimulus Design

A PDP-8e computer was used to present the stimuli. Six letters, H,G,T,F,B and D were plotted in upper and lower case on the oscilloscope using a 7 x 5 dot matrix for each (Figure 5-2). At the beginning of each trial 5 of the 6 letters were displayed, the selection of the letters, case and position in the array being randomly determined. This set was displayed vertically for 2 seconds. After a 2 second interval a single letter flashed for 100 msecs to either the left or right visual field. The visual angle subtended to the centre of this test letter was $7^{\circ}36'$. In 50% of the trials this letter was physically identical to one of the memory set (condition 1), the particular letter being randomly chosen. On 25% of the trials the letter was nominally equal to one of the memory set (condition 2), but in the opposite case. Again the

Figure 5-2

Illustration of the Stimuli Used in Experiment Three

(enlarged)



selection of the letter was random. The remaining 25% of the trials consisted of those in which the flashed stimulus was the letter not included in the memory set (condition 3), the choice of case being random. In each condition there was an equal number of RVF and LVF stimuli. The subject yes/no response was input to the computer via buttons mounted on the chair arm. The response time and other relevant information were punched onto paper tape by the high speed punch in preparation for later analysis. Between the test stimulus display and the following trial there was a 4 second interval. The computer programs used in this experiment are presented in Appendix One.

Subjects

The subjects were 20 undergraduate and postgraduate volunteers (age range 18 to 24 years). There were 10 males and 10 females. All subjects had normal or corrected to normal vision and were right handed, scoring 7 or more right-handed responses on Annett's Handedness Questionnaire (Annett, 1970).

Procedure

The subject was seated in a chair with attached chin-rest, which served to maintain his head in the correct central position. The subject's eyes were 40 cms., from the fixation point. The oscilloscope screen was evenly illuminated. The response buttons were placed on the left or right arm of the subject's chair, half of the subjects in each condition. Half of each of these two groups responded "yes" with the index finger and "no" with the ring finger. The other half of each group reversed these positions. The buttons were labelled to save confusions.

The subject was instructed to scan the memory set of 5 letters for the 2 seconds for which it was displayed and to remember the letters. The instructions were then to fixate the central dot inked to the screen. This dot did not obscure information falling beneath it. After the test stimulus was flashed the subject had to press the "yes" button if the test stimulus was exactly the same as one of the memory set stimuli (condition 1) or the "no" button if the test stimulus was nominally but not physically identical to one in the memory set (condition 2), or if it had not been included in the memory set (condition 3). The importance of speed and accuracy were equally stressed. Subjects were told that they should always press a button, otherwise the computer would not continue with the trial series. A "not sure" button was provided.

Each subject received 32 practice trials during which time any difficulties were solved. After a 3 minute break the 120 experimental trials commenced. Annett's Handedness Questionnaire was given to the subjects after the experiment.

Results

Table 5-1 shows the means and standard deviations of the percentage of errors in each condition. It can be seen that the variances are heterogeneous (F_{max}=13.03, df 6,19, p<.05). Rather than violate the assumption of homogeneity of variance in an analysis of variance, a series of Wilcoxon tests was performed on the data, comparing the left and right visual field stimuli in each condition (Table 5-2) and the effect of condition (Table 5-3). There were more errors to stimuli presented in the LVF than in the RVF in condition 2. Condition 2 stimuli presented in the LVF produced more errors than condition 1 stimuli presented in the LVF.

Table 5-4 presents the means and standard deviations of the correct response times. These were analysed by a 3-way analysis of variance, the summary table of which is Table 5-5. There was no difference between the visual fields in the matching of test to memory set stimuli (F=2.663, df 1,19, p>.05), no effect of condition (F=1.708, df 2,38, p>.05) and no interaction between visual field and condition (F=1.197, df 2,38, p>.05).

The incorrect response times were then analysed. This analysis was performed on the data of only 8 subjects. There were only 11 subjects who responded incorrectly at least once in each condition. In order to counterbalance the conditions in terms of finger and hand of response 3 subjects were randomly discarded from the

Table 5-1

Means and Standard Deviations of the Percentage of Errors

Condition	LVF		RVF	
	$\bar{X}$	s.d.	$\bar{X}$	s.d.
1	12.33	5.63	14.17	11.13
2	26.33	20.33	18.00	15.47
3	20.33	17.10	13.67	11.93

Table 5-2

Wilcoxon Tests Comparing the Percentage of Errors in the Left and Right Visual Fields

Condition	T	n
1	75	18
2	37.5	18 *
3	34.5	16

* $p < .05$

Table 5-3

Wilcoxon Tests Comparing the Percentage of Errors Across Conditions

Conditions	T	n
1 (left) vs 2 (left)	14	18**
1 (left) vs 3 (left)	54	19
2 (left) vs 3 (left)	77	19
1 (right) vs 2 (right)	58.5	17
1 (right) vs 3 (right)	82.5	19
2 (right) vs 3 (right)	54	16

** $p < .01$

Table 5-4

Means and Standard Deviations of the Correct Response Times

Condition	LVF		RVF	
	$\bar{X}$	s.d.	$\bar{X}$	s.d.
1	1378.47	266.80	1367.61	343.81
2	1487.61	318.11	1460.80	309.09
3	1470.10	344.33	1381.71	255.34

Table 5-5

Summary of the Analysis of Variance on the Correct Response Times

Source	SS	df	MS	F
Subjects	7637593.67	19	401978.61	
A (visual field)	52977.18	1	52977.18	2.663
A x subjects	377991.78	19	19894.30	
B (condition)	204828.37	2	102414.19	1.708
B x subjects	2278528.96	38	59961.29	
AB	33522.12	2	16761.06	1.197
AB x subjects	531968.37	38	13999.17	
Total	11117410.44	119	93423.614	

conditions with excess subjects. Table 5-6 gives the means and standard deviations of the incorrect response times of the group of 8 subjects and Table 5-7 is the analysis of variance summary. The incorrect response times to stimulii presented in the RVF were longer than those to stimuli presented in the LVF ($F=13.180$, df 1,7, $p<.05$). There was no effect of condition ($F=1.866$, df 2,14, $p>.05$) nor an interaction between visual field and condition ($F=0.500$, df 2,14, $p>.05$).

A measure of variability within each subject's set of correct response times within each condition was required. The standard deviation within each condition for each subject was calculated and the means and standard deviations for the group are presented in Table 5-8. Tbale 5-9 shows the results of 3 Wilcoxon tests comparing left and right visual fields in each condition. The mean standard deviation of response times to condition 3 stimuli presented in the LVF was greater than that of response times to stimuli presented in the RVF. Table 5-10 shows the results of the Wilcoxon tests on the within visual field comparisons of the standard deviations. The standard deviation of the correct response times to RVF stimuli in condition 1 was greater than that of the responses to RVF stimuli in condition 3.

Table 5-6

Means and Standard Deviations of the Incorrect Response Times

Condition	LVF		RVF	
	$\bar{X}$	s.d.	$\bar{X}$	s.d.
1	1603.97	606.24	1767.90	993.92
2	1348.62	486.06	1485.33	351.31
3	1172.14	359.35	1521.94	501.07

Table 5-7

Summary of the Analysis of Variance on the Incorrect Response Times

Source	SS	df	MS	F
Subjects	9495105.60	7	1356443.66	
A (visual field)	564098.49	1	564098.49	13.180**
A x subjects	299594.16	7	42799.17	
B (condition)	1024396.07	2	512198.04	1.866
B x subjects	3842802.71	14	274485.91	
AB	107594.50	2	53798.25	0.499
AB x subjects	1506912.12	14	107636.58	
Total	16840503.69	47	358308.59	

** $p < .01$

Table 5-8

Means and Standard Deviations of the Standard Deviation Scores

Condition	LVF		RVF	
	$\bar{X}$	s.d.	$\bar{X}$	s.d.
1	452.992	136.191	439.531	195.927
2	439.267	176.948	394.368	176.329
3	453.377	170.327	354.206	146.955

Table 5-9

Wilcoxon Tests Comparing the Standard Deviations of the Correct Response Times in the Left and Right Visual Fields

Condition	T	n
1	61	20
2	73	20
3	31	20**

** $p < .01$

Table 5-10

Wilcoxon Tests Comparing the Conditions in Terms of the Standard Deviations of Correct Response Times in the Left and Right Visual Fields

Conditions	T	n
1 (left) vs 2 (left)	71	20
1 (left) vs 3 (left)	102	20
2 (left) vs 3 (left)	90	20
1 (right) vs 2 (right)	76	20
1 (right) vs 3 (right)	38	20**
2 (right) vs 3 (right)	93	20

** p .01

Discussion

The first prediction that there would be visual field differences in correct response times was not upheld. It will be noted that in this experiment, as in experiments one and two, the response times were approximately twice those obtained in studies in which visual field differences in response times have been found. It may be that the task used in this experiment was more complex than those employed by other workers and that the variance in response times was too great for differences between the visual fields to be revealed. It may be suggested that in this particular instance mean response time is not an adequate measure for reasons which will be discussed later. Alternatively, accurate performance may be accomplished in this task by the use of verbal labels such as "capital H" and "small h". Some subjects reported the use of such labels with or without accompanying visual representation. If this was a common strategy then neither hemisphere would be expected to have an advantage as the left hemisphere could perform the task verbally and the right hemisphere could perform it visually.

It had been predicted that if the RVF stimulus has more rapid access to the left hemisphere than does the LVF stimulus, and the left hemisphere automatically verbally encodes the stimuli that it receives, that a conflict in response may arise in condition 2, where the visual code would give rise to a decision of "different" but the verbal code would give a decision of "same". It was suggested that this would give rise to more errors to RVF stimuli. In fact the reverse finding occurred. There were more errors to condition 2 stimuli when they were presented in the LVF than when they were presented in the RVF. One could argue that stimuli which differ on a visual basis must receive analysis in the left hemisphere. This was suggested by Davis and Schmit (1973) as a result of their data. Thus when the right hemisphere detects a visual difference between the test stimulus and those in the memory set, that is in conditions 2 and 3, the stimulus representation must be transferred to the left hemisphere for verbal analysis. However, although there are more LVF errors in condition 2 than in condition 1, condition 3 falls between the two in terms of the number of errors and does not differ significantly from either. Therefore this interpretation may or may not be correct.

The response times when subjects gave incorrect responses were higher to stimuli presented in the RVF, than those to stimuli presented in the LVF. This may be an artifact due to the selection of 8 subjects. Alternatively it may indicate that errors made to LVF stimuli occur at an earlier processing stage (or after fewer stages) than those to stimuli presented in the RVF.

The analysis of standard deviations provides rather interesting evidence. Firstly there is a greater mean standard deviation in condition 3 when stimuli are presented in the LVF than when they are presented in the RVF. The means of these two conditions are not significantly different. This is indicative of different distributions of response times to stimuli in the two visual fields, the LVF distribution being wider than the RVF distribution. This suggests that there are two methods of processing stimuli presented to the right hemisphere, whereas there is only one method of processing stimuli presented initially to the left hemisphere. One could then suggest that when the right hemisphere receives a stimulus, which it judges on a visual basis to differ from those in the memory set, it may, or may not, transfer that stimulus representation to the left hemisphere for a verbal and possibly an additional visual analysis. It does therefore seem clear that the view that different modes of processing stimuli results in different mean response times is too simplistic. It would in fact be rather surprising if there was no redundancy built into the system. One would not, however, wish to attempt to illustrate the possible processing stages to the extent that Davis and Schmit (1973) have done when there is very little data available. A further study involving more trials per subject may clarify the results by allowing more detailed investigation of the distribution of response times in the various conditions. Experiment Four aimed to provide this information.

One of the most striking features of this experiment is that there was no clearcut visual field advantage. This is contrary to the findings of investigators such as Moscovitch (1972) who found that RVF stimuli produced shorter "same" response times than did LVF stimuli. The major features of the two experiments which differ were

a) that he used an auditory memory set, which presumably led to the verbal encoding of the stimuli, whereas the coding in this experiment was likely to have been both visual and verbal; b) subjects in this experiment were given a more complex task in that they were given a combination of upper and lower case letters to remember, whereas Moscovitch (1972) simply required a nominal match. This suggestion is borne out by the fact that the response times in this experiment were longer than those in the experiment reported by Moscovitch.

Davis and Schmit (1973) and Cohen (1973) required subjects to make a simultaneous comparison of stimuli rather than a delayed comparison. One would expect that different mechanisms would underly the two types of experiment as a memory set can undergo transformations prior to the presentation of the test stimulu, and dual coding possibilities are increased. Finally Cohen (1975) concluded that although the right hemisphere is superior for the analysis of visual information, the left hemisphere is superior for synthesis or generation of visual information. If this is correct, this could explain why there are clear LVF advantages when the comparisons of stimuli are immediate (as in Davis and Schmit, 1973) which are no longer evident when stimuli are committed to memory and later matched.

In summary therefore, it can be said that this experiment failed to show any significant differences between the visual fields in terms of correct response times in any of the experimental conditions. It was suggested that this may have been related to the complexity of the task and (or) the use of a verbal processing strategy in all conditions in addition to visual processing. It was also suggested that a simple analysis of mean response times ignores the underlying distributions of response times. There is evidence from an analysis of the standard deviations of the response times and the error data for the suggestion that stimulus material received in the right hemisphere is transferred to the left hemisphere for verbal analysis on some occasions if the right hemisphere's visual analyser detects a difference between the test stimulus and stimuli in the memory set.

The data in this experiment do not provide support for an attentional theory or a scanning theory of visual field asymmetry, as the asymmetry measured in terms of errors varied according to conditions which were presented randomly. Kinsbourne's attentional theory would predict that in such a situation there should be no visual field asymmetry in any of the conditions.

Chapter Six

Experiment Four

Experiment Four

Introduction

This experiment was an extension of experiment three. In this study, however, the stimuli were digits, each digit being represented in three different visual forms. It was anticipated that the use of an increased number of less familiar forms would decrease the use of verbal coding of the stimulus configurations. The experimental design was essentially the same as that of experiment three. One difference between the two experiments was that in experiment four the size of the memory set was reduced from five to three in order to lessen the difficulty of the task. A second major difference was that only three subjects participated in this experiment, each subject being tested on four separate occasions. This was in order to increase the probability of response time and error measures showing differences due to the visual field of presentation and the type of stimulus comparison.

Method

Apparatus and Stimulus Design

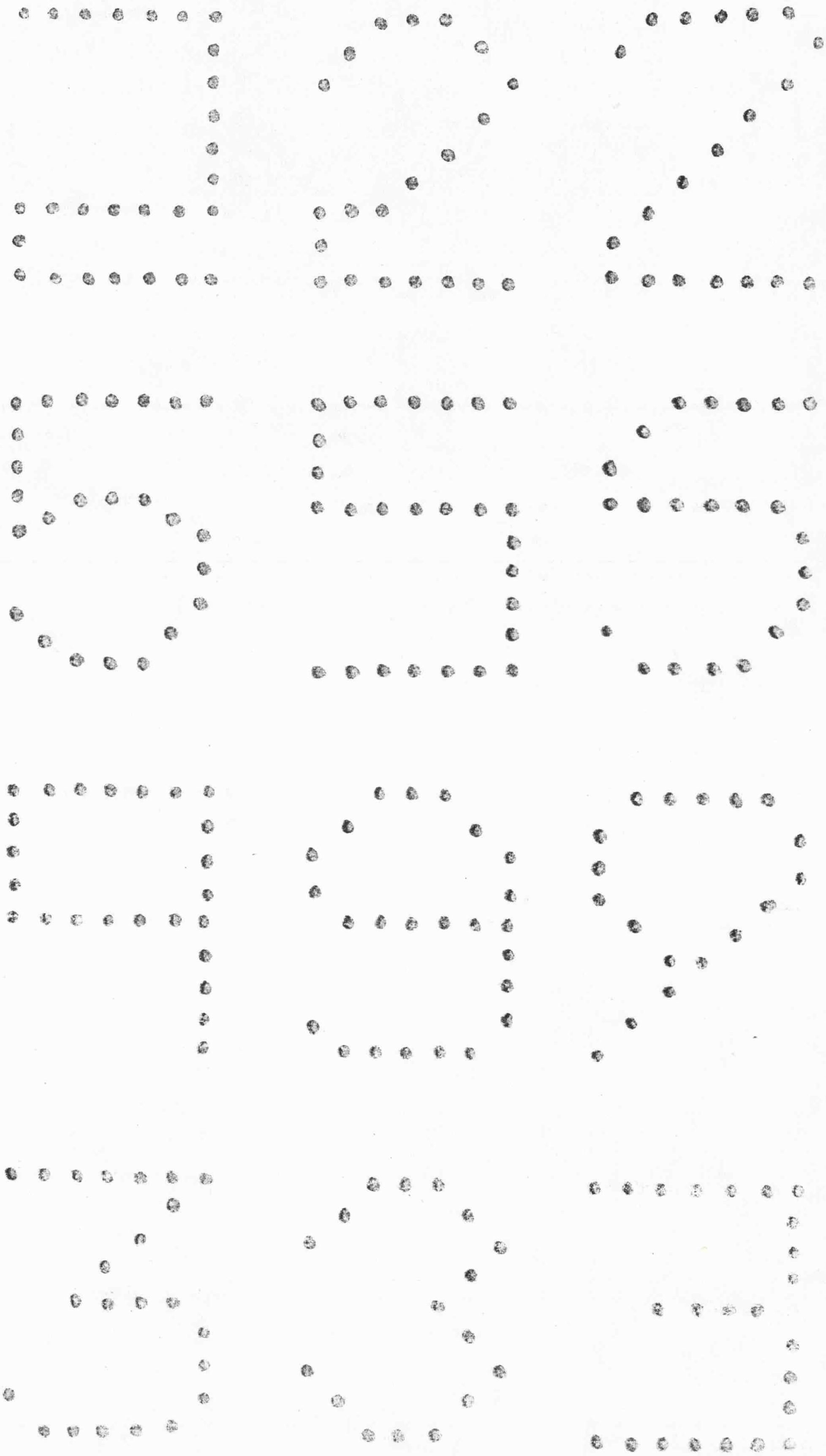
As in experiment three a PDP-8e computer was used to present the stimuli on an oscilloscope screen. The stimuli subtended the same visual angle as those presented in the previous experiment. Four digits, 2,3,5 and 9 were each plotted in three different forms within the confines of a 7 x 9 dot matrix. Figure 6-1 shows the stimulus plots. At the beginning of each trial three of the four digits were displayed, the selection of digits and their form and position in the array being randomly determined. This set of digits was displayed vertically through fixation for 2 seconds. After a 2 second interval a single digit was flashed for 100 msecs to either the right or the left visual field. On 50% of the trials the test stimulus was identical to one of the memory set stimuli (condition 1). On 25% of the trials the test digit was nominally equivalent to one of the memory set but visually different (condition 2). On the remaining 25% of the trials the test digit was a form of the digit which had not appeared in the memory set. Its particular form was randomly determined (condition 3). Within these constraints the test stimuli were selected at random. In each condition there was an equal number of LVF and RVF stimuli. The subject's response was input to the computer and the response time and nature of the response were output on paper tape for later analysis. Between the test display and the following trial there was a 4 second interval. The computer programs are shown in Appendix One.

<u>Subjects</u>

The subjects were three male postgraduate students of Psychology. Their ages were 22, 23 and 24 years. All three subjects were right handed, as shown by Annett's Handedness Questionnaire (Annett, 1970), and all had

Figure 6-1

Illustration of Experiment Four Stimuli (enlarged)



normal, or corrected to normal, vision.

Procedure

Each subject used the four finger/hand combinations for making the responses, one combination per session. In detail the response conditions were:

	Subject 1	Subject 2	Subject 3
Session 1	right index "yes"	left index "no"	right index "yes"
Session 2	left index "no"	right index "yes"	right index "no"
Session 3	right index "no"	right index "no"	left index "yes"
Session 4	left index "yes"	left index "yes"	left index "no"

The subject was instructed to scan the memory set of three digits for the 2 seconds for which it was displayed and to attempt to remember the digits. The instructions were that he was then to fixate the central dot inked to the screen. After the test stimulus was flashed the subject had to press the "yes" button if the test stimulus was exactly the same as one of the memory set, or the "no" button if the test stimulus was nominally but not physically identical to one of the memory set, or if it had not appeared in the memory set. The importance of speed and accuracy was equally stressed. The subjects were told that if they were not sure of their response they may press the "not sure" button placed above the "yes" and "no" buttons and that for this type of response they could use either finger. For the "yes" and "no" responses they were to ensure that they always used the correct finger.

Each subject received 32 practice trials before each session. After a 2 minute break the 128 experimental trials commenced. There was a rest interval after each block of 32 trials. The test sessions were 4 to 7 days apart.

Results

Table 6-1 shows the means and standard deviations of the correct response times. Table 6-2 is the analysis of variance summary table. There was no difference between visual fields in terms of mean correct response times ($F=3.432$, df 1,2, $p>.05$). There was a significant influence of the type of comparison on the response time ($F=8.652$, df 2,4, $p<.05$). Tukey (a) tests revealed that there was a significant difference between conditions 2 and 3 ($q_{3,4}=5.601$, $p<.05$) but no difference between conditions 1 and 2 ($q_{3,4}=1.242$, $p>.05$) or conditions 1 and 3 ($q_{3,4}=4.359$, p .05).

There was a tendency for responses in which the index finger and the third finger of the right hand were used for "yes" and "no" responses respectively to be faster

Table 6-1

Means and Standard Deviations of the Correct Response Times

Field	Condition		R "yes"	R "no"	L "yes"	L "no"
RVF	1	$\bar{X}$	848.089	980.096	925.376	1008.907
		s.d.	188.135	248.875	239.644	421.386
	2	$\bar{X}$	901.630	961.714	1070.238	1032.433
		s.d.	126.133	276.089	312.362	352.783
	3	$\bar{X}$	728.296	886.103	838.670	804.646
		s.d.	114.850	245.839	198.428	233.159
LVF	1	$\bar{X}$	851.849	967.339	910.801	992.933
		s.d.	80.648	254.522	230.565	442.804
	2	$\bar{X}$	857.914	985.804	950.760	959.167
		s.d.	238.338	219.028	214.186	424.398
	3	$\bar{X}$	714.521	940.580	849.633	900.638
		s.d.	136.655	193.915	153.822	305.485

R "yes" = Right index finger "yes"

R "no" = Right index finger "no"

L "yes" = Left index finger "yes"

L "no" = Left index finger "no"

Table 6-2

Analysis of Variance on the Mean Correct Response Times

Source	SS	df	MS	F
Subjects	2312969.87	2	1156484.94	
A (visual field)	1358.96	1	1358.96	3.432
A x subjects	791.93	2	395.96	
B (condition)	230926.94	3	115463.47	8.652*
B x subjects	53383.69	4	13345.93	
C (hand/finger)	221790.41	3	73930.14	
C x subjects	685238.26	6	114206.38	
AB	24316.30	2	12158.15	
AB x subjects	44287.66	4	11071.91	
AC	9848.33	3	3282.78	
AC x subjects	36281.49	6	6046.92	
BC	37023.95	6	6170.66	
BC x subjects	53226.68	12	4435.56	
ABC	17382.76	6	2897.13	3.642*
ABC x subjects	91145.94	12	795.50	
Total	3819973.18	71	53802.44	

* $p < .05$

than responses for which other finger/hand combinations were used. See Table 6-3 for the series of Tukey (a) tests performed on the 3-way interaction between visual field, condition and finger/hand combination ($F=3.642$, df 6,12, $p<.05$), investigating the influence of finger/hand combination within visual field and condition. Figure 6-2 illustrates this aspect of the interaction. Differences between conditions were more evident when the stimulus exposure was in the RVF (see Tukey tests in Table 6-4 and Figure 6-3). Condition 3 response times were generally less than those to stimuli presented in conditions 1 and 2. There were no visual field differences in response times except when the index finger and the third finger of the left hand were used for "yes" and "no" responses respectively. Table 6-5 shows the Tukey (a) tests performed on this aspect of the interaction.

An analysis of variance (Table 6-6) was performed on the percentage of errors (Table 6-7). There was a significant difference between conditions. There were more errors in condition 2 than in condition 1 ($q_{3,4}=6.928$, $p<.05$) or condition 3 ($q_{3,4}=8.637$, $p<.01$). The percentage of errors in conditions 1 and 3 was the same ($q_{3,4}=1.709$, $p>.05$). There was no significant difference between visual fields in terms of errors. There was, however, a significant visual field x condition interaction ($F=16.886$, df 2,4, $p<.05$). This interaction was due to there being a higher percentage of errors in condition 1 than in condition 3 when the stimuli were

Table 6-3

Tukey (a) Tests Performed on the Interaction Between Visual Field, Condition and Hand/Finger Combination

Comparisons Within Visual Fields and Conditions

RVF Condition 1	$\underline{q}(24,12)$	
R "yes" vs R "no"	8.107*	R "yes" RT greater
R "yes" vs L "yes"	4.746	
R "yes" vs L "no"	9.876*	R "yes" RT greater
R "no" vs L "yes"	3.360	
R "no" vs L "no"	1.769	
L "yes" vs L "no"	5.130	
RVF Condition 2		
R "yes" vs R "no"	3.690	
R "yes" vs L "yes"	10.354*	R "yes" RT greater
R "yes" vs L "no"	8.033*	R "yes" RT greater
R "no" vs L "yes"	6.665	
R "no" vs L "no"	4.343	
L "yes" vs L "no"	2.322	
RVF Condition 3		
R "yes" vs R "no"	9.691*	R "yes" RT greater
R "yes" vs L "yes"	6.778	
R "yes" vs L "no"	4.689	
R "no" vs L "yes"	2.913	
R "no" vs L "no"	5.002	
L "yes" vs L "no"	2.089	

Table 6-3 continued

LVF Condition 1	$q_{(24,12)}$	
R "yes" vs R "no"	7.092	R "yes" RT greater
R "yes" vs L "yes"	3.620	
R "yes" vs L "no"	8.664*	R "yes" RT greater
R "no" vs L "yes"	3.472	
R "no" vs L "no"	1.572	
L "yes" vs L "no"	5.044	

LVF Condition 2		
R "yes" vs R "no"	7.854*	R "yes" RT greater
R "yes" vs L "yes"	5.702	
R "yes" vs L "no"	6.218	
R "no" vs L "yes"	2.152	
R "no" vs L "no"	1.636	
L "no" vs L "yes"	0.516	

LVF Condition 3		
R "yes" vs R "no"	13.882**	R "yes" RT greater
R "yes" vs L "yes"	8.297 *	R "yes" RT greater
R "yes" vs L "no"	11.430**	R "yes" RT greater
R "no" vs L "yes"	5.585	
R "no" vs L "no"	2.453	
L "yes" vs L "no"	3.312	

RT = response time.

* $p < .05$

** $p < .01$

FIGURE 6-2

INTERACTION BETWEEN VISUAL FIELD, CONDITION AND FINGER/HAND COMBINATION: The influence of finger/hand combination.

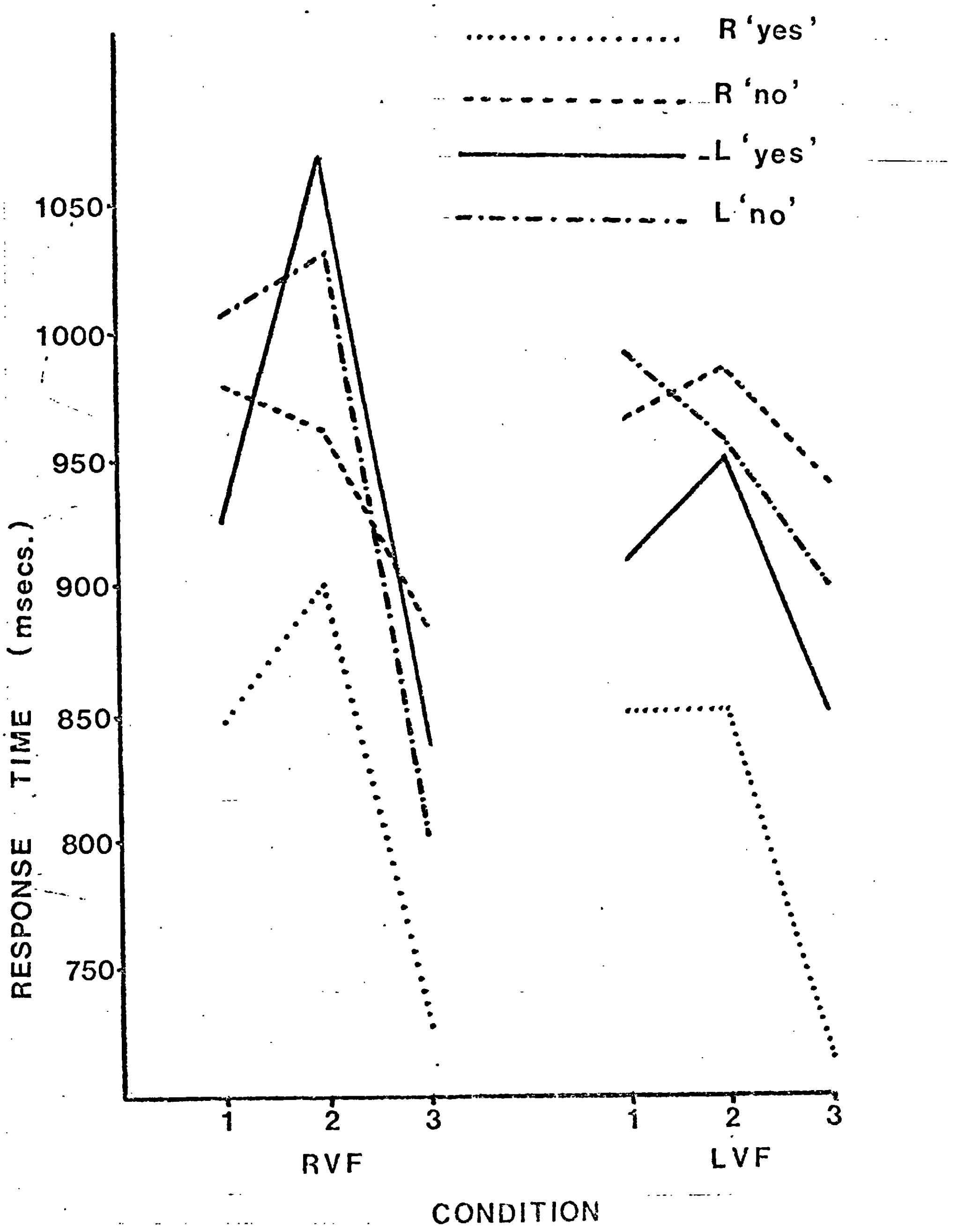


Table 6-4

Tukey (a) Tests Performed on the Interaction Between Visual Field, Condition and Hand/Finger Combination

Comparisons Within Visual Field and Hand/Finger Combination

Right "yes"

		$\underline{q}(24,12)$	
	Condition 1 vs 2	3.288	
RVF	Condition 1 vs 3	7.357*	Cond. 3 RT greater
	Condition 2 vs 3	10.644*	Cond. 3 RT greater
	Condition 1 vs 2	0.372	
LVF	Condition 1 vs 3	8.433*	Cond.3 RT greater
	Condition 2 vs 3	8.806*	Cond.3 RT greater

Right "no"

	Condition 1 vs 2	1.129	
RVF	Condition 1 vs 3	5.772	
	Condition 2 vs 3	4.643	
	Condition 1 vs 2	1.134	
LVF	Condition 1 vs 3	1.643	
	Condition 2 vs 3	2.777	

Table 6-4 continued

		$q_{(24,12)}$	
Left "yes"			
	Condition 1 vs 2	8.896*	Cond. 1 RT greater
RVF	Condition 1 vs 3	5.325	
	Condition 2 vs 3	14.221**	Cond. 3 RT greater
	Condition 1 vs 2	2.454	
LVF	Condition 1 vs 3	3.756	
	Condition 2 vs 3	6.210	
Left "no"			
	Condition 1 vs 2	1.445	
RVF	Condition 1 vs 3	12.544**	Cond. 3 RT greater
	Condition 2 vs 3	13.988**	Cond. 3 RT greater
	Condition 1 vs 2	2.074	
LVF	Condition 1 vs 3	5.668	
	Condition 2 vs 3	3.594	

* $p < .05$

** $p < .01$

RT= response time.

FIGURE 6-3

INTERACTION BETWEEN VISUAL FIELD, CONDITION AND FINGER/HAND COMBINATION: The influence of condition.

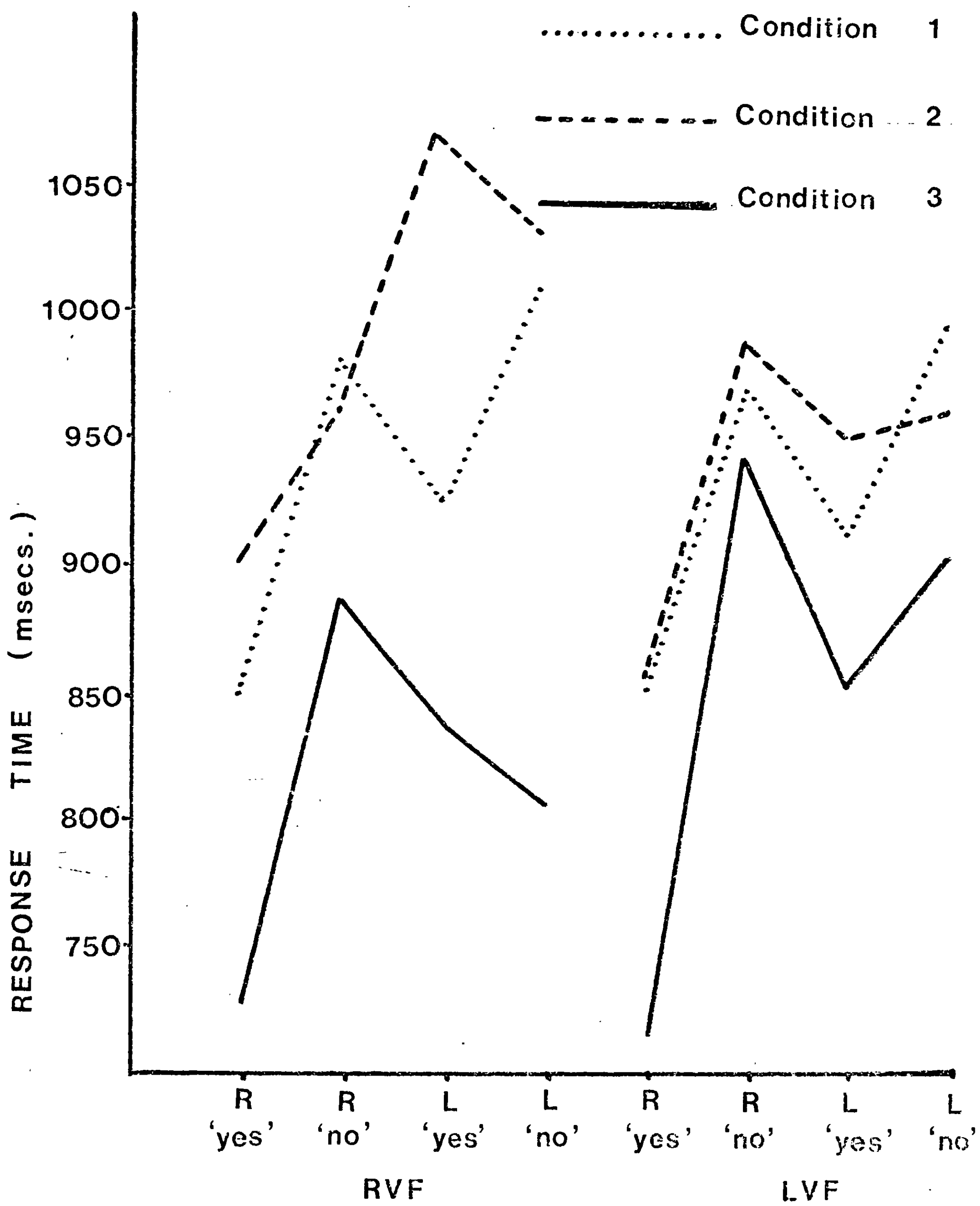


Table 6-5

Tukey (a) Tests Performed on the Interaction Between Visual Field, Condition and Hand/Finger Combination

Comparisons Within Hand/Finger Combination and Condition

		$q_{(24,12)}$	
Right "yes"			
Cond. 1	RVF vs LVF	0.231	
Cond. 2	RVF vs LVF	2.685	
Cond. 3	RVF vs LVF	0.846	
Right "no"			
Cond. 1	RVF vs LVF	0.783	
Cond. 2	RVF vs LVF	1.479	
Cond. 3	RVF vs LVF	3.345	
Left "yes"			
Cond. 1	RVF vs LVF	0.895	
Cond. 2	RVF vs LVF	7.337*	RVF RT greater
Cond. 3	RVF vs LVF	0.673	
Left "no"			
Cond. 1	RVF vs LVF	0.981	
Cond. 2	RVF vs LVF	4.499	
Cond. 3	RVF vs LVF	5.895	

* $p < .05$ RT = response time

Table 6-6

Summary of the Analysis of Variance on the Percentage of Errors

Source	SS	df	MS	F
Subjects	2529.296	2	1264.648	
A (visual field)	3.389	1	3.389	
A x subjects	17.363	2	8.682	
B (condition)	17637.526	2	8818.763	20.920**
B x subjects	1686.204	4	421.551	
C (hand/finger)	619.981	3	206.660	2.120
C x subjects	584.852	6	97.475	
AB	512.974	2	256.486	16.886*
AB x subjects	60.754	4	15.189	
AC	137.126	3	45.709	
AC x subjects	1490.882	6	248.48	
BC	968.157	6	161.360	5.647**
BC x subjects	342.863	12	28.572	
ABC	497.226	6	82.871	
ABC x subjects	1503.915	12	125.326	
Total	28592.508	71	401.711	

* $p < .05$

** $p < .01$

Table 6-7

Means and Standard Deviations of the Percentage of Errors

	Condition		R "yes"	R "no"	L "yes"	L "no"
RVF	1	$\bar{X}$	12.500	16.667	10.417	25.000
		s.d.	9.373	4.774	7.864	11.276
	2	$\bar{X}$	43.750	31.250	41.667	56.250
		s.d.	18.750	6.250	25.259	12.500
	3	$\bar{X}$	6.250	4.1167	0.000	0.000
		s.d.	6.250	3.608	0.000	0.000
LVF	1	$\bar{X}$	14.583	7.292	9.375	9.375
		s.d.	10.975	6.505	10.906	3.125
	2	$\bar{X}$	37.500	39.583	35.417	52.083
		s.d.	25.000	23.662	7.217	28.183
	3	$\bar{X}$	6.250	16.667	6.250	8.333
		s.d.	10.825	9.547	6.250	9.547

presented in the RVF. There was no difference between conditions 1 and 3 when the stimuli were presented in the LVF (see Table 6-8 for the Tukey a tests). The condition x finger/hand combination interaction was significant ($F=5.647$, df 6,12, $p<.01$). This was due to there being intersession differences in condition 2. The session in which the index finger of the left hand made the response "no" produced markedly more errors than the other sessions (see Table 6-9 for Tukey tests).

Discussion

In this experiment there was a significant interaction between visual field of presentation, condition and finger/hand combination used in making the response when the response time was the dependent variable. Differences between conditions were more frequent when the RVF was stimulated than when the LVF received the stimuli. As it was generally found that condition 3 produced faster responses and that this was more frequently the case when the stimuli were presented in the RVF it suggests that verbal processing was important in this task. It is likely that the left hemisphere makes a rapid verbal encoding of stimuli. This encoding would occur more rapidly to stimuli received initially in the left hemisphere than to stimuli which were received in the right hemisphere and then transferred to the left hemisphere. If the right hemisphere is capable of verbal encoding one would not expect that it would be as rapid or

Table 6-8

Tukey (a) Tests Performed on the Interaction Between Visual Field and Condition in terms of the Percentage of Errors

RVF	$\underline{q}(6,4)$
Condition 1 vs 2	24.073 **
Condition 1 vs 3	12.073 **
Condition 2 vs 3	36.109 **
LVF	
Condition 1 vs 2	27.545 **
Condition 1 vs 3	0.694
Condition 2 vs 3	28.239 **

Condition 1	LVF vs RVF	5.324
Condition 2	LVF vs RVF	1.852
Condition 3	LVF vs RVF	6.018

** $p < .01$

Table 6-9

Tukey (a) Tests Performed on the Interaction Between Condition and Hand/Finger Combination in Terms of Errors

Right "yes"	$q_{(12,12)}$
Condition 1 vs 2	12.41 **
Condition 1 vs 3	3.341
Condition 2 vs 3	15.752 **
Right "no"	
Condition 1 vs 2	10.740 **
Condition 1 vs 3	0.716
Condition 2 vs 3	11.456 **
Left "yes"	
Condition 1 vs 2	13.127 **
Condition 1 vs 3	3.103
Condition 2 vs 3	16.230 **
Left "no"	
Condition 1 vs 2	16.946 **
Condition 1 vs 3	5.967 *
Condition 2 vs 3	22.913 **

* $p < .05$

** $p < .01$

automatic as coding performed in the left hemisphere. A simple verbal encoding of the digit name would be adequate for the correct response in condition 3. A similar coding would not be adequate in conditions 1 or 2.

When the "yes" responses were made using the index finger of the right hand the response times were less than those obtained in the other finger/hand combinations. It is probable that this finger/hand combination provided the greatest stimulus-response compatibilty. In the error analysis the superiority of this conditions was not apparent. However, the left index finger "no" combination produced significantly more errors than did the other combinations. This may indicate that the use of the index finger of the subordinate hand to indicate "no" provides the lowest stimulus-response compatibility. It may be the case that the two dependent variables interact to some degree so that either more errors or longer response times are produced, rather than both response times and errors increasing simultaneously in the more difficult conditions.

In the right index finger "yes" combination it was found that responses to stimuli presented in both visual fields in condition 3 were faster than responses to condition 2 stimuli. Responses to condition 1 stimuli fell between those of conditions 2 and 3. Therefore subjects did not make the response "yes" immediately they detected a correspondence between a member of the memory set and the test stimulus in terms of their verbal label. Therefore, as "yes" responses under certain conditions took longer than "no" responses, a serial self-terminating model of processing is not appropriate. The longer processing time required by condition 2 stimuli indicates that there is some interference at a late decision stage between the results of both verbal and visual processing of the stimulus. This is apparent in this particular finger/hand combination in both visual fields. Interestingly, when the third finger of the right hand was used in making the "yes" responses there was no significant difference between conditions when the stimuli were presented in either the left or the right visual field. If the complexities of this 3-way interaction are due to experimental variables rather than to some extraneous inter-session differences, then it appears that there is a complex interaction between not only the visual field and the hand of response but also involving the finger used to make the response. It would not be appropriate to propose any underlying reasons for this interaction at this stage because a large number of paired comparisons were made, some of which may have occurred by chance. However, on the basis of this finding it is clear that the task processing and response processing are not entirely independent.

In this experiment, as in experiment three, there was a significant number of errors. Irrespective of visual field, there was a higher percentage of errors when stimuli were presented in condition 2 than in conditions 1 or 3. This provides support for the response time data in suggesting that there is a conflict at a decision stage in the processing sequence. This result implies either that all the material is processed at some stage in a single hemisphere or that a similar type of conflict arises in both hemisphere. If one first considers the former alternative, it may be assumed that all the material is processed, at least in part, by the left hemisphere as the left hemisphere has been assumed by most workers to have access to some visual coding in addition to having a monopoly in verbal coding. This would then necessitate a transfer of stimulus information from the right to the left hemisphere when material has been presented initially to the right hemisphere. One may expect that this transfer would result in an increase in processing time of LVF stimuli. If there is such an increase it was not detected by the response time measure. This may be due to a lack of sensitivity of the response time measure. However, one might also expect that there would be more errors resulting from the presentation of stimuli to the right hemisphere. This was not the case. It is unlikely that the error measure is insensitive as many other differences between conditions have been detected in terms of errors in this experiment and in experiments one, two and three. However, it has been suggested that the view of a single transfer of stimulus information across the corpus callosum is too simplistic and a complex continuing interchange of informations between the two hemispheres may be impossible to detect in this type of experiment. One finding is difficult to explain, if it is true that the left hemisphere is involved in all stimulus processing, is the fact that there was a higher percentage of errors to stimuli presented in condition 1 than in condition 3 only when the stimuli were presented in the RVF. Therefore there can not be a complete interdependence of processing between the hemispheres. One can not argue that stimulus information from the right hemisphere is only transferred to the left hemisphere if the right hemisphere's visual analysis records a "difference" between the memory set stimuli and the test stimulus because there is no difference in terms of errors between stimuli presented in condition 1 (in which the test stimulus is physically identical to one of the memory set stimuli) and condition 3 (in which the test stimulus is the digit not contained in the memory set). Therefore the error data lead towards the conclusion that the right hemisphere can process the information, which it receives, using a verbal code. Recent clinical research suggests that the right hemisphere has sufficient linguistic capacity to provide digit names.

The data can not be interpreted by a scanning model as such a model would predict a constant visual field asymmetry irrespective of condition. As this experiment used single letter test stimuli a scanning mechanism related to reading habits would not be expected to be operating (White, 1969a). An attentional theory could explain the lack of visual field asymmetry by arguing that as both hemispheres were equally active, attention would be symmetrical about the fixation point. The most appropriate model to use in the present situation appears, however, to be a direct access model.

This can explain both the lack of visual field asymmetry and the fact that differences between conditions did not occur equally in both visual fields.

In this experiment, as in experiment three, it appears possible that errors and response times were interdependent. The solution to this problem may be to use a single measure. As the response times have proved to be exceptionally long in experiments one to four, errors were considered to be the most appropriate dependent variable for use in further experiments. Subjects could then be given the instructions to be as accurate as possible and could be allowed a theoretically unlimited response time. There is no strong evidence from the previous four experiments to show that response times and errors measure different underlying mechanisms, as was suggested by Gross (1972). However, without direct evidence obtained from studies manipulating both subjects' error scores and response times, perhaps by means of a payoff schedule, there is little evidence to suggest that they do not measure the same mechanisms.

Experiment three suggested that information received in the right hemisphere is transferred to the left hemisphere for verbal analysis if the right hemisphere's visual analyser detects a difference between the memory set stimuli and the test stimulus. This conclusion was not reached in experiment four. In fact, experiment four suggested that both hemispheres are capable of using a visual and a verbal coding of the information. The underlying reason for this is unclear, although a mechanism may be suggested. It may be the case that the verbal coding used for the stimuli in experiment three was more complex than that used in experiment four. In experiment three it was suggested that subjects labelled the stimuli as "capital H" and "small h" for example, whereas in experiment four it may be that they used a visual code for the specific stimulus configurations and the verbal coding was simply in the form of the digit names. As it appears to be extremely difficult to prevent subjects from coding letters verablly and visually the following experiments involve stimuli which are more clearly either verbal or visual.

Chapter Seven

Experiment Five

Experiment Five

Introduction

As discussed in the previous chapters, there have been three major interpretations of visual field asymmetries. The previous four experiments have tended to support the direct access theory, although an attentional theory has not been ruled out. The former theory proposes that asymmetries arise purely as a result of structural factors, whereas the latter maintains that the visual field asymmetry will vary according to the differential activation of the two hemispheres. This activation is dependent partly on the irrelevant thoughts of the subject. Although a scanning theory could not interpret the data collected in the previous experiments as they did not involve whole word stimuli, a scanning process may be involved in an experiment in which word stimuli are presented.

If visual field differences arise purely due to structural factors, that is if a direct access theory is adequate, then one would not expect that "priming" the subject to receive a particular type of stimulus information in each visual field would produce asymmetries different from those observed in a non-primed situation. Irrespective of priming, the left hemisphere (RVF) should be superior in tasks which involve fairly complex verbal processing and the right hemisphere (LVF) should have the advantage when the processing required is non-verbal.

If priming the subject does produce asymmetries different from those in a non-primed condition then either a scanning or an attentional theory would be a more appropriate explanation of the data.

In the following experiment three types of stimuli were presented to the subjects. These were photographs of faces, previously found to give rise to a LVF advantage in terms of response times and errors, random shapes (Vanderplas and Garvin, 1959), which have not shown such clearcut perceptual asymmetry, and words, which should lead to a RVF advantage. Stimuli were presented bilaterally in three combinations: a face was presented in one visual field and a shape in the other (F-S/S-F), a shape was presented in one visual field and a word in the other (S-W/W-S), or a word was presented in one visual field and a face in the other (W-F/F-W). In the primed condition the subjects were told prior to stimulus exposure the visual field in which each type of stimulus would occur. In the non-primed condition they did not have this information. It was predicted that if a perceptual scan is important in determining perceptual asymmetry, at least in the perception of words (Braine, 1968, argued for its importance in all tachistoscopic recognition) informing the subject of the stimulus orientation should alter his perceptual scan.

It has been argued by McKeever and Huling (1971a; 1971b) that a LVF advantage for verbal information occurs when stimuli are presented bilaterally because fixation is often inadequately controlled. When fixation is ensured by presenting a digit at fixation, which must be reported prior to any stimulus information, the RVF is superior in the recognition of verbal information. There is some dispute about the significance of a fixation task as McKavey et al (1974) obtained a RVF superiority without a fixation task and Kaufer et al (1976) found a LVF superiority without a fixation task. One difference between the latter two studies was that McKavey et al (1974) used an exposure duration of 100 msecs and Kaufer et al (1976) varied it according to the subject's ability to detect the stimuli (8 to 20 msecs). Bryden (1965) has shown that exposure duration can have an influence on the visual field asymmetry obtained when digits are presented unilaterally, although his data are open to question. It is therefore possible that exposure duration may influence the asymmetry obtained in the bilateral perception of words. A fixation digit was used in the following experiment as it was the only means available of ensuring the subjects' fixation. It was considered most important that subjects did not bias their fixation in either direction particularly in the primed condition.

Method

Apparatus and Stimulus Preparation

A Cambridge Two-Field tachistoscope was used to display the stimulus cards at an exposure of 40 msecs. The pre-exposure field was a white card, in the centre of which was a square just large enough to "frame" the centre digit when the stimulus card was exposed.

Each stimulus card had a digit between 1 and 9 typed in black at the fixation point (Hines, 1975). The words were typed in black pica capitals with one space between each of the letters. The inner edge of each word subtended a visual angle of 1.7° and the outer edge subtended an angle of 4.5° from fixation. Ten 4-letter words: CAKE, LANE, DOVE, BEAR, HARE, MASK, EPIC, GOLD, FARM, POST (McKeever and Huling, 1971b; Hines, 1975) were presented in two types of pairing (W-F/F-W and W-S/S-W).

The ten shapes used in this experiment were 8 point randomly generated shapes of low verbal association value (Vanderplas and Garvin, 1959) and their mirror-images (Kimura, 1966). Figure 7-1 illustrates the shape stimuli. The visual angle subtended by the inner edge of each shape was 1.7°. The minimum outer visual angle subtended was 4.5°, while the maximum was 6.2°. These stimuli were presented in the S-W/W-S and S-F/F-S pairings.

There were ten photographs of faces (students at the University of Leicester, unknown to the subjects of this experiment) and their mirror-images presented in the F-S/S-F and F-W/W-F combinations. Figure 7-2 shows the face stimuli. The inner edge of each photograph subtended a visual angle of 1.7° and the outer edge subtended an angle of 5.5° from fixation.

There were ten cards prepared in each stimulus orientation. Each word appeared once in each orientation involving words. Each shape and face appeared once in each orientation in which they were used, the

Figure 7-1

The Shape Stimuli Presented in Experiments Five, Six and Seven

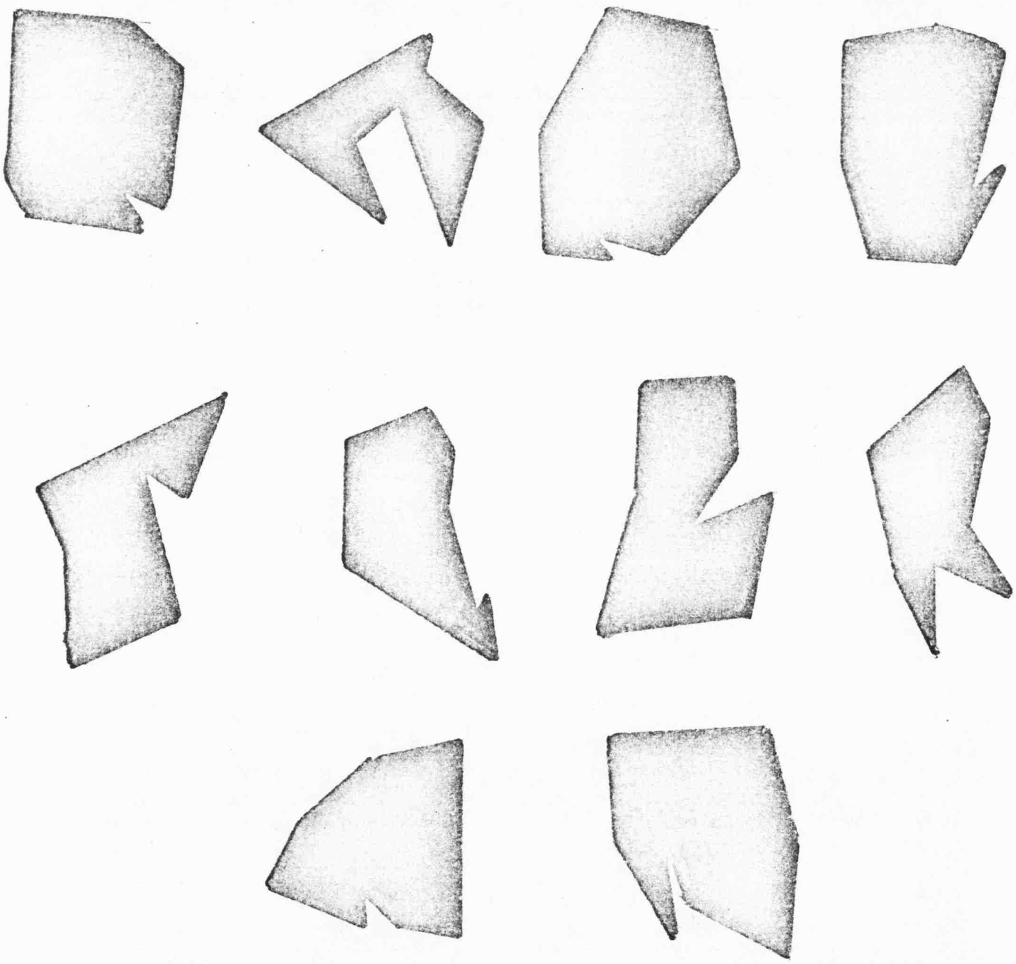


Figure 7-2

The Face Stimuli Presented in Experiments Five, Six and Seven

choice of normal or mirror-image form was random. Within these conditions, the preparation of stimulus pairings was randomised.

A set of response cards was prepared for each stimulus pairing, four alternative stimuli being provided for each visual field. Left and right visual field stimuli were randomly assigned to upper and lower rows and positions within each row.

Subjects

16 undergraduate volunteers (9 males), age range 17 to 30 years with a mean age of 19.75 years, served as subjects. All had normal, or corrected to normal, vision and were right handed. All subjects scored 7 or more right handed responses on Annett's Handedness Questionnaire (Annett, 1970).

Procedure

The stimuli were presented in 6 blocks of 20 trials. Within a block only one type of stimulus pairing was shown. 16 trials in each block consisted of cards of one orientation (for example F-S). This was the primed condition. Each of the cards of that stimulus orientation was displayed once and 6 were randomly chosen for a second showing. The remaining 4 trials consisted of cards on which the stimuli were arranged in the opposite orientation (in this example S-F). These cards were randomly selected for each subject from the pack of 10. This was the non-primed condition. Primed and non-primed cards were presented in random order within a block, with the proviso that a non-primed card did not appear either first or last. One block of each stimulus pairing was presented, the orientation of the primed condition being selected randomly. In the second 3 blocks the opposite orientations of the 3 types of stimulus pairing were presented. Within these constraints the order of blocks was randomised.

Within a block all stimulus pairs were reported in the same order. The RVF was reported first for 3 of the blocks and the LVF first for the other 3 blocks. Within this structure the order of report of the blocks was randomised for half of the subject group. The other half of the group reported the stimuli in the opposite order.

The subjects were given 12 practice trials (2 cards in each stimulus orientation chosen randomly), in which they knew which stimulus orientation would be presented. Each trial was initiated by the signal "ready, go" one second before the stimulus field was exposed. It was stressed that the central digit had to be reported verbally correctly before the response card, placed to the left of the subject, was turned face up and the stimuli displayed in the left and right visual fields were identified by pointing. The instructions given to the subjects before each block of trials were:

"In this set of 20 trials most of the cards will show a face (eg.) on the left and a shape (eg.) on the right. Always report the central digit followed by whatever is on the left (eg.) and then whatever is on the right."

Subjects had no difficulty in maintaining the correct order of report. During the experimental trials the scoring was performed outside the subject's field of vision and in silence. Feedback was given during the series of practice trials, however. There was a 2 minute break between blocks. After the experiment the subjects completed the Handedness Questionnaire.

Results

Three separate analyses of variance were to have been performed on the percentage of correct recognitions of words, faces and shapes. However, heterogeneity of variance precluded such an analysis of the word and shape stimuli. The F_{max} statistic for the three types of material was 6.622 (words), 5.739 (shapes) and 4.554 (faces). The critical value for this test using the .05 level of significance is 5.19. As the F_{max} statistic approached significance for faces and no transformation, which would remove the heterogeneity of variance, could be found, a series of Wilcoxon tests was considered to be the most appropriate way of dealing with the data. It must be noted that this may have resulted in two to three spurious positive results if the critical level is set at 5%. Table 7-1 presents the means and standard deviations of the percentage of correct recognitions for each type of material in each condition. Table 7-2 shows the results

Table 7-1

Means and Standard Deviations of the Percentage of Correct Recognitions

Stimulus Orientation	Primed		Non-Primed	
	$\bar{X}$	s.d.	$\bar{X}$	s.d.
Recognition of Words				
W-S	59.06	14.86	48.75	19.28
S-W	72.50	11.25	71.25	14.55
W-F	57.81	20.89	46.25	28.95
F-W	71.56	13.99	70.00	17.89
Recognition of Faces				
F-W	58.44	13.13	62.50	22.95
W-F	43.75	14.20	51.25	23.06
F-S	42.19	17.03	50.00	21.91
S-F	48.75	16.38	46.25	28.02
Recognition of Shapes				
S-W	64.38	12.89	61.25	19.96
W-S	66.56	14.80	61.25	27.78
S-F	56.56	18.14	42.50	30.88
F-S	59.06	16.95	48.75	26.30

Table 7-2

Results of Wilcoxon Tests Comparing Primed and Non-Primed Conditions

Stimulus Orientation	T	n
Words Correct		
W-S	24.5	15 +
S-W	19.0	9
W-F	23.0	14 +
F-W	32.0	11
Faces Correct		
F-W	57.0	16
W-F	44.0	16
F-S	37.5	15
S-F	60.0	15
Shapes Correct		
S-W	50.0	14
W-S	30.5	12
S-F	37.0	16
F-S	32.5	15

+ $p < .025$ (1-tailed test)

of the Wilcoxon tests comparing primed and non-primed conditions for each stimulus orientation. Table 7-3 gives the results of the Wilcoxon tests comparing right and left visual fields in the primed and non-primed conditions. The next analysis is addressed to the question of whether a particular stimulus type presented in a particular visual field is recognised more frequently when it is paired with one type of stimulus rather than another. For example, the percentage of words correctly identified when words appeared in the LVF compared in the W-S and W-F combinations in both primed and non-primed conditions. See Table 7-4 for the results of this series of Wilcoxon tests.

The final analysis (Table 7-5) was performed in order to discover which type of stimulus in each stimulus orientation was the most frequently correctly recognised. Thus the recognition of the shapes and words in the S-W orientation were compared , for example, and it was found that the words were the more frequently recognised stimulus.

Discussion

McKeever and Huling's (1971a; 1971b) findings that the presence of a central digit ensures a RVF advantage for words has been supported. McKeever et al (1972) showed that when the central digit was present on only half of the trials the RVF advantage persisted. They regarded this as evidence against a post-exposural scanning theory,

Table 7-3

Results of the Wilcoxon Tests Comparing the Left and Right Visual Fields in the Primed and Non-Primed Conditions

Stimulus Pairing	Primed		Non-Primed	
	T	n	T	n
Words Correct				
W-S vs S-W	7.0	14**	0.0	12**
W-F vs F-W	10.0	15**	12.0	13"
Faces Correct				
F-W vs W-F	4.0	13**	20.0	12
F-S vs S-F	44.0	16	47.0	14
Shapes Correct				
S-W vs W-S	45.5	14	13.5	7
S-F vs F-S	58.0	16	43.5	14

** $p < .01$

" $p < .02$

Table 7-4

Results of the Wilcoxon Tests Comparing the Stimulus Pairings in the Primed and Non-Primed Conditions

Stimulus Pairing	Primed		Non-Primed	
	T	n	T	n
Words Correct				
S-W vs F-W	19.5	9	10.0	6
W-S vs W-F	47.0	14	25.0	10
Faces Correct				
F-S vs F-W	11.0	16**	22.0	12
S-F vs W-F	33.5	14	40.5	13
Shapes Correct				
S-F vs S-W	24.0	14	31.5	15
F-S vs W-S	41.0	15	7.0	9

** $p < .01$

Table 7-5

Results of the Wilcoxon Tests Comparing the Recognition of Stimuli in the Left and Right Visual Fields in the Primed and Non-Primed Conditions

Stimulus Pairing	Primed		Non-Primed	
	T	n	T	n
S-W	12.5	13*	21.5	12
W-S	30.5	15	34.5	14
F-W	9.0	15**	19.0	11
W-F	26.5	15	33.0	12
F-S	21.0	15*	44.0	13
S-F	46.5	16	25.5	10

* $p < .05$

** $p < .01$ (2-tailed)

arguing that when the subject's fixation is maintained at the centre of the display visual field differences due to functional differences between the hemispheres are revealed. However, anticipation of a central digit may affect the subject's perceptual scan and therefore their experiment can not be regarded as conclusive evidence against a scanning hypothesis. In fact, the presence, or anticipation, of a central digit may prevent a left to right scan but may lead to a centre to right scan. Detection in the LVF would then require a scan back from the extreme right to the left.

In the present experiment, priming influenced only word recognition significantly and here the effect was to increase the recognition of words from the LVF in the primed condition. This suggests that when the subjects expected the majority of words to fall in the RVF they continued to scan from the centre to the right after reading the central digit. This is the behaviour which a scanning theory would predict in the unprimed condition also. The data suggests that when the subjects knew that it was more probable that the words would fall in the LVF than in the RVF, they altered their perceptual scans in order to attend to the LVF before the RVF word. Why should the subjects' behaviour be governed by the word stimuli alone? It is probable that the word stimuli are the easiest type of stimulus material to identify. More words were recognised than non-word stimuli in the S-W and F-W orientations, although when words were presented in the

LVF in the W-S and W-F orientations this was not the case. In the latter cases it may be that the advantage which the word stimuli have in being the easiest type of material to recognise is obscured by a RVF advantage conferred by the presence of a central digit, which may encourage a scan towards the RVF. As subjects were encouraged to maximise their recognitions it is probable that they would pay most attention to the easier stimulus type on any single exposure.

The lack of visual field asymmetry in the perception of shapes is in agreement with Hannay et al (1976) and extends their finding to different stimulus pairings. Faces have been found by several workers to be better recognised from the LVF than from the RVF. In this experiment, however, faces were only recognised better from the LVF when the subject was expecting a face to be presented in the LVF and a word in the RVF. This suggests an attentional or scanning mechanism favouring the LVF if one considers this data in isolation. However the words in the F-W orientation are also recognised correctly more frequently than those presented in the opposite orientation. One cannot therefore, argue for a left to right scan as this would predict an adverse effect on the recognition of the RVF word. This data can not be interpreted by Kinsbourne's (1970) theory because that would predict that if words are better recognised from the RVF because the left hemisphere is active, relative to the right hemisphere, then faces and shapes should also be better recognised from the RVF. Therefore there may appear to be a structural basis for the observations in some instances.

Although it could be argued that there may be a ceiling effect in operation in this experiment, that is, subjects performed so well when required to recognise words presented in the RVF that there was no observable advantage of priming, another tentative explanation may be advanced for the data. It appeared that priming was only of help to the subject when it prepared him for making a left to right scan of the word stimulus. It is more probable that a left to right scan is required for the correct recognition of words than for shapes or faces. It also appears that there is an additional underlying asymmetry due to structural factors.

The outcome of this experiment therefore, is that a direct access theory of visual field asymmetry is again supported but in addition there is an influence of perceptual scanning on the results. There is no support for Kinsbourne's theory of percpptual asymmetry.

Chapter Eight

Experiment Six

Experiment Six

Introduction

The direct access theory appears to provide the "best fit" of the data collected in experiments one to five, although a scanning theory appears to be implicated to some degree in experiment five and an attentional theory can not be ruled out as an explanation of the data in the earlier experiments. Experiments one to four were concerned with unilateral presentation of stimuli, while experiment five dealt with bilateral presentation of stimuli. Hines (1975) proposed that different mechanisms underly the results obtained in studies involving unilateral and bilateral presentation of visual stimuli with central fixation control. He suggested that the two hemispheres function as separate channels for "recognising" bilaterally presented stimuli. Therefore the differences between the visual fields in this situation reflect actual differences between the hemispheres for "recognising" different types of stimuli. In this case his use of the word "recognising" presumably refers to the entire analysis process. In the unilateral presentation situation he hypothesised that both hemispheres contribute towards "recognising" (registering?) incoming stimuli. He argued that the visual field asymmetry observed in this paradigm reflects information loss during callosal transmission to the appropriate hemisphere when required.

The view that the two hemispheres act as separate channels in experiments using bilateral stimulus displays has a fair degree of support (Dimond, 1972; Dimond and Beaumont, 1974). Although some authors do not present sufficient evidence to show that the two hemispheres operate independently (Davis and Schmit, 1971; 1973; Dimond and Beaumont, 1971; White and Silver, 1975), there is data accumulating which suggests that under some conditions independent hemisphere operation may occur (Hellige and Cox, 1976) and can increase the subject's processing capacity (Dimond and Beaumont, 1974).

There were several difficulties with Hines' (1975) experiment, in which he studied performance under five conditions of bilateral presentation. In the "unlike" pairing conditions (that is, a word in one visual field and a face or a shape in the other) he gave 40 trials to each subject. In the "like" pairing conditions (that is, a word with a word, a face with a face and a shape with a shape) there were only 20 trials per subject. Therefore the effects of practice and fatigue may have varied across conditions. Secondly the exposure duration varied according to stimulus pairing, making it difficult to interpret the effects of the type of stimulus pairing.

This experiment aimed to replicate Hines' (1975) study, taking account of these criticisms, introducing practice trials, controlling the order of report of the stimulus pairs and using a repeated measures design.

Method

Apparatus and Stimulus Preparation

The 3 types of stimuli were presented in a Cambridge Two-Field tachistoscope in 6 conditions: word paired with word (W-W), word with face (W-F/F-W), word with shape (W-S/S-W), face with face (F-F), shape with shape (S-S) and also shape with face (S-F/F-S), which was not included by Hines (1975). Each stimulus card had a digit from 1 to 9 typed in black at the fixation point. The words, taken from Hines (1975) were typed in black pica capitals with one space between the letters. The inner edge of each word subtended a visual angle of 1.7° and the outer edge of each word subtended an angle of 4.5° from fixation. Each word (see previous chapter) appeared once in each visual field in the W-F/F-W and W-S/S-W conditions and twice in each visual field in the W-W condition.

The 10 shapes were solid black 8 point forms of low verbal association value (Vanderplas and Garvin, 1959) and their mirror-images, which were produced in order to control for any visual field advantage which may be inherent in the stimuli (see previous chapter for an illustration of these stimuli). The visual angle subtended by the inner edge of each shape was 1.7°. The minimum visual angle subtended by the outer edge of a shape was 4.5° and the maximum was 6.2°. In the "like" condition (S-S) each shape appeared once in each visual field in each orientation. In the "unlike" conditions

(S-W/W-S and S-F/F-S) each shape appeared once in each visual field, tha particular orientation being randomly selected.

There were 10 photographs of faces (students at the University of Leicester, unknown to the experimental subjects) and the mirror image of each face (see the previous chapter). These stimuli were presented in the F-F, F-S/S-F and F-W/W-F conditions within the constraints outlined for shapes. The inner edge of each photograph subtended a visual angle of 1.7° and the outer edge subtended an angle of 5.5° from the central fixation point.

Within all the above constraints and allowing no cards to be alike, all stimuli were randomly paired. An exposure of 60 msecs was used in all conditions.

A set of response cards was prepared for each condition, 4 alternative stimuli being provided for each visual field. Left and right visual fields were randomly assigned to the upper and lower rows and within a row the position of the correct choice was randomly determined.

Subjects

17 undergraduates of the University of Leicester (11 males) served as volunteer subjects. All had normal, or corrected to normal, vision and were right handed, having a score of 7 or more right handed responses on Annett's Handedness Questionnaire (Annett, 1970). Their mean age was 20 years (age range 18 to 30 years).

Procedure

Subjects began each trial by viewing a white card on which there was a central square, which was just large enough to "frame" the central digit when the stimulus card was exposed. Subjects were instructed to fixate the centre of the square before each trial, which was initiated by the signal "ready, go" one second in advance of stimulus exposure, and to maintain fixation throughout the trial. All subjects were given 2 practice trials with each stimulus pairing. The order of these 6 pairs of trials was randomised for each subject. The subject was told to report the central digit, turn the response card, on his left, face up and then point to the left and right visual field stimuli in the order previously specified by the experimenter. During the practice trials the subject was given feedback as to the accuracy of his responses. This was not the case in the experimental session. The experimental trials were presented in 6 blocks of 20 trials. Each block contained one type of stimulus pairing. Blocks were presented in random order. Within a block of trials the experimenter specified an order of report for the first 10 trials, which was reversed for the second set of 10 trials. In the "unlike" stimulus pairings there was an equal number of stimulus cards of a particular left-right orientation in each report order. Three blocks commenced with LVF report followed by RVF report and three blocks commenced with RVF report followed by LVF report. Within these constraints the order of report was randomised for each subject. Between blocks the subject had a 2 minute break. After the experiment subjects were requested to complete a copy of Annett's Handedness Questionnaire.

Results

The mean percentage of correct responses in each condition and the standard deviations of those responses are shown in Table 8-1. Three 3-way analyses of variance were performed, each type of material being considered separately.

Table 8-2 is the analysis of variance summary for the analysis of word stimuli. Significantly more words were recalled from the RVF than from the LVF ($F=44.78$, df 1,16, $p<.005$) in all stimulus pairings. Stimulus pairing did not affect overall recall of words ($F=1.023$, df 2,32, $p>.05$) or visual field asymmetry ($F=0.107$, df 2,32, $p>.05$).

Table 8-3 is the analysis of variance summary table for the analysis of faces. There was no significant difference between visual fields in the recall of faces ($F=4.117$, df 1,16, $p>.05$). Although stimulus pairings did not affect visual field asymmetry ($F=0.914$, df 2,32, $p>.05$), they did affect overall recall ($F=16.287$, df 2,32, $p<.005$). Tukey (a) tests showed that this was due to there being a higher percentage of faces recalled from the F-W/W-F pairing than from the F-F pairing ($q_{3,16}=8.01$, $p<.01$) and a higher percentage recall in the F-S/S-F pairing condition than in the F-F condition ($q_{3,16}=6.579$, $p<.01$).

Table 8-1

The Mean Percentage of Correct Recognitions as a Function of the Stimulus Pairing

Stimulus Pairing	Percentage of Correct Recognitions			
	LVF		RVF	
	$\bar{X}$	s.d.	$\bar{X}$	s.d.
Words correct when paired with:				
WORD	72.05	20.60	84.41	16.50
SHAPE	66.47	16.95	81.17	22.05
FACE	70.00	16.20	85.29	25.75
Faces correct when paired with:				
FACE	46.47	14.45	38.53	14.75
WORD	65.29	13.30	57.06	17.60
SHAPE	55.88	13.70	53.53	12.70
Shapes correct when paired with:				
SHAPE	47.35	16.50	48.82	14.00
WORD	66.47	17.65	70.59	22.50
FACE	65.29	15.85	62.35	19.55

Table 8-2

Summary of the Analysis of Variance on the Percentage of Correct Recognitions of Words

Source	SS	df	MS	F
Subjects	756.63	16	47.29	
A (stimulus pair)	15.61	2	7.80	1.023
A x subjects	243.73	32	7.62	
B (visual field)	203.29	1	203.29	44.777 *
B x subjects	72.71	16	4.54	
AB	1.65	2	0.82	
AB x subjects	244.35	32	7.64	
Total	1537.96	101	15.23	

$^{*} < p$ .005

Table 8-3

Summary of the Analysis of Variance on the Percentage of Correct Recognitions of Faces

Source	SS	df	MS	F
Subjects	285.65	16	17.85	
A (stim. pairing)	244.65	2	122.32	16.287**
A x subjects	240.65	32	7.51	
B (visual field)	38.91	1	38.91	4.117
B x subjects	151.25	16	9.45	
AB	7.47	2	3.74	0.914
AB x subjects	130.86	32	4.09	
Total	1099.15	101	10.88	

** $p < .01$

Table 8-4 is the summary table for the analysis of the responses to shape stimuli. There was no significant difference between the visual fields in the recognition of shapes ($F=0.101$, df 1,16, $p>.05$), nor was there an interaction between visual field and stimulus pairing ($F=0.926$, df 2,32, $p>.05$). There was a significant overall effect of stimulus pairing ($F=14.823$, df 2,32, $p<.01$). This was due to there being a higher percentage of shapes recalled in the S-W/W-S condition ($q_{3,16}=7.35$, $p<.01$) and the S-F/F-S condition ($q_{3,16}=5.658$, $p<.01$) than in the S-S condition.

The data were then analysed to determine whether correct recognition of a stimulus in one visual field was associated with incorrect recognition of the stimulus in the opposite visual field. For each subject the number of trials in which both visual field stimuli were correctly reported was compared eith the number of paired correct responses which would be expected simply on the basis of total recall in each visual field. For example, Hines (1975), if in a series of 20 trials a subject has 8 correct responses in one visual field and 10 correct responses in the other, simply by chance 10 x 8 / 20 or 4 trials should have occurred in which both responses were correct. The differences between actual and chance distributions were tested by paired t-tests, the results of which, together with the mean number of paired correct responses observed and expected by chance, are presented in Table 8-5.

Table 8-4

Summary of the Analysis of Variance on the Percentage of Correct Recognitions of Shapes

Source	SS	df	MS	F
Subjects	604.166	16	37.76	
A (stim. position)	311.794	2	155.897	14.823**
A x subjects	336.540	32	10.517	
B (visual field)	0.882	1	0.882	0.101
B x subjects	139.285	16	8.705	
AB	8.559	2	4.280	0.926
AB x subjects	147.774	32	4.618	
Total	1549.000	101	15.337	

** $p < .01$

Table 8-5

The Mean Number of Trials in which both Visual Field Stimuli were Correctly Reported Compared with the Number of Correct Pairs Expected by Chance

Stimulus Pairing		Number of Pairs Correct		t_{obs}
LVF	RVF	Chance	Observed	
WORD	WORD	12.641	12.353	1.656
WORD	FACE	4.129	4.000	0.732
FACE	WORD	5.624	5.471	1.512
FACE	FACE	3.812	2.824	3.052†
WORD	SHAPE	4.476	4.353	0.712
SHAPE	WORD	5.459	5.824	1.395
SHAPE	SHAPE	4.853	3.882	3.987†
FACE	SHAPE	3.559	3.235	1.800*
SHAPE	FACE	3.553	2.235	1.687

† $t_{<.005}\ (16) = 2.921$

* $t_{<.05}\ (16) = 1.746$

Discussion

The results of this experiment with reference to the superior recognition of words presented in the RVF are in agreement with studies using bilateral presentation of stimuli with a central fixation task (Hines, 1972; 1975; 1976; McKavey et al, 1975; McKeever, 1971; McKeever and Huling, 1971a; 1971b) and some work not involving a central fixation digit (Ellis and Shepherd, 1974; McKavey et al, 1975). Hines (1975) argued that the asymmetry observed in the W-W condition can not be due to interference resulting from competition for access to left hemisphere language mechanisms on the basis of two types of evidence. Firstly there is a similar asymmetry observed when words are paired with other types of stimuli. However it must be noted that in Hines' (1975) investigation there was no significant difference between the visual fields in the perception of faces and in the experiment presented here there was no significant visual field asymmetry in the perception of faces or shapes. Therefore these stimuli may be analysed by mechanisms involved in verbal processing and competition for these mechanisms may account for the data.

Secondly Hines (1975) argued that if competition between two verbal stimuli had occurred then correct recognitions of stimuli from one visual field would be correlated with incorrect recognitions from the opposite visual field. That is, when an incorrect response was made to a stimulus which appeared in the dominant visual field (in this case the RVF) it would be more probable that the subordinate visual field (LVF) stimulus would be correctly processed than when the response to the RVF stimulus was correct. This argument assumes that all RVF stimuli, to which erroneous responses are given, require little, or no, processing capacity and therefore allow LVF stimuli access the the left hemisphere. However, this is unlikely to be the case. It is more probable that both correct and incorrect RVF stimuli require a similar processing capacity. However some stimuli will require less processing than others in order to produce a correct response, or an error may occasionally occur early in the processing sequence. In such instances the left hemisphere will possibly then be freed from processing RVF stimuli at a stage when the LVF stimulus may still be sufficiently intact (that is, it will not have decayed to too large an extent in the iconic store) in order to be transferred to the left hemisphere and successfully processed. Transfer from the right to the left hemisphere of stimulus information would be expected to occur randomly, therefore, and the number of paired correct responses would be expected to be at chance level. In this experiment and in that of Hines (1975) there were in fact fewer correct responses to word stimuli presented in the LVF and a chance distribution of paired correct responses. It may be that there is competition between the two hemispheres for the processing of stimulus information although,as outlined above, stimulus detection in the visual fields may be independent. Although Hines argued that each hemisphere processes the stimulus information which it receives, the data obtained in his and the present experiment are not sufficient to uphold this hypothesis.

The predictions made by Kinsbourne's attentional theory are more difficult to specify. If the attentional bias of the subject remains constant throughout a block of trials then there should be fewer correct responses to stimuli in the visual field ipsilateral to the active hemisphere. Unless attending to one visual field precludes the processing of information reaching the other, one would expect that there would be a chance detection of stimuli in the unattended visual field and that paired correct responses would occur at random. If there is a switching of attention during a block of trials there would be no visual field asymmetry observable in terms of correct responses. In this case there would also be a chance distribution of paired correct responses. There is no evidence in this experiment of an attentional bias of this type towards a single visual field except in the W-W condition. If there was such a bias then all stimuli presented in the favoured visual field would be recognised at a higher frequency than those presented in the unattended visual field. Thus in the W-F orientation, for example, there would be more faces recognised than in the F-W orientation.

There is similarly some evidence against a scanning theory. Although a scan from the fixation digit towards the right may not favour face and shape stimuli to the same extent as it would favour word stimuli, nevertheless one would anticipate that face and shape stimuli presented in the RVF would be recognised more frequently than similar stimuli in the LVF, which could not be scanned until after the RVF.

Therefore the data are most adequately explained by a direct access interpretation. There may be attentional biases operating, which are not apparent in terms of visual field asymmetry, but they are not the primary factor involved.

Although there were more faces recognised from the LVF than from the RVF, this, in agreement with Hines (1975) was not a significant difference. Klein et al (1975) using a similar procedure did find a LVF superiority. The reason for these conflicting findings remains obscure.

Hines (1975) found a small RVF superiority for the recognition of inkblot-like shapes (Hines, 1972). There was no visual field asymmetry shown for the perception of the shapes used in the present study. This supports the findings of Hannay et al (1976), who used a unilateral presentation procedure.

Stimulus pairings affected the recognition of shapes and faces, the "like" pairings producing fewer correct responses than the "unlike" pairings. This was probably due to the recognition task in which the subject had to select two similar stimuli from an array of eight in the "like" conditions and one stimulus from an array of four in the "unlike" conditions.

As competition for a single processing system and Kinsbourne's attentional theory can be discounted as being responsible for the finding that there are fewer paired correct responses in the S-S, F-F and F-S pairings than one would expect by chance, three explanations are offered. 1) It reflects the subjects' inability to hold two unfamiliar stimuli in short term memory, as suggested by Hines (1975). This would be expected to be a limited effect as stimuli appeared frequently on stimulus and response cards throughout the experiment. 2) It may be due to forgetting the second stimulus at the response stage due to interference from alternative stimuli on the response card. 3) The subjects perceived the non-word stimulus pairs as more difficult and therefore chose to lose information from one of the stimuli in order to be sure of retaining the other. As there is no reason for choosing one stimulus rather than the other, the net result would be a random loss of information from each visual field, which would occur at the input stage. The remaining stimulus could then be processed by mechanisms in the appropriate hemisphere. This could also explain the lack of visual field asymmetry in the perception of faces and shapes.

In this experiment it appeared as if subjects experienced some control over the experimental situation when they knew, prior to stimulus exposure, the order in which they had to report the stimuli. It was noted that they often had difficulty when told to change their report order and subjects reported that knowing the order of report prior to stimulus exposure assisted their task. Experiment seven is a modification of experiment six.

In experiment seven the subjects were not told the order of report until after the stimulus exposure. It was considered that in this situation the subjects would attempt to retain as much stimulus information as possible. This should remove the suspicion, at least in the case of face stimuli, that the lack of visual field asymmetry is due to extraneous factors related to the report of the stimuli.

In summary therefore, it may be said that the direct access theory of visual field asymmetry provided the best explanation of the asymmetry observed in the perception of words. It is not possible to determine from these data whether material arriving in the right hemisphere is processed by that hemisphere or whether it is transferred to the left hemisphere, resulting in a processing delay and consequent loss of fidelity.

Chapter Nine

Experiment Seven

Experiment Seven

Introduction

When stimuli are presented bilaterally the order of report of those stimuli will influence the visual field asymmetry. It is important that neither field is always the first to be reported as this would confer an advantage on material presented in that field. Although the order of report from each visual field was balanced in experiment six another problem, associated with report order, arose. In experiment six the report order required was specified prior to stimulus exposure. It was suggested that this may have led to the subjects altering their processing strategies in some conditions in order to report at least one of the two stimuli correctly. It was suggested that they may have processed only one of the stimuli in these conditions. In the experiment to be considered in this chapter the subjects were informed of the order of report after stimulus exposure. They were therefore required to retain the stimulus information until they had received and interpreted the report order instructions. It is suggested that this would encourage the subjects to retain as much of the stimulus material as possible and to process both of the stimuli. As experiment seven provided a more difficult task than experiment six, in that subjects had to retain the stimulus information for a longer period prior to report, it was anticipated that there would be a lower percentage of correct recognitions in experiment seven than there were in experiment six.

Method

Apparatus and Stimulus Design

The apparatus, stimulus cards and response cards were those used in experiment six. There was one additional item of equipment. A red and green L.E.D. miniature filament bulb were mounted horizontally on a vertical metal plate above the tachistoscope.

Subjects

The subjects were 15 undergraduate volunteers from the University of Leicester (12 males) with a mean age of 21.6 years (range 18 to 31 years), selected according to the same criteria as those taking part in previous experiments. They were all right handed as shown by 8 or more right handed responses on Annett's Handedness Questionnaire (Annett, 1970) and had normal, or corrected to normal, vision.

Procedure

The procedure was the same as that of experiment six apart from the order of report of the stimuli and the instructions to the subjects concerning report order. They were told to report the central digit verbally immediately after the stimulus exposure and then to refer to the indicator lights above the tachistoscope. When the light on the right (red) was showing they had to report the RVF stimulus followed by the LVF stimulus. When the left (green) indicator light was on they had to report the stimuli in the reverse order. This procedure presented no difficulty to the subjects after the 12 practice trials. The order of report of the stimuli was randomised with the proviso that the number of trials in each report order was equal for each stimulus orientation in the "unlike" conditions.

Results

The mean percentage of correct recognitions in each condition is shown in Table 9-1. Three analyses of variance were performed, each type of material being considered separately.

Table 9-2 is the summary of the analysis of variance on the percentage of correct recognitions of words. There were more words recalled from the RVF than from the LVF ($F=23.605$, df 1,14, $p<.01$), but stimulus pairings affected neither overall recall ($F=1.192$, df 2,28, $p>.05$) nor visual field asymmetry ($F=1.21$, df 2, 28, $p>.05$)

Table 9-3 is the analysis of variance summary table for the analysis of face stimuli. There was no significant difference between visual fields in the recognition of faces ($F=1.680$, df 1,14, $p>.05$). However, there was a significant interaction between visual field and stimulus pairing ($F=11.390$, df 2,28, $p<.01$). The nine unconfounded comparisons of this interaction (Cicchetti, 1972) were

Table 9-1

The Mean Percentage of Correct Recognitions as a Function of the Stimulus Pairing

Stimulus Pairing	Percentage of Correct Recognitions			
	LVF		RVF	
	$\bar{X}$	s.d.	$\bar{X}$	s.d.
Words correct when paired with:				
WORD	78.30	16.75	90.66	12.65
SHAPE	67.30	19.80	90.00	13.65
FACE	78.00	22.75	92.67	11.00
Faces correct when paired with:				
FACE	49.33	14.75	35.33	17.35
WORD	67.33	24.65	60.00	21.40
SHAPE	56.66	21.60	64.00	21.95
Shapes correct when paired with:				
SHAPE	47.33	13.60	56.00	13.00
WORD	74.00	17.65	71.33	16.85
FACE	70.66	18.30	69.33	22.20

Table 9-2

Summary of the Analysis of Variance on the Percentage of Correct Recognitions of Words

Source	SS	df	MS	F
Subjects	279.955	14	19.996	
A (stim. pairing)	28.422	2	14.211	1.192
A x subjects	333.912	28	11.925	
B (visual field)	240.100	1	240.100	23.605**
B x subjects	142.400	14	10.171	
AB	13.267	2	6.634	1.208
AB x subjects	153.733	28	5.490	
Total	1191.789	89	13.391	

** $p < .01$

Table 9-3

Summary of the Analysis of Variance on the Percentage of Correct Recognitions of Faces

Source	SS	df	MS	F
Subjects	630.622	14	45.044	
A (stim. pairing)	316.089	2	158.044	8.247*
A x subjects	536.578	28	19.164	
B (visual field)	19.600	1	19.600	1.683
B x subjects	163.067	14	11.648	
AB	71.466	2	35.733	11.386**
AB x subjects	87.867	28	3.138	
Total	1825.289	89	20.509	

* $p < .05$

** $p < .01$

submitted to Tukey (a) tests. The faces in the LVF were recognised correctly more frequently than the faces in the RVF in the F-F condition ($q_{5,28}=6.12$, $p<.01$). There was no visual field difference in the F-W/W-F condition ($q_{5,28}=3.21$, $p>.05$) or the F-S/S-F condition ($q_{5,28}=3.21$, $p>.05$). The faces in the LVF in the F-F condition were recognised correctly less frequently than the faces in the F-W orientation ($q_{5,28}=7.87$, $p<.01$) but as frequently as the faces in the F-S orientation ($q_{5,28}=3.21$, $p>.05$). The faces in the RVF in the F-F condition were recognised correctly less frequently than the faces in the W-F orientation ($q_{5,28}=10.79$, $p<.01$) and faces in the S-F orientation ($q_{5,28}=12.54$, $p<.01$). The faces in the F-W orientation were recognised correctly more often than the faces in the F-S orientation ($q_{5,28}=4.66$, $p<.05$). The faces in the W-F and S-F orientations were recognised equally often ($q_{5,28}=1.75$, $p>.05$). There was a significant effect of stimulus pairing on the overall recognition of faces ($F=8.25$, df 2,28, $p<.01$). Tukey (a) tests revealed that the percentage of faces recognised correctly was greater in the F-S/S-F condition than in the F-F condition ($q_{3,28}=4.50$, $p<.05$). There was also a higher percentage of faces recognised correctly in the F-W/W-F condition than in the F-F condition ($q_{3,28}=5.34$, $p<.01$).

Table 9-4 is the summary table of the analysis of variance on the recognition of shapes. There was no significant difference between the visual fields in the recognition of shapes ($F=0.52$, df 1,14, $p>.05$). Although there was a significant effect of stimulus pairing

Table 9-4

Summary of the Analysis of Variance on the Percentage of Correct Recognitions of Shapes

Source	SS	df	MS	F
Subjects	429.156	14	30.654	
A (stim. pairing)	313.689	2	156.845	14.123**
A x subjects	310.978	28	11.106	
B (visual fields)	2.178	1	2.178	0.521
B x subjects	58.489	14	4.178	
AB	33.022	2	16.511	2.355
AB x subjects	196.311	28	7.011	
Total	1344.034	89	15.103	

** $p < .01$

($F=14,12$, df 2,28, $p<.01$) this did not affect visual field asymmetry ($F=2.34$, df 2,28, $p>.05$). The S-W/W-S condition ($q_{3,28}=6.90$, $p<.01$) and the S-F/F-S condition ($q_{3,28}=6.03$, $p<.01$) were superior, in terms of correct shape recognition, to the S-S condition.

Table 9-5 presents the number of correct paired responses observed and the number that would be expected by chance (as in experiment six), together with the results of a series of t-tests performed on the data. Table 9-6 presents the degree of visual field asymmetry (that is, the difference between LVF and RVF scores) for each condition in each report order. The visual field differences obtained in the two report orders were then compared by a series of t-tests (1-tailed) as it was predicted that visual field asymmetry should favour the first reported visual field.

Discussion

The lack of visual field asymmetry in the perception of shapes replicated the finding of experiment six. This suggests that shapes may be analysed by either hemisphere. The finding that the recognition of shapes and faces was more frequent in the "unlike" conditions than in the "like" conditions also replicated experiment six. This was again considered to be due to the difference between the response cards in the "like" and "unlike" conditions.

When faces were presented in the RVF they were correctly recognised more frequently when there was a shape in the

Table 9-5

The Mean Number of Trials in which both Visual Field Stimuli were Correctly Reported Compared with the Number of Correct Pairs Expected by Chance

Stimulus Pairing		Number of Pairs Correct		t_{obs}
LVF	RVF	Chance	Observed	
WORD	WORD	14.470	14.800	1.465
WORD	FACE	4.493	4.267	1.744
FACE	WORD	6.287	6.200	1.598
FACE	FACE	3.673	3.667	0.026
WORD	SHAPE	4.980	5.000	0.110
SHAPE	WORD	6.687	6.667	0.250
SHAPE	SHAPE	5.823	4.333	2.924**
FACE	SHAPE	3.940	3.800	1.020
SHAPE	FACE	4.527	4.400	0.785

** $t_{.01}$ (14) =1.761

Table 9-6

Visual Field Asymmetry: LVF-RVF Recognitions Scores as a Function of Report Order and Stimulus Pairing

Stimulus Pairing	First Reported Visual Field LVF	First Reported Visual Field RVF	t_{obs}
Words correct when paired with:			
WORD	-0.733	-1.467	1.385
SHAPE	-0.867	-1.333	1.023
FACE	-0.533	-0.933	0.764
Faces correct when paired with:			
FACE	2.133	0.667	2.087*
WORD	0.267	0.467	0.425
SHAPE	0.267	-1.000	3.106'
Shapes correct when paired with:			
SHAPE	1.533	-3.267	5.095****
WORD	0.533	-0.267	2.037*
FACE	0.533	-0.400	1.793*

* $t_{.05}$ (14) =1.761 ' $t_{.005}$ (14) =2.977

**** $t_{.0005}$ (14) =4.120

LVF than when there was a face in the LVF. When faces were presented in the LVF they were recognised equally frequently irrespective of whether there was a face or a shape in the RVF. When two faces were presented simultaneously, the LVF recognition level was superior to the RVF recognition level. These findings taken together suggest that faces presented in the RVF are transferred to the right hemisphere for analysis. When the right hemisphere is already occupied with analysing the LVF stimulus, that is, when the LVF stimulus is also a face, the RVF stimulus may not receive immediate analysis and therefore it becomes subject to more errors. When the LVF stimulus is a shape and the RVF stimulus is a face, the face may be transferred to the right hemisphere for analysis and the shape may either be transferred to the left hemisphere, thereby freeing the right hemisphere mechanisms, or the shape may be analysed in the right hemisphere by mechanisms not involved in the processing of face stimuli.

However if this interpretation is correct, then faces in the RVF in the S-F orientation would be expected to be degraded in their transfer across the corpus callosum relative to the faces in the LVF in the F-S orientation. This was not the case. It is therefore suggested that in the F-F condition the faces could be analysed by the left hemisphere. The faces analysed in the left hemisphere may be more susceptible to interference from a large number of response alternatives than those analysed by the right hemisphere. Alternatively, the left hemisphere may use a different coding strategy from that used by the right hemisphere. This strategy may be less efficient than the right hemisphere's strategy in dealing with unfamiliar faces.

As in experiment six, there were more words recognised from the RVF than from the LVF in all stimulus pairings. This may have arisen as a result of the LVF words having to be transferred to the left hemisphere from the right hemisphere in order to be processed. Alternatively, the right hemisphere may be capable of processing the words but does so less efficiently than the left hemisphere. A different type of explanation would be that it is more difficult to scan the word in the LVF post-exposurally when fixation is controlled by a central digit.

As was anticipated, it was probable that the report instructions led to the subjects attempting to retain as much stimulus information as they were able, because the number of paired correct responses was equal to chance in all except the S-S condition. In this condition it is possible that after one stimulus had been reported the second stimulus was forgotten as a result of interference from stimuli on the response card. That this may account for the data in the S-S condition is borne out by the finding that report order had a significant effect on the recall of shapes and, to a lesser extent, faces. It is probable that these response factors were both operating in this experiment to differing degrees in each condition.

In arguing that the two hemispheres act as separate channels and that each is capable of analysing the material which it receives, one should present evidence to show that they operate independently and do not have a common bottle-neck. The dual channel hypothesis is contrary to the more traditional single channel theory (Broadbent, 1958; 1971) and also requires that the hemispheres process material for which they are generally not regarded as being specialised. Hines' (1975) evidence was not sufficient to support his position, as argued previously, and his interpretation of his data was incorrect.

Under conditions of unilateral presentation, Dimond and Beaumont (1973) obtained results suggestive of two vigilance systems within the brain and differential fatigue of the two hemispheres (Dimond and Beaumont, 1972), which suggests independent operation of the two hemispheres during the particular tasks involved. Hellige and Cox (1976) showed that a verbal memory set had differential effects on the recognition of shapes presented in the left and right visual fields. Their results suggest that the two hemispheres operate independently when the right hemisphere is involved in visual processing. However when the left hemisphere is receiving the non-word stimuli and also has to process a large memory set of words, interference occurs. It may therefore be the case that the two hemispheres act as separate channels under conditions of bilateral presentation in situations where each hemisphere receives material for which it is specialised. Experiment seven does provide some evidence contrary to this however, in that it has been suggested that the two hemispheres each process shape and face stimuli.

Experiments six and seven demonstrate that minor procedural changes may produce differences in experimental findings and it is necessary to understand more fully the operation of these factors. Unless stimuli, for which visual field asymmetry is well established, are used it will prove difficult to distinguish between a dual and a single channel hypothesis in the bilateral presentation situation.

Chapter Ten

Experiment Eight

Experiment Eight

Introduction

The previous experiments have shown a direct access theory of visual field asymmetries to be the most appropriate interpretation of the data. Experiments five, six and seven have suggested that a scanning interpretation may be necessary under some circumstances of bilateral presentation when word stimuli are involved. In addition, experiments six and seven have demonstrated that relatively minor changes in the experimental procedure may affect the observed visual field asymmetries. Thus small procedural differences between experiments reported by various workers in the field may account for the conflicting data in some instances. It has also been suggested (Cohen, 1975) that Kinsbourne's (1970) theory of visual field asymmetries may account for some of the discrepancies between experimental results. Kinsbourne argued that there are no means of controlling covert shifts in attention and that these shifts in attention may arise due to experimental procedures or be related to the irrelevant thoughts of the subject. It is the subject's visual attention which gives rise to the observable visual field asymmetries. Thus minor procedural changes may give rise to attentional shifts and consequently to differing asymmetries. Kinsbourne's theory may account for some of the data collected in the previous experiments, particularly in experiments one and two. In experiments five, six and seven, word stimuli were paired with other stimulus materials, which make it difficult to predict the direction of attentional shifts if these did occur.

The following experiment set out to test Kinsbourne's theory as an explanation of the laterality observed in the visual detection of words. The presentation of words alone should activate the left hemisphere and if Kinsbourne is correct, bias attention towards the RVF, thus increasing detection from the RVF. Kinsbourne's model predicts a continuous perceptual gradient across the visual field, extending in this instance from the extreme RVF through fixation to the extreme LVF. A direct access theory of visual field asymmetry would not predict such a gradient.

In this experiment subjects were asked to search for target words. A target word may, or may not, occur on any single trial. In condition 1 two words were presented horizontally in the LVF, in condition 2 there was a word in the LVF and one in the RVF and in condition 3 the two words were presented horizontally in the RVF. These visual field positions follow the pattern of Kinsbourne's (1975) experiment one, in which he was concerned with the detection of gaps in the vertical sides of a square. He presented the square in the LVF, RVF and across fixation.

Conditions 4, 5, and 6 are included as an extension to experiments six and seven. They are concerned with the question of whether material divided between the hemispheres is processed more accurately than material solely presented to one hemisphere. If material is processed more accurately when both hemispheres are involved, then both hemispheres must be able to perform most, if not all, of the processing of the stimuli and they must be able to operate as independent channels. In each of the conditions 4,5 and 6 there is a word presented in each visual field. Figure 10-1 illustrates the stimulus layouts.

Kinsbourne (1975) does not mention any method of fixation control and therefore it is possible , if verbal problems produce overt gaze shifts towards the RVF, that detection differences between visual fields are due to gaze shifts and not to attentional shifts. In the following experiment, therefore, as in experiments five, six and seven, subjects were required to report a digit presented at the fixation point prior to reporting the presence of absence of the target word. The inclusion of such a digit is, as previously mentioned, open to the criticism that it may lead to a perceptual scan from the central digit towards the right. Alternatively, being a verbal task it may enhance the attentional bias (if such a bias exists) towards the RVF. This would not adversely affect the results. However, it may be argued that the digit may prevent an attentional bias producing a full RVF advantage because, prior to detection of the target word, the subject's attention has to shift towards the centre of the display in order to detect the centre digit. This simply exemplifies the problems of interpretation of the data generated in this field.

Method

Apparatus and Stimulus Design

Stimulus cards were presented in a Cambridge Two-field tachistoscope at an exposure duration of 30 msecs. Stimuli were consonant-vowel-consonant trigrams selected for high meaningfulness (Noble, 1961) and high frequency of usage in the English language (Thorndike and Lorge, 1944). See Appendix Two for a list of the words used in this experiment. Figure 10-1 shows the six conditions in which the words were presented and the visual angles subtended by them. In condition 1 both stimulus words fell in the LVF. In condition 3 both stimuli fell in the RVF. In conditions 2,4,5 and 6 there was a stimulus word in each visual field. Conditions 1,2 and 3 parallel Kinsbourne's presentations, while conditions 4,5 and 6 are included to control for stimulus eccentricity in the both visual field (both hemisphere) condition 2.

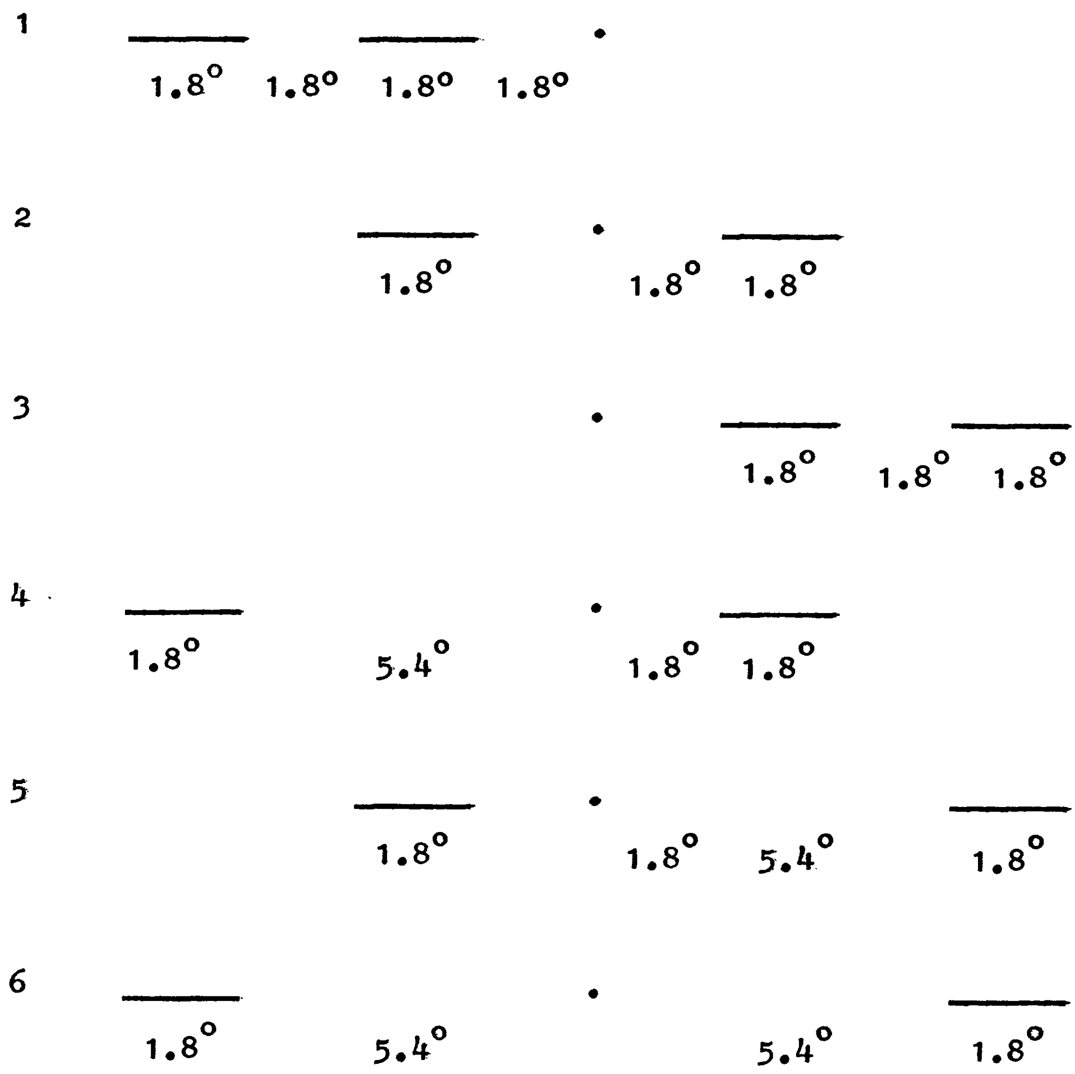
Each stimulus word subtended a visual angle of 1.8^{o}. The innermost letter of the inner word was 1.8^{o} from the central fixation point, the innermost letter of the outer word was 5.4^{o} from the central fixation point.

The 240 stimulus cards were divided into 4 blocks of 60. For each block a consonant-vowel-consonant trigram was chosen as a target word. The 4 randomly chosen target words were LET, JOY, RAN and HIT. This should have reduced visual field asymmetries peculiar to the choice of word. A target word appeared on 50% of the stimulus cards. Targets were equally distributed between

Figure 10-1

Illustration of the Conditions in which the Word Stimuli were Presented

Conditions



______ = stimulus word position

• = fixation point

left and right stimulus positions and conditions (that is 10 per position per condition).

The non-target words on the stimulus cards each appeared three or four times in the series of 240 cards. Selection of non-target words for each stimulus card was randomised. A word did not appear twice on a card. Words were typed horizontally in black capitals with a space between letters. A digit between 2 and 9 was randomly selected and typed in black at the central fixation point on each card.

Two practice sets of stimulus cards were also prepared. The target words used were CAT and SAY. There were 6 cards (1 per condition) in each practice set. Non-target words were chosen randomly and in each set the target word appeared on 3 of the cards in a random position.

Subjects

20 Foundation Year undergraduates of the University of Keele (15 males) served as volunteer subjects. The age range was from 18 to 25 years, with a mean of 19.45 years. All subjects gave 9 or more right handed responses to Annett's Handedness Questionnaire (Annett, 1970). Four of the subjects had a left handed parent or sibling. All had normal, or corrected to normal, vision.

Procedure

The subject was instructed to fixate the centre of the black outline square at the centre of the white pre-exposure field. The subject was given the instruction "ready" by the experimenter and when he was confident of his fixation he pressed the automatic stimulus exposure button. Allowing the subject to trigger the exposure helps to ensure that he is accommadated and fixating at the time of exposure. The hand used to press the button was alternated for blocks of trials. Immediately after the stimulus exposure the subject verbally reported the central digit, which he had seen "framed" by the central square of the pre-exposure field. He then said "yes" or "no" according to whether or not he had seen the target word. Three pilot subjects were asked, in addition, to give the position of the target if seen, in order to allow a signal detection analysis of the data. Unfortunately this task of localisation was too difficult and the experimental subjects were not asked to give this information.

There were 6 practice trials before the experiment began. Half of the subjects received each set of practice cards, in order to remove any biases due to the particular practice trials received. There were 4 blocks of experimental trials. Before each block the target word was spelt out to the subjects and they were asked to be quite sure that they knew what it was. There was a 3 minute break between blocks. Trials were presented at the rate of approximately 6 per minute. If the subject failed to report the central digit correctly on any trial, the card was randomly inserted at a later point in that block. This occurred very infrequently. The order of block presentation for each subject was randomised. Stimulus cards within each block were shuffled for each subject. Scoring was performed outside the subject's field of vision. After completing the experiment subjects were requested to complete Annett's Handedness Questionnaire and state whether anyone in their immediate family was left handed.

Results

The number of errors was scored in terms of missed detections and false alarms. In order to ascertain whether the mean number of false alarms (Table 10-1) was equal in all conditions, an analysis of variance was performed. Table 10-2 is the summary table of this analysis, which shows that there was a significant difference between conditions in the number of false alarms ($F=6.426$, df 5,95, $p<.01$). Tukey (a) tests showed that there was not a significant difference in false alarm rates between conditions 1 and 2 ($q_{6,95}=1.602$, $p>.05$), conditions 1 and 3 ($q_{6,95}=1.725$, $p>.05$) or between conditions 2 and 3 ($q_{6,95}=0.123$, $p>.05$). Therefore the number of missed detections in conditions 1, 2 and 3 could be analysed without reference to the false alarm rates.

Table 10-3 presents the mean number of misses in each condition. As the variances were heterogeneous ($F_{max}=4.625$, df 12, 19, $p<.05$) an analysis of variance could not be performed on the entire set of data. Therefore only conditions 1, 2 and 3 with homogeneous variance data were

Table 10-1

Mean Number of False Alarms in Conditions 1, 2, 3, 4, 5 and 6

Condition	$\bar{X}$	s.d.
1	2.050	1.877
2	2.700	3.164
3	2.750	2.099
4	2.750	3.143
5	4.300	3.080
6	4.650	3.066

Table 10-2

Analysis of Variance on the False Alarms in Conditions 1, 2, 3, 4, 5 and 6

Source	SS	df	MS	F
Between subjects	574.53	19	30.239	
Within subjects	418.67	100	4.187	
Treatments	105.80	5	21.160	6.426**
Residual	312.87	95	3.293	
Total	993.200	119	8.346	

** $p < .01$

Table 10-3

Mean Number of Misses in each Condition

Condition	Left targets		Right targets	
	$\bar{X}$	s.d.	$\bar{X}$	s.d.
1	6.900	1.651	4.700	2.515
2	3.500	2.039	1.600	1.501
3	2.850	2.289	5.250	2.403
4	5.555	2.625	1.000	1.294
5	2.700	2.080	4.350	2.110
6	5.300	2.494	3.450	2.783

considered in the first analysis. These data were subjected to a 3-way analysis of variance (Table 10-4), which allows a direct comparison with Kinsbourne's (1975) experiment one. There was a significant effect of relative stimulus position ($F=8.700$, df 1,19, $p<.01$), that is, right hand targets were more frequently detected than left hand targets. There was also a significant effect of condition ($F=32.746$, df 2,38, $p<.01$). The relationships between conditions 1, 2 and 3 were investigated by three Tukey (a) tests. There were more missed detections in condition 1 than in conditions 2 ($q_{3,38}=11.433$, $p<.01$) and 3 ($q_{3,38}=6.156$, $p<.01$). There were more missed detections in condition 3 than in condition 2 ($q_{3,38}=5.277$, $p<.01$). Thus when both stimuli fell in the RVF, targets were more frequently detected than when both stimuli fell in the LVF. However when each visual field received one stimulus, target detection was superior to that in conditions 1 and 3.

The significant interaction between position and condition ($F=19.920$, df 2,38, $p<.01$) was elucidated by a series of Tukey (a) tests. These results are summarised in Figure 10-2. In condition 1, target stimuli were more frequently detected from the right than from the left ($q_{6,38}=5.396$, $p<.01$). Similarly in condition 2, the right hand targets were more frequently detected than the left hand targets ($q_{6,38}=4.660$, $p<.05$). In condition 3 the left hand targets were more frequently detected than the right hand targets ($q_{6,38}=5.886$, $p<.01$). Comparing the right hand stimuli in the three conditions, it was found

Table 10-4

Summary of the Analysis of Variance on the Misses in Conditions 1, 2 and 3

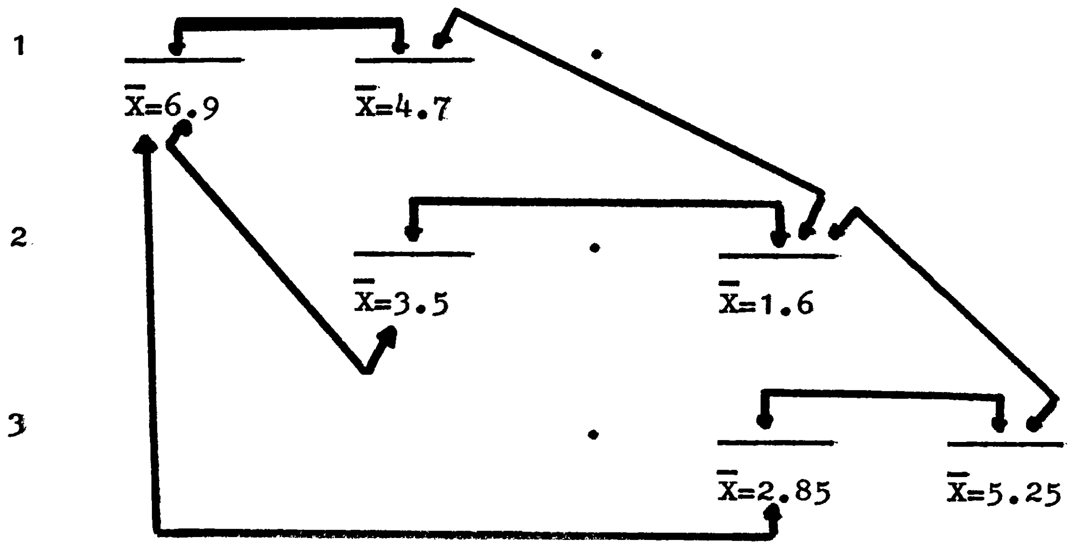
Source	SS	df	MS	F
Subjects	235.87	19	12.41	
A (position)	9.63	1	9.63	8.70**
A x subjects	21.03	19	1.11	
B (condition)	211.67	2	105.83	32.746**
B x subjects	122.83	38	3.23	
AB	132.47	2	66.23	19.92**
AB x subjects	126.37	38	3.33	
Total	859.87	119	7.23	

** $p < .01$

Figure 10-2

Illustration of the Results of the Analysis of Variance on the Misses in Conditions 1, 2 and 3

Conditions



______ = stimulus word position

• = fixation point

⟷ = significant difference

that the extreme right hand targets in condition 3 were less frequently detected than the right hand targets in condition 2 ($q_{6,38}=8.952$, $p<.01$). There was no difference in the number of misses between the right hand position in condition 3 and the right hand position in condition 1 ($q_{6,38}=1.349$, $p>.05$). The right hand targets in condition 2 were more frequently detected than the right hand targets in condition 1 ($q_{6,38}=7.603$, $p<.01$). Comparing left hand target detection in the three conditions it was found that the extreme left hand targets in condition 1 were less frequently detected than the left hand targets in condition 2 ($q_{6,38}=8.339$, $p<.01$). There was no difference between conditions 2 and 3 in the frequency of detection of left hand targets ($q_{6,38}=1.594$, $p>.05$). There were fewer left hand targets in condition 1 detected than in condition 3 ($q_{6,38}=9.933$, $p<.01$).

The detection of right hand targets in condition 1 was compared with the left hand target detection in condition 2, these occupying the same objective position in the LVF. There was no significant difference between the mean detection rates ($q_{6,38}=2.943$, $p>.05$). A similar comparison was made between right hand target detection in condition 2 and left hand target detection in condition 3. Again there was not a significant difference ($q_{6,38}=3.066$, $p>.05$).

In order to interpret the missed detection data arising from conditions 4, 5 and 6, further Tukey (a) tests were performed on the false alarm data. There was a significant difference between conditions 4 and 6 in the number of false alarms ($q_{6,95}=4.682$, $p<.05$). However there was no difference between conditions 4 and 5 ($q_{6,95}=3.820$, $p>.05$) and 5 and 6 ($q_{6,95}=0.863$, $p>.05$) in false alarm rates. Therefore the number of missed detections in condition 6 may be less than would have been the case had the false alarm rates been equal across conditions.

The number of missed detections in conditions 4, 5 and 6 were analysed by Wilcoxon tests due to the heterogeneity of variance. Comparisons involving condition 6 must be treated with caution. Further caution in the interpretation of these tests is necessary because of the increased probability of type 1 errors. Table 10-5 shows the tests comparing left and right stimulus detection in these conditions. There was a significant difference between the left and right hand target detection. In conditions 4 and 6 the right hand targets were missed less frequently than the left hand targets. In condition 5 the reverse was the case. Table 10-6 presents the results of Wilcoxon tests comparing conditions 4, 5 and 6 in terms of detection of left and right hand targets. Left hand targets in condition 5 were more frequently detected than left hand targets in conditions 4 and 6. There was no difference between conditions 4 and 6 in terms of the detection of left hand targets. In condition 4 right hand targets were more frequently detected than right hand targets in conditions 5 and 6. There was no difference between conditions 5 and 6 in the detection of right hand targets. Figure 10-3 summarises

Table 10-5

Results of the Wilcoxon Tests Comparing Left and Right Missed Targets in Conditions 4, 5, and 6

Condition	T	n
4	4.5	20**
5	24.0	17+
6	26.5	16*

** $p < .01$

+ $p < .025$

* $p < .05$

Table 10-6

Results of the Wilcoxon Tests Comparing the Conditions in Terms of Missed Left and Right Targets

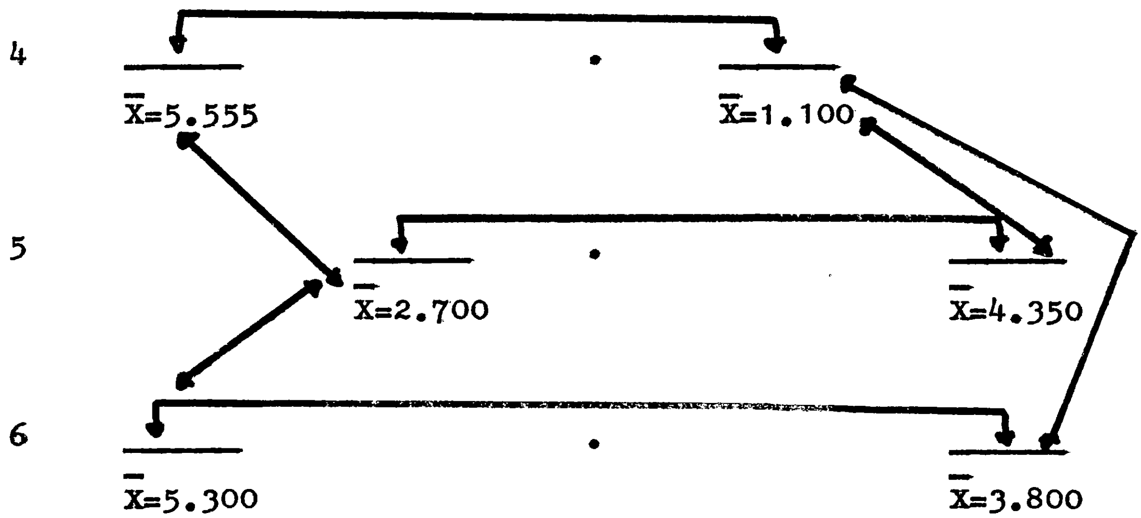
Conditions	T	n
4 (left) vs 5 (left)	12.0	20**
4 (left) vs 6 (left)	49.0	15
5 (left) vs 6 (left)	17.5	18**
4 (right) vs 5 (right)	0.0	19**
4 (right) vs 6 (right)	2.5.	17**
5 (right) vs 6 (right)	39.5	15

Figure 10-3

Illustration of the Results of the Wilcoxon Tests

Comparing the Misses in Conditions 4, 5 and 6

Conditions



______ = stimulus word position

• = fixation point

↔ = significant difference

the results shown in Tables 10-5 and 10-6.

Comparisons between targets presented in different conditions in the same objective visual field positions were made. The results of Wilcoxon tests making comparisons, not already made, are given in Table 10-7. Figure 10-4 summarises this group of comparisons. The extreme left targets in condition 1 were less frequently detected than the left hand targets in condition 5. The left hand targets in condition 3 were less frequently detected than the right hand targets in condition 4. The right hand targets in condition 3 were less frequently detected than the right hand targets in condition 6.

The mean number of missed detections in the "both visual field" conditions (2, 4, 5, and 6) was then compared with the mean number of missed detections in the "single visual field" conditions (1 and 3) by a Wilcoxon test. The mean number of misses in the "both visual field" conditions was 6.9875 and the mean number of misses in the "single visual field" conditions was 9.85. The difference was significant ($T=5.5$, $n=19$. $p<.005$, 1-tailed). Although the difference is large, it must be noted that the inclusion of condition 6 casts some doubt on this finding.

Conditions 2 and 6 were compared in terms of visual field asymmetry. There was no difference between them ($T=60$, $n=17$, $p>.05$).

Table 10-7

Results of Wilcoxon Tests Making Additional Comparisons of Target Detection in Identical Stimulus Positions Across Conditions

Conditions	T	n
1 (left) vs 4 (left)	39.0	18*
1 (left) vs 6 (left)	20.5	18**
1 (right) vs 5 (left)	17.0	18**
2 (left) vs 5 (left)	27.5	15
2 (right) vs 4 (right)	14.0	14
3 (left) vs 4 (right)	4.0	15**
3 (right) vs 5 (right)	36.0	16
3 (right) vs 6 (right)	25.0	16*

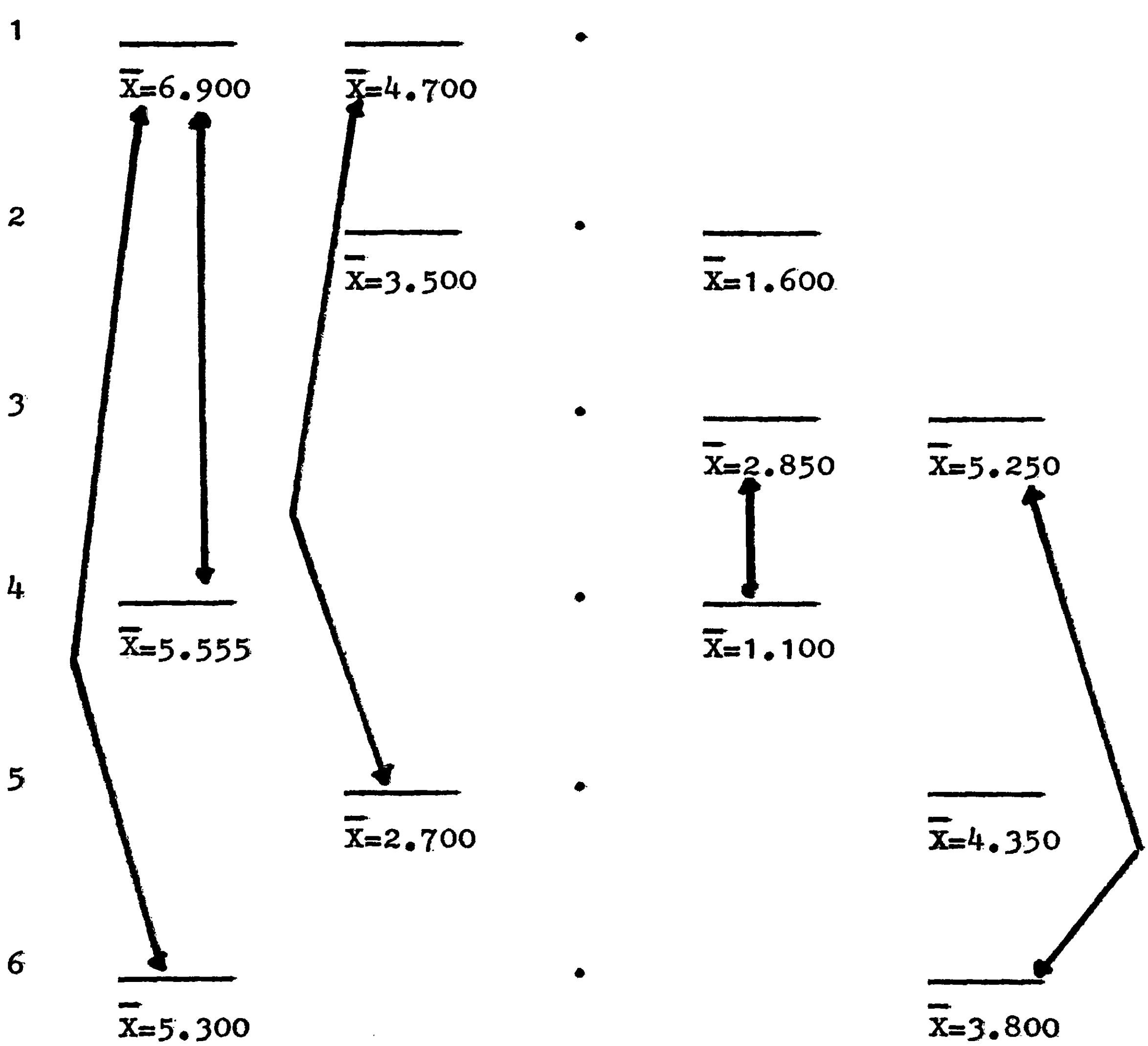
** $p < .01$

* $p < .05$

Figure 10-4

Illustration of the Results of the Wilcoxon Tests
Comparing the Misses in Equivalent Positions in Conditions
1, 2, 3, 4, 5 and 6

Conditions



= stimulus word position

= fixation point

= significant difference

Discussion

There is not a clear gradient in stimulus detection frequency from right to left, as suggested by Kinsbouren's theory. This failure to support Kinsbourne's attentional theory may be due to the central fixation digit in this experiment. As noted previously, the presence of the digit may encourage a post-exposural trace scan (Heron, 1957) from the central digit to the right. If this were the case it would be predicted that the detection accuracy gradient would be from inner right to the outer right and then to the LVF stimuli. Although the results of conditions 2, 3, 4 and 6 support this view, condition 5 does not. In condition 5 the inner left stimuli were more frequently correctly detected than the outer right stimuli. Another hypothetical effect of the central digit is that the requirement to report it may draw the subject's attention to the centre. This may either abolish the attentional bias towards the RVF, or more likely, if Kinsbourne's phenomenon of an attentional shift due to unequal hemispheric activation does occur, require a rapid attentional scan from right to centre. Such a scan may allow only an insufficient read-out of the RVF stimulus information if present. However, as the RVF stimuli are more frequently detected than the LVF target stimuli the latter alternative can not apply. Therefore, either the digit abolishes Kinsbourne's phenomenon, or Kinsbourne's phenomenon was an artifact due to the fact that he did not control his subjects' fixation, or it has not been clearly demonstrated in this experiment due to the acuity differences between the inner and outer visual fields.

Stimuli presented in the outer left and right visual fields were less frequently detected than those presented in the inner left and right visual fields. It is likely that this was due to the fall off in visual acuity towards the periphery. This can not be a complete explanation as stimuli in the same visual field positions were not detected with equal frequency in all conditions.

An interesting pattern of stimulus detection emerges. It may be noted that, although all the differences in terms of mean detections missed are not significant, the detection of a stimulus in a specific visual field position is more frequent the further away the second stimulus. This is modified by an additional effect. If one stimulus falls in the LVF and the other in the RVF, stimulus detection is more frequent than in conditions 1 and 3, where both stimuli fall in the same visual field. There are several explanations which may be advanced to explain this.

1) If the subject directs his attention to one visual field he is more likely to detect a stimulus in a "both visual field" condition than in a "single visual field" condition.

2) There may be a lateral masking mechanism such that in conditions 1 and 3 the two words mask, or interfere with each other. There does not appear, however, to be any significant masking or interference between the digit and

inner words.

3) The material presented in conditions 1 and 3 is received by a single hemisphere, whereas in conditions 2, 4, 5 and 6 it is shared between the hemispheres. Unless a sequential scan of the information is necessary, there would be an advantage in this task of a parallel analysis of the stimuli. This may not be possible within a single hemisphere. This last explanation of the three appears to be the most likely.

If one considers that Kinsbourne's theory can not completely account for the data, it may nevertheless account for the gross visual field asymmetry. The left hemisphere, coding the information verbally, may be more active than the right hemisphere. Therefore attention would be directed towards the RVF. The outer visual field stimuli may have been more peripheral than the extent of the attentional bias produced by the task.

Alternatively, a direct access model may explain the data. In this case a wide variety of alternative mechanisms may be postulated and it is not possible to distinguish between them. Although the stimuli were 3-letter words and therefore verbal stimuli, they may have been visually codable as they were highly frequent in the English language. The left hemisphere would then have access to a verbal coding and probably a visual coding. The right hemisphere, similarly, would be likely to have access to a visual coding of the words and as they occur frequently in the language it is probable that the right hemisphere would be capable of coding the stimuli in a verbal form also. As detection of targets received in the left hemisphere was superior to the detection of those received in the right hemisphere, there are two interpretations of the data within this model, discussed in the previous chapters. Either the material was processed in the hemisphere receiving the information, in which case the right hemisphere was less accurate, or all processing beyond simple registration was performed in the left hemisphere. If this was the case then the transfer of information from the right to the left hemisphere led to the visual field asymmetry.

It appears that a direct access model may be the most appropriate explanation of the data. However one can not rule out the possibility that there is an attentional bias towards the RVF due to the higher level of activity in the left hemisphere. There are several reasons why an attentional bias may not have been observed to lead to a gradient of detection from the extreme RVF through to the extreme LVF. It has been suggested that there may be an influence of the fixation digit in drawing subjects' attention towards the centre of the visual field. There may not have been a strong RVF bias in this experiment as both hemispheres may have been actively involved in the processing and therefore attention may have been directed to a point in the RVF nearer the fixation point. Lastly, there was a large acuity gradient across the visual field which made the data rather difficult to interpret. Experiment nine was designed to overcome this problem, by using single letter stimuli, which would therefore not extend as far into the periphery as did the stimuli in this last experiment.

Chapter Eleven

Experiment Nine

Experiment Nine

Introduction

This experiment is a modification of experiment eight. In this study the target stimuli were single letters. This reduced the visual angle subtended by the extreme left and right visual field stimuli in order to reduce the effect of poor visual acuity on the detection of these stimuli. As it was suggested in experiment eight that a gradient of attention, if present, may not have extended to the extreme RVF, the reduction of the extent of the visual field would limit the application of this argument in the following experiment. The conditions under which the stimuli were presented were the same as those used in experiment eight.

As the stimuli were single letter targets it is probable that the most efficient form of coding would be visual. If the coding is visual and the right hemisphere is specialised for visual processing one may predict two general outcomes of the following experiment based on either a direct access model or Kinsbourne's model. The former model would predict that there will be a L VF advantage due either to the superiority of the right hemisphere's processing of the information or to its exclusive processing of the information. Kinsbourne's model predicts a gradient of detection running from the extreme LVF through fixation to the extreme RVF as the right hemisphere will be more active than the left.

Method

Apparatus and Stimulus Design

Stimulus cards were presented in a Cambridge Two-field tachistoscope at an exposure duration of 20 msecs. Stimuli were single letters of the alphabet. The conditions were as in experiment eight. Figure 11-1 illustrates the six conditions in which the letter stimuli were presented and the visual angles subtended by them.

The 240 stimulus cards were divided into 4 blocks of 60. For each block a letter was choeen as the target. The four targets, randomly selected from the symmetrical letters of the alphabet were T, U, W and A. A single target letter appeared on 50% of the stimulus cards. Targets were equally distributed between the left and right stimulus positions and conditions (that is, 10 targets per position per condition). The non-target letters were the remaining letters of the alphabet and each occurred approximately as frequently as the others. Their selection for each stimulus card was randomised with the constraint that a letter did not occur twice on a card. Letters were typed in black capitals. A digit between 2 and 9 was randomly selected and typed in black at the centrla fixation point on each card.

Subjects

18 undergraduates of the University of Keele (8 males) volunteered to be subjects for the experiment. Their age range was from 18 to 28 years with a mean of 19.83 years.

Figure 11-1

Illustration of the Conditions in which the Letter Stimuli were Presented

Condition									
1	x	1.8^{o}	x	1.8^{o}	•				
2			x	1.8^{o}	•	1.8^{o}	x		
3					•	1.8^{o}	x	1.8^{o}	x
4	x		3.6^{o}		•		3.6^{o}		x
5			x	1.8^{o}	•		3.6^{o}		x
6	x		3.6^{o}		•		3.6^{o}		x

x = stimulus position

• = fixation point

All subjects gave 7 or more right handed responses on Annett's (1970) Handedness Questionnaire. One subject had a left handed sibling and two subjects had fathers showing mixed handedness. All subjects had normal, or corrected to normal vision.

Procedure

The subject was instructed to fixate the centre of the black outline square in the centre of the pre-exposure field, which was white. The subject was given the instruction "ready" by the experimenter and when he was confident of his fixation he pressed the automatic exposure button. The hand used to press this button was alternated for blocks of trials. Immediately after the stimulus exposure the subject verbally reported the central digit, which had been framed by the central square of the pre-exposure field. He then said "no" if he believed that there had been no target letter present. If the subject thought that there had been a target letter present he said "yes".

Six stimulus cards (one from each condition) from the first block of trials were randomly selected and presented to the subject as practice trials. These cards were then placed at random in the block of experimental trials. Before each block of trials was presented, care was taken to ensure that the subject knew which letter was the target. There was a 3 minute pause between blocks. Trials were presented at the rate of approximately six per minute. If the subject failed to report the central digit correctly on any trial, that particular stimulus card was randomly inserted at a later point in the block. This occurred very infrequently (no more than once per block). The order of block presentation was randomised for each subject. Stimulus cards within a block were shuffled for each subject. Scoring was performed outside the subject's field of vision. After the experiment the subjects were asked to complete the handedness questionnaire.

Results

The analysis was performed in the same manner as that of experiment eight. The number of errors was scored in terms of false alarms and missed detections. The mean number of false alarms in each condition (Table 11-1) was found to be equal (see Table 11-2 for the summary table of the analysis of variance).

The number of missed detections (Table 11-3) was then submitted to a 3-way analysis of variance (Table 11-4). There was a significant effect of relative stimulus position ($F=15.996$, df 1,17, $p<.01$). Left hand targets were more frequently detected than right hand targets. There was also a significant effect of condition ($F=9.491$, df 5,85, $p<.01$). This was investigated with a series of Tukey (a) tests. There were more missed detections in condition 1 than in conditions 2 ($q_{6,85}=6.780$, $p<.01$) and 4 ($q_{6,85}=5.384$, $p<.01$). That is, "both visual field" conditions 2 and 4 led to higher detection rates than "within visual field" conditions 1 and 3. There were more

Table 11-1

Mean Number of False Alarms in Conditions 1, 2, 3, 4, 5 and 6

Condition	$\bar{X}$	s.d.
1	3.000	2.169
2	1.889	1.278
3	2.278	1.994
4	2.944	2.461
5	2.667	1.879
6	3.333	2.223

Table 11-2

Summary of the Analysis of Variance on the False Alarms

Source	SS	df	MS	F
Between subjects	237.29	17	13.96	
Within subjects	210.00	90	2.33	
Conditions	24.96	5	4.99	2.294
Residual	185.04	85	2.18	
Total	447.29	107	4.18	

Table 11-3

Mean Number of Misses in Conditions 1, 2, 3, 4, 5 and 6

Condition	Left targets		Right targets	
	$\bar{X}$	s.d.	$\bar{X}$	s.d.
1	3.833	2.618	4.667	2.679
2	2.000	2.787	2.722	2.421
3	2.778	2.211	5.111	2.398
4	3.056	2.689	1.833	2.256
5	1.500	2.307	5.556	2.854
6	2.889	2.928	5.556	2.255

Table 11-4

Summary of the Analysis of Variance on the Misses

Source	SS	df	MS	F
Subjects	599.04	17	35.24	
A (position)	132.23	1	132.23	15.996**
A x subjects	140.52	17	8.27	
B (condition)	132.59	5	26.52	9.491**
B x subjects	237.49	85	2.79	
AB	153.19	5	30.64	7.557**
AB x subjects	344.56	85	4.05	
Total	1739.63	215	20.47	

** $p < .01$

missed detections in condition 5 ($q_{6,85}=4.188$, $p<.05$) and condition 6 ($q_{6,85}=6.681$, $p<.01$) than in condition 2. There were more missed detections in condition 6 than in condition 4 ($q_{6,85}=6.381$, $p<.01$).

There was a significant interaction between position and condition ($F=7.557$, df 5,85, $p<.01$). This was examined with a series of Tukey (a) tests. The results are summarised in Figure 11-2. Considering the positions to the outer left, outer right and inner right, there was no difference in target detection between conditions. In the inner left position there were significant differences between conditions. Targets presented in the inner left in condition 1 were more frequently missed than targets in the inner left in conditions 2 ($q_{12,85}=5.619$, $p<.01$) and 5 ($q_{12,85}=6.673$, $p<.01$). There were differences in detection of left and right targets in conditions 3 ($q_{12,85}=4.917$, $p<.05$), 5 ($q_{12,85}=8.546$, $p<.01$) and 6 ($q_{12,85}=5.619$, $p<.01$), that is, in the conditions where an extreme right stimulus was involved.

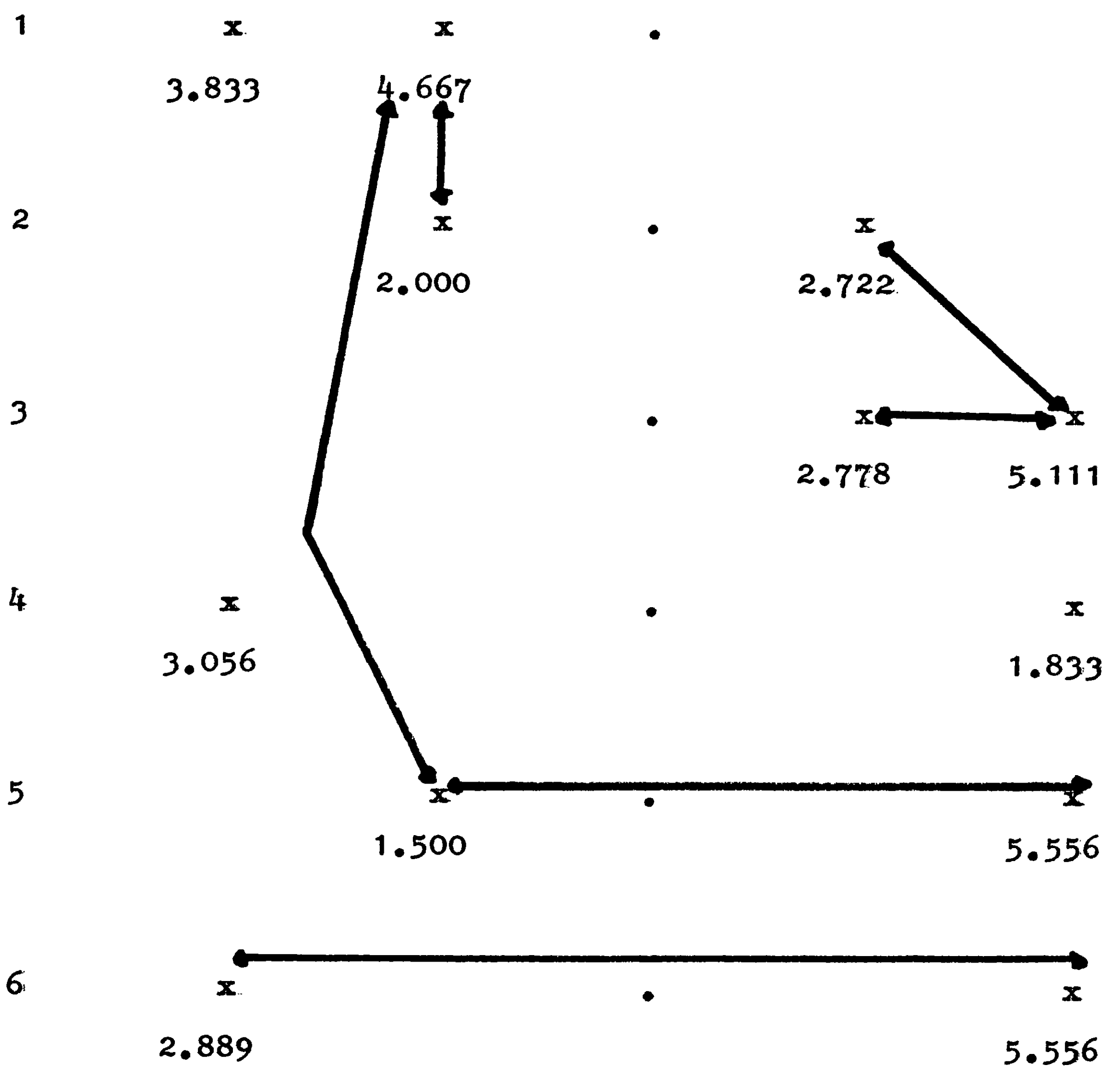
Comparing right hand targets, detection between conditions 1, 2 and 3 showed only one significant difference. There were more right hand target detections in condition 2 than in condition 3 ($q_{12,85}=5.034$, $p<.05$). There was no difference between conditions 1, 2 and 3 in left hand target detections.

A Wilcoxon test showed that subjects were more likely to miss targets in the "within visual field" conditions (1 and 3) than in the "between visual field" conditions (2, 4, 5 and 6). The mean number of misses in the "within

Figure 11-2

Illustration of the Significant Differences Observed

Condition



x = stimulus position

• = fixation point

= significant difference

visual field" conditions was 8.194. The mean number of misses in the between visual field conditions was 6.278 ($T=2$, $n=18$, $p<.01$).

Discussion

Subjects detected a higher proportion of the targets presented in the LVF than those presented in the RVF. Extreme RVF target detection was very poor, relative to the extreme LVF detection. This finding is not easily interpreted by a scanning theory as such a theory would predict, as discussed in chapter ten, that a scan would be most likely to commence from the central digit and travel towards the right prior to scnnning the LVF. There is no evidence that the scan commenced in the extreme LVF and travelled through fixation into the RVF. The LVF targets were not all correctly detected and yet the central digit had to be correctly reported in order for a particular trial to be included in the analysis. Therefore the most likely explanation of the LVF superiority appears to be that the task was performed primarily in the visual mode and that the right hemisphere is specialised for visual processing of the type involved in this experiment.

In this experiment, as in experiment eight, there was no clear gradient across the visual field in terms of target detections. Such a gradient, in this case from the extreme LVF to the extreme RVF, would provide strong support for Kinsbourne's theory. There is, however, no evidence of an attentional bias in favour of the LVF.

Although LVF target detection was superior to RVF target detection, the LVF target detection was not markedly superior to inner RVF target detection. There was also the incidence in condition 1 of the inner LVF targets being detected less frequently than those in the same position in conditions 2 and 5. If there was an attentional bias towards the LVF then one would expect that the inner LVF targets in condition 1 would be more frequently detected than was the case.

It therefore appears that a direct access interpretation of the data may be more appropriate. However, there are other factors, such as visual acuity, which are likely to have been involved. For example, the inner RVF targets in condition 4 were more frequently detected than the outer LVF targets.

As in experiment eight, there were more missed targets in the "within visual field" conditions than in the "between visual field" conditions. It is unlikely that a lateral masking phenomenon could account for this finding as the stimuli were single letters in this experiment and the central digit was the same size as the letters. If masking did occur one would expect that the digit would have been masked by the inner stimulus in the right and left visual fields. There was no evidence of this. Therefore the most parsimonious explanation appears to be that material divided between the two hemispheres is processed more rapidly than material presented to a single hemisphere. If the material is processed rapidly, then one would anticipate that there would be less information decay and that target stimuli would be more likely to be accurately identified.

Therefore in summary of the findings of this experiment, it appears that a direct access interpretation fits the data more satisfactorily than the other theories. As material presented to both hemispheres is more accurately processed than material presented to a single hemisphere it appears that both hemispheres are capable of processing the stimuli. The right hemisphere however, performs the processing more accurately. The major difficulty with the interpretation of this experiment, however, is that the visual field asymmetry is primarily due to the poor detection in the outer RVF position. Therefore experiment ten was designed to investigate this problem.

Chapter Twelve

Experiment Ten

Experiment Ten

Introduction

It was argued in the previous chapter that when subjects had to search for a single letter target they coded the information visually. It was suggested that the LVF superiority in target detection was due to the right hemisphere's superiority in visual analysis. In experiment nine a visual coding of the target letters would have been more appropriate than a verbal coding of the letters as it is probable that a visual analysis of the information on the stimulus cards could occur more rapidly than a verbal analysis (Posner, 1969; Posner et al, 1969). The following experiment was designed with the aim of encouraging subjects to make both a verbal and a visual encoding of the target stimuli and to search the stimulus card in a corresponding verbal or visual mode. The task was basically the same as that in experiment nine. In this experiment there were two types of target search. Subjects were either asked to search for a specific visual form of the letter "A" or they were asked to search for the letter "A" irrespective of its visual form. In the former condition the target was specifically either an upper case "A" or a lower case "a". In the latter condition the target could be an "A" or an "a". Thus the latter condition involved a nominal search. When subjects were performing in this latter condition they would have to code the information verbally as the sound "A" or retain the two visual forms. The former coding would be the most economical. When subjects were searching for the specific visual form a simple verbal code of the letter would be inadequate as it would not specify the visual form. Subjects could code the information verbally as "capital A" and "small a" as it was suggested that they had done in experiment three. However, as subjects appeared to code the information visually in experiment nine it is more probable that in this experimental paradigm they would code the information in the more economical visual mode in this condition.

If subjects make a visual search in this experiment there should be a LVF superiority in target detection. If they make a verbal search there should be a RVF superiority in target detection. In this experiment it was anticipated that the visual field asymmetry should be dependent on the condition. This experiment allows for the testing of Kinsbourne's theory in the same manner as experiments eight and nine. If Kinsbourne is correct there should be a gradient across the visual field, the visual field contralateral to the more active hemisphere showing the higher rate of target detection. In the previous two experiments, however, there was no evidence of an attentional gradient. The direct access theory has appeared to be the most appropriate explanation of the observed asymmetries. Therefore, if this theory is again the most appropriate, there should be a LVF superiority in target detection in the visual condition and a RVF superiority in the verbal condition. This experiment will also provide a further test of whether both hemispheres are involved in the information processing and have the possibility of load-sharing.

One difficulty with experiment nine was that there was very poor detection in the extreme RVF despite the fact that the visual angle subtended by the most extreme stimuli was not very great. This experiment will show whether this effect is replicable and also whether it is dependent upon the mode of processing. It may be the case that the extreme RVF detection is very poor when the subject is processing the stimuli visually and that there is a correspondingly poor detection from the extreme LVF under conditions of verbal processing.

Method

Apparatus and Stimulus Design

A Cambridge Two-field tachistoscope was used to present the stimuli at an exposure of 30 msecs. The exposure was greater than that used in experiment nine because the lower case stimuli used in this experiment were smaller than the upper case stimuli and pilot trials suggested that a longer exposure was necessary. Four sets of stimulus cards were prepared. In the visual condition there was a set of cards in which the target letter was "A" and a set in which the target letter was "a". In the verbal condition there were two parallel sets of cards "Aa"$_1$ and "Aa"$_2$. In this condition half of the targets were the lower case "a" and half of the targets were upper case "A". Each subject received each set of stimulus cards once. Within each set of cards there were four conditions. These were conditions 1, 2, 3 and 6 of experiments eight and nine. In condition 1 the two stimuli fell in the LVF. In condition 3 the two stimuli fell in the RVF. In conditions 2 and 6 (condition 4 in this experiment) a stimulus appeared in each visual field. In condition 2 the stimuli occupied the inner visual field positions, whereas in condition 4 the stimuli occupied the outer visual field positions. Within each condition, within a set, there were 16 stimulus cards prepared. In 8 of these cards there was a target present and in the other 8 there was no target. Targets were presented with equal frequency in the left and right positions. In the target sets having both "A" and "a" as targets, each form of the letter occurred with equal frequency in the left and right positions in each condition.

There were 256 experimental trials in all. Upper and lower case letters were used for the non-targets. All letters of the alphabet were used as non-targets with approximately equal frequency.

Each card was typed in black. A digit between 2 and 9 was randomly selected and typed at the fixation point on each card. Stimulus letters were typed in the same positions and subtended the same visual angles as those used in experiment nine.

Subjects

The 16 (9 male) subjects in this experiment were all volunteers. They were undergraduates of the University of Keele. Their ages ranged from 18 to 24 years with a mean of 20.4 years. Each subject scored 8 or more right handed responses on Annett's Handedness Questionnaire (Annett, 1970). None knew of any familial left handedness. All subjects had normal, or corrected to normal, vision.

Procedure

Set order was counterbalanced across subjects. Before each set of trials, subjects were given four practice trials, one per condition. The practice trial cards were selected at random within the constraint that a target should occur on two of the four trials. In the "Aa"$_1$ and "Aa"$_2$ sets (that is, the "verbal" sets) each target appeared once in the practice trial sequence. The practice cards were then shuffled into the pack of experimental cards of that set. The experimental procedure was identical to that of experiment nine. Subjects were required to report the central digit immediately after the stimulus exposure and then respond "yes" or "no" according to whether they thought that they had seen a target letter.

Results

Table 12-1 shows the means and standard deviations of the false alarm rates. Although the variances were not

Table 12-1

Means and Standard Deviations of the False Alarm Rates

Condition		Target			
		A	a	Aa_1	Aa_2
1	$\bar{X}$	0.3125	1.875	1.1875	1.7500
	s.d.	0.7041	1.5864	1.6820	1.7321
2	$\bar{X}$	0.4375	1.5625	1.5625	1.4375
	s.d.	1.0935	1.4127	1.1529	1.8963
3	$\bar{X}$	1.000	1.1250	1.0625	2.1875
	s.d.	0.9661	0.9574	1.3401	1.5152
4	$\bar{X}$	0.5000	2.6875	1.8750	1.5625
	s.d.	0.7303	1.7017	1.9279	1.0935

homogeneous (F_{max}=7.497, df 16,15, $p<.05$) an analysis of variance (Table 12-2) was performed on the entire set of false alarm data as an increased probability of significant F ratios was not a disadvantage in this case. The particular target for which the subject searched was found to influence the false alarm rate (F=8.590, df 3,45, $p<.01$). This was investigated using Tukey (a) tests. There were more false alarms when subjects were searching for "a" than for "A" ($q_{4,45}$=6.400, $p<.01$). There were more false alarms when they were searching for "Aa"$_1$ ($q_{4,45}$=4.400, $p<.05$) and "Aa"$_2$ ($q_{4,45}$=6.000, $p<.01$) than for "A". Searching for "Aa"$_1$, "Aa"$_2$ and "a" produced equal false alarm rates.

Although there was no overall difference between conditions 1, 2, 3 and 4 in terms of false alarms (F=2.360, df 3,45, $p>.05$) there was an interaction between condition and target (F=3.060, df 9,45, $p<.01$). This was elucidated by a series of Tukey (a) tests. When "A", "Aa"$_1$ and "Aa"$_2$ were the targets there was no difference between conditions. When "a" was the target, condition 4 produced significantly more false alarms than condition 3 ($q_{16,135}$=5.959, $p<.01$).

The difference in false alarm rates between targets "A" and "a" and "Aa"$_1$ and "Aa"$_2$ was largely due to conditions 1 and 4. In condition 1 there were fewer false alarms to "A" than to "a" ($q_{16,135}$=8.343, $p<.01$) and "Aa"$_1$ ($q_{16,135}$=5.244, $p<.05$).

As a consequence of the false alarm data, separate analyses of the missed detections were performed in each

Table 12-2

Summary of the Analysis of Variance on False Alarms

Source	SS	df	MS	F
Subjects	168.61	15	11.24	
A (condition)	6.67	3	2.22	2.36
A x subjects	42.20	45	0.94	
B (target)	62,89	3	20.96	8.59**
B x subjects	109.98	45	2.44	
AB	30.30	9	3.37	3.06**
AB x subjects	147.83	135	1.10	
Total	568.48	255	2.22	

** $P < .01$

target set. Table 12-3 shows the means and standard deviations of the missed detections. As the variances in the target "A" set were not homogeneous (F_{max}=8.098, df 8, 15, $p<.05$) an analysis of variance was not performed on the data as an increased probability of significant F ratios was regarded as undesirable. Table 12-4 summarises the Wilcoxon tests performed and Figure 12-1 summarises the interaction between condition and position. There were more misses in conditions 1 and 3 than in conditions 2 and 4. There was not a linear gradient in detection scores as the stimuli were moved across the visual field. Detection was particularly poor in the extreme right position in condition 1.

Table 12-5 is the summary table of the analysis of variance on the set of trials in which "a" was the target. There was a significant difference between conditions in terms of missed targets (F=7.741, df 3,45, $p<.01$). This was investigated with a series of Tukey (a) tests. There were more misses in conditions 1 ($q_{4,45}$=6.115, $p<.01$), 3 ($q_{4,45}$=4.417, $p<.05$) and 4 ($q_{4,45}$=5.606, $p<.01$) than in condition 2. Figure 12-2 summarises the results of target set "a" detection.

Table 12-6 is the summary table of the analysis of variance on misses when the target set was "Aa"$_1$. There were more misses when the targets were located in the right positions than when they were located in the left positions (F=7.580, df 1,15, $p<.05$). There was a significant difference between conditions (F=4.535, df 3,45, $p<.01$). This was examined by Tukey (a) tests. There were more

Table 12-3

Means and Standard Deviations of the Missed Targets

Condition			Target			
			A	a	Aa_1	Aa_2
1	Left	$\bar{X}$	0.188	1.875	1.063	1.063
		s.d.	0.544	0.957	1.124	0.929
	Right	$\bar{X}$	2.313	1.938	1.750	1.563
		s.d.	1.401	1.289	1.390	1.315
2	Left	$\bar{X}$	0.500	0.625	0.438	0.500
		s.d.	1.095	0.957	0.629	0.894
	Right	$\bar{X}$	0.563	0.938	0.688	0.813
		s.d.	1.263	1.289	1.015	1.109
3	Left	$\bar{X}$	1.438	1.313	1.000	1.250
		s.d.	1.548	1.493	1.317	1.291
	Right	$\bar{X}$	1.063	1.875	1.438	1.125
		s.d.	1.289	1.628	1.153	1.204
4	Left	$\bar{X}$	0.438	1.750	0.750	1.375
		s.d.	0.892	1.000	0.775	1.148
	Right	$\bar{X}$	0.938	1.875	1.125	1.063
		s.d.	1.482	1.500	1.025	1.063

Table 12-4

Results of the Wilcoxon Tests Performed on Target Set "A" Data

Comparing Conditions

Conditions	T	n
Cond. 1 vs Cond. 2	10.5	13+
Cond. 1 vs Cond. 3	43.5	13
Cond. 1 vs Cond. 4	16.0	14+
Cond. 2 vs Cond. 3	11.0	13+
Cond. 2 vs Cond. 4	15.5	9
Cond. 3 vs Cond. 4	14.5	14

Comparing Left and Right Positions

Conditions		T	n
1	Left vs Right	0.0	13**
2	Left vs Right	9.5	6
3	Left vs Right	43.0	14
4	Left vs Right	7.5	7

+ $p < .025$ (2-tailed)

** $p < .01$ (2-tailed)

Table 12-4 continued

Comparing Identical Visual Field Positions

Conditions	T	n
Cond. 1 (left) vs Cond. 4 (left)	0.0	2
Cond. 1 (right) vs Cond. 2 (left)	0.0	13**
Cond. 2 (right) vs Cond. 3 (left)	8.0	9
Cond. 3 (right) vs Cond. 4 (right)	16.5	8

Comparing Detection as the Targets Move Across the Visual Field

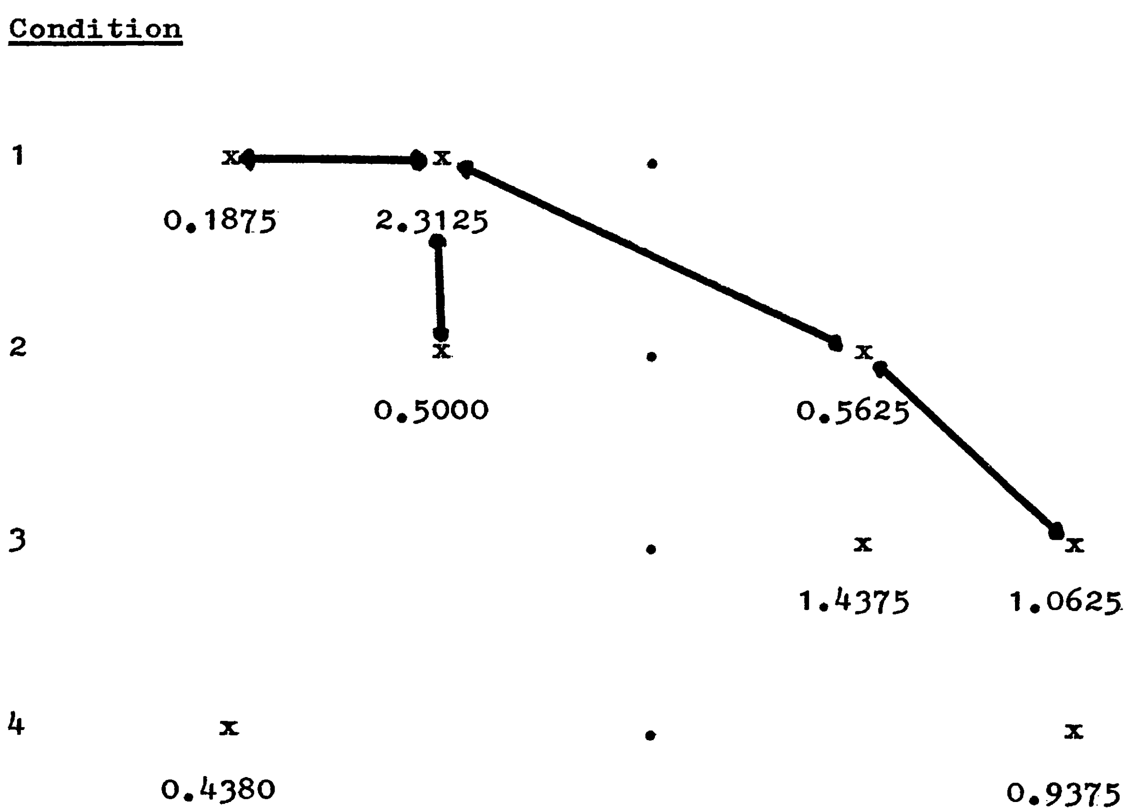
Conditions	T	n
Cond. 1 (left) vs Cond. 2 (left)	4.0	5
Cond. 2 (left) vs Cond. 3 (left)	9.0	10
Cond. 1 (right) vs Cond. 2 (right)	11.0	14**
Cond. 2 (right) vs Cond. 3 (right)	4.0	8*

* $<p$ .05

** $p<.01$

Figure 12-1

Illustration of the Significant Differences Observed in the Analysis of Target Set "A" Misses



x = stimulus position

• = fixation point

= significant difference

Table 12-5

Summary of the Analysis of Variance on the Misses in Target Set "a"

Source	SS	df	MS	F
Subjects	91.555	15	6.104	
A (position)	2.258	1	2.258	1.514
A x subjects	22.367	15	1.491	
B (condition)	25.149	3	8.383	7.741**
B x subjects	48.727	45	1.083	
AB	1.211	3	0.404	0.496
AB x subjects	36.664	45	0.815	
Total	227.931	127	1.795	

** $p < .01$

Figure 12-2

Illustration of the Significant Differences Observed in the Analysis of Target Set "a" Misses

Condition					
1	x 1.8750	x 1.9375	•		
2		x 0.6250	•	x 0.9375	
3			•	x 1.3125	x 1.8750
4	x 1.7500		•		x 1.8750

x = stimulus position

• = fixation point

⟵⟶ = significant difference

Table 12-6

Summary of the Analysis of Variance on the Misses in Target Set "Aa"[1]

Source	SS	df	MS	F
Subjects	42.125	15	3.075	
A (position)	6.125	1	6.125	7.580*
A x subjects	12.125	15	0.808	
B (condition)	12.938	3	4.313	4.535**
B x subjects	42.813	45	0.951	
AB	0.813	3	0.271	0.313
AB x subjects	38.938	45	0.865	
Total	159.877	127	1.259	

* $p < .05$

** $p < .01$

misses in conditions 1 ($q_{4,45}=4.894$, $p<.01$) and 3 ($q_{4,45}=3.807$, $p<.05$) than in condition 2. Figure 12-3 summarises the data.

Table 12-7 is the summary table of the analysis of variance on the misses when the target set was "Aa"$_2$. There was, unlike in set "Aa"$_1$, no difference in the detection of left and right targets ($F=0.281$, df 1,15, $p>.05$). However there was a significant difference between conditions ($F=3.028$, df 3,45, $p<.05$). Tukey (a) tests showed that there were more misses in condition 1 than in condition 2 ($q_{4,45}=3.852$, $p<.05$). Figure 12-4 summarises the data.

Discussion

When searching a stimulus card some visual analysis must precede a verbal analysis. In order to identify a target letter when searching in the "A" and "a" conditions a subject need only code the information visually and make a visual analysis of the stimulus information when it is presented. A verbal analysis of the material would not, as discussed previously, be adequate as the target is a specific visual form of the letter. When subjects were searching for target letters in the "Aa"$_1$ and "Aa"$_2$ conditions a preliminary visual analysis would have occurred, followed it was suggested by a verbal analysis of the stimulus information. Hence the visual analysis in this instance would not necessarily need to be as detailed as that in the former conditions. In this case a

Figure 12-3

Illustration of the Significant Differences Observed in the Analysis of Target Set "Aa"$_1$ Misses

Condition					
1	x 1.0625	x 1.7500	•		
2		x 0.4375	•	x 0.6875	
3			•	x 1.000	x 1.4375
4	x 0.7500		•		x 1.1250

x = stimulus position

• = fixation point

⟷ = significant difference

Table 12-7

Summary of the Analysis of Variance on the Misses to Target Set "Aa_2"

Source	SS	df	MS	F
Subjects	55.625	15	3.708	
A (position)	0.281	1	0.281	0.184
A x subjects	22.969	15	1.531	
B (condition)	8.438	3	2.813	3.028*
B x subjects	41.813	45	0.929	
AB	3.406	3	1.135	1.579
AB x subjects	32.344	45	0.719	
Total	164.876	127	1.298	

* $p < .05$

Figure 12-4

Illustration of the Significant Differences Observed in the Analysis of Target Set "Aa"$_2$ Misses

Condition					
1	x 1.0625	x 1.5625	•		
2		x 0.500	•	x 0.8125	
3			•	x 1.2500	x 1.1250
4	x 1.3750		•		x 1.0625

x = stimulus position

• = fixation point

$\longleftrightarrow$ = significant difference verbal analysis would be adequate to detect the target letters. These arguments, of course, only apply if the subjects adopt the optimum strategies.

Under these task conditions the two hemispheres may operate in several different ways. When an accurate and detailed visual analysis is required in the "A" and "a" conditions it may be the case that only the right hemisphere is involved in the processing. However in the light of the previous experiments this seems unlikely. Earlier experiments have shown that there is some redundancy in the system. If the two hemispheres are involved in the visual processing one would anticipate that between hemisphere presentations of stimuli would result in more frequent target detections than within hemisphere presentations of stimuli. When the information is divided between the hemispheres each hemisphere may be able to contribute towards the processing. When "A" was the target there were more target detections in the between hemisphere conditions (2 and 4) than in the within hemisphere conditions (1 and 3). However in the condition where "a" was the target stimulus there were more target detections in the between hemisphere condition 2 than in the within hemisphere conditions 1 and 3 and the between hemisphere condition 4. As conditions 1, 3 and 4 all contained more extreme stimuli than condition 2, the lower visual acuity in the outer retinae may account for the fewer target detections of the small target stimuli in these conditions. This suggestion is supported by the finding that target detection was poorer for the lower case "a". However, an inspection of the data shows that this can not be the entire cause as although lack of visual acuity may account for poor detection in the right and left extreme positions in all conditions, thus decreasing detection in condition 4 relative to condition 2, there were fewer stimuli detected in the inner positions in conditions 1 and 3 than in condition 2. Therefore it appears that some of condition 2's superiority is due to the between hemisphere presentation in this condition. There should be similarly superior detection in condition 4 were it not for the poorer acuity in the outer positions.

The above findings suggest strongly that both hemispheres are capable of processing the stimulus material in the visual condition. It may be the case that the left hemisphere analyses the stimuli in a purely visual mode or combines the use of visual and verbal processing. In either case it would be less efficient than the right hemisphere, if the assumptions regarding the mode of processing of these stimuli are correct. Considering the condition in which the subjects were searching for the "A" targets, it was found that in conditions 2 and 4 where there was a stimulus in each visual field, there was no difference between the visual fields in target detection. In condition 1 the detection of targets in the right position (inner LVF) was extremely poor compared with target detection in other positions in the other three conditions. This left to right gradient supports the view that the processing was visual and that Kinsbourne's theory may explain the data. It is not easily explained by the direct access theory. However this left to right gradient is not observable in the other conditions 2, 3 and 4. When subjects searched for the target "a" there was similarly no difference between the left and right visual fields. There was also no left to right gradient in detection accuracy. Therefore it appears to be the case that both hemispheres were involved in the processing of the stimulus material. This processing may have been either verbal or visual, although visual processing would have been more appropriate and there is a slight suggestion of an attentional bias towards the LVF.

When subjects were required to detect the letter "A" irrespective of its visual form, that is, in conditions $"Aa"_1$ and $"Aa"_2$ it was suggested that the verbal mode may be the dominant processing mode. In this instance it may be the case that the left hemisphere performed the initial visual processing of the stimuli and the final verbal processing. The right hemisphere may be inactive. Again, in the light of earlier evidence this is unlikely. In these conditions there is less evidence to support the load-sharing view of hemispheric functioning. In the $"Aa"_1$ condition there were more target detections in condition 2 than in conditions 1 and 3. In the $"Aa"_2$ condition there were more targets detected in condition 2 than in condition 1. Therefore, although the data do not provide strong support for the proposition that between hemisphere presentation of stimuli leads to more accurate processing than within hemisphere presentation, the data taken together do lead to this, rather than an alternative conclusion.

When subjects were searching for targets in the "Aa"$_1$ and "Aa"$_2$ conditions, there should, if all the assumptions are correct, be a RVF superiority in target detection. There was no evidence of such a superiority. On examining the data in the "Aa"$_1$ condition it may be seen that there was, in fact, superior detection of the left-hand targets in all conditions. This was not the case in the "Aa"$_2$ condition. As conditions "Aa"$_1$ and "Aa"$_2$ were designed to provide a within experiment replication of the data, being parallel sets of stimulus cards, it is not clear as to why they differ in this respect. Presentation orders were counterbalanced across the subject group. The lack of replication may be due to the different trial orders affecting subjects differently. A larger group of subjects would eliminate this problem if it occurred. However, it must be noted that a group of 16 subjects has usually been considered a respectable sample. This lack of replication within an experiment illustrates very clearly the effect that obscure procedural factors may have on the data. It is not surprising that the findings of separate experiments differ. This would be particularly the case when they were performed in different laboratories by different researchers.

The data collected in the "Aa"$_1$ condition but not in the "Aa"$_2$ condition indicate that Kinsbourne's theory may apply in this study. When a stimulus card was presented the stimulus on the left was analysed more accurately and a target, if present, was more likely to be detected if it was in the left-hand position. This is in fact the reverse of the asymmetry predicted. It is unlikely that this left-hand superiority was due to scanning because, as has been argued previously, the central digit would be more likely to lead to a scan from the centre towards the right rather than a left to right scan. It may therefore be suggested that the right hemisphere was more active in this task than the left hemisphere.

Taking the above findings together, it may be suggested that both hemispheres are actively involved in the processing of the stimuli irrespective of the condition. In conditions "A", "a" and "Aa"$_2$ neither hemisphere appears to have been more active than the other. Attention was symmetrical about the fixation point and detection was equally accurate in both visual fields. In the "Aa"$_1$ condition however, the evidence suggests that the right hemisphere was more active than the left hemisphere. It was suggested that this resulted in the subjects' attention being biassed towards the left and target detection being superior for the left-hand targets. This finding is not readily explained by the direct access theory.

It is not clear whether the right hemisphere processed information in an exclusively visual mode and the left hemisphere in a primarily verbal mode, or whether both hemispheres used a combination of the two modes, It is possible that the right hemisphere's linguistic ability extendes to simple letter naming. Similarly, the left hemisphere may be capable of providing a detailed visual analysis of frequently occurring verbal stimuli. The frequent transfer of information between the two hemispheres is not ruled out. Such frequent transfer would tend to eliminate visual field differences.

The within hemisphere conditions led to less target detections than the between hemisphere conditions when all the findings are taken together. In the between hemisphere conditions each hemisphere received some information and may have been able to commence processing immediately. In the within hemisphere conditions it is not clear whether the hemisphere receiving the information processed the stimulus information without the assistance of the other hemisphere, thus taking longer due to the larger amount of processing required, or whether there was a sole transfer of information between the hemispheres in order to divide the load between them. This hypothetical transfer of information may result in some transcallosal decay.

In summary, therefore, it appears that Kinsbourne's theory may be applied to this study. However the evidence is extremely limited. As between hemisphere presentations led to a higher rate of target detection than did within hemisphere presentations, the direct access mechanisms must nevertheless be important.

Chapter Thirteen

A Summary of the Research and General Conclusions

A Summary of the Research and General Conclusions

In order to draw conclusions from the research that has been presented here the findings from the experiments will first be summarised. The experiments fall into three groups. Each group involved the use of a different experimental paradigm aimed at different problems in the field. These three groups of studies will be discussed individually.

The first four experiments involved the use of short term memory tasks. The subject was presented with a stimulus (experiments I and II), or stimuli (experiments III and IV) to both hemispheres, two seconds prior to the presentation of a single lateralised stimulus. The subject was thus required to encode the former stimulus, or stimuli, in order that he could compare the lateralised stimulus with the encoded material. Stimuli may be encoded in short term memory in a visual or verbal form, both of which were investigated in this set of experiments. Experiments I and II were concerned with the perception of complex non-verbal stimuli, which it was argued, were coded in a predominantly visual mode. Experiments III and IV employed more simple stimuli than those used in the first two studies. These stimuli may have been coded both visually and verbally. In addition to the consideration of the nature of the encoding of the memory stimulus, or stimuli, one must also consider the process of analysis of the lateralised stimulus. Stimuli may be processed in a serial or parallel mode. That is, the elements of the stimulus may be compared in turn with the encoded representation of the memory stimulus, or the separate stimulus elements may be compared simultaneously. This question was investigated in experiment II. It was suggested that the hemispheres may use distinct modes of analysis of the lateralised stimulus. An alternative way of viewing the processing of the lateralised stimulus is to ask whether one hemisphere uses a visual mode of analysis while the other hemisphere uses a verbal mode of analysis irrespective of whether there are serial or parallel processes involved. This approach was used in experiments III and IV.

The four experiments in this group will now be discussed in more detail. As noted previously, the stimuli used in experiments I and II were believed to be non-verbal. They were complex outline drawings of "stickmen". It was argued that there was a sufficient number of them used in the experiments to prevent the subjects encoding them verbally. Although it has been suggested that non-verbal stimuli may have "directionality" in a similar sense to verbal stimuli, there was no support for this view from these two experiments. Therefore a scanning interpretation of the data was not considered as being appropriate. Rather the results were interpreted in terms of the direct access theory of visual field asymmetries. There was a clear LVF recognition superiority, in terms of errors to lateralised stimuli. The cause of this LVF superiority is not immediately obvious. It is not sufficient to argue that there is a LVF superiority because the right hemisphere is specialised for non-verbal processing. There are several stages involved in a task of this nature. Firstly there is the encoding of the memory stimulus, or stimuli. This encoding may occur in both hemispheres, although given the nature of the stimuli, it may be expected that the right hemisphere may encode the material more adequately than the left hemisphere. However, this is only an assumption and it may be the case that the left hemisphere is capable of encoding the stimuli competently in a visual form. The next stage in the task occurs when the lateralised stimulus is presented. This is the registration stage. At this point in the process there is evidence of right hemisphere superiority. However, when the stimuli involved are complex the effect of this hemispheric difference would be expected to be marginal. The third and fourth stages present the most difficulty in discussion. The third stage will be considered to be the process of the analysis of the stimulus into its elements and the fourth stage is the comparison of the analysed lateralised stimulus with the encoded memory stimulus. The division of these processes may be artificial. They may occur in parallel. The question to be asked is whether the right hemisphere is superior in the analysis stage, or the comparison stage. In addition, if it is superior in the comparison stage is this merely due to there being a more adequate encoded memory stimulus in the right hemisphere. We do not have the answers to these questions. To further complicate the issue, there is the question of whether the left hemisphere is involved in the processing of the lateralised stimulus beyond the registration stage. If it is involved in the analysis and comparison stages, to what extent is it involved? There is evidence from later experiments which suggests that the left hemisphere is capable of analysing non-verbal material. In a non-competitive situation, such as that of this group of experiments, which used unilateral presentation, material arriving in the left hemisphere may be partially analysed by the less active right hemisphere.

Experiment II investigated the above question in more detail than experiment I. It attempted to distinguish between the two extreme alternative processes which may underly the direct access interpretation. Visual field differences, according to this theory,may arise because all the stimulus information presented to the subject must be processed by the hemisphere specialised for that type of processing (this is unlikely in the view of later results). In this case the specialised hemisphere is the right hemisphere. Alternatively, both hemispheres may be involved in the stimulus processing but one hemisphere may be slower and less accurate than the other. In this case the left hemisphere should be slower and less accurate than the right hemisphere. In experiment II the subjects were required to perform the same task as that used in experiment I but in this case the stimulus comparisons were controlled so that it may have been possible to distinguish between a serial and a parallel mode of processing. If it had been shown that information presented to the right hemisphere had been processed in a manner different from that of material presented to the left hemisphere then it would have been clear that both hemispheres were involved in the information processing, but that the right hemisphere used the more efficient mode. However, the experiment failed to distinguish between a serial non-self-terminating and a parallel mode of processing. Experiment II failed to solve the problem of whether all the information was analysed in the right hemisphere or not. As the problem of distinguishing between a parallel and a serial processing mode appeared to be intractable, experiments III and IV concentrated on the visual-verbal distinction.

The conclusions discussed above were based on the analysis of the error stimuli. There was no corresponding visual field asymmetry in terms of response times. Several reasons for this discrepancy were considered. It was suggested that any LVF advantage in terms of response times was due to the requirement of a right hand response, which would have favoured the RVF. Although the right hemisphere may have processed the information faster than the left hemisphere, or in fact been the sole information processor, the left hemisphere would necessarily have produced the manual response as it was a single finger response which would have been controlled by the hemisphere contralateral to the responding hand. It was further suggested that subjects may have "traded" response times for errors in a manner which kept response times constant across the visual field. A third explanation was that visual field asymmetries measured in terms of response times are usually small and that given a complex task, the performance of which may differ from trial to trial, only large effects, such as acuity differences across the visual field, reached significance. Experiments III and IV attempted to overcome this problem by using more simple stimuli.

Experiments III and IV, therefore, used more simple stimuli, which could be encoded both visually and verbally. In experiment III the stimuli were letters and in experiment IV they were digits. Both types of stimuli are usually considered to be verbal stimuli. In each experiment, however, more than one visual form of each stimulus was used and the subjects were required to make the comparison of the stimuli on the basis of visual characteristics, rather than on a nominal basis. As discussed earlier, the same experimental paradigm was employed in these two experiments as that used in experiments I and II. In experiments III and IV, however, the memory set was increased to five and three stimuli respectively. During the retention interval between the presentation of the memory set and the lateralised stimulus, it was suggested that the subjects would encode the stimuli visually as the comparison was to be performed on the basis of the visual characteristics of the stimulus. It was argued in addition that the left hemisphere would automatically encode the memory set in a verbal mode. The verbal encoding, however, would not be adequate in order to match the memory stimuli to the lateralised stimulus. It was suggested that this factor would lead to more errors and increased response times to stimuli presented in the RVF when the test stimulus was nominally equivalent to a member of the memory set, but visually different. This was not found to be the case. Although the findings of experiments III and IV did differ in some respects there are some general conclusions which may be drawn from them. The error data in experiment III suggested the possibility that stimuli which differed on a visual basis must receive analysis by the left hemisphere. Thus, when the right hemisphere detected a difference between memory set stimuli and the lateralised stimulus the lateralised stimulus information was transferred to the left hemisphere for further analysis. In experiment IV, however, the data suggested that the right hemisphere did not transfer information to the left hemisphere during the trials in which a visual comparison produced the decision "different", but that both hemispheres were capable of analysing the stimulus information entirely and used both a visual and verbal encoding of the stimuli. Unlike the findings of experiments I and II, there was no overall visual field asymmetry. Therefore there was no support for a scanning or an attentional theory. Again, the direct access theory appeared to be the most appropriate.

One of the most interesting points emerging from experiment III in particular was the suggestion that mean response times are not an adequate means of measuring hemispheric activity. The mean response times conceal the underlying variability in response times. It was suggested that there are two methods of processing stimuli presented to the right hemisphere and only one method of processing information presented to the left hemisphere. The response time data suggested that when the right hemisphere received a lateralised stimulus, which it judged to be visually different from the memory stimuli, it may or may not, have transferred the stimulus information to the left hemisphere in order to make a verbal comparison. When information was presented to the left hemisphere initially, both a visual and a verbal comparison would be made in that hemisphere.

It was concluded from these two experiments that it is improbable that in a complex task, such as the ones used here, that there is either a lack of any interhemispheric communication or transfer of information, or merely a single interhemispheric transfer. It is most probable that there are several interhemispheric transfers of information involved, which would introduce a large degree of redundancy into the system. The same pattern of interhemispheric transfer would not necessarily occur on every trial.

Although there is no evidence from experiments I and II or III and IV to suggest that response time and error measures tap different underlying mechanisms, there is also little evidence to suggest that they measure the same mechanisms. Although the two measures do contribute towards the interpretation of the underlying mechanisms there is the question, raised previously, of whether there is a "trade-off" between errors and response times by the subjects. It has also been shown that the complex tasks used in these studies produce long response times with a large variance. Any small differences between visual fields are indetectable due to this large variance. In addition it has been argued that mean response times are an inadequate measure of hemispheric activity. Therefore the studies which followed concentrated on the error measure alone.

Experiments V, VI and VII formed the second group of studies. In these experiments subjects were presented with two lateralised stimuli, one in each visual field. These lateralised stimuli had then to be recognised from a set of stimuli presented on a response card. This series of experiments used three types of stimulus material. These were words, faces and shapes. Words presented bilaterally have previously been found to lead to a RVF advantage when central fixation is assured by the use of a fixation digit. Unfamiliar faces have been shown to lead to a LVF advantage, but the experimental findings have been difficult to interpret in the case of other non-verbal stimulus material,such as the shapes used in these studies.

Experiment V investigated the role of scanning in determining visual field asymmetry. Subjects in this experiment were presented with three types of stimuli in different stimulus pairings. In the primed condition they were informed of the visual field in which each type of stimulus would appear. It was predicted that if a perceptual scan is important in determining visual field asymmetry, at least in the perception of words, priming should cause the subject to alter his perceptual scan in order to maximise his chances of accurately perceiving the stimuli. There were two major findings in this experiment. Firstly, previous findings that a central digit ensures a RVF advantage for word perception in the bilateral presentation situation were supported. Additional support was provided by the following experiments. Although the RVF advantage for word perception persisted in both the primed and non-primed conditions in experiment V, there were more LVF words recognised in the primed condition. It was argued that the subjects could alter their perceptual scan in favour of the LVF when they knew that the word stimuli, which were the easiest stimuli to identify, were likely to be presented in the LVF. This alteration of perceptual scan, however, did not appear to over-ride the underlying visual field asymmetry. This underlying asymmetry was considered to be due to structural factors. Thus experiment V provided further support for the direct access theory.

Experiments VI and VII used the same stimuli as those used in experiment V. However these two later experiments were aimed at a different problem. Experiment VI was a replication of an experiment performed by Hines (1975), with which there were several difficulties. Experiment VII was an extension of experiment VI. Hines (1975) suggested that different mechanisms underly the results obtained in studies involving bilateral and unilateral presentation of visual stimuli. He suggested that in the unilateral situation both hemispheres may be involved in the processing of a stimulus initially received in one hemisphere. Hines argued that the hemisphere in which the stimulus is received may perform the preliminary analysis and then, if necessary, will transfer the stimulus information to the hemisphere specialised for that type of information processing. Experiment III in this series showed that this load-sharing may occur in some conditions, although experiment IV demonstrated that it is often unnecessary even in the case of simple verbal processing and may serve only as a means of incorporating redundancy into the system. Hines argued that in the bilateral presentation situation, the two hemispheres function as separate channels, as do the separated hemispheres of the split brain individual. This, he suggested, is the underlying reason for the greater asymmetry observed in the bilateral situation. Independent hemispheric operation should increase the subject's processing capacity as there should be no interference between simultaneous tasks, which may require entirely different processing modes. However, if each hemisphere is specialised for the processing of a particular type of material, it will not process all types of material equally well. Therefore a hemisphere acting in isolation, when presented with material for which it is not specialised will perform particularly badly if it has no access to the more specialised mechanisms of the other hemisphere.

Experiments VI and VII produced slightly different findings due to different experimental procedures. In both studies there was a strong visual field asymmetry in the perception of words. Words were more accurately perceived when they were presented in the RVF then when they were presented in the LVF. In neither experiment was there an observable visual field asymmetry for the perception of shapes. This finding was not surprising as the literature in the field of shape perception is conflicting. Although there was no visual field asymmetry in face perception in experiment VI, in experiment VII there was a LVF advantage. It was argued that faces may be analysed by either hemisphere, but that those presented to the left hemisphere may be more susceptible to the interference caused by the number of response alternatives.

If one is to argue that the two hemispheres act as separate channels, then evidence must be presented which shows that there is no common bottle-neck, contrary to the traditional single channel theory. Hines (1975) argued that if the hemispheres act as independent channels there should be no relationship between the response occurring to the stimulus presented in the LVF and the response to the stimulus presented in the RVF on any given trial. That is, the number of paired correct responses in a series of trials should be equal to the number of paired correct responses expected by chance. However, it was pointed out in chapter eight, that the lack of a non-random relationship between the responses to left and right visual field stimuli does not necessarily rule out the possibility, as Hines argued, that there is a common bottle-neck. It was suggested that the left hemisphere was primarily involved in the processing of words and that, contrary to Hines' suggestion, words received in the right hemisphere may well be transferred to the left hemisphere for analysis. It was, however, suggested that the two hemispheres may operate as separate channels in the processing of shape and face stimuli. Both hemispheres appeared to equally capable of processing shapes, but the right hemisphere was superior for face processing. This is in line with other research (Hellige and Cox, 1976), which suggested that visual processing may be performed by either hemisphere. Each hemisphere may act independently.

The experiments summarised above have shown a direct access theory of visual field asymmetries to be the most appropriate interpretation of the data. It has been shown, however, that small differences between experiments may produce different results. The stimuli may be changed from one experiment to another, as in experiments III and IV. Both of these studies involved the use of simple verbal stimuli, which nevertheless produced different data. The experimental procedure may be modified slightly as in experiments VI and VII. Again, different findings occurred. The data collected from the study of individual subjects in detail may show a large amount of seemingly inexplicable fluctuation from session to session, which statistical treatment may obscure. This was the case with the data obtained in experiment IV. Of course, in experimental psychology, statistical techniques are employed with the specific purpose of highlighting the differences between conditions which are significant.

However, these techniques not only eliminate random variation but also mask genuine individual differences between subjects. That is, statistical analysis may obscure data which in the study of an individual case may be psychologically meaningful. Therefore one is not studying what happens within the brain of a particular subject. One is studying the general case. There may, in fact, be very few individuals who actually follow the pattern of the general case. This is particularly probable when the data are complex. In experiments I and II there was a complex pattern of response time and error data to interpret. It is therefore questionable that the conclusions, which have been reached as a result of these experiments are relevant to the study of individuals. The same is true of experiments III to VII. With this problem in mind, the final three experiments will be discussed. These were again group studies. Therefore the above problem applies to them. However, experiments VIII, IX and X investigated Kinsbourne's theory, which may offer some explanation of both the differences between one experiment and the next when there have been only minor changes in the methodology and the problem of individual differences.

It has been suggested that the subject's thoughts, which are irrelevant to the experimental task, and will vary from session to session and from subject to subject, will affect the outcome of the experiment. Kinsbourne argued that a subject's mentation will influence the interhemispheric balance of attention in the same manner as will an experimental task. These thoughts will be largely uncontrollable and it is not possible to assess whether a subject's thoughts are predominantly verbal or non-verbal, for example. Therefore, it is not possible to predict the direction in which they will bias attention. There is however, little point in discussing the possibility of the influences of attentional biases, due to the subject's irrelevant thoughts, on the experimental outcome until one can show that attentional biases will occur predictably as a consequence of different types of stimulus processing. Although irrelevant thoughts may lead to attentional biases, these will be random across the group of subjects in this type of experiment. If Kinsbourne is correct, attentional biases due to the experimental procedures should be observable statistically. Although a finding of visual field asymmetry linked with experimentally imposed attentional biases does not necessarily imply that the irrelevant mentation of the subject may lead to altered visual field asymmetry, it does allow for that possibility. If it can not be shown that attentional biases occur due to the types of processing involved in the task, it is unlikely that a subject's thoughts will lead to such a bias. Experimants VIII, IX and X were designed to test Kinsbourne's theory directly. These experiments used the same basic experimental paradigm as the previous group of studies. Two stimuli were presented on each trial. These stimuli fell in two of the following positions across the horizontal visual field: outer left, inner left, inner right and outer right. On 50% of the trials one of the stimuli was a target stimulus, memorised previously by the subject. The subject's task was to detect as many of the target stimuli as possible. In experiment VIII the stimuli used were three-letter words. Those used in experiments IX and X were single letters, thus reducing the visual angle subtended by the outer stimuli as this was believed to have been a problem in experiment VIII.

According to Kinsbourne's theory, verbal stimuli should activate the left hemisphere more than the right hemisphere as the left hemisphere is the dominant one for verbal processing. The subject's attention will then be directed towards the right side of the body and right auditory and visual space. There should be a target detection accuracy gradient extending from the extreme RVF through fixation to the extreme LVF, when allowances have been made for the lowered visual acuity in the periphery. Experiment VIII used verbal stimuli and the results should have fitted this pattern if Kinsbourne is correct. However, this prediction was not upheld. There was an interesting pattern of stimulus detection accuracy observed in experiment VIII, which was not observed in the later studies. There was also evidence to suggest that both hemispheres are involved in the processing of the verbal stimuli employed in this study. When target stimuli were presented in the conditions in which one stimulus fell in each visual field (that is, one received by each hemisphere), the target stimuli were more likely to be detected. This finding supports earlier research, which has suggested that a load-sharing between the two hemispheres is beneficial to stimulus processing in situations where the presentation of the same stimuli to a single hemisphere would overload the system. It is possible that the right hemisphere may have processed the simple verbal stimuli involved in this experiment in either a verbal or a visual mode, but in view of earlier evidence in this series of studies, it appears unlikely that the right hemisphere acted as an independent processor. It was suggested in Chapter Nine that the two hemispheres only act as separate channels when each receives the type of stimulus material for which it is specialised, particularly in instances where verbal stimuli are involved. Therefore it is likely that the right hemisphere's involvement is in the form of a visual pre-processing of the stimuli, which will remove some of the load from the left hemisphere. If the direct access theory is the most appropriate interpretation of the data, which it appears to be, then the left hemisphere appears to have been involved at the higher levels of processing all stimuli presented to both the right and left hemispheres in this experiment.

Experiment IX was a modification of experiment VIII. Although experiment VIII provided no support for Kinsbourne's theory, there was some doubt as to its interpretation due to the apparently diminished visual acuity in the outer left and right visual field positions. Therefore experiment IX involved the use of single letter stimuli. It was argued that these stimuli would be processed visually. Therefore the right hemisphere should have been the more active hemisphere, being more dominant for visual processing than the left hemisphere. If Kinsbourne's theory is correct, there should have been a bias in visual attention towards the LVF. As in experiment VIII, there was no gradient of target detection accuracy extending across the entire visual field. Subjects did, however, report more targets from the LVF than from the RVF. Again there was some evidence to suggest that when material is divided between the two hemispheres it is processed more adequately than when it is presented solely to one hemisphere. Although the data appear to support the view that the stimuli were processed visually rather than verbally and that the direct access theory is the most appropriate explanation of the data, there was some doubt remaining as to the origin of the visual field asymmetry obtained in this experiment. It was suggested that it may have arisen from peripheral factors of visual acuity rather than from central factors. Therefore experiment X was designed to investigate this problem further.

Experiment X was designed with the aim of encouraging subjects to code the material in both a visual and a verbal mode. This should involve both hemispheres in the stimulus processing. Each hemisphere should employ the mode for which it is specialised. There were two conditions under which stimuli were presented in this experiment. In one condition the subjects had to search for a specific visual form of the letter "A", which was presented as either upper or lower case. This was the visual condition. In the verbal condition the subjects had to search for the letter "A", irrespective of its visual form.

In this experiment, as in previous ones, there was good evidence in favour of the view that material shared between the hemispheres is processed more accurately than an equivalent amount of material presented only to one hemisphere. In this experiment, although it was anticipated that subjects would employ a visual and verbal mode where appropriate in the two different conditions, this did not in fact appear to occur. It appeared that both hemispheres were able to process the material equally well and the modes of processing used by the two hemispheres remain obscure. There was some support for Kinsbourne's theory in one of the experimental conditions. Thus although Kinsbourne's theory had virtually been discounted in the earlier studies, it now appears that attention may have a role to play in visual field asymmetries. However, the observable effects of attentional biases of this type appear to be somewhat elusive. Thus the final study still leaves the question of how important attentional biases are in determining visual field asymmetries.

Having reviewed the findings from each experiment, some general conclusions may now be drawn from them. Each major point will be discussed in turn.

1) It appeared from the results of the earlier experiments that the more suitable dependent variable for the type of study involved here was the error measure. It was shown that the two measures did not produce the same pattern of results when they were both employed within the same experiment. It was suggested that there was a "trade-off" between the two measures.

When the task is fairly complex, there will inevitably be a larger number of errors and longer response times than is usual in studies which involve more simple tasks. In experiments I to IV the response times were approximately twice those obtained by other workers in the field. One of the major difficulties in using response times as a dependent variable is that although it appears to give precise information (in terms of accuracy to the nearest millisecond) it is not clear what this information means. If the experimenter takes the mean response time obtained from the subject under one condition it is not possible to say whether the stimulus information has within this time interval traversed the corpus callosum or not. If the information has traversed the callosum, did it do so once or more than once and in what form? The time taken to cross the corpus callosum when very simple stimuli are involved is of the order of 5 msecs. Experiments using more complex stimuli have, as noted in chapter two, obtained widely differing interhemispheric transfer times. It is of course not clear what these so-called interhemispheric transfer times represent. It is doubtful that they do represent a single callosal transfer of simple information. In the studies considered in the preceding chapters, such a transfer of unprocessed visual information between the visual cortices would involve the splenium. It is possible that in the complex tasks involved in these experiments the material was partially analysed prior to interhemispheric transfer. It is then possible that this partially analysed material was transferred between the hemispheres along different callosal routes (Gazzaniga, 1975).

A further difficulty is that it is not possible to say whether the mean response time is a mean of many almost identical transfers of information across the corpus callosum or whether it conceals a number of widely differing methods of dealing with the information. The processing and interhemispheric transfer mechanisms may operate differently from trial to trial. The probability of this occurring would presumably increase as the complexity of the stimuli and task requirements increased. Therefore the error measure, which merely provides the experimenter with the information that a particular stimulus was either processed accurately or not, is certainly in this type of study, no less useful. It also removes any obvious time pressure from the subject.

2) The direct access interpretation of visual field asymmetries appears to be the most appropriate explanation of the data collected in this series of studies. The scanning theory advanced by Heron (1957) may be involved to some degree in the asymmetrical perception of words.

However it may be involved only on occasions when the subject is aware of the possibility of using a particular perceptual strategy to increase his accuracy. Thus in experiment V, where the subjects were primed to receive particular types of stimuli in each visual field, they could use this pre-trial information in order to change their scanning strategies. This would appear to be the only means of conscious control over performance open to the subjects. This argument ties in with the experiments discussed in Chapter two in which mirrored stimuli were presented to subjects and a scanning theory was supported. Given that the subject knows prior to each trial that he will receive stimulus information which is orientated in a particular direction then he will scan the material in that direction. If however, he does not realise that the letter stimuli are mirrored words he will not scan the material in the right to left direction. His scan will follow the usual left to right direction. This view was supported by an unpublished study by the present author. In this experiment, three-letter words were presented bilaterally. The task of the subject was to report as many of the letters as possible. It was found that the accuracy and order of report of the stimuli proceeded from left to right irrespective of whether the words were well separated from fixation or presented closely adjacent to the fixation point, and irrespective of whether the words were presented in the normal or reverse orientation. This study was assumed to differ from those of other investigators in that the experimenter did not suggest to the subjects that the stimuli would be words or that some of the words would be reversed. It differed from the studies presented here, in that the emphasis was placed upon the correct report of individual letters, which presumably produced the observed LVF superiority rather than the RVF superiority for word perception found in this series of experiments.

Kinsbourne's theory has not been totally discounted by the experiments performed here. There was no strong evidence, however, of a clear gradient of perception accuracy across the visual field. It is possible that the visual field asymmetry in some of the experiments may be explained by the attentional theory. In the majority of the cases, however, the direct access theory received stronger support. It is doubtful that shifts in attention due to the irrelevant thoughts of the subjects are a major cause of either individual differences or of the unreliability of visual field asymmetries.

Therefore the direct access theory appears to providedthe best fit of the data. There may be slight influences of scanning and attention overlying the major structural basis of the phenomenon. If one accepts that the direct access theory is the correct explanation of the data, then one may proceed to consider the implications which this has for the more detailed interpretation of the data.

3) It does not appear to be the case that the hemisphere specialised for the processing of a particular type of

material must necessarily process all material of that type whenever it is presented to the individual. There is evidence from this series of experiments which suggests that both hemispheres certainly have some involvement in the processing of nonverbal material such as shapes and faces. Other investigators have shown that the left hemisphere tends to predominate in the processing of familiar faces, which may lend themselves to verbal encoding. The face stimuli used in the present series of experiments were not familiar to the subjects. They were not believed to lend themselves readily to verbal coding, although clearly the subjects would become more familiar with them as the experiment progressed. Subjects, however, did not report the use of verbal encoding. Therefore it appears possible that both hemispheres employed similar types of encoding, which were presumably visual.

Although simple verbal stimuli in the form of single letters may be processed by both hemispheres, possibly using their respective modes, it is possible, considering the evidence, that it is the left hemisphere which is predominantly concerned with the processing of more complex verbal stimuli, such as words. However, this is not to argue that the right hemisphere is incapable of processing these words. It is possible that in the intact brain the left hemisphere exerts an inhibitory influence on the right hemisphere when verbal processing is required, thus preventing the right hemisphere from becoming involved in the processing. There may be a corresponding inhibition of the left hemisphere by the right hemisphere when visual processing of a complex nature is required.

Kinsbourne (1974b) has argued that much of our knowledge of the capabilities of the two hemispheres has been derived either from observing the limitations on behaviour imposed by the lack of one cerebral hemisphere, or by the isolation of one hemisphere from the other by callosal section. In these cases it is generally argued that the extent to which the use of a single hemisphere limits the subject's performance is indicative of the functions of the other hemisphere were it able to participate in the processing. Kinsbourne makes the point that when focal lesions within a hemisphere are studied, it appears that they result in deficits not observed when the whole hemisphere or lobe is removed. Therefore he suggested that the whole brain is less than the sum of its parts. One similarly, can not easily extrapolate from one brain damaged subject to another and from brain damaged patients to the normal population.

4) There is fairly strong support for the view that both hemispheres share in the processing of the stimulus material. This emerges from the series of studies as a whole rather than from a single experiment. It has been shown several times that when material is presented to the two hemispheres simultaneously, rather than all of the material being presented to a single hemisphere, more of the material is adequately processed. Therefore the

traditional view that there is a single channel, which is of limited capacity, within the brain, does not appear to be strictly tenable. It would appear that each hemisphere operates as a limited capacity channel. Under ideal conditions, in which each hemisphere receives the type of stimulus information for which it is specialised the brain capacity may be approximately doubled relative to single hemispheric reception of information.

This statement, however, says little of the functioning of the normal brain under every-day conditions. It is true that in the split brain the two hemispheres may operate to a large extent independently. It is unlikely that this is the case in the normal brain, under most circumstances. It would be very strange if the two hemispheres did operate independently when there is a large neural system interconnecting them. This system carries high order information from one neocortex to the other. Specific regions of the system carry specific types of information. Therefore in the performance of any single task there is the possibility of transfer of information between the hemispheres at several stages in the processing sequence. It has been argued (Dimond and Beaumont, 1974) that there appears to be no general mechanism for shifting operations between one hemisphere and the other. They suggested that each hemisphere performs the initial processing of the information independently before communicating with its partner. It may be suggested that this independent processing only applies to the initial preprocessing or registration stage and not to later analysis stages. It appears, from the data presented in this series of experiments, to be the case that there is an interchange of information between the hemispheres at several processing stages prior to the final decision and response stages. In experiment III, for example, it was suggested that there were at least two alternative processing routes which may be taken by material presented to the right hemisphere. In experiments VI and VII there is further evidence of an interplay between the hemispheres. Faces and shapes produced no visual field asymmetry. It is unlikely that this lack of visual field asymmetry was due to both hemispheres processing the material equally well as there was certainly no ceiling effect. It may be suggested, therefore, that although the two hemispheres are capable of processing these types of stimulus material independently, that they do not operate completely independently. It may be argued that the complete lack of visual field asymmetry was due to there being a continual interchange of information between the hemispheres, which tended to obscure any slight difference in processing capacity that there may have been. The amount of interchange of information between the hemispheres may depend on the type of material which each hemisphere is processing. Clearly in some situations the left hemisphere may be involved in the processing of verbal material, which would preclude its sharing of the processing with the right hemisphere. Why should there be an interchange of information between the hemispheres when it is not absolutely necessary?

If one is to consider the interaction between the hemispheres via the neocortical commissures, it is useful to review the evolution of the function of these structures. In animals lower down the evolutionary scale than man, the corpus callosum serves to transfer motor information and enables one hemisphere to have access to learned information present in the other. In man, however, higher cognitive functions have developed and these are lateralised within the brain. Although Levy-Agresti and Sperry (1968) have suggested that the lateralisation of function occurred because the two modes of processing are incompatible, this view is not based on any evidence. Our current classification of processing into visual and verbal modes is extremely crude and there is no sound reason for assuming that the same single dichotomy exists within the functioning of the brain. It may be argued that lateralisation of function developed for a different reason.

It may be suggested that lateralisation of function develops in the majority of individuals because it allows related processes to occur in adjacent structures in the brain. This would allow a faster transmission between structures involved in the different processing stages of a task. It may also be expected to result in greater accuracy. IQ tests involve tasks of a very specific nature. They may well be the type of task which rely to a greater extent on the proximity of processing structures within the brain than do other more general tasks. Left handers, who are believed to have a more diffuse brain organisation than right handers, do tend to perform less well on IQ tests. This argument is, however, extremely speculative and one would not wish to become involved in a discussion of the relative survival values of the two types of brain.

Although adjacent structures may be involved in similar types of processing and many tasks will only involve the use of closely adjacent structures (at least in the analysis stage) there will be instances in which other regions of the brain will be necessarily involved in the task. Therefore there must be rapid communication between regions, which may be accessed at the appropriate processing stage. This would apply within and between hemispheres. It would be advantageous to the individual if there were some redundancy built into the system. If each stimulus entering the system is analysed only a single time it is conceivable that given complex stimuli and a noisy information processor there would be a great amount of innaccuracy. In the real-life situation it may often be necessary to have extremely accurate information processing. Therefore it would be desirable to have some redundancy built into the system. This redundancy may take two major forms. Each stimulus may be processed by parallel systems within the same hemisphere, using very similar, if not identical processing programs. Alternatively, each stimulus may be processed, at least to some extent, in both hemispheres. This may then involve the use of entirely different processing programs, which would provide a superior double check. The system, which is being suggested,is a long way from the strict localisation view. Although it is not denied that there may be types of material , which must necessarily be processed by the specialist hemisphere, many types of information may be processed by either.

5) The next question to consider is the use of the divided visual field technique in the study of individual cases. As has been suggested earlier, there is a problem in attempting to relate studies of groupd of individuals to the single individual case. Group studies, subjected to statistical analysis, erase individual differences and evolve a general picture of the "typical" individual. Such an individual may not actually exist. Many subjects may produce results in a testing situation which are completely contrary to those of the "typical" case. This difficulty has been discussed recently by Westland (1978). However, several points have been made by this series of experiments which are relevant to the individual case. Firstly, it has been shown that the results are not easily predictable and not very reliable. This is a factor which must be considered very seriously. It has been shown that the lack of predictability is not due to attentional factors dependent on the subjects' irrelevant mentation. Therefore it appears that the problem lies with the types of stimulus materials used and the specific experimental paradigms employed. One of the more fruitful ways of proceeding would therefore appear to be the study of the individual case. A single subject or small group of subjects could be used to

investigate closely the reliability of the measures of visual field asymmetry.

There is still the need to relate visual field asymmetry to ear asymmetry in dichotic listening tasks. One of the problems in establishing a relationship between these two measures, which are related to the lateralisation of function within the brain, is that it is not clear how tasks presented in the visual and auditory modes are related. It is, for example, hard to equate the tasks in terms of difficulty and in terms of the relative amounts of visual and verbal processing involved. In addition to this, it has not been demonstrated that there is a relationship between the degree of visual field or ear asymmetry in any specific task and the degree of lateralisation of function. Therefore this latter problem may be usefully investigated. This, however, is not possible using normal intact subjects. There is no adequate measure of lateralisation which may be used with normal subjects. It would be necessary to study subjects whose laterality had been established during investigations of brain damage. The use of sodium amytal, for example, would establish whether there was bilateral representation of language, although it would be difficult to establish the degree of bilateral representation with any precision. Until such studies have been performed one may remain somewhat sceptical of studies of normal subjects, which purport to show (for example) differences between the sexes in the extent of lateralisation of cognitive functions.

Finally, how useful has the study of visual field asymmetries been to psychological research in general and to the understanding of brain functioning in particular? Have investigators simply become involved in the study of an experimental paradigm?

One of the major contributions of research in this field to cognitive psychology in general may be its investigation of the visual/verbal distinction. It is clear that this distinction relates to the right and left hemispheres. However the issue is more complex than has generally been acknowledged. It is not a simple serial-parallel dichotomy, for example. Each hemisphere is specialised for a particular type of processing and yet both hemispheres appear to be involved in both types of processing. Why should this be the case? Is there any distinction between right hemisphere visual processing and left hemisphere visual processing (or verbal processing). Although the right hemisphere is superior to the left hemisphere in its use of this processing mode, is this superiority purely quantitative or is there a qualitative difference? The same question may be applied to verbal processing, regarding the left hemisphere's superiority. In this area, however, more detailed investigation has begun (Gazzaniga, 1967; Gazzaniga and Hillyard, 1971). There is, however, some conflict between the findings from studies of brain damaged patients (Gazzaniga, 1971) and from normal subjects (Caplan et al, 1974). It is clear that a greater understanding of the visual/verbal dimension is required.

The study of visual field asymmetries has, as yet, contributed very little, relative to clinical research, to our understanding of the human brain. Many early experiments suffered from methodological flaws. More recent studies have tended to demonstrate hemispheric asymmetries, which had already been observed in studies of brain damaged patients. They have added little additional information. It is now clear, however, that there is a sound structural basis for visual field asymmetries. The divided visual field technique does provide a measure of hemispheric asymmetry of function. However, there is still some difficulty in selecting meaningful data from artifactual data, which may arise from an inadequate understanding of the tasks used and the methodology. There needs to be a more detailed study of these factors before data collected in different laboratories can be usefully compared and before one may be confident that all the observed visual field asymmetries relate to asymmetrical functioning of the brain.

A further problem, however, presents more difficulty. If complex functions are to be studied it is often necessary to use complex tasks. The more complex the task, the greater the opportunity there is for a diversity of processing methods within the brain. It was found in this series of experiments that memory tasks produced long response times, which were therefore of little use as a dependent variable. Although the study of normal subjects does allow the investigator to observe normal brain functioning, this may be so complex that it is impossible to tease apart the different processing stages and thereby understand the brain functioning.

It has been argued that it is extremely valuable to study the normal brain as it is difficult to extrapolate from one brain damaged subject to another and to the normal subject. One of the major problems of divided visual field studies, however, is that they only distinguish between the left and right hemispheres. They do not distinguish between regions within a hemisphere. Therefore in this field at least they are not as valuable as studies of lesioned patients have been.

Nevertheless, brain research still has a long way to go. There is much still to be learned regarding hemispheric functioning. If the remaining difficulties are overcome, the divided visual field technique should provide much useful information as a research technique. It should also provide a safe means of assessing the lateralisation of function in normal and brain damaged subjects.

Appendix One

Computer Programs

Program One - Experiment Three

The following program presented the experimental trials and output the subject's responses on to paper tape via the high speed paper tape punch. The stimuli were plotted by this program on the oscilloscope screen.

```
10 DIM P(100)
15 USE P
20 PRINT "N"
25 INPUT N
30 FOR I=1 TO N\Y=.8\X=.55
32 R=DIG(0)
35 PTR\FOR J=1 TO 5\INPUT S
40 GOSUB 230
60 Y=Y-.15\NEXT J
65 INPUT S,L,C\Y=.5\X=X+.3*L\IF L=-1 THEN L=2
70 SET RATE 2,100
71 DELAY\IF TIM(0)<2 THEN 71
75 CLEAR\GOSUB 230
80 IF TIM(0)<4 THEN 80
85 SET RATE 3,1
86 DELAY\IF TIM(0)<1 THEN 86
90 R=DIG(0)\IF R=0 THEN 90 \T=TIM(0)
95 SET RATE 2,100\CLEAR
100 PTP\PRINT C\PRINT L\PRINT R\PRINT T\TTY OUT
105 IF TIM(0)<4 THEN 105 \NEXT I
106 STOP
230 IF S=1 THEN GOSUB 300
231 IF S=2 THEN GOSUB 315
232 IF S=3 THEN GOSUB 330
233 IF S=4 THEN GOSUB 345
234 IF S=5 THEN GOSUB 360
235 IF S=6 THEN GOSUB 375
236 IF S=7 THEN GOSUB 470
237 IF S=8 THEN GOSUB 390
238 IF S=9 THEN GOSUB 410
239 IF S=10 THEN GOSUB 425
240 IF S=11 THEN GOSUB 440
241 IF S=12 THEN GOSUB 455
242 RETURN
300 REM CAPITAL H
301 FOR Z=1 TO 7\PLOT X+.02,(Y-.04)+Z*.01\PLOT X-.02,(Y-.04)+Z*.01
302 NEXT Z
303 PLOT X+.01,Y\PLOT X,Y\PLOT X-.01,Y
304 RETURN
315 REM CAPITAL G
316 FOR Z=1 TO 5\PLOT X-.02,(Y+.03)-Z*.01\NEXT Z
317 FOR Z=1 TO 3\PLOT (X-.02)+Z*.01,Y+.03\PLOT (X-.02)+Z*.01,Y-.03
318 NEXT Z\PLOT X+.02,Y+.03\PLOT X+.02,Y-.02\PLOT X+.02,Y-.01
319 PLOT X+.01,Y-.01\RETURN
330 REM CAPITAL F
331 FOR Z=1 TO 7\PLOT X-.02,(Y+.04)-Z*.01\NEXT Z
332 FOR Z=1 TO 4\PLOT (X-.02)+Z*.01,Y+.03\NEXT Z
333 PLOT X-.01,Y\PLOT X,Y\PLOT X+.01,Y\RETURN
345 REM CAPITAL T
346 FOR Z=1 TO 7\PLOT X,(Y-.04)+Z*.01\NEXT Z
347 PLOT X-.02,Y+.03\PLOT X-.01,Y+.03\PLOT X+.01,Y+.03\PLOT X+.02,Y+.03
348 RETURN
360 REM CAPITAL B
361 FOR Z=1 TO 7\PLOT X-.02,(Y-.04)+Z*.01\NEXT Z
362 FOR Z=1 TO 3\PLOT (X-.02)+Z*.01,Y-.03\PLOT (X-.02)+Z*.01,Y+.03
363 PLOT (X-.02)+Z*.01,Y\NEXT Z\PLOT X+.02,Y-.02\PLOT X+.02,Y-.01
364 PLOT X+.02,Y+.01\PLOT X+.02,Y+.02\RETURN
375 REM CAPITAL D
376 FOR Z=1 TO 7\PLOT X-.01,(Y+.04)-Z*.01\NEXT Z
377 PLOT X-.02,Y+.03\PLOT X-.02,Y-.03\PLOT X,Y+.03\PLOT X,Y-.03
378 PLOT X+.01,Y+.03\PLOT X+.01,Y-.03
379 FOR Z=1 TO 5\PLOT X+.02,(Y+.03)-Z*.01\NEXT Z\RETURN
390 REM SMALL G
391 FOR Z=1 TO 6\PLOT X+.02,(Y+.04)-Z*.01\NEXT Z
392 FOR Z=1 TO 3\PLOT (X-.02)+Z*.01,Y+.03\PLOT (X-.02)+Z*.01,Y
393 PLOT (X-.02)+Z*.01,Y-.03\NEXT Z\PLOT X-.02,Y-.02
394 PLOT X-.02,Y+.02\PLOT X-.02,Y+.01\RETURN
```

```
410 REM SMALL F
411 FOR Z=1 TO 6\PLOT X-.02,(Y+.03)-Z*.01\NEXT Z
412 FOR Z=1 TO 3\PLOT (X-.02)+Z*.01,Y+.03\PLOT (X-.02)+Z*.01,Y
413 NEXT Z\PLOT X+.02,Y+.02\RETURN
425 REM SMALL T
426 FOR Z=1 TO 6\PLOT X-.02,(Y+.04)-Z*.01\NEXT Z
427 FOR Z=1 TO 3\PLOT (X-.02)+Z*.01,Y+.01\PLOT (X-.02)+Z*.01,Y-.03
428 NEXT Z\PLOT X+.02,Y-.02\RETURN
440 REM SMALL B
441 FOR Z=1 TO 7\PLOT X-.02,(Y+.04)-Z*.01\NEXT Z
442 FOR Z=1 TO 3\PLOT (X-.02)+Z*.01,Y\PLOT (X-.02)+Z*.01,Y-.03
443 NEXT Z\PLOT X+.02,Y-.01\PLOT X+.02,Y-.02\RETURN
455 REM SMALL D
456 FOR Z=1 TO 7\PLOT X+.02,(Y-.04)+Z*.01\NEXT Z
457 FOR Z=1 TO 3\PLOT (X+.02)-Z*.01,Y\PLOT (X+.02)-Z*.01,Y-.03
458 NEXT Z\PLOT X-.02,Y-.01\PLOT X-.02,Y-.02\RETURN
470 REM SMALL H
471 FOR Z=1 TO 7\PLOT X-.02,(Y-.04)+Z*.01\NEXT Z
472 FOR Z=1 TO 3\PLOT (X-.02)+Z*.01,Y\PLOT X+.02,(Y)-Z*.01
473 NEXT Z\RETURN
480 END
```

Program Two - Experiment Three

The following program produced the random stimulus orders and balanced the visual field of presentation and condition within the constraints outlined in Chapter V. This program produced a paper tape sufficient for the 120 trial experimental session. This paper tape was fed into the computer as Program One was running.

```
10 DIM A(120),B(120),P(6),Y(6),C(6)
20 FOR I=1 TO 120
21 A(I)=0\B(I)=0\NEXT I
25 M=0
30 FOR I=1 TO 4\M=M+1\L=-3
31 FOR Q=1 TO 2\L=L+2
35 FOR Z=1 TO 15
36 X=INT(RND(0)*121)\IF A(X)>0 THEN 36 \IF X=0 THEN 36
40 A(X)=M\B(X)=L\NEXT Z\NEXT Q\NEXT I
50 FOR I=1 TO 120
55 IF A(I)=4 THEN A(I)=1
58 IF A(I)>1 THEN A(I)=A(I)
60 NEXT I
65 FOR I=1 TO 120
68 IF A(I)=1 THEN GOSUB 200
70 IF A(I)=2 THEN GOSUB 300
75 IF A(I)=3 THEN GOSUB 400
80 PTP\PRINT P(1)\PRINT P(2)\PRINT P(3)\PRINT P(4)
81 PRINT P(5)\PRINT P(6)\PRINT B(I)\PRINT A(I)
90 NEXT I
100 STOP
200 FOR J=1 TO 6\Y(J)=0\C(J)=0\P(J)=0\NEXT J
210 FOR J=1 TO 5
215 X=INT(RND(0)*7)\IF X=0 THEN 215
220 IF Y(X)=1 THEN 215
230 Y(X)=1\P(J)=X
235 Q=INT(RND(0)*3)\IF Q=0 THEN 235
240 IF Q=1 THEN P(J)=P(J)
245 IF Q=2 THEN P(J)=P(J)+6
250 Z=INT(RND(0)*6)\IF Z=0 THEN 250
255 IF C(Z)=1 THEN 250
260 C(Z)=1
265 IF Z=1 THEN P(6)=P(J)
270 NEXT J
280 RETURN
300 FOR J=1 TO 6\Y(J)=0\C(J)=0\P(J)=0\NEXT J
310 FOR J=1 TO 5
315 X=INT(RND(0)*7)\IF X=0 THEN 315
320 IF Y(X)=1 THEN 315
325 Y(X)=1\P(J)=X
330 Q=INT(RND(0)*3)\IF Q=0 THEN 330
335 IF Q=1 THEN P(J)=P(J)
340 IF Q=2 THEN P(J)=P(J)+6
350 Z=INT(RND(0)*6)\IF Z=0 THEN 350 \IF C(Z)=1 THEN 350
355 IF Z=1 THEN GOSUB 380
360 C(Z)=1
370 NEXT J
377 RETURN
380 IF P(J)>6 THEN P(6)=P(J)-6
385 IF P(J)<7 THEN P(6)=P(J)+6
390 RETURN
400 FOR J=1 TO 6\Y(J)=0\P(J)=0\NEXT J
410 FOR J=1 TO 6
415 X=INT(RND(0)*7)\IF X=0 THEN 415
420 IF Y(X)=1 THEN 415
425 P(J)=X\Y(X)=1
430 Q=INT(RND(0)*3)\IF Q=0 THEN 430
435 IF Q=1 THEN P(J)=P(J)
440 IF Q=2 THEN P(J)=P(J)+6
450 NEXT J
480 RETURN
500 END
```

Program Three - Experiment Three

The following program analysed the subject's responses and output means and standard deviations of individual subject's errors and response times in all conditions.

```
1 DIM U(2),Y(2),B(2),M(2),N(2),X(2)
2 FOR J=1 TO 2
3 U(J)=0\Y(J)=0\B(J)=0\M(J)=0\N(J)=0\X(J)=0
4 NEXT J
5 PRINT "SUBJECT NUMBER"
6 INPUT Z
10 DIM K(3,2),T1(3,2),T2(3,2),T3(3,2),T4(3,2)
20 FOR I=1 TO 3\FOR J=1 TO 2\K(I,J)=0\T1(I,J)=0
25 T2(I,J)=0\T3(I,J)=0\T4(I,J)=0\NEXT J\NEXT I
30 FOR I=1 TO 120
35 PTR\INPUT C,L,R,T\TTY IN
40 IF R=2 THEN 115
100 IF C=1 THEN 110 \K(C,L)=K(C,L)+1
105 T1(C,L)=T1(C,L)+T\T2(C,L)=T2(C,L)+T^2\
106 T6=T6+T\T7=T7+T^2\Q1=Q1+1
107 GO TO 130
110 T3(C,L)=T3(C,L)+T\T4(C,L)=T4(C,L)+T*T\GO TO 130
115 IF C>1 THEN 125 \K(C,L)=K(C,L)+1
120 T1(C,L)=T1(C,L)+T\T2(C,L)=T2(C,L)+T^2
121 T6=T6+T\T7=T7+T^2\Q1=Q1+1
122 GO TO 130
125 T3(C,L)=T3(C,L)+T\T4(C,L)=T4(C,L)+T*T
130 NEXT I
135 PRINT "NO. CORRECT"
140 PRINT "CONDITION","RVF","LVF"
145 FOR C=1 TO 3
150 PRINT C,K(C,1),K(C,2)\NEXT C
155 PRINT "CONDITION 2+3"
156 PRINT (K(2,1)+K(3,1)),(K(2,2)+K(3,2))
160 PRINT "CORRECT RT.S"
161 PRINT "CONDITION","RVF","LVF"
165 FOR I=1 TO 3
166 PRINT I,(T1(I,1)/K(I,1)),(T1(I,2)/K(I,2))
167 NEXT I
168 PRINT "STANDARD DEVIATION"\PRINT "CONDITION","RVF","LVF"
169 FOR I=1 TO 3\PRINT I,SQR((T2(I,1)/K(I,1))-((T1(I,1)/K(I,1))^2)),
170 PRINT SQR((T2(I,2)/K(I,2))-((T1(I,2)/K(I,2))^2))
171 NEXT I
175 PRINT "CONDITION 2+3"
176 FOR J=1 TO 2
178 X(J)=T1(2,J)+T1(3,J)
179 N(J)=K(2,J)+K(3,J)
180 M(J)=X(J)/N(J)\NEXT J
185 PRINT M(1),M(2)
190 FOR J=1 TO 2
191 K(1,J)=30-K(1,J)
193 K(2,J)=15-K(2,J)\K(3,J)=15-K(3,J)\NEXT J
220 PRINT "INCORRECT RT.S"
221 PRINT "CONDITION","RVF","LVF"
225 FOR I=1 TO 3\PRINT I,T3(I,1)/K(I,1),T3(I,2)/K(I,2)
230 NEXT I
240 PRINT "STANDARD DEVIATION"
241 PRINT "CONDITION","RVF","LVF"
245 FOR I=1 TO 3\PRINT I,
255 PRINT SQR((T4(I,1)/K(I,1))-((T3(I,1)/K(I,1))^2)),
256 PRINT SQR((T4(I,2)/K(I,2))-((T3(I,2)/K(I,2))^2))
260 NEXT I
270 FOR J=1 TO 2
280 B(J)=T3(2,J)+T3(3,J)
290 U(J)=K(2,J)+K(3,J)
300 Y(J)=B(J)/U(J)
301 NEXT J
310 PRINT "CONDITIONS 2+3"
320 PRINT Y(1),Y(2)
330 PRINT "TOTAL STANDARD DEVIATION"
331 D1=SQR((T7/Q1)-((T6/Q1)^2))
332 PRINT D1
340 PRINT "TOTAL CORRECT "
341 PRINT Q1
342 PRINT "MEAN"
343 PRINT T6/Q1
344 PRINT "SS"
345 PRINT T7
360 PRINT "DEFINITION OF A BLOCK"
361 PRINT (T6/Q1)+D1*2
370 FOR J=1 TO 120\PTR\INPUT C,L,R,T\TTY IN
371 IF R=2 THEN 900
372 IF C=1 THEN 990
373 IF T>(T6/Q1)+D1*2 THEN 960
900 IF C>1 THEN 990
910 IF T>(T6/Q1)+D1*2 THEN 960
920 GO TO 990
960 PRINT C,
965 IF L=1 THEN PRINT "RVF",
966 IF L=2 THEN PRINT "LVF",
967 PRINT T
990 NEXT J
995 END
```

Program Four - Experiment Four

The following program presented the experimental trials and output the subject's responses on to paper tape via the high speed punch. The stimuli were plotted by this program on the oscilloscope screen.

```
1 DIM P(80)\USE P
3 PRINT 'N'\INPUT N
5 FOR I=1 TO N\Y=.65\X=.55\R=DIG(0)
20 PTR\FOR J=1 TO 3\INPUT S\GOSUB 81
26 Y=Y-.15\NEXT J
30 INPUT S,L,C\Y=.5\X=X+.3*L\IF L=-1 THEN L=2
35 SET RATE 2,100
36 DELAY\IF TIM(0)<2 THEN 36
37 CLEAR\GOSUB 81
40 IF TIM(0)<4 THEN 40
45 SET RATE 3,1
50 DELAY\IF TIM(0)<1 THEN 50
51 R=DIG(0)\IF R=0 THEN 51 \T=TIM(0)
52 CLEAR
53 PTP\PRINT C\PRINT L\PRINT R\PRINT T
54 SET RATE 3,1
55 Y=DIG(0)\IF Y=R THEN 55 \IF Y>0 THEN 58 \IF TIM(0)<3500 THEN 55
58 PTP\PRINT Y
68 IF TIM(0)<4000 THEN 68 \NEXT I
70 STOP
81 IF S=1 THEN 400
82 IF S=2 THEN 300
83 IF S=3 THEN 600
84 IF S=4 THEN 500
85 IF S=5 THEN 410
86 IF S=6 THEN 310
87 IF S=7 THEN 610
88 IF S=8 THEN 510
89 IF S=9 THEN 430
94 IF S=10 THEN 320
95 IF S=11 THEN 630
96 IF S=12 THEN 530
100 RETURN
300 PLOT X+.03,Y\GOSUB 900
301 FOR Z=1 TO 3\PLOT X-.03,(Y-.04)+Z*.01\PLOT X+.03,(Y+.04)-Z*.01
302 NEXT Z\FOR Z=1 TO 6\PLOT (X-.03)+Z*.01,Y-.01\NEXT Z\GOSUB 905
304 RETURN
310 FOR Z=1 TO 3\PLOT (X-.04)+Z*.01,(Y-.04)+Z*.01\NEXT Z\GOSUB 950
311 PLOT X-.03,Y+.03\FOR Z=1 TO 4\PLOT (X+.04)-Z*.01,(Y+.04)-Z*.01
312 NEXT Z\GOSUB 905
315 RETURN
320 FOR Z=1 TO 2\PLOT (X-.04)+Z*.01,(Y+.01)+Z*.01
321 PLOT X-.03,(Y-.04)+Z*.01\PLOT (X-.03)+Z*.01,Y-.02\NEXT Z\GOSUB 965
322 PLOT X,Y-.01\PLOT X+.02,Y+.03\GOSUB 920
324 GOSUB 905
326 RETURN
400 PLOT X-.03,Y\GOSUB 900
401 GOSUB 940
402 GOSUB 910
403 GOSUB 970
404 GOSUB 995
406 RETURN
410 FOR Z=1 TO 4\PLOT (X-.04)+Z*.01,(Y-.05)+Z*.01\NEXT Z\GOSUB 965
411 PLOT X-.02,Y\PLOT X-.01,Y-.01\GOSUB 950
412 PLOT X+.03,Y+.03\GOSUB 940
415 RETURN
430 FOR Z=1 TO 2\PLOT X-.03,(Y)+Z*.01\PLOT X+.03,(Y)+Z*.01\NEXT Z
431 PLOT X-.02,Y+.03\PLOT X+.02,Y+.03\GOSUB 920
432 GOSUB 970
433 GOSUB 995
434 PLOT X-.03,Y-.03\GOSUB 980
440 RETURN
500 PLOT X+.03,Y+.01\GOSUB 900
501 GOSUB 940
502 GOSUB 990
503 GOSUB 995
504 GOSUB 905
506 RETURN
```

```
510 FOR Z=1 TO 5\PLOT (X-.02)+Z*.01,Y+.04\NEXT Z\PLOT X-.03,Y+.01
512 FOR Z=1 TO 4\PLOT (X-.03)+Z*.01,Y-.04\NEXT Z\FOR Z=1 TO 3
514 PLOT X+.03,(Y+.01)-Z*.01\NEXT Z\PLOT X-.03,Y+.02\PLOT X-.02,Y+.03
515 PLOT X-.03,Y-.03\PLOT X+.02,Y-.03\GOSUB 990
516 RETURN
530 PLOT X-.03,Y\GOSUB 940
532 FOR Z=1 TO 3\PLOT (X-.02)+Z*.01,Y+.01
533 PLOT X+.03,(Y+.01)-Z*.01\PLOT (X-.02)+Z*.01,Y-.04\NEXT Z
534 PLOT X-.02,Y+5.000000E-03\PLOT X+.02,Y+5.000000E-03\GOSUB 900
535 PLOT X+.02,Y-.035\PLOT X-.02,Y-.035\PLOT X-.03,Y-.03
536 PLOT X+.03,Y-.03\RETURN
600 FOR Z=1 TO 3\PLOT X+.03,(Y-.04)+Z*.01\NEXT Z\GOSUB 900
601 GOSUB 910
602 GOSUB 985
603 GOSUB 905
606 RETURN
610 FOR Z=1 TO 3\PLOT (X-.01)+Z*.01,(Y)+Z*.01\PLOT X+.03,(Y-.04)+Z*.01
611 NEXT Z\GOSUB 900
612 GOSUB 985
613 PLOT X-.03,Y-.03\GOSUB 980
616 RETURN
630 FOR Z=1 TO 2\PLOT (X-.04)+Z*.01,(Y+.01)+Z*.01
631 PLOT (X-.04)+Z*.01,(Y-.01)-Z*.01
632 PLOT (X+.04)-Z*.01,(Y-.01)-Z*.01\NEXT Z\GOSUB 920
633 FOR Z=1 TO 3\PLOT (X-.02)+Z*.01,Y-.04\NEXT Z\GOSUB 965
634 PLOT X+.02,Y-.01\PLOT X,Y\PLOT X+.02,Y+.03\RETURN
900 FOR Z=1 TO 7\PLOT (X-.04)+Z*.01,Y+.04\NEXT Z\RETURN
905 FOR Z=1 TO 7\PLOT (X-.04)+Z*.01,Y-.04\NEXT Z\RETURN
910 FOR Z=1 TO 3\PLOT X+.03,(Y+.04)-Z*.01\NEXT Z\RETURN
920 FOR Z=1 TO 3\PLOT (X-.02)+Z*.01,Y+.04\NEXT Z\RETURN
940 FOR Z=1 TO 3\PLOT X-.03,(Y+.04)-Z*.01\NEXT Z\RETURN
950 FOR Z=1 TO 5\PLOT (X-.03)+Z*.01,Y+.04\NEXT Z\RETURN
965 FOR Z=1 TO 3\PLOT (X+.04)-Z*.01,(Y+.03)-Z*.01\NEXT Z\RETURN
970 FOR Z=1 TO 5\PLOT (X-.03)+Z*.01,Y\NEXT Z\RETURN
980 FOR Z=1 TO 5\PLOT (X-.03)+Z*.01,Y-.04\NEXT Z\RETURN
985 FOR Z=1 TO 4\PLOT (X-.02)+Z*.01,Y\NEXT Z\RETURN
990 FOR Z=1 TO 5\PLOT (X-.03)+Z*.01,Y+.01\NEXT Z\RETURN
995 FOR Z=1 TO 4\PLOT X+.03,(Y+.01)-Z*.01\NEXT Z\RETURN
1000 END
```

<u>Program Five</u> - <u>Experiment Four</u>

The following program produced the stimulus orders, as in Program Two. This program produced the orderings for 16 trials.

```
10 DIM A(16),B(16),Y(4),C(4),W(4),P(4)
20 FOR I=1 TO 16\A(I)=0\B(I)=0\NEXT I
25 M=0
30 FOR I=1 TO 4\M=M+1\L=-3
31 FOR Q=1 TO 2\L=L+2
33 FOR Z=1 TO 2
36 X=INT(RND(0)*17)\IF A(X)>0 THEN 36 \IF X=0 THEN 36
40 A(X)=M\B(X)=L\NEXT Z\NEXT Q\NEXT I
50 FOR I=1 TO 16\IF A(I)=4 THEN A(I)=1
55 NEXT I
60 FOR I=1 TO 16
61 IF A(I)=1 THEN GOSUB 200
62 IF A(I)=2 THEN GOSUB 300
63 IF A(I)=3 THEN GOSUB 400
80 PTP\PRINT P(1)\PRINT P(2)\PRINT P(3)\PRINT P(4)
81 PRINT B(I)\PRINT A(I)
90 NEXT I
101 STOP
200 FOR J=1 TO 4\C(J)=0\P(J)=0\NEXT J
201 FOR J=1 TO 3\Y(J)=0\NEXT J
210 FOR J=1 TO 3
215 X=INT(RND(0)*5)\IF X=0 THEN 215
220 IF Y(X)=1 THEN 215
225 Y(X)=1\P(J)=X
230 Q=INT(RND(0)*3)
231 IF Q=0 THEN P(J)=P(J)
232 IF Q=1 THEN P(J)=P(J)+4
233 IF Q=2 THEN P(J)=P(J)+8
250 Z=INT(RND(0)*4)\IF Z=0 THEN 250
255 IF C(Z)=1 THEN 250
260 C(Z)=1\IF Z=1 THEN P(4)=P(J)
270 NEXT J\RETURN
300 FOR J=1 TO 4\P(J)=0\W(J)=0\C(J)=0\NEXT J
301 FOR J=1 TO 3\Y(J)=0
302 NEXT J
310 FOR J=1 TO 3
315 X=INT(RND(0)*5)\IF X=0 THEN 315
320 IF Y(X)=1 THEN 315
330 Y(X)=1\P(J)=X\W(J)=X
335 Q=INT(RND(0)*3)
336 IF Q=0 THEN P(J)=P(J)
337 IF Q=1 THEN P(J)=P(J)+4
338 IF Q=2 THEN P(J)=P(J)+8
345 Z=INT(RND(0)*4)\IF Z=0 THEN 345
348 IF C(Z)=1 THEN 345
350 IF Z=1 THEN GOSUB 380
355 C(Z)=1\NEXT J
375 RETURN
380 N=INT(RND(0)*4)
383 IF P(J)=(W(J)+4*N) THEN 380
384 P(4)=(W(J)+3*N)
385 RETURN
400 FOR J=1 TO 4\Y(J)=0\P(J)=0\NEXT J
410 FOR J=1 TO 4
420 X=INT(RND(0)*5)\IF X=0 THEN 420 \IF Y(X)>0 THEN 420
425 Y(X)=1\P(J)=X
435 Q=INT(RND(0)*3)
436 IF Q=0 THEN P(J)=P(J)
437 IF Q=1 THEN P(J)=P(J)+4
438 IF Q=2 THEN P(J)=P(J)+8
450 NEXT J\RETURN
900 END
```

Program Six - Experiment Four

The following program analysed the subject's responses and output the means and standard deviations of individual subject's errors and response times in all conditions.

```
1 DIM T1(3,2),T2(3,2),T3(3,2),T4(3,2),K1(3,2),K2(3,2)
2 FOR I=1 TO 3\FOR J=1 TO 2\T1(I,J)=0\T2(I,J)=0\T3(I,J)=0
3 T4(I,J)=0\K1(I,J)=0\K2(I,J)=0\NEXT J\NEXT I
4 T6=0\Q1=0\T7=0
34 FOR I=1 TO 128
35 PTR\INPUT C,L,R,T,Y\TTY IN
36 IF Y>0 THEN 120
40 IF R=2 THEN 90
41 IF C=1 THEN 80
42 T1(C,L)=T1(C,L)+T\T2(C,L)=T2(C,L)+T^2\K1(C,L)=K1(C,L)+1
44 T6=T6+T\T7=T7+T^2\Q1=Q1+1\GO TO 130
80 T3(C,L)=T3(C,L)+T\T4(C,L)=T4(C,L)+T^2\K2(C,L)=K2(C,L)+1
81 GO TO 130
90 IF C>1 THEN 100
91 T1(C,L)=T1(C,L)+T\T2(C,L)=T2(C,L)+T^2\K1(C,L)=K1(C,L)+1
92 T6=T6+T\T7=T7+T^2\Q1=Q1+1\GO TO 130
100 T3(C,L)=T3(C,L)+T\T4(C,L)=T4(C,L)+T^2\K2(C,L)=K2(C,L)+1
101 GO TO 130
120 PRINT C,L,R,T,Y
130 NEXT I
135 PRINT 'NUMBER CORRECT'
136 PRINT 'CONDITION','RVF','LVF'
137 FOR I=1 TO 3\PRINT I,K1(I,1),K1(I,2)\NEXT I
138 PRINT 'CORRECT RESPONSE TIMES'
139 PRINT 'CONDITION','RVF','LVF'
140 FOR I=1 TO 3\PRINT I,T1(I,1)/K1(I,1),T1(I,2)/K1(I,2)\NEXT I
145 PRINT 'STANDARD DEVIATION'
146 PRINT 'CONDITION','RVF','LVF'
147 FOR I=1 TO 3\PRINT I,
148 PRINT SQR((T2(I,1)/K1(I,1))-((T1(I,1)/K1(I,1))^2)),
149 PRINT SQR((T2(I,2)/K1(I,2))-((T1(I,2)/K1(I,2))^2))
150 NEXT I
160 PRINT 'INCORRECT RESPONSE TIMES'
161 PRINT 'CONDITION','RVF','LVF'
162 FOR I=1 TO 3\PRINT I,T3(I,1)/K2(I,1),T3(I,2)/K2(I,2)
163 NEXT I
164 PRINT 'STANDARD DEVIATIONS'
165 PRINT 'CONDITION','RVF','LVF'
166 FOR I=1 TO 3\PRINT I,
168 PRINT SQR((T4(I,1)/K2(I,1))-((T3(I,1)/K2(I,1))^2)),
169.PRINT SQR((T4(I,2)/K2(I,2))-((T3(I,2)/K2(I,2))^2))\NEXT I
170 PRINT 'GRAND MEAN'\PRINT T6/Q1
171 PRINT 'TOTAL STANDARD DEVIATION'
172 PRINT SQR((T7/Q1)-((T6/Q1)^2))
180 PRINT 'DEFINITION OF A BLOCK'
181 PRINT T6/Q1+((SQR((T7/Q1)-((T6/Q1)^2)))*2)
900 END
```

Appendix Two

Stimulus Words in Experiment Eight

Words Used as Stimuli in Experiment Eight

Target words: HIT, LET, JOY, RAN.

Non-target words:

JOB	PAY	WET	CAT	RED	DOG	HOT
FAR	BUY	WAY	TEN	SET	SAT	BEG
CUP	CAN	FIT	PUT	PAN	BID	BOY
WIN	RUN	FIX	SON	BOW	BAY	KEY
SAD	BAD	FUN	COW	RAY	TEN	SIX
DAY	SAW	BIT	BAR	NUT	ROW	SAY
LEG	NEW	FUR	WAR	CUT	TIP	HER
BOX	YES	WIT	SIT	TAX	SUN	HIS
MAN	BED	LOG	MAD	HIM	LAY	LOW
BAG	BUT	FAT	MIX	GOT	FEW	LOT
FOR	GAS	HAT	PAY	NOW	MEN	GUN
MAP	NET	GET				

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Abstract

It was suggested that in addition to its value as a research tool, there may be practical applications of the divided visual field technique. If it is to be used as a method of investigating individual cases in order to assess hemispheric lateralisation of function, it must be fully understood. The relative merits of the three major theories of visual field asymmetries were reviewed. A series of ten experiments was performed in which stimuli were presented tachistoscopically to the right and left visual fields. Both verbal stimuli in the form of words and single letters and nonverbal stimuli in the form of shapes, drawings and faces were employed. A variety of problems were considered. The relationship of the serial-parallel processing dichotomy to the left and right hemispheres was considered and not believed to be useful. The distinction between the hemispheres was in terms of visual-verbal processing, although this separation of functioning was not as clearcut as has been thought. It was concluded that the direct access theory was the most adequate explanation of the data, although the results may be partially influenced by scanning and attentional phenomena. Load-sharing between the hemispheres was discussed.