DOUBLE DISSOCIATION: ASYMMETRY IN VISUAL HALF FIELD RECALL SUPERIORITY AS A FUNCTION OF TYPE OF STIMULUS MATERIAL

By

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Considerable research with normal Ss has sought to investigate hemispheric mechanisms underlying the asymmetries in higher cortical functioning that appear in clinical studies of unilateral brain injury in humans. Experimental studies within the visual modality have been the most numerous, primarily as a function of the expectation that the unique visual neuro-anatomical structure and the use of lateral stimuli presentation in the visual half fields (VHF) would permit selective testing of inferences about normal cortical asymmetry. Recent studies have developed a short-term memory (STM) paradigm which overcomes many of the procedural and methodological limitations of earlier paradigms.

Using this STM paradigm, the present research presents three major studies: First (Study I), the development of a new verbal task. This development involves separate efforts:

a) a change in the nature of the presentation stimuli previously employed (i.e., digits to letters); b) an increase in the number of stimuli at fixation and in the VHF, making the task more analogous to the Dichotic Listening Test; c) an assessment of the effects of rate of presentation upon the VHF asymmetry; and d) an assessment of serial order effects. Second (Study II), the development of a non-verbal recall analogue of the STM verbal paradigm (Study I). This development involves: a) generating a set of non-verbal design stimuli; b) an assessment of recognition parameters of these non-verbal design stimuli with serial presentation; c) an assessment of the effects of rate of presentation upon the VHF asymmetry for non-verbal designs; and d) the assessment of serial order effects. The third major study (Study III) involved the utilization of the procedures developed in Study I and Study II with a new group of Ss to determine whether VHF performance (within Ss) varied as a function of the type of stimulus material (verbal and non-verbal).

Results from Study I confirm the previously reported right visual half field (RVHF) recall superiority on this STM task with verbal stimuli. Further, Study I, with fixed order of report, demonstrates a significant serial position effect and extends the previous findings to letter stimuli with increased demands upon recall. Results from Study II suggest more difficulty in the processing of the unfamiliar non-verbal design stimuli in immediate serial presentation than in the processing of the verbal stimuli (letters) presented in the same manner. Development of an appropriate non-verbal STM task needed to take this increased difficulty into account.

The major test of hemispheric mechanisms underlying performance on the VHF tasks was demonstrated in Study III. Results showed a consistent double dissociation: asymmetries in the VHF performance varied as a function of the type of stimulus materials. Verbal stimuli (letters) presented to the RVHF were recalled significantly better than from the LVHF and, conversely, non-verbal stimuli (designs) were significantly better recognized when presented to the LVHF than to the RVHF. Both types of stimuli exhibit significant serial position effects in the asymmetries produced.

Results are discussed in terms of hypotheses of functional cortical asymmetry in man and appear to offer strong evidence from normal Ss of the cortical asymmetry hypothesized initially on the basis of clinical patient data.

This present research is the first STM study with controlled fixation to demonstrate differences in VHF recall superiority as a function of the type of stimulus material. Replication (verbal stimuli) and extension (non-verbal stimuli) of the STM paradigm makes a particular methodological contribution in that this paradigm has previously been shown to correlate with the Dichotic Listening Test whereas previous paradigms (tachistoscopic studies) have not. The present data suggest that this STM controlled fixation paradigm may yield a sensitive behavioral index of functional hemispheric differences in normal human Ss.

INTRODUCTION

Lateralization is a phenomenon uniquely demonstrated in man and expressed most dramatically in the asymmetrical specialization of manual skills (handedness) and the more complex cognitive speech and language skills. This functional asymmetry has no clear phylogenetic precedent. Thus, the development of language representation in the left hemisphere in man appears to have altered the functional equivalence of the two temporal lobes seen in infrahuman species (Milner, 1962). Further, this striking functional asymmetry has not been clearly correlated with underlying morphological differentiation. Minor structural hemispheric differences, particularly in the left hemisphere, have recently been demonstrated (Geschwind and Levitsky, 1968), but these differences are small when compared to the evidence of functional differences following unilateral damage to the cerebral hemispheres.

Clinico-pathological studies (experiments in nature, electro-cortical stimulation, hemispheric brain surgery, brain bisection studies, etc.) have each provided various methodological approaches to the understanding of this phenomenon of hemispheric functional lateralization in man.

Taken together, data from these varied clinical studies of brain injured adults have primarily demonstrated a dual functional asymmetry between the cerebral hemispheres in man: the left hemisphere has been long known to subserve speech and language functions and,more recently,the right hemisphere has been shown to subserve higher spatial configural functions (Milner, 1968).

Left Hemisphere

Virtually all the currently recognized symptoms of language deficits were described prior to the nineteenth century (Benton, 1964). However, it was the interest and controversy over the mechanisms of organic language disorders (Hécaen and Dubois, 1969) which established a receptive Zeitgeist for Broca's 1861 presentation of evidence for the localization of motor aphasia. With the studies of Broca, Dax, Wernicke, and their contemporaries, the consistent occurrence of aphasic symptoms subsequent to left hemispheric damage became the clinical basis for the traditional concept of cerebral dominance (Lenneberg, 1967). Within a few decades of Broca's first studies, specific patterns of language dysfunction began to be reliably associated with specific areas within the language hemisphere. Wernicke in 1874, for example, described a syndrome associated with lesions of the first temporal gyrus which produced disturbances in the comprehension of language while expressive vocabulary and verbal fluency remained uninterrupted.

Broca in 1861 had earlier described a syndrome associated with the posterior part of the inferior frontal convolution in which patients understood language but whose verbal expression was markedly impaired and non-fluent. These frontal lobe lesions, in contrast to the posterior temporal lobe lesions, also produced hemiparesis to the contralateral body side.

These hemispheric and intrahemispheric effects on language skills provided considerable support for the selective differentiation of the left cerebral hemisphere in man (Palmer, 1964).

More recent clinical studies continue to validate this asymmetry of language skills. For example, recent evidence with right-handed patients with anatomically verified lesions has offered strong support for the earlier clinical observations in showing a significant incidence of impairment on four categories of verbal behavior (verbal comprehension, expressive language form, expressive language content, and naming) subsequent to left hemisphere lesions. In contrast, dextrals with lesions of the right hemisphere showed no aphasic symptoms (Gloning, Gloning, Haub and Quatember, 1969). This finding is remarkably consistent with earlier clinical reports of aphasic symptoms associated with only one percent of right hemisphere lesions in right-handers (Zangwill, 1960).

The predominance of language representation in the left hemisphere has been buttressed by recent developments in human brain bisection research (Sperry, 1964). While able to attach noun labels to pictures and objects, the surgically isolated right hemisphere of dextrals is unable to relate subject to object via a verb, to respond to verb commands, or to comprehend the semantic aspects of verbs (Gazzaniga and Hillyard, 1971). Like Geschwind and Kaplan's (1962) report of the human disconnection syndrome, afferent verbal stimuli are linguistically uninterpretable when presented primarily to the right hemisphere and isolated from the dominant language hemisphere by collosal sectioning.

Right Hemisphere

The early fascination with language dysfunction focused primary, if not complete, attention to the left cerebral hemisphere. Only in the last decade have lesion studies demonstrated that the right hemisphere is neither non-dominant nor silent, as often presumed. The selective occurrence of visuo-spatial constructive deficits (Milner, 1960) following unilateral right hemisphere lesions has suggested that the right hemisphere subserves a number of higher cortical functions and plays a non-subordinate role in the processing of non-verbal spatial information (Piercy, Hécaen and de Ajuriaquerra, 1960; Patterson and Zangwill, 1944; Kimura, 1963a;Warrington, James and Kinsbourne, 1966; De Renzi,Faglioni and Scotti, 1968; Luria, 1966). Right hemisphere lesions have been associated with deficits in visual and tactile patterning (Milner, 1964), perceptual closure (Lansdell, 1969), visual memory for faces and delayed recall of geometric figures (Milner, 1960), melodic memory (Kimura, 1963,1964), complex pattern visual discrimination (Kimura, 1966), proprioceptive maze learning (Corkin, 1965) and reversible operations in space (Butters, Barton and Brody, 1970). These deficits do not appear to be a function of type of cortical insult and have been observed after surgical ablation, electrical stimulation, and after cortical lesions regardless of type (i.e., neoplastic, trauma, vascular, etc.). The localization of specific skills within the right hemisphere has been less clear and has raised the possibility that spatial skills may be more diffusely represented (Kimura, 1963a;Kimura and Milner, 1964). However, recent clinical evidence suggests some clear intrahemispheric differences. For example, performance of right parital lobe lesion patients has been shown to be significantly inferior to all other right hemispheric patients on a non-verbal spatial task. Matched left hemisphere lesion patients with intact right hemispheres performed not dissimilarly from normal controls (Warrington and James, 1967a).

The primary lateralization of spatial configural skill has also recently been shown with commissurotomized patients, who demonstrated an asymmetry of performance on a spatial configural task consistent with patients with lateralized lesions (Milner and Taylor, 1972). On a tactile-tactile matching task, patients using their left hand (thereby sending primary somatosensory input to the right hemisphere) achieved correct matching even with experimental delay. Alternatively, with the right hand (with the primary contralateral projections isolated from the right hemisphere by the collosal lesions), most patients were unable to perform the tactile-tactile matching even with zero delay. All patients made fewer errors with the left hand in five different intratrial delay conditions than with the right hand in the zero delay condition alone. The one commissurotomized patient with a right hemisphere lesion performed least well, suggesting that both the primary lateralization of spatial functioning and the locus of the right hemisphere lesion were reflected in this inferior performance.

This lateralization of spatial configural skill within the right hemisphere does not appear limited to any one modality. On the contrary, observations of visual (Kimura, 1963), auditory (Kimura, 1963,1964) and tactile (Carmon and Benton, 1969; Dee and Benton, 1970; Fontenot and Benton, 1971) deficits subsequent to right hemisphere insult, and in the absence of contralateral tactile and motor deficits (Dee and Benton, 1970; Semmes, 1965), support the hypothesis of a supramodal general spatial factor (Semmes, 1965; Carmon and Benton, 1969) which may be primarily subserved by the right hemisphere.

Yet while lesion studies have generated considerable support for the concept of specific right hemisphere functions, this lateralization is less clear than that of the left hemisphere for language functions. In particular, some evidence exists of spatial configural deficits associated not only with right hemisphere lesions but also associated with more posterior left hemisphere lesions (Semmes, 1965). Controversy still exists concerning the degree of visuo-spatial constructive skill (Milner, 1962) subserved by hemispheric specialization, i.e., laterality (De Renzi, Faglioni and Scotti, 1968; Semmes, 1965; Dee and Benton, 1970). Part of the problem in understanding these results has been the numerous sampling difficulties presented with this subject population. Human clinical investigations, for example, are typically based on brain injured individuals who may vary in I.Q., age, education, type of lesion, locus of lesion, duration of lesion, etc. To control for these many possible sources of variance can be extremely difficult. Yet, failure to do so can severely limit the interpretation and generalization of data from these studies. Fortunately, many of these sources of variance are idiosyncratic to brain damaged patients.

As a consequence of sampling problems within patient populations, considerable recent effort has been addressed to the development of techniques with which to investigate brain behavior relationships with normal Ss. Again, most of the procedural developments have been directed to the assessment of how the left hemisphere processes verbal or linguistic information. In recent years, considerable laboratory effort has been addressed to the development of special techniques to assess or tease out possible hemispheric differences in normal Ss. Procedures have been developed to investigate higher hemispheric processing mechanisms in audition, somathesis, and vision.

Auditory Studies

In audition the technique of simultaneous stimulation (Broadbent, 1954) has been utilized as a means of investigating functional hemispheric asymmetries in response to linguistic and non-linguistic input. In this paradigm, Ss are presented with a series of different stimuli to each ear simultaneously (via stereo headphones) and are asked for recall after each trial. On this Dichotic Listening Test, Ss have consistently demonstrated a right ear superiority of recall for verbal material (Kimura, 1961a,1967; Satz, Achenback, Pattishall and Fennell, 1965; Shankweiler and Studdert-Kennedy, 1967). This recall asymmetry appears independent of a variety of procedural and methodological variables and appears to result from both the more efficient contralateral pathways (Rosenzweig, 1951; Sparrow, Kanp, King and Roberts, 1968; Tunturi, 1946; Hall and Goldstein, 1968) and from the suppression of competing information from ipsilateral ear input (Kimura, 1967). More recent data suggest this asymmetry also results from the oral report disadvantage of left ear information that arrives in the left hemisphere after coursing to the right hemisphere and then via a transcollosal pathway back across to the left auditory association area (Sparks, Goodglass, and Nickel, 1970). Increased similarity in the dichotic messages increases the degree of competition which, in turn, increases the magnitude of the ear asymmetry. With the increased competition, the more direct contralateral signals to the left hemisphere appear to be processed more readily and the ipsilateral left ear verbal signals (both those direct to the left cortex and those via transcollosal pathways) are attenuated and processed less effectively by the left hemisphere (Schwartz, 1970). Further, increased asymmetry appears to be a function of increased short-term memory demands (Satz, 1967; Goodglass and Peck, 1972).

The Dichotic Listening paradigm has been primarily developed with a focus on the processing of verbal information. Consequently, there are considerably fewer non-verbal auditory studies. Kimura (1964) and Shankweiler (1966) demonstrated a dissociative left ear recall superiority for non-verbal melodic patterns presented dichotically. Both the sounds (Studdert-Kennedy and Shankweiler, 1970) and the auditory sequences (Zurif and Sait, 1970), which appear less easily decodable into phonological features, exhibit either a reduced right ear asymmetry or a left ear preference. In other words, as sounds become less linguistically decodeable,there is a shift away from the right ear advantage in the direction of increased left ear superiority. With within Ss control, Curry (1967) found a similar shift with Ss who recalled more dichotically presented words from the right ear and more accurate identification of non-verbal sounds from the left ear.

Tactile Studies

Experimental tactile studies with normal Ss have only recently been used as an alternative modality within which to assess functional asymmetry in the processing of different types of informational stimuli. For example, Hermelin and O'Conner (1971) recently instructed blind children and adults with no primary tactile deficits to read Braille letters vertically. More efficient reading and significantly fewer errors were made using the left hand, the hand difference being even more marked by performance with the unpracticed middle finger. Some of the blind children who were fluent when reading with their left hands displayed the peculiar manifestation of being able to only produce gibberish when reading with their right hands. The finding of a bias toward left-handed Braille reading (Hermelin and O'Conner, 1971) was felt to result from the initial primary need to process the tacile Braille input spatially (right hemisphere) prior to verbal labeling, and therefore in part this study presents results consistent with a hypothesis of increased lateral specialization of tactile spatial processing in the right hemisphere (Kimura, 1966). This inference is consistent with the demonstration that patients with split brains (collosal disconnections) are able to construct design patterns significantly better with their left hands, presumably because of the "dominance" of spatial analyzers in the contralateral right hemisphere (Gazzaniga, 1970).

Studies within the auditory and somasthetic modalities with normal Ss thus provide additional support for the results of brain injured patients: that the left hemisphere subserves the major acoustic and language analyzers for verbal reception and expression and that the right hemisphere subserves a primary, but less clearly lateralized,role in the processing of spatial configural non-verbal information.

However, even with normal Ss the specialization of non-verbal spatial functions in the right hemisphere has not been shown to be as robust as the lateralization of verbal functions in the left hemisphere. The possible reasons for this limited effect are as follows: First, this reduced effect may be a result of either more diffuse representation for non-verbal spatial functions within the right hemisphere or bilateral though unequal representation of spatial skills. These possibilities point out the necessity of assessing performance of both hemispheres on clearly specified experimental tasks. Second, this limited effect may be a function of the use of stimuli which involve both verbal and spatial components. This possibility suggests the need for clear definition and specification of both the stimuli and the operations involved in the tasks developed to assess right hemispheric functioning (Teuber, 1962; Satz, 1966). Third, this limited right hemisphere effect may be a function of the modality in which hemispheric asymmetry is assessed. Because of the presence of ipsilateral and contralateral pathways, the auditory and tactile modalities do not clearly provide a means of isolating stimulation to one hemisphere.

However, in contrast, the visual modality provides a unique means to specify the hemisphere to which stimulus material is most immediately projected. Specifically, the lateral retinal fibers project directly to the ipsilateral hemisphere while the medial retinal nerve fibers project to the contralateral hemisphere via decussation of the medial fibers at the optic chiasm. With this nerve fiber arrangement, stimuli presented lateral to a point of fixation will be projected most immediately via the lateral fibers of one eye and the medial retinal fibers of the other eye to the contralateral hemisphere. Thus, lateral presentation of stimuli provides a means of isolating the most immediate hemispheric stimulation in normal Ss and this isolation provides a methodological advantage not available to auditory and tactile laterality studies. Indeed, experimental studies within the visual modality have been more numerous, primarily as a function of the expectation that this unique neuro-anatomical structure and lateral stimuli presentation would permit selective testing of inferences about normal cortical asymmetry with a potentially wide range of visual stimuli. Nevertheless, developments within visual studies have been replete with numerous methodological and procedural limitations that have obscured possible brain behavior relationships and restricted their clinical interpretations.

The following section provides a brief review of the studies using lateral stimuli presentations in the visual half fields (VHF) and formulates a series of questions which are experimentally investigated in this present study.

VISUAL HALF FIELD STUDIES

The vast majority of visual half field experiments have employed tachistoscopic procedures which utilize a recognition rather than a recall (short-term memory, STM) paradigm. These studies contrast with the dichotic listening recall paradigm and have been classified into two types of designs (Hines, Satz, Schell and Schmidlin, 1969): successive random tachistoscopic presentation (Type I), and simultaneous tachistoscopic presentation (Type II). In both designs, stimulation is to the lateral visual half fields which in turn projects directly via crossed and uncrossed pathways to the contralateral hemisphere (i.e., before decussation).

Successive Random Tachistoscopic Designs (Type I)

Experiments with successive random tachistoscopic stimuli presentations instruct *Ss* to focus on a central fixation point and to report recognition of stimuli presented in the lateral visual half field (VHF) on each trial.

The majority of Type I studies (stimuli presented to *either* the left or right of fixation) have demonstrated superior recognition for verbal material presented to the right visual half field (RVHF). Mishkin and Forgays'(1952) initial demonstration of an RVHF recall superiority for words has been replicated on numerous occasions (Bryden, 1966; Forgays, 1953; Goodglass and Barton, 1963; Harcum and Finkel, 1963; Orbach, 1952; Terrace, 1959; Winnick and Dornbush, 1965; Overton and Wiener, 1966). Superior RVHF recognition (binocular presentation) has also been demonstrated for a variety of verbal stimuli including letters (Bryden, 1965; Bryden and Rainey, 1963; Bryden, 1966; Heron, 1957, Kimura, 1966; Fontenot, 1973), single letters in mirror image (Bryden, 1966), outlines of familiar objects (Wyke and Ettlinger, 1961; Bryden and Rainey, 1963), and digits (Hines, 1968; Hines, Satz and Schell, 1969; Hines and Satz, 1971). Monocular successive tachistoscopic presentation of verbal stimuli has also demonstrated an RVHF recognition superiority for both eyes (Barton, Goodglass and Shai, 1965; Goodglass and Barton, 1963; Overton and Wiener, 1966; Shai, Goodglass and Barton, 1972).

The cerebral dominance hypothesis suggests that this VHF asymmetry is due to the use of verbal stimuli and the more direct connections between the RVHF and the speech/language analyzers on the left hemisphere (Kimura, 1967; Bryden, 1965). In contrast, an alternative hypothesis (Heron, 1957) explains the VHF asymmetry in terms of a left-right reading habit. This direction-scanning hypothesis suggests that when words are presented to the right of fixation, both the directional scanning and the intrinsic characteristics of the stimuli follow the normal left to right reading habit. However, when stimuli are presented to the left of fixation the scanning hypothesis suggests two competing scanning movements are necessary: a right to left movement to the beginning of the word and an additional left to right movement to read the stimulus. The demonstration of an LVHF superiority by Heron (1957), for example, in this Type I design, offered at least partial support for the directional scanning hypothesis.

However, Orbach (1952) demonstrated a limiting case of the scanning hypothesis by showing that the LVHF superiority for Hebrew words occurred only if Hebrew was the S's native language (where early reading training was from right to left). Goodglass and Barton (1963) further argued that the method of stimuli presentation, horizontally presented words, itself induced a scanning bias confounding the possible demonstration of lateral hemispheric mechanisms. The vertical presentation of words with native-speaking Israeli Ss (Barton, Goodglass and Shai, 1965) indeed demonstrated lower recognition thresholds in the RVHF for both English and Hebrew words. Despite the fact that Hebrew is read from right to left, native readers of Hebrew, whose scanning training is the opposite of English, produced an RVHF recognition superiority, a finding consistent with CNS effects but inconsistent with the scanning hypothesis. Orbach (1967) subsequently showed that both scanning and hemispheric differences are determinants of the RVHF superiority for verbal material. Native-born Israeli Ss who learned English as a second language had more accurate recognition for both English and Hebrew words from the RVHF. Yet, the larger RVHF recognition superiority occurred with English words, where both directional scanning and hypothesized hemispheric differences favor a larger RVHF effect.

A second line of evidence in support of a reading habit interpretation derived from Forgays' (1953) finding that an RVHF superiority was obtained in school children beyond the eighth grade but was absent below the eighth grade. McKeever and Huling (1970) have pointed out, however, that if the RVHF superiority is the result of training, then there should be an accumulative effect over the developmental years producing a gradual increase in the RVHF superiority rather than the step function observed at the eighth grade level. These authors found a clear RVHF superiority independent of acquired reading skills: two groups of seventh grade children, one with normal reading ability and a second with third grade reading skill both produced an RVHF recognition superiority.

A second line of evidence in support of a central effects (CNS) hypothesis in Type I studies is the reversal of VHF superiority with the presentation of non-verbal stimuli. Kimura's (1967) demonstration of more accurate enumeration of "non-verbal" stimuli (dots) from the LVHF was explained in terms of more direct access between the LVHF and the hypothesized non-verbal spatial processors in the right hemisphere. However, this LVHF effect has demonstrated no consistency: no significant VHF difference was found for simple geometric forms (Bryden, 1960; Bryden and Rainey, 1963; Heron, 1957); in fact, outlines of objects produced the opposite VHF effect (Wyke and Ettlinger, 1961; Bryden and Rainey, 1963). These conflicting results have recently been explained (Fontenot, 1973) in terms of the high verbal codeability of these stimuli, e.g., a familiar spatial three equal-sided outline form is readily verbally labeled. In a study with codeability as an independent variable, Fontenot (1973) demonstrated that VHF performance varied as a function of the type of stimulus material: superior recognition of verbal stimuli from the RVHF; superior recognition of the complex non-verbal stimuli from the LVHF.

The only studies which have demonstrated a non-verbal LVHF superiority have been those of Kimura (1966,1969) and the recent study of Fontenot (1973). Kimura's studies have to date resisted replication (Kinsbourne, 1970) except under one very restricted special condition (Van Nostrand, 1970). Thus, the experimental evidence for an LVHF superiority, using Type I studies, is somewhat inconsistent with brain lesion studies which have shown the right hemisphere to indeed be specialized in the processing of non-verbal spatial configural data. A replication of Fontenot's (1973) study would offer some support for this Type I design.

Nevertheless, even that would not be independent of the RVHF bias (Orbach, 1967) inherent in this recognition procedure or the attentional limitation of the tachistoscopic procedure itself (White, 1969).

Simultaneous Tachistoscopic Designs (Type II)

Experiments with simultaneous tachistoscopic stimuli presentation instruct Ss to focus on a central fixation point and to report recognition of stimuli presented in both lateral visual half fields on each trial.

Under most conditions of simultaneous presentation (stimuli presented to both the left and right of fixation), studies have found an LVHF recognition superiority for both verbal (Bryden, 1960; Bryden and Rainey, 1963; Heron, 1957; Kimura, 1969; Hines, Satz, Schell and Schmidlin, 1969; Harcum, 1964) and for non-verbal stimuli (Bryden, 1960; Kimura, 1969; Bryden and Rainey, 1963). An RVHF recognition superiority has been found only infrequently: for outlines of familiar objects (Wyke and Ettlinger, 1961) and for letters under modified conditions (Kimura, 1969; Heron, 1957).

The more frequent occurrence of an LVHF superiority regardless of the type of stimuli used (i.e., verbal and non-verbal) has been explained in terms of a second kind of directional scanning. That is, under simultaneous stimulation, there is a tendency to scan the LVHF before the RVHF. Kimura (1966) suggests that, indeed, fundamentally different factors underly the VHF asymmetries in the Type I (successive) and Type II (simultaneous) experimental designs. She hypothesized that under successive presentation (Type I) the type of stimulus material (i.e., verbal vs. non-verbal) determined the VHF recognition superiority. Alternatively, she suggested that under simultaneous stimulation (Type II) directional scanning tendencies would predominate (LVHF superiority) and functionally suppress superior RVHF performance. Hines (1973a) has recently demonstrated that interruption in directional scanning process causes a significant shift of lateral asymmetry to the RVHF. Words presented to the lateral VHFs simultaneously produced an LVHF superiority. However, under identical stimuli and presentation conditions with a fixation control, simultaneous stimulation produced an RVHF superiority larger than the previous LVHF effect. Hines (1973b) suggested that the direction of reading hypothesis cannot explain the variation in asymmetry between the two tests, with the shift to the RVHF superiority interpreted as support for the cerebral dominance hypothesis.

Kinsbourne (1970) has pointed out the difficulties involved in interpreting asymmetries observed in various non-verbal tachistoscopic tasks. Nevertheless, Hines' (1973a) demonstration of an RVHF superiority on a non-verbal task with simultaneous stimulation raises serious questions of the utility of this paradigm (Type II design) to assess hemispheric functional differences. The direction of reading effects appeared to have no effects on the non-verbal task (Hines, 1973b), yet the expectation of a non-verbal LVHF superiority was not confirmed. The failure to demonstrate an LVHF superiority with non-verbal material suggests one of two possibilities: (1) either hemispheric functional differences are distributed significantly differently than would be indicated by the quantity of clinico-pathological data (i.e., that the right hemisphere is specialized in processing non-verbal spatial functions), or (2) that this paradigm continues to be confounded by the complexity of tachistoscopic recognition tasks (White, 1969). There is an accumulative evidence from normal auditory and tactile studies as well as from the successive presentation visual studies (Type I) that the first of these possibilities is the less likely.

In summary, while recent progress has advanced both of these methodologies (Type I and Type II), findings suggest that the direction and magnitude of the visual laterality effect is dependent upon several factors including type of stimuli (verbal vs. non-verbal), presentation rate, scoring procedure and method of presentation. Some support from normal Ss for the cerebral dominance hypothesis has obtained; however, the failure to demonstrate a consistent replicable LVHF superiority with non-verbal stimuli weakens the arguments pertaining to the specialized role of right hemisphere mechanisms in the analysis of non-verbal cues.

Simultaneous Stimulation Recall Design (Type III STM)

Type III recall studies present stimuli in a temporal series simultaneously at fixation and in one VHF. This procedure was developed by Hines (1968) in his efforts to develop a visual paradigm similar to the auditory paradigm (dichotic listening) that had been shown to be a reliable measure of cortical asymmetry.

In the dichotic listening studies the magnitude of the asymmetry had been shown to be a function of increased list length and the competition of the simultaneous stimulation. Thus, in his study, Hines (1968) modified the Type II paradigm in order to increase the number of stimuli in each VHF within each trial and thereby more closely approximate the auditory condition producing the greatest auditory asymmetry. Further, Hines varied the location of the simultaneous stimuli: in each trial stimuli appeared in a temporal sequence (in the same location) with series simultaneously either in both VHFs (modified Type II paradigm) or simultaneously at fixation and one VHF (Type III paradigm).

When digit stimuli series were presented simultaneously in both VHFs (modified Type II paradigm) Ss were instructed to focus on a central fixation point (immediately prior to the trial stimuli) and to then recall the series of digits presented simultaneously in the VHFs. Results from this modified Type II paradigm demonstrated superior recall for verbal stimuli presented to the LVHF. However, subsequent analysis of report strategies showed that Ss primarily used a temporal order of report, the LVHF was reported prior to the RVHF. This finding appeared consistent with the Type II studies and substantiated the importance of directional scanning effects in the VHF asymmetries.

However, when the same digit sequences were simultaneously presented to the macula (fixation) and one visual half field (VHF), and when report of the fixation digits was required prior to those in the VHF, then an RVHF recall superiority (Type III paradigm) was obtained. With the fixed order of report, roughly 80% of the Ss had superior recall for digits from the RVHF. Analysis of serial position effects for the three-pair and four-pair digit sequences revealed a significantly higher RVHF effect for those digits most remote in time. As the more recent digits (i.e., last digit within a trial sequence) did not demonstrate the significant VHF difference, the asymmetry was explained in terms of recall or short-term memory (STM) processes rather than visual recognition.

Type III studies not only control for order of report but also provide a most reliable control of fixation and directional scanning, both of which have been poorly controlled for in tachistoscopic studies, Type I and Type II (White, 1969). Replications of Type III studies have without exception continued to demonstrate the RVHF superiority (i.e., verbal effect) for both a wide range of presentation times and stimuli pair sequence lengths. Hines and Satz (1971) showed that the greatest asymmetry was demonstrated with the faster presentation times (177 msec./digit pair) on a 4 x 3 presentation sequence (four digits at fixation, three digits to the left or right VHF, the first six digits presented in pairs followed by the fourth digit at fixation). McKeever and Huling (1971a) have offered additional support that this Type III paradigm continues to display an RVHF superiority for word recall for both left and right eye monocular presentation. Further, in a Type III paradigm a significant RVHF superiority was even demonstrated when the method of presentation employed simultaneous presentation of only one stimulus pair (one word to the left _and_ one to the right of fixation, and a digit at fixation), and thus _recall_ was subsequent to report of only one fixation digit. McKeever and Huling (1971b) suggested that this finding contradicted the earlier studies that displayed an LVHF superiority with bilateral word presentation (e.g., Heron, 1957). This suggestion has, however, been refuted by the demonstration that the procedural control of fixation by the fixation digit is an important determinant in the VHF asymmetry. Hines (1973b) has recently shown that when the center digit was not presented, _Ss_ recognized more words from the LVHF, a finding consistent with the Type II studies of simultaneous VHF stimulation. But, when the center digit was present _Ss_ recognized 5.3

times as many words from the RVHF (Hines, 1973b). For the verbal condition, the Type III design offers consistent evidence of an RVHF superiority while controlling many of the sources of variance evidenced in previous designs (Types I and II). Nevertheless, the strongest support for the hypothesis of dual functional hemispheric differences would come from the demonstration of differences in VHF asymmetry as a function of differences in stimulus material (verbal vs. non-verbal). Hines (1973b) was recently unable to demonstrate this double dissociation, as he failed to demonstrate an LVHF asymmetry with design stimuli using the modified Type III paradigm (one digit at fixation, one non-verbal design in either the left or right VHFs). Only the study of Schell (1970) reported a (significant) non-verbal LVHF superiority using the Type III paradigm; however, this finding is limited because of the failure to employ a verbal condition control.

In summary, the singular consistency of the Type III RVHF effect for verbal stimuli is most often interpreted as being consistent with a CNS brain asymmetry hypothesis (Kimura, 1967). The addition of a fixation control and the recall paradigm (STM) provides a methodology that controls for many of the criticisms of Type I and Type II paradigms. Haber's (1970) recent demonstration that linguistic memory is quite distinct from pictorial memory (i.e., non-verbal) appears consistent with Schell's (1970) suggestion of a VHF shift as a function of stimulus material. There is then both theoretical and empirical support for the utility of the Type III paradigm. This paradigm also offers promise in attempts to explore further parameters of laterality mechanisms in man including the processing of non-verbal information.

While this paradigm appears the more promising in controlling procedural and methodological sources of variance, any further study must also control for those several sources of sample variance that have in earlier studies been shown to obscure the assessment of possible hemispheric effects. Specifically, age (Lenneberg, 1967; Kimura, 1963b; Netley, 1972; Gazzaniga and Hillyard, 1971), handedness (Gloning, Gloning, Haub and Quatember, 1969; Serafetinides, Hoare and Driver, 1965; Zangwill, 1962; Branch, Milner, and Rasmussen, 1964), and familial history of manual preference (Zurif and Bryden, 1969; Hines and Satz, 1971) have been shown to obscure attempts to assess lateralization with normal Ss.

The present study seeks to control these sources of S variance and to address itself to the following general questions.

(1) Can previous findings of an RVHF asymmetry in a Type III paradigm be replicated using letters rather than digit stimuli? Previous Type III studies using digits have been limited by the range of the single digit universe

(0-9). The use of letters would increase the stimulus universe (26-letter alphabet) and would decrease the chances of guessing--a criticism that could be leveled against the use of digits. Failure to produce an RVHF asymmetry with letter stimuli would offer major criticism of the Type III paradigm as a sensitive measure of hemispheric specialization of verbal materials.

(2) What are the effects, if any, of <u>rate of presentation</u> (intrastimulus interval) and increased number of VHF stimuli per trial on the VHF recall? Previous studies with digits (Hines and Satz, 1971) have suggested no significant changes in asymmetry across a wide range of presentation time. Increasing the memory demands of the Type III task as in the present study may, however, alter the asymmetry. Nonetheless, increasing the length of verbal letter pairs within each trial would make the Type III paradigm more analogous to the Dichotic Listening Test which has shown that the magnitude of the ear asymmetry increased as a function of list length.

(3) What are the effects of serial position and perceptual factors on the recall from the VHFs? Specifically, the effects of memory will be evaluated by increasing the number of verbal stimuli within each letter pair sequence and examining recall within each serial position. The effects of backward masking (selective reduction in the accuracy of recall of a stimulus by presentation of another

stimulus immediately subsequent to the presentation of the first stimulus) will be evaluated on the verbal task producing the greatest asymmetry. Comparison will be made between recall from the serial positions most remote in time with recall from the most recent serial position (no subsequent stimuli). On the task producing the greatest asymmetry, perceptual factors will be evaluated by varying presentation time with the same interstimulus interval. Failure to produce a significant difference in performance across VHF when only presentation time is varied would argue against criticism that perceptual factors play a major role in the VHF asymmetry at these presentation rates.

(4) What are the effects on VHF asymmetry when design stimuli are used with the specific intent of creating a non-verbal analogue of the Type III paradigm? This general question requires the development of a set of spatial configural designs that have limited access to verbal coding. These stimuli for fixation and/or VHF presentation (see Method section for specific objectives) will then be used in a Type III paradigm to evaluate the hypothesis that the right hemisphere plays a distinctively important role in the perception of non-verbal spatial configural information. Superior recognition of non-verbal spatial configural stimuli in the LVHF would offer evidence in support of this hypothesis. Rate of presentation will be identical to that found to produce the greatest asymmetry with the letter

stimulus task. The effect of memory will be evaluated by examining the effects of serial position on the VHF asymmetry.

(5) Assuming that a non-verbal analogue can be developed, can it be shown that VHF superiority varies as a function of stimulus material (verbal and non-verbal)? Specifically, Ss will be given both the verbal and the non-verbal task. The consistent demonstration of a superior recall of verbal material from the RVHF has been interpreted as implying left hemisphere superiority in the processing of verbal information. Consequently, subjects in the study will be expected to show this RVHF superiority. If they do not, there would be grounds for questioning the meaningfulness of the results and to suspect the idiosyncrasy of this particular experimental situation. However, if Ss show superior recall for the verbal stimuli presented to the RVHF, then any difference in VHF superiority with the non-verbal stimuli with the same Type III paradigm would appear to be a function of differences in stimulus input. A demonstration of an LVHF recall superiority for non-verbal spatial configural stimuli would offer evidence supporting the hypothesis that the right hemisphere plays a distinctive role in the processing of spatial configural information. In view of the procedural advantages of the control fixation paradigm, a Type III demonstration of an LVHF recall superiority for non-verbal stimuli and a within S's RVHF recall

superiority for verbal stimuli would be strong evidence supporting Kimura's (1966) hypothesis of a dual functional asymmetry in hemispheric organization.

METHOD

This research presents three major studies. First (Study I), the development of a new verbal task within the Type III paradigm. This development involves separate efforts: (a) a change in the nature of the presentation stimuli (i.e., digits to letters); (b) an increase in the number of stimuli at fixation and in the VHF to make this task more analogous to the Dichotic Listening Test; (c) an assessment of the effects of presentation rate upon VHF asymmetry; and (d) an assessment of serial order effects. Second (Study II), the development of a non-verbal recall analogue of the Type III verbal paradigm (Study I). This development involves (a) generating a set of non-verbal design stimuli; (b) an assessment of recognition parameters of these non-verbal stimuli with serial presentation; (c) an assessment of the effects of rate of presentation upon VHF asymmetry for non-verbal designs; and (d) the assessment of serial order effects. The third major study (Study III) is to then utilize the procedures developed in Study I and Study II with a new group of _Ss_ to determine whether VHF performance (within _Ss_) varies as a function of the type of stimulus material (verbal and non-verbal). Study III further involves an attempt to replicate the effects of serial position in Study I and Study II.

Study I

Subjects

All Ss were undergraduates at the University of Florida. Subjects were all right-handed by self-report and had corrected or uncorrected visual acuity of at least 20/20. Visual acuity was established through the use of a Snellen Eye Chart.

Materials

All tests were administered in a dark windowless room with one small 25-watt light to the Ss side and used by the experimenter to record the Ss answers on the answer sheets (see Appendix 1). Subjects were seated at a long table with their heads positioned by a commercial chin rest mounted on the end of the table. Stimuli were projected at about eye level onto a large rear view projection screen 4'10" in front of the Ss. Each experimental procedure employed a motion picture film made with the stimuli and stimulus parameters for that particular procedure. A Kodak Analyst 16 mm projector with a modified governor was used to obtain a variety of speeds ranging from 10-24 frames per second. The projection rate was checked by means of a time loop after the machine had warmed up prior to each experimental session.

Stimuli (letters)

The verbal test stimuli were single block letters of the English alphabet which appeared white against the darker background of the screen. Letters were employed rather than digits in order to be able to increase the stimulus pairs without repetition within any one trial sequence. Each letter subtended one degree of visual arc in height and 45' in width. The inner edge of each VHF stimulus letter was approximately three degrees of visual arc from the center of fixation.

Procedure (5 fixation letters, 5 VHF letters)

At the beginning of each verbal letter trial, a central fixation indicator (a cross the same size as the stimuli) appeared for approximately one and one half seconds depending on the film presentation speed. The cross at fixation was immediately followed by five sequential letter pairs with five letters at fixation and five letters simultaneously in the VHF. Within each trial all five VHF letters were presented to the same VHF. No letter appeared more than once on any given trial. All trials were counter-balanced; each trial letter sequence presented in one VHF was also presented to the other VHF with the same fixation letter sequence. Each five-letter sequence was presented twice to each VHF by repetition of the first 30 experimental trials. Letter sequences were presented at fixation and alternately to each VHF. An intertrial interval of approximately 15 seconds was used for recall.

Subjects were instructed to fixate on the central fixation cross and then on the five-letter sequence presented at fixation. Subjects were instructed to wait for the trial completion and then to report (orally) in any order, the five-letter sequence presented at fixation before recalling any letters presented to the left or right VHF. Subjects were also permitted to recall letters from the VHF in any order and were instructed that they did not need to be sure of their answer but only needed to think they saw a particular letter in the VHF in order to report it. Six practice trials and 60 test trials were administered in each verbal condition. All responses were recorded by E. Trials in which all letters from fixation were not reported correctly were scored as zero and reports of VHF stimuli on these trials were eliminated from subsequent analysis.

Subjects were administered one of three experimental conditions: (1) 280 msec. presentation time, no intrastimulus interval between letter pairs, (2) 330 msec. presentation time, no intrastimulus interval, and (3) 165 msec. presentation time, 165 msec. intrastimulus interval.

Study II

Subjects

Subjects were undergraduates at the University of Florida and selected as in Study I as right-handed by self-report and with corrected or uncorrected visual acuity of 20/20. Different Ss were used in the two parts of Study II (Experiments 1 and 2).

Materials

All tests (Study II, Experiments 1 and 2) were administered as in Study I.

Stimuli (designs)

The non-verbal design test stimuli were single designs of a group of preselected 24 designs of approximately the same complexity as the letter stimuli (see Appendix 2). In a preliminary study, the number of experimental designs had been reduced to 24 by elimination of those designs in which there was any consensus of verbal labeling among five Ss in an age range similar to that of the experimental subjects. Like the verbal letters, the non-verbal designs also appeared white against the darker background of the screen. Each design was approximately the same size as the verbal letters and was positioned like the verbal stimuli with its inner edge approximately three degrees of visual arc from the center of fixation.

Procedure

Experiment 1 (3 fixation designs, no VHF stimuli)

The purpose of this experiment was to examine recognition parameters of these non-verbal fixation stimuli with serial presentation.

In the pilot studies, previous Ss had been administered one of five experimental conditions: (1) three designs at fixation, two designs in the VHF; (2) two designs at fixation, two designs in the VHF; (3) two designs at fixation, two designs in the VHF, forced choice; (4) two designs at fixation, one design in the VHF, at 280 msec.; and (5) two designs at fixation, one design in the VHF at 330 msec. In each of these studies trials appeared too difficult for Ss with response scores at a random level with no significant VHF differences.

To assess the discrepancy between these random level performances and performance on the verbal task (Study I) with five letter pairs, Experiment 1 (Study II) employed only fixation design stimuli and no VHF stimuli.

Like the verbal stimulus film (Study I), the beginning of each non-verbal design trial was preceded by a central fixation cross appearing for approximately one and one half seconds. The cross at fixation was immediately followed by three sequential digits at fixation with no stimuli in the dark VHF. No design was repeated within any one trial. Subjects were instructed to fixate on the central cross and then on the designs presented at fixation. At the end of each trial, Ss were required to select from a visual display of 10 designs, the three designs presented at fixation (see Appendix 2). Subjects were permitted to recognize the designs in any order and were instructed that they did not need to be certain of their decision in order to make a selection. The designs were numbered and all responses were recorded by E on the 20 experimental trials. Subjects were administered one of two experimental conditions: (1) 330 msec. presentation time, no intrastimulus interval, 40 trials, or (2) 500 msec, presentation time, no intrastimulus interval, 40 trials.

The results of Experiment 1 indicated that the initial tasks of fixation recognition (pilot studies) were too difficult: Condition 1 (mean correct = 2.03), Condition 2 (mean correct = 2.03). This performance precluded the use of design stimuli at fixation and the VHF because of the requirements of the Type III paradigm (i.e., perfect fixation recall to control for directional eye movements). For this reason, it was decided to explore the use of digits at fixation and designs in the VHF.

Experiment 2 (2 fixation digits, 1 VHF design)

The purpose of this experiment was to develop a Type III task with non-verbal design stimuli only in the VHF. In this experiment the initial cross at fixation was followed by two digits sequentially at fixation and one design in the VHF. The initial digit of the sequence preceded the onset of the design by one half of presentation time. The second digit remaining on the screen for one half the presentation time after the design was no longer present in order to control for the effects of visual scanning. Identical trials were counterbalanced with each design presented to both VHFs with the same digit sequence at fixation. Rotation of the design stimuli in the counterbalance trials (i.e., what was the left side of the stimulus became the right) was achieved to control for directional cues in the stimuli designs. Designs were presented alternately to each VHF. Subjects were instructed to fixate on the central cross, to report the digits at fixation, and then to select from a visual display of five designs the design presented in the VHF. All responses were recorded by E. Trials in which the digits at fixation were not reported correctly were scored as zero and reports of VHF stimuli on these trials were eliminated from subsequent analyses. Subjects were administered one of two experimental conditions: (1) 330 msec. presentation time, no intrastimulus interval, 16 trials, or (2) 280 msec. presentation time, no intrastimulus interval, 16 trials.

Study III

In Study III Ss were administered both verbal and nonverbal stimuli.

Subjects

Subjects in Study III had not participated in any of the previous VHF studies. Subjects were selected not only as right-handed by self-report but also by evidencing no behavioral indications of mixed dominance (Satz self-administered survey of lateral dominance). Subjects were excluded who reported any history of sinistrality or cerebral, spinal or peripheral nerve disease. No Ss were used whose corrected or uncorrected visual acuity was not at least 20/20 as tested prior to the experiment. The fifteen Ss' ages ranged from 18 to 23 years with a mean age of 20.6 years.

Materials

All tests were administered as in Study I and Study II (Experiments 1 and 2).

Stimuli (letters--5 fixation letters, 5 VHF letters)

The verbal stimuli were those developed in Study I and presented at the rate (330 msec.) found in Study I to produce the greatest VHF asymmetry with verbal stimuli.

Stimuli (designs--3 fixation digits, 2 VHF designs)

The non-verbal design stimuli were those developed in Study II and presented at the rate (330 msec.) found in Study I to produce the greatest RVHF asymmetry with verbal stimuli.

Procedure

The verbal letter film was presented first to all Ss in order to allow for subsequent analysis of the attentional hypothesis (Kinsbourne, 1970). Presentation and scoring were the same as in Study I. The non-verbal design film (with digits at fixation) was presented immediately after the verbal film.

The non-verbal condition was modified on the basis of results from Study II. First, the use of designs at fixation had proved to be too difficult (Experiment 1) and second, the use of two digits at fixation and only one design in the VHF had proved to be too easy (Experiment 2).

For these reasons a new non-verbal design film was created. The center fixation cross of approximately one and one half seconds on each trial was immediately followed by three digits at fixation and two designs in the VHF. The onset of the initial fixation digit in the sequence preceded the onset of the first design in the VHF by 165 msec. and the third fixation digit remained on the screen for 165 msec. after the second design was no longer present. Identical trials were counterbalanced and designs rotated as in Study II, with each design sequence presented twice to each VHF in both the rotated and not rotated orientation for a total of 72 trials. Designs were presented alternately to each VHF and within each trial both designs were presented to the same VHF. No design appeared more than once in any given trial. An intertrial interval of 15 seconds was employed for recognition recall. Subjects were instructed to fixate on the center cross and then on the three digits presented at fixation. At the end of each trial Ss were instructed to report the three digits presented at fixation before pointing to the two designs from a visual display of five designs. Each trial had a different five-design display with the two correct designs and three incorrect designs randomly distributed (see Appendix 3). Subjects were also permitted to recall the designs in any sequence as long as the designs were recalled subsequent to the report of the digits of fixation. Trials on which all three digits from fixation were not reported correctly were scored as zero and reports of VHF stimuli on these trials were eliminated from subsequent analyses. All responses were recorded by E (both the digit report and the designs pointed out; see Appendix 4).

RESULTS

Study I

The purpose of this study was to develop a new verbal task (Type III paradigm) using letters at fixation and in the VHF.

Analysis of VHF mean differences for verbal stimuli

The mean correct responses for each VHF under the three experimental conditions with letter stimuli are shown in Table 1.

The mean correct response scores for the left and right visual half fields were analyzed for VHF mean differences by presentation times. The mean correct scores for the RVHF were superior in all three presentation times. At the 280 msec. presentation time, the VHF mean scores showed an 18.32% RVHF superiority. At the 330 msec. presentation time, the VHF mean scores showed a 32.36% RVHF superiority. At the 165 msec. presentation time the VHF mean scores showed a 29.70% RVHF superiority.

The mean correct response scores for the visual half fields were also analyzed for overall (across three conditions) differences between VHFs. The overall differences between mean correct response scores in the VHFs were highly

Table 1

VHF Mean Correct Responses and Frequency of Right VHF Superiority for Verbal Stimuli at Three Presentation Times

Presentation Time	Intrastimulus Interval	Left VHF Mean	Right VHF Mean	Subject with Right VHF Superiority	Percent Recall from Both VHFs	Percent of Right VHF Superiority*
280 msec.	None	18.40	22.13	11 of 15	13.5	18.32
330 msec.	None	23.67	31.33	14 of 15	18.3	32.36
165 msec.	165 msec.	23.33	30.26	14 of 15	17.9	29.70

*Percent of right superiority determined by subtracting left score from the right, dividing by the left score and multiplying by 100.

significant ($F = 68.04$, $df = 1,14$, $p < .001$) with recall of letters presented to the RVHF superior to recall of letters presented to the LVHF. The mean correct response scores are presented graphically in Figure 1.

A larger RVHF asymmetry was demonstrated at the 165 and 330 msec. presentation times. A trend toward increased overall recall at these presentation times was observed but the scores were not statistically different from the 280 msec. condition.

The differences in mean correct recall by VHF and by presentation rate were also reflected in the frequency of Ss showing higher RVHF correct recall scores. In the 280 msec. condition only 11 of the 15 Ss showed superior RVHF scores. However, in both the 165 and 330 msec. conditions, 14 of the 15 Ss showed superior RVHF scores.

Mean recall by serial position for verbal stimuli

The overall mean recall by serial position for verbal stimuli is presented in Table 2 for each VHF. The mean recall pattern by serial position showed superior recall of the fifth letter followed by decreasing mean recall in the fourth, third, first and second positions. However, while recall of the letters presented to the RVHF was higher in all five serial positions, the percent of RVHF superiority was higher for those letters in serial positions most remote in time from the termination of each trial sequence.

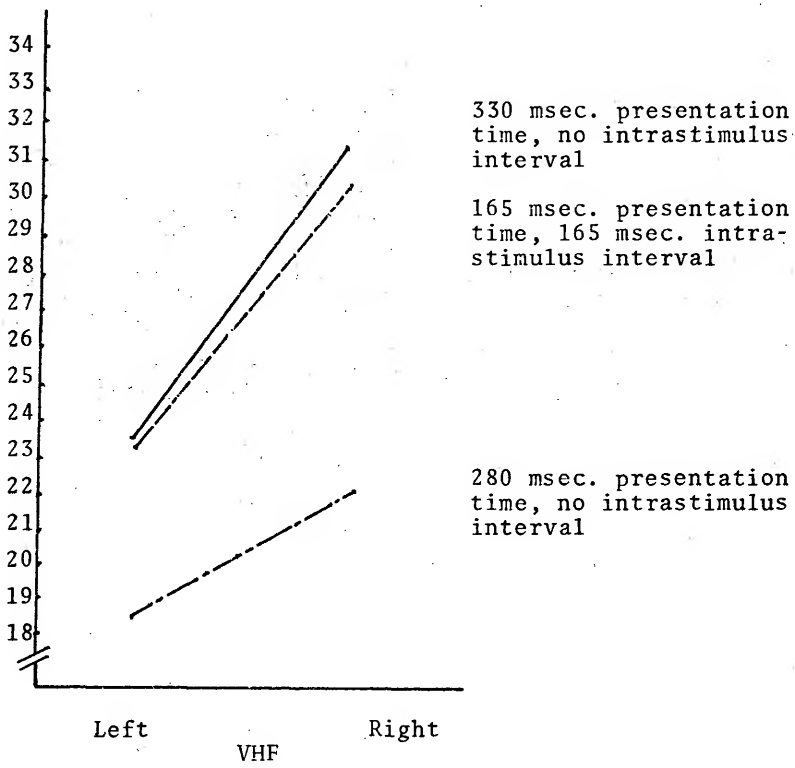


Figure 1. Mean correct response scores by VHF at three presentation times.

Table 2

Mean Correct Recall for Letters and VHF
by Serial Position

	Letters						
VHF	1	2	3	4	5	1 to 4	1 to 5
Left	2.28	2.04	2.82	3.84	10.82	10.98	21.80
Right	3.53	3.44	3.98	4.33	12.42	15.28	27.70
% of Right Superiority	54.82	68.63	41.13	12.76	14.79	39.16	27.06

Study II

The purpose of this study was to develop a non-verbal analogue of the Type III paradigm.

Experiment 1

The purpose of Experiment 1 was to assess recognition parameters of these non-verbal design stimuli with serial presentation at fixation.

Mean recognition for non-verbal designs at fixation

The mean recognition of three designs presented at fixation at two presentation times is presented in Table 3. With no stimuli in the lateral half field, the mean recall for designs presented at fixation at the 330 msec. presentation time was 1.79 designs. With experience (same _Ss_, task repetitions), the mean recall increased to 2.03 designs recalled per trial. At 500 msec. and 40 trials (task repetition), mean design recall performance (same _Ss_) was only slightly improved. When compared to the verbal performance with letter stimuli at the same speed, this experiment suggested increased difficulty in the processing of non-verbal stimuli in immediate serial presentation. Future studies had to be modified in terms of this finding.

Experiment 2

The purpose of Experiment 2 was to assess differences in VHF recall with one design in the lateral VHFs and digits at fixation.

Table 3

Mean Recall for Non-verbal Designs at Fixation

N	Designs at Fixation	Designs in VHF	Time	Number of Trials	Mean Design Recall
6	3	0	500 msec.	40	2.08
10	3	0	330 msec.	20	1.79
10	3	0	330 msec.	40	2.03

Analysis of VHF mean differences for non-verbal design stimuli

The mean correct responses for non-verbal designs presented in the VHF with digits at fixation are presented in Table 4. At 330 msec. presentation time with 2 digits at fixation and 1 design presented to the VHF, performance of 4 of 5 subjects was without error on both the fixation and VHF stimuli. On this film one subject missed only one trial from each VHF, yielding a near perfect 97.5 overall mean percent correct. At the faster presentation time of 280 msec., performance in both VHFs was lower for the same number of trials. However, at the same 280 msec. speed with twice as many trials (16), performance on the second half of the trial was performed with a near perfect 15.6 mean correct. This performance rate in both VHFs raised the overall mean percent correct to 90.6 at the 280 msec. presentation time with 16 trials in each VHF. Performance on the last half of the trials at 280 msec. presentation time paralleled the near perfect performance at the slower 330 msec. presentation speed. This suggested that, with practice, even at the faster speed the task was not difficult enough to tap possible differences in the way non-verbal information was processed when presented to the left or right VHF.

Table 4

Mean Correct Responses for Non-verbal Design Stimuli
by VHF at Two Presentation Times with Digits at Fixation

Presentation Time	N	Number of Trials per VHF	Digits at Fixation	Designs in VHF	Left VHF Mean	Right VHF Mean	Overall Mean % Correct
330 msec.	5	8	2	1	7.8	7.8	97.5
280 msec.	5	8	2	1	6.8	6.6	83.8
280 msec.	5	16	2	1	14.5	14.5	90.6
330 msec.*	15	36	3	2	43.9	41.5	59.3

*From Study III for comparison.

Study III

Analysis of VHF mean differences for subjects presented both verbal and non-verbal stimuli

Verbal stimuli.--The purpose of this study was to determine whether the perception of recall of materials in each VHF varied as a function of the type of stimulus materials (verbal vs. non-verbal). Table 5 presents the VHF means and ANOVA of the VHF performance differences at the 330 msec. presentation time for the verbal letter task. Mean recall of letters presented to the LVHF was 32.33, while mean recall of letters presented to the RVHF was 43.20. The difference between mean letter recall in the two visual half fields was significant with a right field superiority for the recall of letters ($F = 34.743$, $df = 1,14$, $p \leq .001$).

Non-verbal design stimuli.--Table 5 also presents the VHF means and ANOVA of the VHF performance differences at the same 330 msec. presentation time for the non-verbal design stimuli (3 fixation digits, 2 VHF designs). Performance across trials showed a 59.3% overall mean percent correct (Table 4). Mean recall of designs presented to the LVHF was 43.87, while mean recall of designs presented to the RVHF was 41.47. The difference between mean design recall in the two visual half fields was significant with an LVHF superiority for recall of designs ($F = 4.965$, $df = 1,14$, $p \leq .05$).

Table 5

Analysis of Variance of Letter Recall by VHF

Source	SS	df	MS	F
Treatment	885.63	1	885.63	34.743*
Error	356.84	14	25.49	
Total	1242.47	15		

*p < .001 LVHF $\bar{X}$ = 32.33, RVHF $\bar{X}$ = 43.20

Analysis of Variance of
Non-verbal Design Recall by VHF

Source	SS	df	MS	F
Treatment	43.20	1	43.20	4.965*
Error	121.80	14	8.70	
Total	165.00	15		

*p < .05 LVHF $\bar{X}$ = 43.87, RVHF $\bar{X}$ = 41.47

The differences in mean correct recall by VHF and by different types of stimuli (verbal and non-verbal) were also reflected in the frequency of Ss showing higher RVHF correct recall scores with the verbal letter stimuli and showing higher LVHF correct recall scores with the non-verbal design stimuli.

Table 6 presents a chi square analysis of the VHF differences by films. With the verbal letter stimuli all 15 Ss showed an RVHF superiority of letter recall. With the non-verbal design stimuli, 12 of 15 Ss showed an LVHF superiority of recall for designs. The chi square test suggested a significant relationship between type of stimuli (letters and designs) and the VHF superiority of recall ($Z = 24.49489$, $df = 1$, $p \leq .001$).

An analysis of recall performance rank order data with both the verbal and non-verbal design stimuli is presented in Table 7. The relationship between rank order recall performances on the RVHFs was not significant ($t = .484$, $p \geq .05$), indicating that those Ss with the higher RVHF recall scores on the verbal stimuli did not have the higher RVHF recall scores with the non-verbal stimuli. Thus, ability at recall from the RVHF was significantly affected by the type of material presented in that VHF.

The relationship between rank order recall performances in the verbal RVHF and the non-verbal LVHF was significant ($t = 3.23$, $df = 13$, $p < .01$). Higher mean recall

Table 6

Chi Square Relationship Between Verbal and Non-verbal Stimuli and Frequency of VHF Superiority

		VHF Left	VHF Right	
STIMULI	Verbal letters	0	15	15
	Non-verbal designs	12	3	15
		12	18	30

$X^2 = 24.49489$, $p < .001$

Table 7

Spearman Rank Order Correlations Between VHF Performances with Verbal and Non-verbal Stimuli

		Verbal Letters LVHF	Verbal Letters RVHF
Non-verbal Designs	LVHF	.5884 ($p<.05$)	.6678 ($p<.01$)
	RVHF	.028 ($p>.05$)	.1331 ($p>.05$)

performance on the verbal RVHF stimuli appears significantly related to the LVHF performance level on the design stimuli.

The relationship between rank order recall performances in both the LVHFs also appeared significant ($t = 2.63$, $df = 13$, $p < .05$), indicating that those Ss who display the higher mean recall for verbal stimuli in the LVHF also displayed the higher mean recall for non-verbal stimuli in the LVHF.

However, the relationships between rank order recall performances in the verbal LVHF and the non-verbal RVHF was not significant ($t = 1.01$, $df = 13$, $p > .05$), indicating that Ss rank order performance on the verbal letters to the LVHF was not significantly related to the Ss rank order performance with designs presented to the RVHF.

VHF mean recall by serial position for non-verbal stimuli

The VHF mean recalls by serial position for non-verbal design stimuli are presented in Table 8 and in Figure 2. Mean recall of designs in both VHFs was highest for designs presented more recent in time (serial position 2) with both VHFs having lower mean recall for designs more remote in time. However, while recall of designs from serial position 2 was higher (7.33%) from the RVHF, recall from serial position 1 indicated an LVHF superiority (44.11%). On those trials where only one design was recalled there was a similar shift: an RVHF superiority (25.66%) when correct recall was limited to serial position 2; an LVHF superiority (103.63%)

Table 8

Mean Recall of Serial Position by VHF for Non-verbal Design Stimuli

	VHF	Serial Position 1	Serial Position 2	Correct Report for Serial Position 1 Only	Correct Report for Serial Position 2 Only	Position 1 and 2 Reported Together	1,2 Sequence of Report	2,1 Sequence of Report	Total Mean Recall
	Left	14.80	29.07	3.93	18.20	10.87	6.27	4.60	43.87
	Right	10.27	31.20	1.93	22.87	8.33	4.20	4.13	41.47
Superiority	% Right		7.33		25.66				
	% Left*	44.11		103.63		30.49	49.26	11.38	5.79

*Percent of left superiority determined by subtracting right score from the left, dividing by the right score and multiplying by 100.

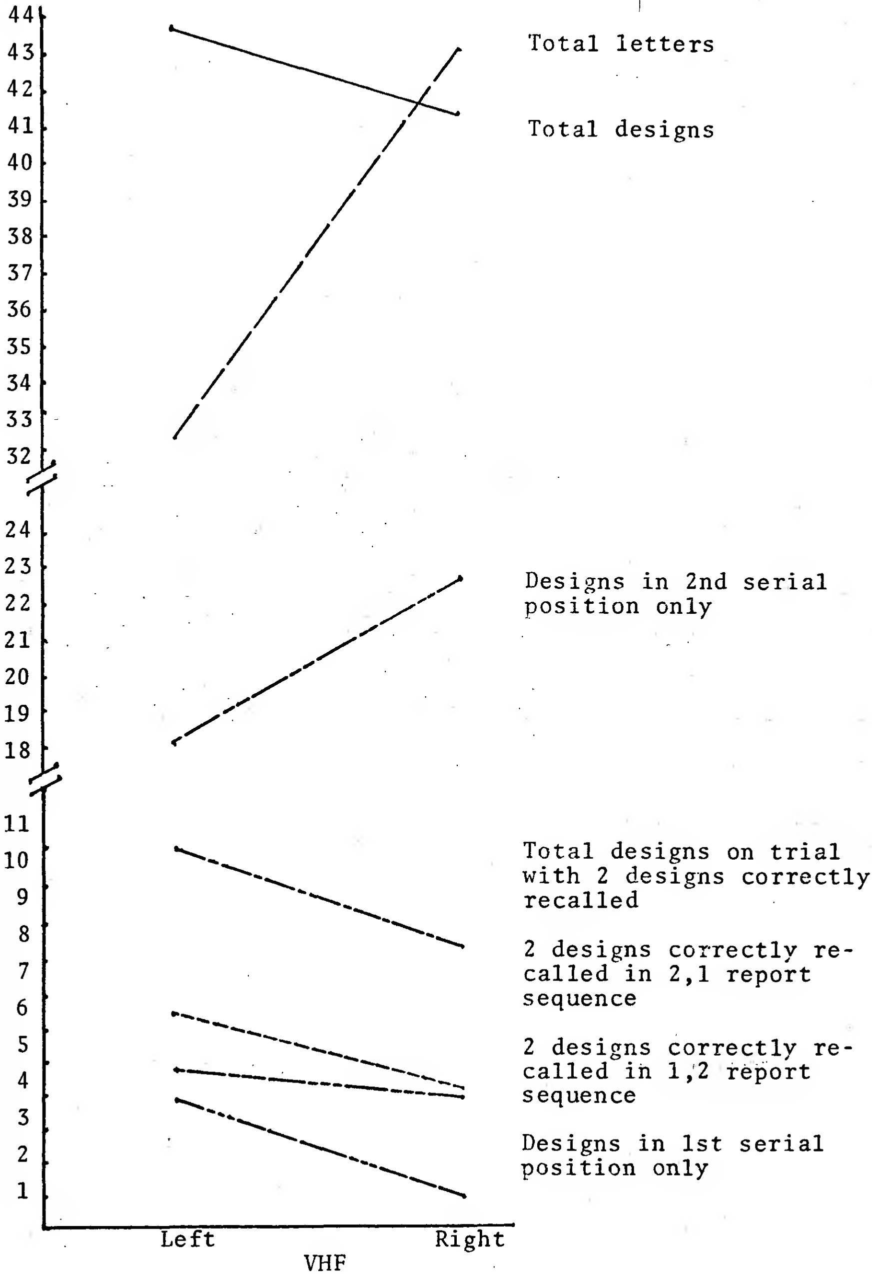


Figure 2. Mean correct stimuli recall.

when correct recall was limited to serial position 1, those designs more remote in time.

On those trials where two designs per trial were recalled, an LVHF superiority was demonstrated regardless of the sequence in which the two designs were reported. Trials with correct recall of two designs showed an LVHF superiority of 30.49%. Total mean recall also yielded an LVHF (5.79%) recall superiority.

VHF mean recall by serial position for verbal stimuli

The VHF mean recalls by serial position for verbal letter stimuli are presented in Table 9 and in Figure 2. Mean recall by serial position in both VHFs was lowest for the first letter, followed by a progressive increase in recall for the second, third, fourth and fifth letters. Recall was higher for letters presented to the RVHF regardless of serial position with an overall right VHF mean superiority of 33.8%. However, the percent of RVHF superiority was higher for those letter serial positions more remote in time.

Analysis of Errors of Report at Fixation

The purpose of this analysis was to determine whether those trials missed at fixation varied as a function of type of stimulus material and field of presentation. Missed trials were computed separately for each film (verbal and non-verbal) and a comparison was made to see whether fixation

Table 9

Mean Recall of Serial Position by VHF
for Verbal Letter Stimuli

	Letters						
VHF	1	2	3	4	5	1 to 4	1 to 5
Left	2.40	2.86	3.86	5.67	17.53	14.80	32.33
Right	4.53	5.00	5.13	9.60	18.93	24.27	43.27
% of Right Superiority	88.9	74.4	32.8	69.4	8.0	63.9	33.8

errors varied as a function of the VHF in which the different stimulus materials were presented.

Errors at fixation for Ss presented both verbal and non-verbal design stimuli are presented in Table 10. With the verbal letter stimuli there were significantly ($p < .05$) more errors in the report of the fixation stimuli when the simultaneous VHF verbal stimuli were presented in the LVHF. By contrast, more errors occurred in the report of fixation stimuli on the non-verbal trials when the simultaneous VHF non-verbal design stimuli were presented in the RVHF.

Table 10

Analysis of Errors of Report at Fixation
by Material and Field of Presentation

		Simultaneous VHF Presentations	
		LVHF	RVHF
Verbal Trials	Errors at fixation	72	54
	(S mean)	$\overline{X} = 4.80$	$\overline{X} = 3.60$*
Non-verbal Trials	Errors at fixation	15	16

*Significant at $p < .05$.

DISCUSSION

The present research was addressed to three major issues. First (Study I), the development of a new verbal task (Type III paradigm) with letters at fixation and in the VHF. Previous studies with the Type III paradigm (Hines, 1968; Hines and Satz, 1971; Hines, 1973) had demonstrated the methodological advantages of employing this controlled fixation paradigm in the assessment of differences in VHF performance. Study I sought to assess the methodological reliability of the verbal Type III paradigm as well as to evaluate criticism of the use of digit stimuli in previous Type III studies.

The second major issue (Study II) addressed in this present research was the development of a non-verbal analogue (VHF design stimuli) employing the Type III paradigm. A series of design stimuli with no reliable verbal labels (pilot studies) were produced. Further, Study II sought to evaluate the appropriate conditions under which the design stimuli could be used to develop a non-verbal Type III task.

The third issue (Study III) addressed the assessment of the effect of type of stimulus material (verbal and non-verbal) on VHF asymmetry (within Ss). Subjects were administered both the verbal and non-verbal films previously developed (Study I and Study II) in order to assess whether the VHF asymmetry varied as a function of type of stimulus material and VHF of presentation.

Study I

Results from Study I confirm the previously reported RVHF recall superiority on a verbal STM task (Hines, Satz, Schell and Schmidlin, 1969; Hines and Satz, 1971) with fixed order of report and extend the findings to letter stimuli with increased demands upon recall.

The magnitude of the RVHF asymmetry with letter stimuli was greater than in previous Type III studies using digit stimuli (Hines and Satz, 1971). For example, in the combined conditions, Ss recalled 33% more from the RVHF with the letter trials as compared with 21% more from the RVHF when the seven-digit trials were employed (Hines and Satz, 1971).

The increased magnitude of the RVHF asymmetry with letter stimuli was also reflected in the frequency with which Ss recalled more letters from this VHF. Twenty-eight of the thirty Ss (93%) in the combined 165 msec. and 330 msec. conditions (Study I) recalled more letters from the RVHF. Ninety-seven percent (97%) of the Ss in the combined 330 msec. conditions (Study I and Study III) recalled more letters from the RVHF. A lower frequency of RVHF superiority was found in all previous studies using the seven-digit trials (Hines, Satz, Schell and Schmidlin, 1969; Hines and Satz, 1971).

The overall mean percent recall (16.6%) was considerably lower than that found in previous studies (33.5%) using fewer digit stimuli within each trial sequence (Hines and Satz, 1971). However, while the larger number of letter stimuli within trials increased the mnemonic demands of the task, the magnitude of the VHF asymmetry also increased. This effect is similar to that found with the Dichotic Listening Test (Satz, 1967).

Decreasing presentation time without altering interstimulus interval had little effect upon either recall efficiency or the VHF asymmetry. This suggests that perceptual factors (forming an iconic image) at these slow speeds are not responsible for the RVHF asymmetry. Haber (1970) has previously shown that, across a wide range of stimulus durations (4 msec. to 200^{+} msec.), the duration of iconic images appears independent of the duration of the original stimulus. The effective duration of all such flashes, regardless of the actual physical stimulus duration, has been shown to be in the range of 200-250 msec. (Haber, 1970). Thus, decreasing the presentation time (165 msec.) without altering the interstimulus interval (330 msec.) would not alter the effective length of each stimulus' iconic image and thus, as shown, would be expected to have little effect on the VHF asymmetry. Decreasing the presentation time (280 msec.)

allowed less time to process the iconic images into short-term memory (STM) before disruption by the subsequent stimulus, i.e., the stimulus duration more nearly equaled the upper limits of dark adapted iconic image formation. Both recall efficiency and the VHF asymmetry decreased as backward masking increased.

Serial position effects further reflect the role of STM factors in the RVHF recall superiority. While mean recall from each serial position was greater from the RVHF, the magnitude of the RVHF asymmetry was greatest for those letter stimuli most remote in time. This finding is consistent with previous reports using the controlled fixation paradigm with digit stimuli (Hines and Satz, 1971) and again suggests the role of central mediating factors in this type of VHF asymmetry task (Type III paradigm).

Study II

Results from Study II suggest that Ss had more difficulty in the processing of unfamiliar non-verbal stimuli (designs) in immediate serial presentation than in processing verbal stimuli (letters) presented in the same manner. Neither practice nor decrease in the rate of presentation (Experiment I) had a significant effect upon increasing mean correct non-verbal recognition from fixation (e.g., two designs). Designs that pilot Ss had suggested to be more complex than letter stimuli had been eliminated from the experimental designs. Yet, mean design recognition from fixation was inferior to recall of the verbal stimuli (86% of verbal trials had correct recall of five fixation letters plus one VHF letter) at the same presentation speeds.

The demonstration of a VHF asymmetry with the design stimuli appeared to be considerably affected by the task difficulty. Data from Experiment I (Study II) had suggested that using designs in the VHF while maintaining designs also at fixation would have exceeded the limits of the recognition of non-verbal designs at these speeds. Thus, with designs in the VHF, digits were employed at fixation. With only one VHF design and fixation digits, high recall performance levels in both VHFs indicate that the task was not difficult enough to produce a VHF asymmetry. However, with only one VHF design but at a much faster presentation rate (modified Type III paradigm), McKeever and Gill (1972) had demonstrated a LVHF asymmetry. In the present study, in order to keep the presentation rate consistent with that used in the verbal studies (Study I, 330 msec.) and yet increase the task difficulty, the number of fixation digits and VHF designs was increased. Increasing the recall demands of the design task lowered the overall mean percent correct and produced a significant LVHF recall superiority (Study III).

Study III

The major test of hemispheric mechanisms underlying performance on these VHF tasks was demonstrated in Study III.

The results showed a consistent double dissociation: the asymmetries in VHF performances varied as a function of the type of stimulus materials. Verbal stimuli (letters) presented to the RVHF were recalled better than from the LVHF and conversely, non-verbal stimuli (designs) were recognized better when presented to the LVHF than to the RVHF. The within Ss experimental control is the strongest evidence that the dual asymmetries are a function of the type of stimulus material.

Letter stimuli.--Results from Study III replicate the findings of Study I in demonstrating a RVHF recall superiority with verbal letter stimuli and buttress the reliability of this effect across Ss. The increased frequency of occurrence of the RVHF asymmetry in Study III (15/15) suggests that the reduced frequency (39/45) observed in Study I may have been in part due to the reliance on the self-report of Ss handedness. The differences in these frequencies suggest the importance of controlling the unreliability of handedness self-report (Satz, Fennell and Jones, 1969) as in Study III in experiments from which inferences about hemispheric dominance are to be drawn. Replication of serial order effects were also observed; that is, those letters most remote in time produced the greatest VHF asymmetry.

Design stimuli.--Results from Study III with non-verbal design stimuli suggest that hemispheric mechanisms probably underlie the superior recognition of the LVHF input; that is, right hemispheric analyzers may be more specialized for this type of visual-spatial analysis of stimuli with no familiar verbal labels. This interpretation is compatible with the results of multiple clinical studies of unilateral brain injury in humans.

Although digits were employed as fixation stimuli on the non-verbal task, it appears unlikely that the LVHF asymmetry is a function of the fixation stimuli. Earlier studies (Hines, 1968) employed more digits at fixation and produced an RVHF asymmetry with digits in the lateral half fields. In the present study there were fewer digits at fixation and one would expect a similar RVHF asymmetry on this easier task if the fixation stimuli were responsible for the asymmetry. The finding of the LVHF asymmetry is contrary to this expectation and alternatively is most parsimoniously explained in terms of the hemispheric differences in the processing of the design stimulus material. Such an interpretation is consistent with the findings of a LVHF superiority with non-verbal stimuli observed by Fontenot (1973) using a Type II paradigm and by Schell (1970) using a Type III paradigm with block designs.

Analysis of serial position data suggests that the sequence of the design identification (always subsequent to correct recall of fixation stimuli) altered the direction of the LVHF asymmetry only when identification was limited to the second stimulus. The occurrence of an RVHF superiority when recall was only from the second serial position (most recent) suggests that at this slow presentation speed directional scanning may take place on the terminal stimulus in a trial sequence. Such an interpretation is consistent with the most typical finding (Hines and Satz, 1971a; McKeever and Huling, 1971; Parker, 1973) of less asymmetry in the terminal serial position with verbal stimuli. Nevertheless, recall of the most remote design stimulus, either alone or with the second stimulus, produced a consistent LVHF asymmetry and suggests that it was the mnemonic processing of the more remote design stimulus that produced the LVHF effect. Stimuli in the LVHF are transmitted via crossed and uncrossed pathways most directly to the spatial processing centers in the right hemisphere. It has already been shown that impairment in right hemisphere functioning specifically impairs mnemonic processing of spatial configural patterns (Goodglass and Peck, 1972).

The preceding LVHF effect for non-verbal designs represents a successful demonstration of the special role of the right hemispheric analyzers in the processing of spatial configural patterns. Previous attempts at such an LVHF have either failed to produce the effect (Hines, 1973b) or have remained unreplicated. For example, the LVHF asymmetry reported by Kimura (1966) has resisted several attempts at replication. The more recent studies by Schell (1970), Fontenot (1973), and Geffen, Bradshaw and Nettleton (1972) have yet to be reported as replicated.

The present LVHF effect is particularly strengthened by the reversal in the VHF superiority when verbal stimuli (letters) are employed. Further, recent evidence suggests that the most common failure of previous studies to produce this LVHF effect may result from the choice of experimental stimuli with which to investigate this effect. This suggestion is consistent with previous studies that have demonstrated smaller RVHF asymmetries with less codeable stimuli (Bryden and Rainey, 1963) and suggest a major source of difficulty in previous studies that have failed to demonstrate an LVHF superiority with "non-verbal" stimuli.

The present non-verbal stimuli were modifications and extensions of tactile stimuli previously used to assess spatial configural deficits in right hemisphere injured patients (Butters, Barton and Brody, 1970). As such, the stimuli are considerably less complex than those used by Fontenot (1973) and yet do not have the limitations of the Hines (1973b) stimuli which produced no VHF differences at a much faster presentation rate. Subjects' descriptions of the Hines (1973b) stimuli as "blobs" apparently indicated that the designs were not easily seen as dissimilar. The lack of easily identifiable distinguishable characteristics at the fast presentation rate employed may have severely limited this previous attempt to demonstrate an LVHF asymmetry with design stimuli.

The lack of consistency in the LVHF asymmetry across Ss (12/15) produced with the present stimuli suggest the difficulty in generating a set of simple stimuli which maintain low codeability or association value across Ss. The report by one S that one design looked like "a Hebrew letter upside down" suggests the S's associative skills that make truly non-verbal stimuli difficult to generate. The advantage of this paradigm (Type III) as developed in this research is the consistency of the RVHF verbal asymmetry (15/15) with pre-selected dextral Ss against which to compare non-verbal effects.

Analysis of the rank order correlations between VHF performances on the two tasks (verbal and non-verbal) suggests additional findings which may indicate how the processing of verbal and non-verbal stimuli is related. The lack of significant correlations between the two RVHF performances suggests that performances on the two tasks are not mediated by a single process and therefore not explainable simply in terms of different levels of verbal coding.

While there is no significant correlation between the RVHF performances, LVHF performances are significantly related. This difference may result from the ability to process both types of stimuli (letters and designs) spatially in the right hemisphere but an inability to process both types of stimuli verbally in the left hemisphere. The increased significance in the RVHF verbal and the LVHF non-verbal correlation suggests that the verbal processing of the left hemisphere may be a specialization of the processing of specific spatial familiar stimuli called verbal stimuli. The non-significant relationship between verbal performance in the LVHF and non-verbal performance in the RVHF suggests that the dual VHF asymmetries demonstrated in this present study do not result from the activation of only one visual processing system. Instead, while there appears to be a common spatial processing facility that is at different levels for individual Ss across stimuli types, this common facility is overridden by the shift in VHF superiority as a result of the type of stimulus material. Indeed, VHF performances appear related most significantly to the specific stimuli being projected to the hemisphere primarily subserving processing of that type of stimuli; i.e., when the non-verbal stimuli are projected to the right hemisphere and the verbal stimuli are projected to the left hemisphere.

In addition, recent research with reaction times (Geffen, Bradshaw and Nettleton, 1972) suggests that the type of task may be as important in the demonstration of hemispheric asymmetry as the type of stimulus material. Geffen, Bradshaw and Nettleton (1972) found faster processing of physically identical stimuli (letters) on a task of spatial comparisons (physical identity) when directed to the right hemisphere. Alternatively, they found faster processing of stimuli with the same name (letters) on a task of verbal label comparison when the stimuli were directed to the left hemisphere. While these results are confounded by the limits of the Type I paradigm previously discussed, they are instructive in cautioning against interpretation of the present results entirely in terms of the types of stimuli material. The differential processing of the specific types of stimuli material appears to play a major role in the asymmetries produced. The present research was directed toward developing a reliable methodology for assessing these asymmetries. Further studies will have to be developed to address the contributions of the type of task (e.g., physical identity) upon the asymmetries demonstrated in the Type III paradigm.

The finding of the double dissociation demonstrated in Study III bears further scrutiny as it raises serious issue with a prominent hypothesis of functional cortical asymmetry. In particular, the attentional hypothesis of Kinsbourne (1970) suggests that concurrent verbal activities bias attentional mechanisms in such a way as to produce an RVHF asymmetry independent of the type of stimulus material employed. The attentional hypothesis suggests that if an S is engaged in language behavior prior or during a test trial a left hemispheric activation will take place and that accompanying that activation would be a directional bias to the RVHF regardless of the type of stimulus material (verbal or non-verbal). This hypothesis suggests that such an orientation would characterize "not only overt language use, but also covert (subvocal) language behavior including the state of expectancy to verbal response" (Kinsbourne, 1970). Initial support for this hypothesis (Kinsbourne, 1970) had inadequate control of fixation and recent evidence with the controlled fixation paradigm (Type III) has been discrepant with the attentional hypothesis and earlier results. Schell (1970), for example, demonstrated an LVHF asymmetry in the presence of concurrent verbal activity.

The present results are consistent with the findings of Schell (1970) in demonstrating an LVHF asymmetry that was produced with five concurrent verbal activities. First, the instructions for the design film were verbal and immediately prior to the film presentation. Second, presentation of the verbal film always preceded the non-verbal film in a single experimental session. Third, fixation stimuli on the non-verbal film were digit stimuli which previously had been shown to produce an RVHF asymmetry when presented in the lateral VHFs. Fourth, the digit fixation stimuli had to be attended to during and after the presentation of the non-verbal stimuli. And fifth, verbal report of the fixation stimuli immediately preceded identification of the non-verbal stimuli.

Nevertheless, with this concurrent verbal activity the non-verbal design film produced a significant LVHF recall superiority. This asymmetry and its strength as measured by the number of Ss who exhibited the asymmetry (12/15) appear inconsistent with the attentional hypothesis and appear more parsimoniously explained in terms of central hemispheric processes.

Further, the attentional hypothesis suggests that attentional mechamisms are involuntarily directed toward the VHF (or ear) contralateral to the hemisphere dominant for the class of stimuli (verbal or non-verbal) presented. However, analysis of the errors at fixation on both the verbal and non-verbal films suggests results at variance with this hypothesis. Errors at fixation occurred most often on those trials in which the class of stimuli were being projected to the hemisphere not dominant for that class of stimuli. Indeed, since performance on the fixation tasks was overall at such a high mean percent correct the distribution of the errors at fixation suggests that they were not simply a function of the task difficulty. Rather, the distribution of fixation errors suggests that attention to the fixation stimuli was most often interrupted when Ss tried to compensate for the fact that the VHF stimuli were not being projected to the hemisphere where they could be most readily processed. The attentional hypothesis would have predicted the opposite distribution.

Despite the methodological and evaluative advantages in the control fixation paradigm (Type III), the present results pose a number of unanswered questions. First, to what extent are the VHF asymmetries demonstrated in the present research a function of perceptual or mnemonic factors? While this question is unanswered, it is striking that on both the verbal and non-verbal tasks the stimulus most remote in time produced the largest percent of VHF superiority. Any argument that the asymmetries are a function of perceptual factors would have to account for the fact that the stimulus durations are more than eleven times longer than those used by Fontenot (1973) in his modified Type III study. Further, Haber's (1970) findings of successful stimulus recognition at presentation rates down to four msec. suggests that the present results can best be understood not in terms of perception but in terms of differential abilities to <u>hold</u> the stimulus.

Conclusions as to the differential laterality of mnemonic functions processing of design stimuli are not without previous clinical and experimental evidence. For example, in the processing of non-verbal information, Milner (1968) concluded that, indeed, right temporal lobe lesions affect both mnemonic and perceptual factors but that the perceptual changes are very difficult to elicit. Wilson (1968) has also suggested that both spatial configural memory and perception are right hemisphere mediated processes. Iwan and Mishkin (1969) have further shown that, indeed, the primary focus of pattern discrimination is in the right hemisphere. Such studies are consistent with hypotheses of functional asymmetry that suggest the LVHF design recall is a function of the more effective processing in the right hemisphere.

Second, while mnemonic processes are implicated, to what extent is the procedure itself a recognition or recall task? Clearly, it is a recall task in that the VHF report is delayed beyond correct report of the intervening fixation stimuli (fixed order of report). It is also the recall demands from the more remote serial position which produced the LVHF asymmetry. On the other hand, identification of design stimuli is essentially a delayed recognition task in that Ss choose from a visual display. The present data do not resolve this issue. However, the development of the Type III paradigm presents a good place to begin to separate the effects of recall and recognition parameters on the VHF asymmetries observed in this type of task.

Third, to what extent are the design stimuli developed in the present study indeed "non-verbal"? While this question is unanswered, results from a replication study in the process of data analysis suggest that this Type III paradigm provides the first replicated demonstration of the double dissociation in VHF asymmetries. The replicability of the paradigm will allow further studies to tease out the relationships between the non-verbalness of the designs and the procedural tasks (e.g., recognition).

The primary significance of this present study lies in its replication of the Type III paradigm with letter stimuli and the extension of the control fixation paradigm to non-verbal design stimuli. As such, the present study provides a contribution in the development of a new visual paradigm for studying central mechanisms in the processing of visual stimuli. The Type III paradigm provides a methodology with which to tease out central effects while controlling for the limitations of the Type I and Type II paradigms previously discussed. The present research is the first control fixation study that has demonstrated significant differences in VHF recall superiority as a function of type of stimulus material. Replication (verbal stimuli) and extension (non-verbal stimuli) of the control fixation paradigm makes a particular methodological contribution in that this paradigm has previously been shown to correlate with the Dichotic Listening Test whereas previous tachistoscopic studies (Type I and Type II) have not (Bryden, 1967). The present data suggest that this extended control fixation paradigm may yield a sensitive behavioral index of functional hemispheric differences in normal human adults.

Further studies employing this present methodology may be addressed to parameters of VHF asymmetries associated with specific differences in the type of stimulus material and in the type of procedural task. Some specific studies are proposed:

1) a replication of Study III with a larger group of dextral <u>Ss</u> to assess the effects of handedness and familial right-handedness upon VHF recall asymmetries.

2) a replication of Study III with the non-verbal film preceding the verbal film to assess the effects of fatigue and attentional set on the non-verbal task performance in the present study.

3) a replication of Study III with sinistral Ss to assess the effects of handedness and familiar left-handedness on VHF performance.

4) the presentation of both verbal and non-verbal films with slower presentation times and varied intrastimulus intervals to assess the relationship between stimulus duration, iconic imagery, and VHF asymmetry.

5) the development of a new film in which similar verbal and non-verbal trials are presented in a random fashion in order to further control attentional set.

6) the development of another film with four letters at fixation and three letters in the lateral VHFs in order to compare the effects of letter stimuli independent of the increased STM demands in the present non-verbal film.

7) the development of a similar non-verbal design film using as stimuli the designs used by Fontenot (1973) with tachistoscopic presentation. Such a film would offer the possibility of replicability independent of the particular stimuli used in the present study and would provide a means of evaluating VHF asymmetry in terms of stimuli codeability.

APPENDIX 1

VERBAL STIMULI IN VHF AND AT FIXATION, STUDY I AND STUDY III

Subject #

Name ____________________
Handedness: ______________

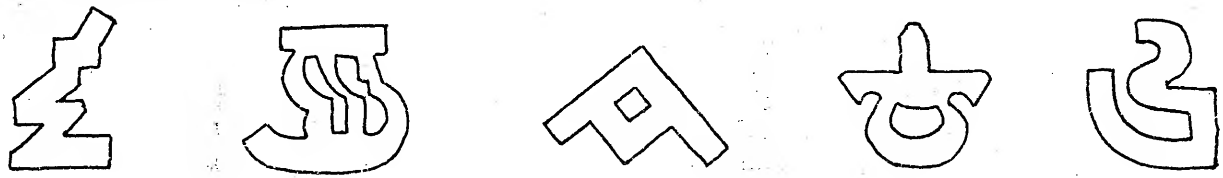
VHF	Trial	Fixation	VHF
L	1	DBJGI	RFACL
R	2	RZMOH	XDLUN
L	3	CPUSW	XRASL
R	4	DPJGI	RFACL
L	5	RZLOH	XDMUN
R	6	CPUSW	XRAFL
L	1	KNQYE	WTBSV
R	2	EVNKY	JIQZD
L	3	EWRMY	QPGJB
R	4	TFIGK	HCAUZ
L	5	SXODM	LTEKV
R	6	PJGOH	BSXUZ
L	7	AYCWF	IRNBT
R	8	TFGOP	RCNBI
L	9	XATDF	HLUWY
R	10	MEZTR	VQRGA
L	11	NISDF	GUZHB
R	12	XKVEW	TNOCJ
L	13	BAZTY	KDIUM
R	14	HGEPL	CQSXR
L	15	NPYSO	LWKJB
R	16	KNQYE	WTBSV
L	17	EVNKY	JIQZD
R	18	EWRMY	QPGJB
L	19	TFIGK	HCAUZ

VHF	Trial	Fixation	VHF	VHF	Trial	Fixation	VHF
R	20	SXODM	LTEKV	R	44	HGEPL	CQSXR
L	21	PJGOH	BSXUZ	L	45	NPYSO	LWKJB
R	22	AYCWF	IRNBT	R	46	KNQYE	WTBSV
L	23	TFGOP	RCNBI	L	47	EVNKY	JIQZD
R	24	XATDF	HLUWY	R	48	EWRMY	QPGJB
L	25	MEZTR	VQRGA	L	49	TFIGK	HCAUZ
R	26	NISDF	GUZHB	R	50	SXODM	LTEKV
L	27	XKVEW	TNOCJ	L	51	PJGOH	BSXUZ
R	28	BAZTY	KDIUM	R	52	AYCWF	IRNBT
L	29	HGEPL	CQSXR	L	53	TFGOP	RCNBI
R	30	NPYSO	LWKJB	R	54	XATDF	HLUWY
L	31	KNQYE	WTBSV	L	55	MEZTR	VQRGA
R	32	EVNKY	JIQZD	R	56	NISDF	GUZHB
L	33	EWRMY	QPGJB	L	57	XKVEW	TNOCJ
R	34	TFIGK	HCAUZ	R	58	BAZTY	KDIUM
L	35	SXODM	LTEKV	L	59	HGEPL	CQSXR
R	36	PJGOH	BSXUZ	R	60	NPYSO	LWKJB
L	37	AYCWF	IRNBT				
R	38	TFGOP	RCNBI				
L	39	XATDF	HLUWY				
R	40	MEZTR	VQRGA				
L	41	NISDF	GUZHB				
R	42	XKVEW	TNOCJ				
L	43	BAZTY	KDIUM				

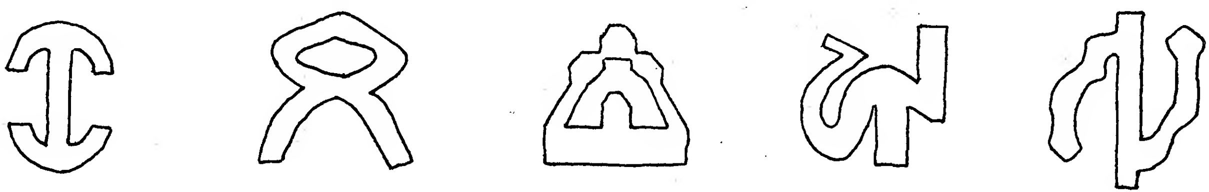
APPENDIX 2

NON-VERBAL DESIGN RECOGNITION DISPLAY,
STUDY II, EXPERIMENT 1

Recognition Display Number 17



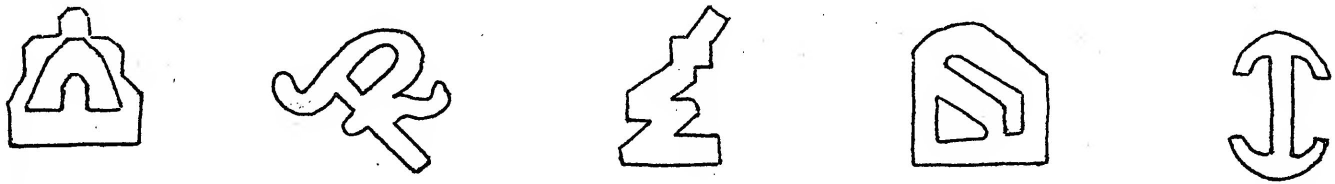
Recognition Display Number 18



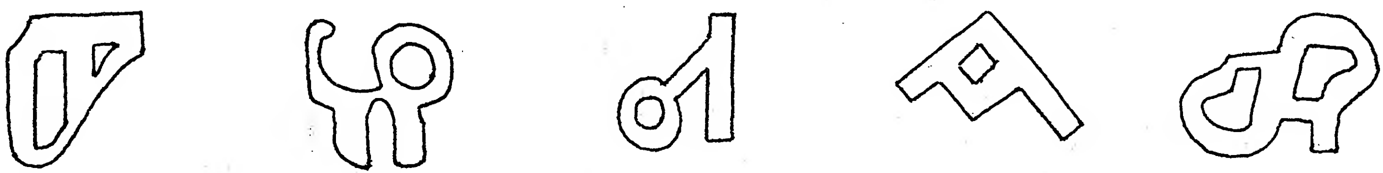
APPENDIX 3

NON-VERBAL DESIGN RECOGNITION DISPLAY,
STUDY II, EXPERIMENT 2, AND STUDY III

Number 17



Number 18



APPENDIX 4

NON-VERBAL DESIGN AND FIXATION DIGIT ANSWER SHEET

Trial	Fixation	Design	VHF	Trial	Fixation	Design	VHF
1	$\overline{724}$	$\overline{14}$	R	19	$\overline{390}$	$\overline{13}$	R
2	$\overline{390}$	$\overline{13}$	L	20	$\overline{172}$	$\overline{53}$	L
3	$\overline{172}$	$\overline{53}$	R	21	$\overline{286}$	$\overline{14}$	R
4	$\overline{286}$	$\overline{14}$	L	22	$\overline{750}$	$\overline{31}$	L
5	$\overline{750}$	$\overline{31}$	R	23	$\overline{549}$	$\overline{13}$	R
6	$\overline{549}$	$\overline{13}$	L	24	$\overline{493}$	$\overline{53}$	L
7	$\overline{493}$	$\overline{53}$	R	25	$\overline{628}$	$\overline{45}$	R
8	$\overline{628}$	$\overline{45}$	L	26	$\overline{135}$	$\overline{53}$	L
9	$\overline{135}$	$\overline{53}$	R	27	$\overline{642}$	$\overline{25}$	R
10	$\overline{642}$	$\overline{25}$	L	28	$\overline{873}$	$\overline{23}$	L
11	$\overline{873}$	$\overline{23}$	R	29	$\overline{065}$	$\overline{42}$	R
12	$\overline{065}$	$\overline{42}$	L	30	$\overline{682}$	$\overline{24}$	L
13	$\overline{682}$	$\overline{24}$	R	31	$\overline{537}$	$\overline{13}$	R
14	$\overline{537}$	$\overline{13}$	L	32	$\overline{410}$	$\overline{24}$	L
15	$\overline{410}$	$\overline{42}$	R	33	$\overline{916}$	$\overline{14}$	R
16	$\overline{916}$	$\overline{14}$	L	34	$\overline{164}$	$\overline{25}$	L
17	$\overline{164}$	$\overline{25}$	R	35	$\overline{293}$	$\overline{53}$	R
18	$\overline{293}$	$\overline{53}$	L	36	$\overline{724}$	$\overline{14}$	L

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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