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Matos, William Douglas, Ph.D.

City University of New York, 1991

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Visual Hemifield Asymmetries in Analytic Versus Holistic Processing

By

William D. Matos

A dissertation submitted to the Graduate Faculty in Psychology in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York.

1991

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Abstract

Visual Hemifield Asymmetries in Analytic Versus Holistic Processing

By

William D. Matos

Advisor: Professor Tina Moreau

The role of instructional set - to identify the gestalt, overall configurations or to identify the elements of the configurations - in visual hemifield asymmetries for the processing of patterned dot stimuli presented at each of five visual field loci (far left, near left, central, near right and far right) was investigated. The direction and degree of lateralized cerebral processing of these stimuli was assessed via accuracy and reaction time measures.

The 16 right handed men were administered a shape judgment (holistic) task followed by a dot enumeration (analytic) task, or vice versa. A trial for each task consisted of (1) assessment of whether the vernier lines (fixation task) were aligned or misaligned, and (2) determination of the shape or number of dots comprising the shape via a keypress response made with either the left or right hand.

The data were subjected to four ANOVAs for each of the two response measures. The initial analyses showed that responses to stimuli presented at the CVF were more accurate than to those presented in both the LVF and the RVF; reaction times to CVF stimuli were faster than to stimuli presented in the far left visual field. Further analyses showed that shape judgments were more accurate and faster than those of dot enumeration, responses to stimuli presented in the RVF were faster than responses to LVF stimuli, and reaction times to near field stimuli were faster than to far field stimuli. For shape judgments, responses were more accurate to RVF than to LVF stimuli, a relationship that was dependent on task order, and responses were more accurate and faster to near than to far loci stimuli. For the dot enumeration task, accuracy differences between the visual fields were dependent upon the responding hand and the task order. Other significant interactions were observed as functions of task (instructions), visual hemifield, responding hand and task order.

The results are discussed in terms of models of hemispheric functioning, the role of spatial frequency of the stimulus, subject strategies and procedural manipulations.

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Lastly, I would like to thank my sponsor, Dr. Tina Moreau, who was there before I had asked, who provided intellectual stimulation, and who offered encouragement and support. It is for these reasons that...

this work is dedicated to

Tina Moreau, Ph.D.

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Introduction

This study examined the visual hemifield asymmetries associated with two different tasks, both involving identical dot outlined forms. One task required a holistic judgment of the shape of each stimulus and the other required the enumeration of its separate elements. The requirments of these tasks were viewed as tapping global/holistic and local/analytic processing, respectively (Kietzman, 1989; Mikitish, 1985). With stimuli held constant for the two tasks, and measuring both reaction time and accuracy, it was predicted that left visual field/right hemisphere (LVF/RH) processing would be dominant for the global task and right visual field/left hemisphere (RVF/LH) processing for the analytic task. It has been shown by a number of researchers (e.g., Morais & Ben Dror, 1985; Nichelli, Manni & Faglioni, 1983; Umilta, Bagnara & Simion, 1978) that judgments requiring gestalt closure or those that require judgments based upon the configurational aspect of the stimulus elicit a LVF/RH advantage. The results of studies of visual dot enumeration (e.g., Boles, 1986; Ohtani, 1985; Sheehan & Smith, 1986; Voglmaier & Bruder, 1990) have shown either a LVF/RH advantage or no visual field differences when the task required the enumeration of random dot forms. One purpose of the present study was to ascertain whether enumeration of the local elements (dots) comprising a configuration would elicit a RVF/LH advantage.

Also examined in this study were the effects of visual field asymmetries of stimulus eccentricity (distance from the center of the visual field in left and right directions) and responding hand. The eccentricity of the visual stimulus was thought to affect the degree of high and low spatial frequency components, with greater degradation of the higher spatial frequencies at eccentricities farther from the center of the visual field (Christman, 1987; Hellige, Corwin & Jonsson, 1984; Sergent, 1983). Additionally, it has been suggested that LVF/RH processing would be less affected by stimulus degradation than RVF/LH processing (Christman, 1987, 1989).

The responding hand was investigated to ascertain whether either or both tasks would be performed with greater accuracy or faster reaction time with the left or right hand, and to assess stimulus - response compatibility.

The study to be described grew out of recent interest in visual field asymmetry using materials other than the verbal-nonverbal stimuli which had been an early basis for such interest. Curiosity about hemispheric differences in processing and attempts to examine experimentally the exact nature of asymmetries have a long and varied history. The following sections summarize selected studies of hemispheric and field laterality effects as related to the holistic/analytic dichotomy.

Historical Background: Functional Hemispheric Asymmetry

More than two millenia ago, the human cerebral cortex was thought to be divided into centers which controlled particular aspects of functioning. For example, the Hippocratic writers (ca. 400 B.C.) considered the brain to be a symmetrical organ such that damage "...to one temple produces a spasm in the opposite side of the body..." (Sarno, 1981). Later, Gall and Spurzheim (ca. 1796) reinforced the notion of brain localization of function by "defining" each part of the brain as dominant for a discrete function. Bouillard (1825, cited in Walsh, 1978) provided further evidence of brain localization of function in his report of a correlation between language disturbances and damage to the frontal lobes.

Beginning with Dax in 1836 (cited in Sarno, 1981), studies of functional deficits in unilaterally brain damaged patients led to the widely held contention that the left hemisphere is the dominant hemisphere for most, if not all, language functions as well as for other higher cognitive functions. The right hemisphere was considered the minor/silent and, perhaps, dispensable hemisphere in that it played no role in any aspect of language functioning nor in any other higher cognitive function. The "dominance" of the left over the right hemisphere was to be found only in right handers; left handers were seen as having the reverse asymmetry and, for this group, the right hemisphere was held to be "dominant". The notion of "cerebral dominance" (left hemisphere in 90% of the population) was supported by the findings of Broca (1861, cited in Walsh, 1978) who observed the connection between damage to the left frontal lobe, particularly the posterior portion of the third frontal convolution, and "aphemia" or aphasia in post mortem examination of right handed stroke patients. Similarly, Wernicke (1874, cited in Springer & Deutsch, 1981) found a loss of comprehension of speech (sensory aphasia) in patients with damage to the superior temporal gyrus of the left hemisphere. Wernicke's finding was particularly important in suggesting that areas other than the frontal cortex might be involved in language function.

Other investigators, such as Flourens (ca. 1800, cited in Sarno, 1981) and Jackson (1878, cited in

Springer & Deutsch, 1981), argued against the strict, localizationist, hemispheric dichotomy, and proposed that the cortex functions as a whole. The argument continued that, with the left hemisphere dominant for certain aspects of language, the right hemisphere has a role in language functioning as well as in perception. Thus, the right hemisphere of right handers was not merely the "minor" or "silent" hemisphere, but rather was differentially specialized for perceptual functions and for certain aspects of language. However, it was not until the mid twentieth century that the views of Jackson were accepted into the mainstream scientific community. The important work of Goldstein (1959), Hecaen (1969), Milner (1971) and Zangwill (1961) with neurologically damaged patients in the 1950's and early 1960's, led to a conceptual shift away from the notion of cerebral dominance to that of cerebral/hemispheric specialization. According to the contemporary view of cerebral asymmetry, the two hemispheres are differentially specialized for different cognitive functions. Thus, cerebral specialization and complementarity of function, i.e., differing degrees or levels of competency for the processing of information by each cerebral hemisphere, came to be seen as the operating principles of the left and right hemispheres. Benson (1985), for example, in a review of the literature, described the two hemispheres as capable of, and participating in, gestural and prosodic language. In contrast, melody of prosodic language was primarily a function of the right hemisphere. In regard to the semantics of language, the left hemisphere was said to be more proficient at verbal meanings, both hemispheres were noted to process concepts within a linguistic structure, and the right hemisphere was noted to be better at associating visual images with linguistic meaning. Syntactic language, on the other hand, was seen to be primarily related to the functioning of the left hemisphere.

A revision of the historical dichotomy was then attempted by a number of investigators, who provided explanations and empirical evidence to elucidate the general underlying principles of functioning of the left and right cerebral hemispheres. The verbal/nonverbal model of Kimura (1961, 1966) considers the left hemisphere to be uniquely specialized for linguistic functioning and, therefore, information of a verbal nature, i.e., letters and words, is more accurately and/or more efficiently processed by the left hemisphere. The right hemisphere, in contrast, is described as more efficient at processing nonverbal material, i.e., that which is not easily labeled verbally, e.g., nonsense forms.

The attentional model of Kinsbourne (1973, 1975) stresses that verbal and nonverbal stimuli activate the left and right hemispheres, respectively, and that this activation influences the subcortical attention centers (priming) which direct attention to the side opposite the activated hemisphere. This directional bias serves to facilitate the processing of information that is in contralateral hemispace.

The analytic/holistic view of hemispheric asymmetry of Levy (1974) and Bogen (1975), and elaborated upon by Bradshaw & Nettleton (1981), suggests that the left hemisphere is especially capable of discriminating among complex stimulus configurations and accomplishes this by attending to the finer details out of which the stimulus is constructed. The right hemisphere, in contrast, is seen as working according to Gestalt principles, enabling holistic judgments about stimuli based upon the overall configuration. Although this conceptualization has its detractors (e.g., McKeever, 1981), it is seen as a useful model which has generated a considerable amount of empirical study.

Motor Asymmetry: Handedness

The distal musculature of the hands is primarily controlled by the contralateral cerebral hemisphere

(Brinkman & Kuypers, 1973; Henneman, 1980). However, as with language function, the concept of specialization has supplanted the concept of dominance in relation to the abilities of the left and right hands to perform certain activities. Although both hands are affected by contralateral cerebral lesions, lesions in the motor cortex of the left hemisphere affect the sequencing of movements of both hands (Kimura, 1977; Kimura & Archibald, 1974; Wyke, 1971), whereas homologous right hemisphere lesions affect the left hand only. Specialized functioning of the left hand/right hemisphere in regard to motor control has not been clearly described in the neuropsychological literature, although reports of the superiority of the left hand/right hemisphere in pointing in space or movement/manipulation in space have been noted (Buffery, 1971; LeDoux, Wilson & Gazzaniga, 1977).

In addition to the qualitative/quantitative assessment of asymmetry of hand performance following hemispheric damage noted above, hand preference has also been studied to deliniate the hand more adept at a particular task and to correlate this hand preference with cerebral specialization for language. The assessment of hand preference has been conducted with questionaires (Annett, 1970; Bradshaw & Nettleton, 1983; Chapman & Chapman, 1987; Crovitz & Zener, 1962;

Harris, 1974; Healey, Liederman & Geschwind, 1986; Oldfield, 1971; Raczkowski, Kalat & Nebes, 1974; Steenhuis & Bryden, 1989), and performance measures (Barnesley & Rabinovich, 1970; Bryden, 1982; Provins & Cunliffe, 1972). These tests of handedness vary in the number of manual activities assessed, ranging from the simple act of writing (Silva & Satz, 1979) to an inventory of 75 items (Provins, Milner & Kerr, 1982). Reliabilty of subject report of hand preference was found to be poor on less frequent activities (e.g., using a broom) and, as such, performance measures are seen as better indicators of subject's handedness than is subject's report (Bryden, 1982). The use of these measures has shown that the incidence of right hand preference in the general population is between 90% and 92% (Hardyck & Petrinovich, 1977).

Hand preference has been correlated with left hemisphere representation of speech/language function. Satz (1979), in a comprehensive review of investigations assessing the incidence of aphasia in left and right handed unilaterally brain damaged patients, reported the incidence of right handers with left hemisphere language lateralization to be approximately 96%. Milner (Rasmussen & Milner, 1977) and her colleagues (Bryden, 1982; Segalowitz & Bryden, cited in Bryden, 1982) have reported similar findings and have further suggested that in left handers, there is left hemisphere representation of language in 70% of the cases, bilateral representation in 15%, and right hemisphere representation in 15%. Thus, the overwhelming majority of right handers have left hemisphere specialization for language, whereas left handers have a higher probability of bilateral or right hemisphere language representation.

Hemispheric Specialization: Non-Visual Sensory Modalities

Support for the analytic/holistic view of functional hemispheric asymmetry has come from numerous studies of lateral differences in somatosensory/tactile/haptic, auditory and visual processing. Beginning in the 1960's, researchers began to identify some of the stimulus factors (Sergent, 1986), response factors (Chiarello, Nuding & Pollock, 1988; Heister & Schroeder-Heister, 1987), task factors (Bradshaw & Sherlock, 1982; Hellige & Sergent, 1986; Magaro & Moss, 1989) and subject factors (Bouma & Ippel, 1983; Kinsbourne, 1970) that play a role in cerebral functional asymmetries. In general, the results of these experiments indicate that inputs that gain access initially to the left hemisphere are processed with greater accuracy and/or faster than are inputs to the right hemisphere when the task requires linguistic encoding/decoding, detailed analysis, or sequential organization (Babkoff, Genser & Hegge, 1985; Howell & Bryden, 1987; Milner, Taylor, & Sperry, 1968; Moscovitch, 1983). Inputs that have initial access to the right hemisphere are processed with greater accuracy and/or faster than are inputs to the left hemisphere when the task requires spatial, configurational categorizations or matching, and Gestalt organizations (Hatta, 1983; Levy, Trevarthan, & Sperry, 1972; Nettleton & Bradshaw, 1983).

(1) Somatosensory and tactuospatial asymmetries.

In studies assessing lateral differences in somatosensory and tactuospatial perception in neurologically normal right handed adults, it has been found that presentations of words, letters, and verbally encodable objects to the right hand/left hemisphere are more accurately processed than are these same stimuli presented to the left hand/right hemisphere (Oscar-Berman, Rehbein, Porfert & Goodglass, 1978). Stimuli such as nonsense shapes and geometric forms are more efficiently processed when presented to the left hand/right hemisphere (Dodds, 1978; Milner & Taylor, 1972). Data obtained from tests administered to commissurotomized patients suggest a left hand superiority on tasks such as identifying which presented arc belongs to a particular circle (Nebes, 1971), choosing the appropriate pieces to construct a geometric shape (Nebes, 1972), completing analogies on a tactile form of the Ravens Coloured Progressive Matrices (Zaidel & Sperry, 1973), and identification of nonsense forms (Milner & Taylor, 1972). In contrast to the left hand superiority for tactile perception, a right hand superiority has been found in these patients for verbal naming of objects presented to the right hand (Milner & Taylor, 1970).

In normal children and adults, the use of Witelson's dichaptic stimulation task (1974, 1976, 1977; Gardner, English, Flannery, Harnett, McCormick & Wilhelmy, 1977; Tinkcom, Obrzut & Poston, 1983), which involves the presentation of two different three dimensional forms simultaneously to both hands, has shown a left hand/right hemisphere superiority for the palpation of nonsense shapes and a right hand superiority, though more difficult to elicit, for the matching of alphabetic letters. However, there have been some difficulties in attempted replication of the findings (Cranny & Ashton, 1980; La Breche, Manning, Goble & Markam, 1977).

Hermelin and O'Connor (1971) have reported a left hand superiority in Braille reading by blind adults, and Rudel, Denkla, and Spalten (1974) have reported a similar left hand superiority in normally sighted 13 year old girls and 11 year old boys. In a concurrent task paradigm, the presentation of music to the left ear of normal adults reduced the left hand superiority on a braille matching task (Smith, Chu, & Edmonston, 1977).

The research reporting hand differences in the enumeration of palpated dots is of particular relevance to the current investigation. Young and Ellis (1979) found superior performance of the left hand when right handed adults were asked to palpate and judge the number of randomly patterned dots, although no hand differences were observed when the dots were in a linear array. However, because no hand differences were found in two other studies (Carmon & Benton, 1969; Myers, 1976), it was suggested that when a left hand superiority is found for Braille reading or dot enumeration, it is probably best explained in terms of right hemispheric superiority for spatial analysis, rather than to left hemisphere analytic/enumeration strategies. Therefore, the right hemisphere is superior in spatial analysis; dot enumeration of palpable forms is processed equivalently by both cerebral hemispheres.

Lechelt and Tanne (1976) found that the application of mechanical pulses to the middle fingers of the right and left hands of normal adult subjects yielded different hand/hemisphere advantages that were dependent upon the number of pulses administered. Accuracy of enumeration of pulses less than eight was greater when these were applied to the subjects' middle finger of the dominant hand, while accuracy of enumeration of nine or more pulses was better when these stimuli were applied to the middle finger of the nondominant hand. It was suggested that the processing of fewer pulses involves a left hemisphere sequential/analytic counting strategy and the greater number of pulses requires a more right hemisphere/holistic strategy. Thus, the type of stimulus may not be as important as the cognitive strategy required, i.e., the level/type of cerebral processing preferentially activated, to perform the task.

(2) Auditory asymmetries. The use of the dichotic listening technique pioneered by Kimura (1961), in which different auditory information is simultaneously presented to both ears, has shown that in normal right handed adults, digits (Kimura, 1961) and consonant-vowel-consonant (CVC) pairs (Studdert-Kennedy & Shankweiler, 1970) presented to the right ear/left hemisphere are more accurately reported than when these stimuli are presented to the left ear/right hemisphere.

The left hemisphere superiority for the recognition and recall of CVC stimuli was interpreted in regard to Milner's (1962, cited in Segalowitz, 1983) finding that the left hemisphere is activated more by speech transitions (CVC) while the right hemisphere is activated more by voice onset time. The sequential aspect of these speech transitions may have been responsible for the obtained right ear/left hemisphere advantage (Bradshaw & Nettleton, 1981). The recall of letter sequences has also been found to be more accurate when presented to the right ear/left hemisphere (Kimura, 1969). In contrast, left ear/right hemisphere advantages have been reported for melodies (Kimura, 1964, 1969), emotionally based words (Bryden, Ley, & Sugarman, 1982) and sounds, e.g., laughs (Mahoney & Sainsbury, 1987), and environmental sounds such as steam whistles and coughing (Curry, 1967; Knox & Kimura, 1970). Auditory stimuli which require, or lend themselves to, Gestalt-like, holistic processing are processed more efficiently/effectively by the right hemisphere. This is supported by the finding of a reversal in ear advantage, from the left to the right ear, in subjects who are musically sophisticated (Bever & Chiarello, 1974) or who have a greater aptitude in music (Gaede, Parsons & Bertera, 1978) and who may use a strategy of analysis of the musical elements.

Papcun, Krashen, Terbeek, Remington and Harshman (1974) found a right ear/left hemipshere advantage when Morse Code patterns of up to seven tones were used. An opposite ear advantage (left ear/right hemisphere) was found with longer codes of up to thirteen tones. These results were found for right handed adults inexperienced with Morse Code. When Morse Code operators were tested, there was a clear right ear/left hemisphere superiority for all code lengths, as measured by accuracy of recall. Interpreted within the analytic/holistic model, sequential processing of Morse Code signals may have been used on codes of seven or less, while for longer strings of tones, a more holistic strategy may have been used by the inexperienced subjects. The left hemisphere advantage found with experienced listeners may be accounted for by the more analytic strategy and/or semantic nature of the task for these subjects. The findings for the inexperienced subjects for auditory patterns are remarkably similar to those of Lechelt and Tanne (1976) discussed above, where mechanical pulses of less than nine were more accurately processed when delivered to the finger of the dominant hand than when delivered to the finger of the nondominant hand, while more than nine pulses were more accurately processed when administered to the finger of the nondominant hand as compared to that of the dominant hand.

This sample of studies assessing lateral asymmetries in the processing of information to the somatosensory and auditory modalities provides support for the analytic and holistic model for analyzing hemispheric functioning. In general, the results indicate that the right cerebral hemisphere plays a greater role than the left cerebral hemisphere in mediating those tasks which involve spatial analysis of geometric forms, braille configurations, and multi dot enumeration, and the perception of melodies, emotional aspects of stimuli, and environmental sounds. Left hemisphere superiorities are noted for words, letters, digits, nonsense syllables (CVCs), transitions in stimuli, letter sequences, and enumeration via sequential processing of mechanical pulses of less than nine and strings of tones less than seven.

Hemispheric Specialization: Visual Modality

The visual modality is especially suited to the investigation of lateral differences in the processing of information. This is due to the anatomical projection of inputs from the right visual field/left hemiretina of each eye to the left cerebral hemisphere, and the projection of inputs from the left visual field/right hemiretina of each eye to the right cerebral hemisphere. The temporal half of the left eye and the nasal half of the right eye, therefore, project to the left hemisphere, whereas the nasal half of the left eye and the temporal half of the right eye project to the right hemisphere.

The primary means of accessing a single hemisphere has been with the use of the tachistoscope, an apparatus that enables the presentation of stimuli in the LVF or RVF for very brief periods of time so that the laterally presented stimuli have initially limited access to the contralateral cerebral hemisphere. Results of numerous tachistoscopic studies of visual hemifield asymmetries, in which the same or different visual stimuli are presented unilaterally or bilaterally (a method which is analogous to dichotic listening in audition and dichaptic stimulation in tactuospatial processing), have shown a high degree of agreement. Fairly consistent findings have been reported in right-handed normal and brain damaged adults and children (Sergent, 1986).

As with the investigations of functional asymmetries in the processing of auditory and somatosensory information, studies using tachistoscopic presentation of visual stimuli of a verbal nature such as letters, words, and nonsense syllables, have typically found greater accuracy and/or faster processing of RVF than LVF stimuli (Babkoff, Genser & Hegge, 1985; Bradshaw, Hicks & Rose, 1979; Kimura, 1961; Mishkin & Forgays, 1952; Sperry, 1969; Zaidel, 1982). On the other hand, visual stimuli of a spatial nature such as dots, orientational and directional lines, nonsense shapes, and faces, have been found to be more accurately and/or more rapidly processed when the stimulus is projected in the LVF than when projected in the RVF (Fontenot, 1973; Hellige, 1978; Krynicki, 1976; McKeever & Huling, 1970; Virostek & Cutting, 1979; White & Barr-Brown, 1972). These fairly consistent findings have led to the conclusion that, at least in right handers, there is a RVF/LH superiority/advantage for the processing of linguistic/speech-like material, and a LVF/RH superiority/advantage for the processing of visuospatial/Gestalt-like/configurational material. However, not all subjects exhibit this pattern; indeed, the pattern is more clearly and consistently found in males than in females (McGlone & Davidson, 1973) and in right handers rather than left handers. Prior to reviewing the evidence of visual hemifield asymmetries in normal adults, a brief review of the findings from clinical studies will be presented.

Visual hemifield asymmetries in clinical groups.

Studies of commissurotomized patients have provided evidence in support of visual functional lateral asymmetries. The procedure of commissurotomy, if total, divides the two cerebral hemispheres by separating the corpus callosum, hippocampal and anterior commissures, and the massa intermedia. For the visual system, the neural fibers from the contralateral visual field are spared and are projected, cortically, to only that hemisphere.

From studies of commissurotomized patients, it has been found that the left hemisphere, rather than the right hemisphere, is primarily responsible for the functions of speech, writing, reading, and mathematical calculation (Sperry, 1982). A RVF/LH advantage has also been obtained with pictorial material of an overlearned nature (e.g., photographs of the subject, the subject's relatives and home (Sperry & Zaidel, 1973) and letters (Kinsbourne, Trevarthan & Sperry, 1973). The right hemisphere, in addition to the left hemisphere, was found to be capable of comprehension of single, high frequency nouns and some verbs (Johnson, 1984; Sperry, Gazzaniga & Bogen, 1969) (although Myers and Sperry (1985) suggested that this naming ability is mediated by subcortical mechanisms), expressed emotional reactions to personal pictures, and the identification of novel pictures via a pointing response (Zaidel, 1973). In addition, the right hemisphere was seen as more capable of mental imagery; Farah, Gazzaniga, Holtzman and Kosslyn (1985) reported superior mental imagery of verbal (letter) stimuli presented to the RVF/LH in one right-handed male. A superiority of the right hemisphere has also been documented for mental rotation tasks (Corballis & Sergent, 1989).

The studies of commissurotomized patients provide evidence of left hemisphere superiority on verbal tasks (letters, words, semantics and syntactics) and of right hemisphere superiority for visual perceptual apprehension, mental rotation, mental imagery, emotional reactions, and identification of novel percepts. The obtained patterns of hemifield differences suggested (Levy, Trevarthan & Sperry, 1972; Myers & Sperry, 1985; Sperry, 1982) that the functioning of the hemispheres did not simply adhere to the verbal/nonverbal dichotomy; the left hemisphere was seen as superior in the use of the details of the stimulus that can be symbolically/conceptually transformed into verbal codes, and the right hemisphere was seen as advantaged in its ability to preferentially process the whole stimulus and to apprehend the basic overall pattern.

The studies of visual hemifield asymmetries in commissurotomized patients have been criticized on several grounds: (1) there may be commissural fibers left intact which permit interhemispheric transfer of information; (2) there is the possibility of subcortical transfer of information; (3) the patients had different degrees and types of brain damage prior to surgery, thereby reducing the comparability of studies; and (4) the applicability of the findings to normals may be questionable. Nevertheless, many of the findings are consistent with those reported in more well controlled experimental studies of neurologically intact adults.

Studies of patients with unilateral brain damage have further elucidated the roles of the left and right hemispheres. Lesions or excisions of cortical areas of the left hemisphere, specifically, the posterior lobes of temporal, parietal and occipital cortex have been found to disrupt aspects of language functioning (particularly verbal comprehension), recognition of objects, colors and letters, whereas lesions of the right hemisphere have been found to impair visuospatial processing and to lead to spatial agnosia and face recognition deficits (prosopagnosia) (Friedrich, 1990). Rubino (1970) tachistoscopically presented CVC trigrams to adult patients with left or right temporal lesions and found the performance of the left temporal lesioned group to be impaired relative to the right temporal lesioned group. Warrington and James (1967) presented single letters to right handed adults with left- or right-sided lesions of various areas of the cortex. Right brain damaged patients were more impaired than those with left brain damage for verbal identification of letters. The reversal in lateral advantage in this study was possibly the result of the use of very brief exposure durations of 2-16 ms. Kimura (1963), however, using a pointing response, found no differences in recognition of single letters between patients with left and right temporal lesions. Poorer performance on dot enumeration tasks has been found for patients with damage to the right hemisphere (Kimura, 1963; Warrington and James, 1967). Benton and Allen (1968) and Hamsher, Levine and Benton (1979) each found greater deficits on facial recognition matching tests in patients with right hemisphere damage than in those with left hemisphere damage. Yin (1970) also found that patients with right posterior cerebral lesions were more impaired in the recognition of upright faces than other lesioned groups. Additionally, when these groups of subjects were presented with inverted faces, those with lesions in areas other than the right posterior area did more poorly. Yin (1970) suggested that the right posterior cerebral area may be a "special face processor". Robertson and Delis (1986; Lamb, Robertson & Knight, 1989) found that right handed, right hemisphere damaged males were more impaired on the extraction of the holistic, configurational aspects on a form or letters task.

The use of the tachistoscopic technique with unilaterally brain damaged patients has not yielded as great a wealth of information as in commissurotomized and normal subjects concerning left versus right hemisphere advantages in the processing of stimulus information. This seems to be due to the nature of the deficit following left or right cerebral lesions. Patients with large lesions of the right hemisphere tend to be brought to clinical attention as often as patients with small circumscribed lesions of the left hemisphere. In addition, the right hemisphere has more diffuse representation of function than the left hemisphere; the left hemisphere has a more focal representation of function (Semmes, 1968). The focal representation may mean that specific deficits on particular aspects of tasks may not be found with a general methodology. As a consequence, studies comparing left and right hemisphere lesioned groups tend to be biased towards finding deficits in right hemisphere processing. Furthermore, the spatial deficits of right hemisphere damaged patients put them at a disadvantage in visual tachistoscopic studies, as at least basic visual/visuospatial skills are necessary on such tasks. Subject factors are also problematic as age, sex, and handedness tend not to be well controlled in these studies.

Visual hemifield asymmetries in normal adults as a function of stimulus materials. Studies with normal adults have investigated the types of stimulus materials that are differentially/preferentially processed by the left and right hemispheres. These stimuli include, but are not limited to, letters and words, patterns of dots, nonsense shapes and facial stimuli. Additionally, task parameters (instructional set) and stimulus qualities (e.g., clarity, luminance) have been found to interact with the particular type of stimulus under investigation. Lastly, the findings have been interpreted within the conceptual framework of one or another of the explanatory models of functional hemispheric specialization (e.g., verbal/nonverbal, analytic/holistic, high/low spatial frequency).

Letters and words. Left hemisphere superiority has been observed, with a high degree of consistency, for the processing of letters, letter pairs and strings, and words. Futhermore, the higher the level of processing required, e.g., identification, semantic association, the more effective the stimulus in eliciting the left hemisphere advantage. However, not all presentations of verbal/linguistic material elicit a left hemisphere advantage; in some cases, a right hemisphere superiority has been reported. The finding of reversals of hemifield advantage suggests that under certain experimental conditions (to be discussed below), the cerebral hemispheres exhibit specific types of processing modes above and beyond the stimulus category, in this instance verbal material.

Several studies of visual hemifield asymmetries have used single letters of the alphabet as "linguistic" stimuli. In an early study, Kimura (1966) presented both large and small sized capital letters to the LVF and RVF to right handed male and female adults and found significantly greater accuracy in vocal identification of both types of letters presented in the RVF/LH than in the LVF/RH. This finding of a RVF/LH superiority for letter identification has also been obtained by Bryden (1966) for accuracy, and by Geffen, Bradshaw and Wallace (1971) for reaction time of verbal identification. A RVF/LH advantage was also reported for Hebrew letters (Carmon, Nachshon, Isseroff and Kleiner (1972).

Support for the view of different processing modes of each cerebral hemisphere has also been found for letter pairs. Bryden (1963) presented letter pairs either successively in each hemifield or simultaneously to both fields; the subjects were to report the names of the letters. A LVF/RH advantage was found for simultaneous presentations and a RVF/LH advantage for successive presentations. It is possible that the RVF/LH advantage for successive presentations may have tapped a left hemisphere sequential processing mode leading to greater accuracy of performance, whereas simultaneous presentation may have elicited apprehension of the gestalt of the letter pattern, resulting in a LVF/RH advantage. Similar qualitative differences between the functioning of the cerebral hemispheres were found in an investigation (Jonides, 1979) using a letter classification test in which two sets of letters were presented to the same hemifield on each trial, an easy-to-discriminate pair and a difficult-to-discriminate pair. It was found that the easy-to-discriminate pairs were (manually) responded to faster when presented to the RVF/LH, while the more difficult-to-discriminate pairs were responded to faster when presented to the LVF/RH. Jonides suggested that verbal codes can readily be applied to easy-to-discriminate letter pairs, whereas their application to difficult-to-discriminate pairs is not as parsimonious, and so a right hemisphere holistic strategy was used, resulting in faster reaction times.

Using whole words rather than single letters, a RVF/LH superiority in verbal recall has been established (Mishkin & Forgays, 1952). The RVF/LH superiority for words is quite robust, having been obtained not only for words placed horizontally in the visual field, but also for words in mirror reversed orientations (Isseroff, Carmon and Nachson, 1974) and for words presented along the vertical axis of the visual field (Bryden, 1970).

However, as with those studies in which single letters and letter pairs were used, reversals in the pattern of asymmetry, or the failure to find hemifield asymmetries for word stimuli, have been found with procedural variations. For example, Bradshaw, Hicks and Rose (1979) administered a lexical decision task (word-non word discrimination) to normal adults, who were required to vocally state whether the stimulus was a word or non-word. A LVF/RH superiority for accuracy was found for very fast exposure durations (14 and 17 ms), whereas a RVF/LH superiority was found for somewhat longer durations (23 and 26 ms). The LVF/RH superiority was thought to be due to the necessity of apprehending the whole or global characteristics of the stimulus in the very brief exposures, whereas the longer durations permitted greater attention to detail and analysis of the component elements of the words and non-words, yielding a left hemisphere advantage. Howell and Bryden (1987) used the same lexical decision task to examine hemifield asymmetries, but presented the words/non-words in each visual field in horizontal or vertical orientations. The subjects' task was to discriminate the words from the non-words via a manual response. A RVF/LH superiority for accuracy of discrimination was found for horizontal items, and no asymmetries emerged with vertical items. The authors suggested that the novelty of the vertically oriented items and perhaps, a requirement for a spatial rotation/transformation of the items led to greater involvement of the right hemisphere.

These studies provide clear evidence of a left hemisphere superiority for the processing of verbal/linguistic material, although the advantage decreases or becomes a right hemisphere advantage when the task demands change. The left hemisphere advantage is most clearly and consistently seen with verbal stimuli when these stimuli can be easily labeled, and especially when procedures optimize labelability, thereby allowing higher cognitive transformations (language processing) to take place. Right hemisphere advantages are seen when the task is made perceptually more difficult (as opposed to semantically more difficult) by using a novel presentation, briefer exposure durations, and/or reducing the verbal codability of the stimuli.

The use of nonverbal stimuli in tachistoscopic studies of hemifield asymmetries has been associated with a right hemisphere advantage. The types of stimuli that have been consistently found to reveal a right hemisphere advantage include those that are not easily verbally coded, those that elicit a visuospatial processing strategy, and those that involve or require learning/training or are used in novel tasks.

Patterns of dots. A number of studies have investigated lateral asymmetries in the processing of dot stimuli. Dot stimuli, as contrasted with verbal stimuli which show a left hemisphere advantage, do not seem to be preferentially processed by either hemisphere, but rather are lateralized to one or the other hemisphere as a function of the procedural/task demands in which the dot(s) are presented. The processing of dot stimuli has been addressed in primarily four contexts: detection, localization, movement and enumeration. In studies of visual hemifield differences in dot detection, Kimura (1969) and Bryden (1976) found no hemifield differences, as measured by verbal report, in right handed men and right handed men and women, respectively. Filbey and Gazzaniga (1969) found a RVF/LH advantage in right handed women for accuracy of dot detection, but only under conditions in which subjects were given trial-by-trial verbal feedback as to accuracy and only over a long period of testing (5 sessions over 5 days). Davidoff (1977) found a LVF/RH advantage for verbal report of dot detection for dot stimuli of low contrast. In summary, dot detection seems to be performed equally well by both hemispheres. The RVF/LH advantage emerged in the course of a lengthy procedure (Filbey and Gazzaniga, 1969) which has been obtained in other studies investigating the effect of length of testing (Kittler, Turkewitz & Goldberg, 1989). The LVF/RH advantage for dot stimuli of low contrast would seem to preferentially activate the right hemisphere because the details of the low contrast stimuli are not as available.

Dot localization has been reported to be more accurate with stimuli presented to the LVF/RH in right handed men (Kimura, 1969). However, Bryden (1976), in an attempted replication of Kimura's (1969) experiment, failed to find a significant hemifield advantage. What Bryden did find was a significantly greater number of guesses to LVF/RH stimuli, which suggested that Kimura's results may have been due to differences in detection frequency and response bias. Bryden further suggested that the right hemisphere may be more "uncritical" of stimulus information, assessing input in a more global and diffuse manner.

Asymmetries in the detectability of dot movement were studied by Eals (1987), who presented rectilinear dot patterns of two to five dots to the LVF or RVF. Apparent movement of the dot stimulus was achieved by presenting two slightly differing patterns in succession to the same hemifield. A LVF/RH superiority was found, although it was unclear whether the right hemisphere advantage reflected better movement detection or better ability to predict the position of the second dot pattern.

Several investigations of lateral hemifield differences in dot enumeration have supported either a LVF/RH advantage or equal capabilities of both cerebral hemispheres. Sheehan and Smith (1986) and Young and Bion (1979) found a LVF/RH superiority for dot enumeration in 11 to 13 year old boys and 5 to 11 year old children. Kimura (1966) obtained a LVF/RH superiority for dot enumeration in right handed adults, which she attributed to both the nonverbal nature of the stimuli and the use of spatial analysis to perform the task. The LVF/RH advantage for dot enumeration was also found by Bruder, Quitkin, Stewart, Martin, Voglmaier and Harrison (1989) and McGlone and Davidson (1973). Although Voglmaier and Bruder (1990) found no visual field differences for dot enumeration when a verbal report of the number of fixation digits was required, a LVF/RH advantage was found with a nonverbal/matching response. The matching task required a judgment as to whether a fixation digit matched the number of dots presented in each hemifield and, thus, eliminated verbal reports of numbers of dots, which may weaken the LVF/RH advantage. Of interest in the Voglmaier and Bruder study (1990) was the finding that for the first half of the trials (30 per hemifield) for the nonverbal condition, no difference was found between the hemifields, whereas a strong LVF/RH advantage was observed for the second half of the trials. Practice, fatigue, or "warm up" time were offered as possible explanations of the shift in hemispheric processing. Finally, neither Boles (1986), assessing manual accuracy (subjects keypressed one of eight keys corresponding to one to eight dots) and reaction time, nor Ohtani (1985), assessing speed of verbal identification, found significant differences between the hemifields for enumeration of random dot patterns in right handed adults.

When LVF/RH advantages in dot enumeration tasks have been found, enumeration, in itself, has not been offered as the reason for the hemifield asymmetry. Rather, the hemifield difference is said to be due to the nonverbal nature of the stimuli or to the need for spatial analysis prior to enumeration (e.g., Kimura, 1966). This is supported by the report of Voglmaier and Bruder (1990) that the obtained LVF/RH advantage was strongest when a nonverbal same/different matching response was required. The results do suggest that visual hemifield differences in regard to the processing of dots are somewhat fragile and may depend upon stimulus parameters (e.g., exposure duration) and task factors (e.g., same/different nonverbal responses).

Nonsense shapes. Shapes, mainly consisting of abstact, nonrepresentational, dot and line configurations, have been noted to be processed preferentially by the right hemisphere. For example, Nichelli, Manni and Faglioni (1983) found a LVF/RH superiority for manual reaction time to nonsense shapes constructed of dots in right handed males but not in females. Dee and Fontenot (1973), using the geometric figures of Vanderplass and Garvin (1959), reported LVF/RH advantages for the twelve sided figures, but not for the six sided figures, for which equal hemifield performance was found. Others (Hannay, Rogers & Durant, 1976; Birkett, 1978) using these figures have obtained various results (LVF/RH or RVF/LH superiorities, or no differences). Krynicki (1976) failed to find a LVF/RH superiority for the twelve sided figures in right handed adults, but confirmed the LVF/RH advantage for eight and sixteen sided figures when these were presented in different orientations. Varying the orientation was thought to decrease the ability of the left hemisphere to use the details inherent in the figures to aid in task performance, as would be the case if the same stimulus was repeatedly shown in the same orientation. Thus, negative or contradictory findings of a LVF/RH superiority may have been due to the analysis of the details of the repeatedly shown complex figures rather than judging the whole figure.

Other types of forms have been used in studies of visual hemifield asymmetries. Morais and Ben-Dror (1985) reported a LVF/RH advantage for shapes that were either novel, not easily discriminable, or when the shapes to be matched were presented successively. Umilta, Bagnara, and Simion (1978) also reported a LVF/RH superiority for novel shapes and a RVF/LH advantage for familiar, more discriminable shapes when the match was presented simultaneously. Thus, it seems that greater hemispheric proficiency at a task, at least with shapes, is determined by factors other than the nature of the stimuli used, form in this case; these factors include the elements of the stimuli, its capacity to be coded, whether it is novel or unfamiliar, nameable or non-nameable, and the strategy -analytic or holistic - used by the subject to perform the task.

Facial stimuli. Facial stimuli, usually photographs and occasionally drawings, represent a special class of nonverbal visual materials. Yin (1969), in a study comparing accuracy of recognition of upright and inverted facial stimuli to stimuli of other classes (e.g., houses, planes), found that facial stimuli were easier to remember in their normal orientations and most difficult to remember when inverted, as contrasted with responses to the other stimulus categories. Questioning of the subjects revealed that they were completing the task involving upright facial stimuli by gaining an overall impression (gestalt) of the stimulus rather than by assessing its details, as was the strategy reportedly used with the other stimulus materials. In general, Yin's results have been supported in the laterality literature by the findings of LVF/RH superiorities with hemifield presentations of facial stimuli (Ellis and Shepard, 1975; Hilliard, 1973; Rizzolatti, Umilta and Berlucci, 1971). Hilliard (1973) found a LVF/RH superiority in accuracy of matching/discrimination of faces. Additionally, Umilta, Brizzolara, Tabossi and Fairweather (1978) reported a LVF/RH superiority in the matching accuracy of unfamiliar faces and a RVF/LH superiority for familiar faces, a finding congruent with the findings of Sperry and Zaidel (1973) with commissurotomized patients.

Addressing the issue of analytic/holistic processing of facial stimuli, Leehey, Carey, Diamond and Cahn (1978) found that upright facial stimuli presented to the LVF/RH were significantly more accurately matched than those to the RVF/LH, whereas responses to inverted facial stimuli only approached significance for better performance to LVF/RH presentations. The difference in results between the stimulus categories may be due to the processing of the upright facial stimuli holistically but processing analytically those stimuli which were inverted, as greater discernment of the details of the inverted facial stimuli would seem necessary. Bradshaw and Sherlock (1982) had right handed adults attend to either the configuration of a schematic face or the details of the face. A RVF/LH superiority was found when the subjects attended to the details of the faces, and a LVF/RH superiority was found when attending to the facial configurations. Furthermore, Keenan, Whitman and Pepe (1989) presented photographs of real faces to the visual hemifields of right handed adults and found that when the total configuration of the face was made less perceptible (via masking grids) accuracy of matching was greater for faces presented in the RVF/LH than in the LVF/RH. In contrast, when the details (facial features) of the stimuli were made less perceptible, a LVF/RH superiority was found.

In summary, the findings of the studies assessing lateral differences in the processing of facial stimuli suggest that the right hemisphere is superior to the left hemisphere in processing efficiency. Furthermore, the LVF/RH superiority seems to be dependent on the utilization of configurational/spatial attributes of the facial stimuli. When attention is directed to the details of the faces, whether by task instructions or stimulus manipulations, a RVF/LH advantage is obtained.

Overall, the right hemisphere seems to be involved in visuospatial analysis of stimuli and the visual processing of novel stimuli, nonsense forms and facial stimuli. Procedural manipulations of exposure duration and relative perceptibility of the overall configuration and its details can affect the degree and direction of the hemifield advantage, leading to the conclusion that the right hemisphere is an holistic processor and the left hemisphere is an analytic processor.

Manipulations of instructional set. The results obtained in many of the previously cited visual hemifield studies have been explained in terms of the analytic/holistic model of functional hemispheric asymmetries. However, few of these studies have tested the model directly; instead, most have used the model to explain the findings, and the explanations have been invariably *post hoc.* For example, Bashore, Nydegger and Miller (1982) presented letters tachistoscopically and hypothesized that because of the verbal nature of the stimuli, there would be a RVF/LH superiority. Instead, they found a LVF/RH advantage for verbal identification which they explained by arguing that the subjects' used an holistic strategy. As both hemispheres were capable of doing the task, it is unknown whether the task elicited a lateral asymmetry in higher cognitive processing, whether the perceptual characteristics of the stimuli were more salient in one hemisphere and, therefore, more quickly processed in that hemisphere, or whether an unidentified subject bias directed attention to one hemifield. Furthermore, in other studies attempting to identify dissociation of the processing strategies of the cerebral hemispheres, two different kinds of stimuli were often used. Even when the hypothesized differences - left hemisphere advantage for analytic tasks, right hemisphere advantage for holistic stimuli/tasks - are found, it makes a difficult case to say that the hemispheres have been "dissociated". Rather, it would seem that each cerebral hemisphere was more adept at the task for unknown or inadequately explained reasons. Bradshaw and Sherlock (1982) tested the analytic/holistic model directly in a single experiment by having right handed adults attend (target/nontarget) either to the overall configuration (holistic) or to specified features (analytic) of the stimuli - face and bug drawings. For the holistic task, the subjects were instructed to identify, via a bimanual response, a schematic drawing of a human face with appropriate dimensions. For the analytic task, the subjects were required to identify faces with noses with the apex up (versus apex down). Similar instructions were given for the "bugs" drawings. The analytic/holistic model was supported - a LVF/RH superiority (faster bimanual RTs) was obtained for configurational judgments of both faces and bugs, and a RVF/LH advantage was found for analytic judgments, also for both faces and bugs.

Magaro and Moss (1989) presented sets of letters containing the target, X, to subjects given different instructional sets. The surrounding letters consisted of those letters which are similar in configuration to the X, e.g., K, N, or dissimilar, e.g., O, S. The subjects' task was to keypress "yes/no" to indicate whether the target was present under the following conditions - (1) with similar or dissimilar surround letters, (2) with holistic instructions and (3) with analytic instructions. Holistic instructions yielded faster reaction times than analytic instructions. Responses to LVF/RH presentations were the fastest for both instructional sets. The lack of dissociation between the hemispheres in regard to task instructions was not explained. In comparison to the faces and bugs stimuli of Bradshaw and Sherlock (1982), Magaro and Moss (1989) did not have an overall configuration which was semantically meaningful, nor were there details other than the identities (names) of the letters, each of which could have been viewed as a separate stimulus. It is therefore possible that the stimuli were not conducive to a processing strategy other than visuospatial analysis.

Other studies have examined lateral asymmetries with the use of an instructional set (analytic/holistic, also referred to as local/global, see Navon, 1981 and Hoffman, 1980) in conjunction with the presentation of a large letter (holistic) made of smaller letters (analytic), similar in principle to the faces and bugs task of Bradshaw and Sherlock (1982). This stimulus, a large letter (e.g., H) constructed of small letters (e.g., H) was initially used to study global/holistic processing, i.e., the large letter, versus local/detailed/analytic processing, i.e., the small letters (Kinchla, 1977; Kinchla & Wolfe, 1979). Navon (1977) reasoned that global analysis precedes local analysis in time, and that this sequence is adaptive in the sense that knowledge of the whole narrows the range of other processing alternatives. i.e., knowing that the overall configuration of the stimulus is a face then leads one to look for details, e.g., eyes, nose, to further classify the face as a specific face, different from others. In Navon's (1977) study, as well as in those of others who have used this paradigm, the subjects' task was to identify, according to instructional set, either the large or small letters in each of the hemifields. Using manual reaction time as the response measure, Martin (1979) found that right handed adults responded more rapidly to the holistic stimulus (large letter) than to the analytic stimulus (small letters), and more rapidly to the analytic stimuli presented in the RVF than in the LVF, indicating a left hemisphere advantage. A LVF/RH advantage was also found when the subjects responded to the configuration (large letter) when the task was made more difficult by constructing the large letter from small letters of a different name (e.g., large letter "S", small letter components "H"). As lateral asymmetries were not found on the simpler task of same large and small letters, it was concluded that the verbal nature of the stimulus (a letter) led to greater left hemisphere involvement, thereby subtracting from the potential right hemisphere advantage on the task.

Sergent (1982), using a similar letter task, replicated Martin's results (1979) and found a LVF/RH advantage for the overall configuration even when the large and small letters were the same. Van Kleek (1989), in an attempted replication of these results, found significantly shorter reaction times to the large than to the smaller letters, but only nonsignificant trends for the identification of configurations to be faster when the stimuli were presented in the LVF/RH than in the RVF/LH, and for identification of the details to be faster to stimuli presented in the RVF/LH than in the LVF/RH. These results are congruent with other studies in the literature. Van Kleek then performed a meta-analysis on six of these studies that assessed hemifield differences with a similar stimulus. (The studies were those of Alivastos and Wilding (1982), Boles (1984), Martin (1979), Sergent (1982) and

Van Kleek (1989).) Significant hemifield differences for the two task conditions were reported in two of these studies (Martin, 1979; Sergent, 1982); the other three experiments did not reveal asymmetries, although trends in the expected direction were found in two of the (three) studies. When the results of all six studies were entered into the meta-analysis, the probability that five would show the same direction of asymmetries - a LVF/RH advantage for the large letters and a RVF/LH advantage for the small letters - was statistically significant. The failure to find statistically significant hemifield asymmetries in individual studies (especially Boles, 1984) was said, by Van Kleek (1989), to be due to the fact that stimuli were presented at greater eccentricities (Boles, 1984; Alivastos & Wilding, 1982), and/or that too many trials were administered (Boles, 1984). Neither explanation seems adequate, however, as the eccentricity of the stimuli was within the range generally used (2.2^{o} -2.7^{o}), and it has been reported that large eccentricities may even have an enhancing effect on hemifield differences (see below). Increasing the number of trials may serve to change the visual field asymmetry from a RVF/LH to a LVF/RH advantage (Kittler, Turkewitz & Goldberg, 1989). Moreover, because the stimuli are verbal, one would expect to find (Martin, 1979) an enhanced RVF/LH advantage for the small letters and attentuation of the hemifield differences for the large letters.

In summary, the studies assessing visual hemifield asymmetries have noted RVF/LH advantages to verbal types of stimuli. Furthermore, the research has shown that even when the material is of a nonverbal nature, the application of a verbal encoding strategy enhances the proficiency of processing by the left hemisphere, thereby leading to greater accuracy and/or faster reaction times to these stimuli presented to the RVF. In addition, the task demands and/or cognitive strategies, as well as experimentally-manipulated instructional sets (e.g., to attend to the details or local aspects of the stimuli - analytic orientation) have been found to affect the pattern of lateral asymmetry toward a RVF/LH advantage. It has been noted that task requirements may conflict with and override the verbal nature of the stimuli so that verbal stimuli are processed in an holistic manner.

Nonverbal stimuli (i.e., those stimuli which are not easily verbally encoded) are also preferentially processed; many studies report greater accuracy and/or faster reaction times to LVF/RH presentations than to RVF/LH presentations. The degree to which nonverbal inputs are primarily and/or more efficiently processed in the right hemisphere is dependent on stimulus novelty and the possibility/likelihood of visuospatial analysis. Task demands may also accentuate the right hemisphere advantage, as when the subject is directed or primed to attend to/focus on the configuration of the stimulus rather than on the elements of which it is constructed.

Additional influences on both the direction and magnitude of visual hemifield asymmetries include factors associated with the physical properties of the stimulus such as the eccentricity, the size, the luminance, the contrast, the degree of clarity and the exposure duration (Christman, 1989; Sergent, 1983; Sergent & Hellige, 1986). Several studies have shown that as the size of the stimulus is decreased, the luminance of the stimulus is increased, and the contrast between the stimulus and its field is increased, a greater RVF/LH advantage is obtained; when the size is increased, and/or the luminance and the contrast are/is decreased, there is an enhancement of the LVF/RH advantage. Both Sergent (1983) and Christman (1989, 1990) consider all these factors to reflect variations in the spatial frequency of the stimulus. Low spatial frequency stimuli are those which are more global/holistic, whereas stimuli of high spatial frequency are details of the holistic stimulus. Therefore, these investigators view the left hemisphere as being particularly attuned to high frequency information and the right hemisphere as attuned to low frequency information. One method of testing the spatial frequency hypothesis directly has been to manipulate stimulus eccentricity.

Stimulus eccentricity. As eccentricity increases in the visual hemifield, the amount of high frequency information available to be processed decreases, while the availability of low frequency information remains relatively unchanged, at least within 10° of the fovea.

It has been shown that as the eccentricity of the visual stimulus is increased from 0.0°(CVF), the processing of LVF stimuli is less affected than is RVF stimuli. For example, McKeever and Gill (1972) had subjects identify a single letter at 1.5° and 3.6°. Reaction time was faster to stimuli in the RVF/LH than in the LVF/RH at both eccentricities, but the RVF superiority was greater at the near eccentricity. Sergent (1983) had subjects keypress a same-different response to letters with the same or different name. Eccentricity was manipulated at 2.5° and 11.0°. A significant increase in reaction time from near to far field positions was found. In addition, the far field stimulus was responded to more quickly in the LVF than in the RVF; at near positions, reaction time was faster overall in the RVF.

The role of eccentricity has also been examined using nonverbal stimuli. Hellige, Corwin and Jonsson (1984) presented facial stimuli (yearbook photographs) to right handed males at 0.0°, 1.0°, 4.0° and 9.0° in the LVF and RVF. Facial stimulus recognition decreased at the greater retinal eccentricities of 4.0° and 9.0°. Significant hemifield differences emerged only at 1.0° with greater accuracy for LVF/RH presentations than for RVF/LH presentations. The lack of lateral aymmetries at the greater eccentricities did not support the notion that faces presented in the LVF/RH would be better processed at greater eccentricities as compared to corresponding eccentricites in the RVF/LH. Christman (1987) presented digits in a temporal integration task in which the digit was to be verbally identified following temporal integration of parts of the stimulus. Eccentricity of the digit was varied at 3.0° and 6.0°. He predicted that at 3.0°, there would be a RVF/LH advantage, and that at 6.0° there would be a shift towards better performance in the LVF/RH. Contrary to the predictions, however, it was found that as the eccentricity of the stimulus was increased, performance dropped sharply in the LVF/RH while remaining unchanged in the RVF/LH. Significantly greater accuracy was found to stimuli presented at 3.0° in the LVF/RH, and no difference was found between the hemifields at 6.0°. In a followup experiment, Christman (1990) reported that when the stimulus luminance energy was equated for both the large and small elements, lesser eccentricities impaired RVF/LH performance more than LVF/RH performance, whereas greater eccentricities impaired LVF/RH performance, presumably because the small elements/details could still be used for task completion.

Other studies have obtained consistent visual field asymmetries at various eccentricities. Haun (1978) presented letters monocularly at eccentricities of 0.21°, 1.74°, and 3.74° in the LVF and RVF. The reaction times for vocal identifications of the letters were faster in the RVF/LH than in the LVF/RH. Chiarello, Senehi and Soulier (1986) presented words and non-words at 1.0°, 2.0° and 3.0° and found a RVF/LH superiority at all eccentricities. Similarly, no differences as a function of eccentricity were obtained for detecting gaps in circles (Chastain, 1981) or in squares (Levy-Schoen, 1977). Christman (1989) concluded that tasks involving simple sensitivity to and detection of stimuli composed of varying spatial frequency components do not yield reliable asymmetries

(Christman, 1990; Kitterle & Kaye, 1985). It has been suggested by Sergent (1983) and Christman (1989) that in order to find eccentricity differences, the task should require higher cognitive operations, i.e., identification or discrimination, which would require the processing of many of the elements comprising the stimulus.

An overview of these studies allows several conclusions to be drawn. It has been shown that at least in right handed men, the left cerebral hemisphere is specialized for analytic processing. Such processing includes analyzing the details of stimuli by formulating these stimuli within a verbal (left hemisphere) code. The conditions which foster analytic processing are, first and foremost, use of stimuli of a verbal/semantic nature. In addition, the stimulus qualities which draw attention to its respective details via high contrast, luminance, and small size (and, thus of high spatial frequency) increase the likelihood of analytic processing.

Holistic processing, the mode for which the right hemisphere is specialized, seems most clearly to be involved in the apprehension of patterned gestalts. Facilitators of holistic processing include configurational types of stimuli of low spatial frequency, low contrast, luminance and large size.

Both analytic and holistic processing can be enhanced or hindered by the demands placed on the subject via manipulations of instructional set, and/or of task requirements, and, if the stimulus conditions are met, the choice of type of processing may override the traditionally anticipated RVF superiority for linguistic stimuli, and the LVF superiority for spatial/configurational stimuli.

The main thrust of the present experiment was to investigate visual hemifield asymmetries in the processing of global (shape, gestalt closure task) and local (enumeration task) information by using identical dot patterns - for two different tasks. Based upon the findings cited earlier, which indicate that configurational, holistic information, exemplified by shape/form identifications, is processed more rapidly and/or more accurately than detailed information, which requires analysis of component/constituent elements (e.g., enumeration), it was hypothesized that (1) performance on the global, shape judgment task would be significantly faster and more accurate than on the local, dot enumeration task; (2) there would be a LVF/RH advantage for both accuracy and reaction time on the shape judgment task; and (3) there would be a

RVF/LH advantage for both accuracy and reaction time on the dot enumeration task. The last hypothesis was based upon the fact that the dot pattern comprised an identifiable geometric form (rather than random dots), the numbers of dots to be enumerated were less than seven, and the task instructions required that the subject attend to the local details/elements.

In addition, the effect of visual field position of the stimuli, two each in the LVF and RVF and one at central visual field (CVF), on hemifield asymmetries was investigated. The CVF stimuli were used to optimize central fixation and to compare bihemispheric stimulation (CVF) with unilateral stimulation (LVF, RVF). The near and far eccentricites within each visual field were used to examine the role of retinal eccentricity in visual hemifield asymmetries. A near (towards CVF) LVF/RH superiority was hypothesized for the global stimuli (shape judgment task), and a near RVF/LH superiority was hypothesized for the local stimuli (enumeration task). As eccentricity is increased, degradation of the stimulus occurs (see pp. 47) and is noted to affect processing asymmetries differently. At the far eccentricities, global stimuli were expected to result in maintenance of the LVF/RH superiority, whereas local stimuli were expected to be better processed in the LVF/RH rather than in the

RVF/LH, due to the decrease in high frequency information at the greater eccentricity. Lastly, the accuracy and reaction times of left and right hand responses were compared for each task at each of the visual field positions, in order to enable examination of input - output, stimulus - response, compatibility.

Method

Subjects

Sixteen males between the ages of 18 and 25 years (mean = 20.25 years) participated in this experiment. The criteria for inclusion were: age (18 to 25 years), normal visual acuity, right handedness, and no reported parental sinistrality.

All of the subjects were undergraduate students who were recruited via sign postings on the Queens College campus. Each subject who completed experimental testing was paid $20.00 for his participation. If the subject failed to meet the screening criteria, he was paid _pro rata._

A total of 45 subjects volunteered. Five failed to meet the age requirement, 5 failed to meet the visual acuity criterion, 8 failed to meet the parental handedness criterion, 6 did not appear for the appointment, and 4 could not be reached. One subject was tested but was found to have a "circular eye motion problem" and, consequently, his data were discarded. The final sample consisted of 16 subjects.

Voluntary informed consent was obtained from each subject (see Appendix A) and each was given general information regarding the "rights" of subjects, in compliance with the "Ethical Principles of

Psychologists" (American Psychological Association, 1981). The subjects were naive as to the nature and purpose of the experiment, although descriptions of the tasks and stimuli were provided prior to experimental testing.

Initially, each subject was given a visual acuity test, a handedness inventory of activities, and questions of parental handedness, in random order (see Appendix B). A standard Snellen chart was used to assess visual acuity for each eye separately. Visual acuity of at least 20/25, with or without correction, was required for participation in the experiment.

Handedness was assessed via a five-item performance task (Bryden 1977, 1982). Hand used for the five activities of writing, drawing, throwing a ball, and for manipulating a scissors and a toothbrush was assessed by the experimenter, who placed each item in front of the subject, at the subject's midline, and asked the subject to use the item. The criterion for right handedness was 100% use of the right hand, i.e., right hand usage on all five items. Each subject was asked to indicate the hand preference of both parents; only those with two right handed parents were included.

Each subject was then assigned, in alternating order, to one of the two possible task orders - judgement of shape task followed by dot enumeration, or the reverse order of tasks.

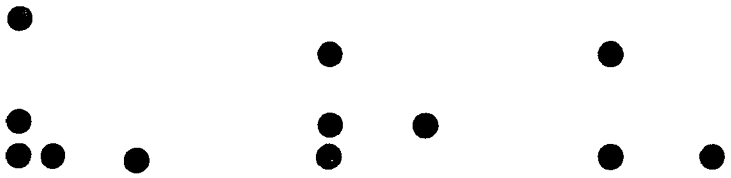
Stimuli

Experimental task stimuli. The experimental stimuli consisted of 9 geometric dot patterns: three shapes - a square, rectangle, or rhombus - each with four, five, or six dots (3 X 3 = 9) (see Figure 1). Each dot pattern was approximately 2.0° visual angle in size. Each dot was 0.1° visual angle in diameter and was placed at certain locations on the imaginary perimeter of each figure with three of the four corners of the form defined by a dot. The additional dots, one to three, were on one or two sides (those sides bordered by dots) of the figure with the visual angle between dots being either 0.38° or 0.76° visual angle from the corner of the figure. The angle defining the rhombus was 75°.

Each stimulus was projected to one of five locations within the visual field. These five locations were: (1) at central fixation with 1.0° of the 2.0° stimulus on each side, (2) 2.5° from central fixation to the inner border of the stimulus in the near left or near right visual fields, and (3) 4.5° from central fixation to the inner border of the stimulus in the far left or far right visual fields.

Vernier task stimuli. The vernier alignment

Figure 1. Samples of stimuli presented at each locus - rectangle, rhombus and square (each shape consisted of 4, 5 and 6 dots).



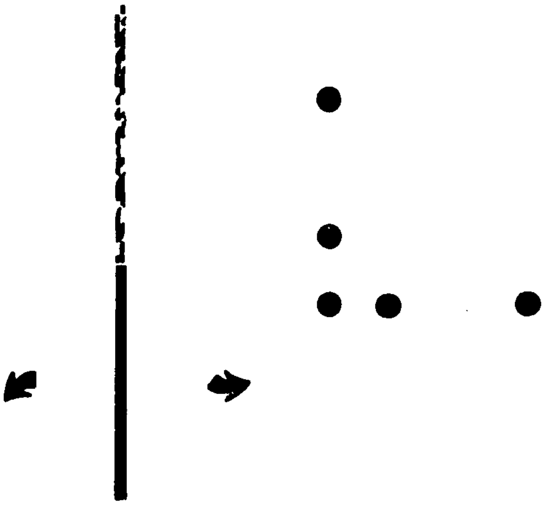
stimuli (fixation task, see Krynicki, 1976) were concurrently presented with the test stimuli and consisted of 1) a standard 2.0° vertical line (width of 0.25° visual angle) centered at 0.0° visual angle, with its lower boundary at the horizontal meridian which served as the fixation line, and 2) a comparison 2.0° vertical line with its upper boundary at the horizontal meridian, presented either at 0.0°(centrally) or 0.5° to the left or the right of central fixation (see Figure 2).

All stimuli were photographed in the positive and made into Kodak slides. There were 45 slides, each of a particular shape (n = 3), a particular number of dots (n = 3), and a particular field placement (n = 5).

Apparatus

An IBM PC-XT computer was used to control the timing of the slide presentations via a Gerbrands Three-Field Projection Tachistoscope (Model 1175) equipped with two Kodak Carousel Ektagraphic Model B-2 Projectors with corresponding shutters with synchronous contacts. Output from and input to the computer was conducted through a Lab Tender Digital In/Digital Out (I/O) board (Scientific Solutions, Inc., 1985) connected to an Opto 22 PB16a module mounting rack (with four (4) IDC5 input modules, and eight (8) ODC5

Figure 2. Sample of the stimulus configuration with the vernier alignment stimulus. The fixation line, crosshatched in this diagram, appears first (2s) and is immediately followed by the comparison line with the stimulus. The comparison line may be presented, as here, directly beneath the fixation line or 0.5° to the left or right.



and three (3) OAC5 output modules) and then to a three-way switch in the keypad, two tachistoscope shutters, and the projector advance inputs. Turbobasic language in conjunction with the IBM PC/XT was used to control the warning signal, the stimulus exposure durations, the interstimulus and intertrial intervals, and the slide advance routines. Stimuli were projected onto a glass screen 0.5 m in front of the subject. Luminance of the visual field was maintained at approximately 80 lx.

Two response keypads, each with three keys, were anchored to the table at the subject's right and left of body midline (Harvey, 1978). The keys were symmetrically placed with a radius of 10.0 mm from a circular piece of velcro which served as the finger rest pad. The keys were tagged with the numerals 4, 5, and 6 for the dot enumeration task and with the figural representations of a square, rectangle, and rhombus for the shape judgement task. Reaction time, accurate to the nearest tenth of a ms, and response choice (square, rectangle, rhombus; 4, 5, 6 dots) were computer recorded for each trial.

Pilot Testing

In pilot testing of nine 18-25 year old left and right handed adults (8 women, 3 men) drawn from the same population as that for the experimental study, a number of factors were investigated to determine the optimal testing procedures. The exposure duration of the stimuli, initially set at 100 ms, was found to be too short to complete both the vernier alignment task and the experimental task. It was then increased to 150 ms, a value that was adequate for the 9 pilot subjects so tested to complete both tasks. The original length of the testing procedure was found to be too long for the subjects to consistently attend to the tasks. It was, therefore, shortened from a within subjects ABBA counterbalancing of tasks (shape judgment = A; dot enumeration = B) to a between subjects counterbalancing of tasks - AB, BA. In addition, the testing session was halved so that the subjects received one of the two tasks, either A (of AB) or B (of BA), in the first session followed by the remaining task to be completed in the second session. The direction of the visual hemifield asymmetries obtained by the male (pilot) subjects (n=3) appeared to support the hypotheses posed at the outset, although no formal parametric tests of significance were conducted. The results for the (pilot) female subjects were somewhat equivocal. As a consequence, the study was conducted with 16 men who satisfied the screening criteria.

Procedures

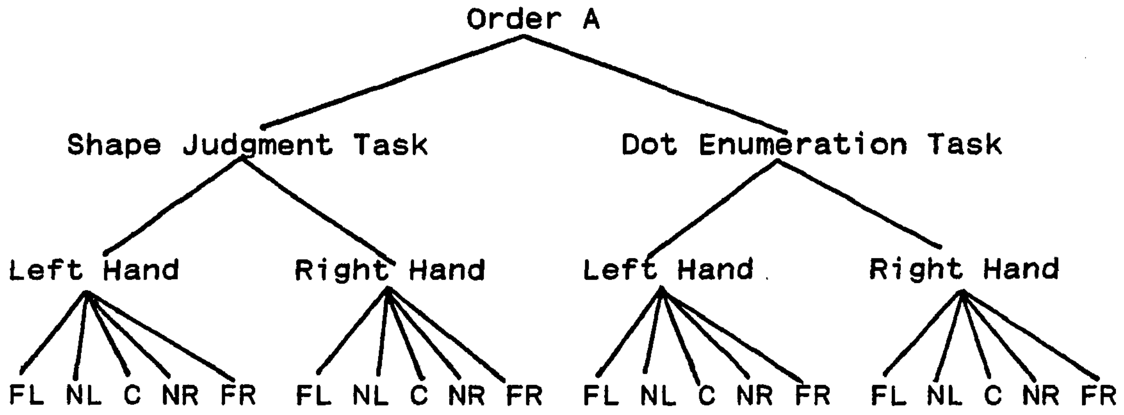
There were two experimental tasks - judgement of shape and dot enumeration - performed in a within groups design (see Figure 3). The subjects were assigned the two tasks, judgement of shape or judgement of dot enumeration, in counterbalanced order (AB,BA). Each task was performed during a separate testing session, on different days and within five days of one another.

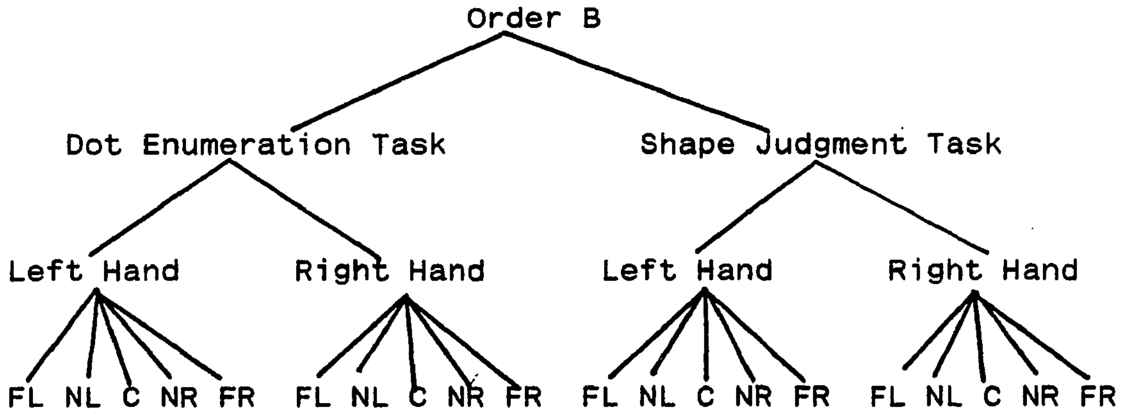
The vernier alignment task, which served as the fixation task, was presented concurrently with each experimental task. Thus, the subjects were required to perform an experimental task (shape judgement or dot enumeration) and vernier alignment simultaneously. On each trial, the subject judged whether or not the sequentially presented vernier lines were aligned, and identified the dot pattern presented simultaneously with the vernier comparison line.

Identification of the dot pattern was accomplished on half of the trials (n = 117) of each experimental task by keypressing with the left hand, and for the remaining half by keypressing with the right hand. The order of the hand used was arranged via block randomization.

For the vernier alignments, a vocal response of "yes" was required when the subject judged the comparison and the standard lines as misaligned; if the

Figure 3. Schematic of the experimental design. The factor of Order is a between subjects variable, and all others are within subjects variables (FL, NL, C, NR and FR are the loci of stimulus presentation).


Order A
Shape Judgment Task
Dot Enumeration Task
Left Hand
Right Hand
Left Hand
Right Hand
FL NL C NR FR
FL NL C NR FR
FL NL C NR FR
FL NL C NR FR


Order B
Dot Enumeration Task
Shape Judgment Task
Left Hand
Right Hand
Left Hand
Right Hand
FL NL C NR FR
FL NL C NR FR
FL NL C NR FR
FL NL C NR FR

comparison was seen as aligned with the standard, the subject was instructed not to make any verbal report.

A practice task was administered prior to each experimental task. The primary purpose of the practice task was to familiarize the subject with the vernier alignment task and with performing the two tasks (vernier and dot identification) simultaneously. This was accomplished by requiring that each subject achieve a 90% criterion of correct judgements of vernier alignment.

Practice task. The 30 trial practice task consisted of the presentation of 30 different stimuli. The first 6 trials required vernier alignments only. On 3 of these trials, the standard and comparison lines were aligned, and on 3, they were misaligned. The remaining 24 trials consisted of the presentation of experimental dot patterns which were simultaneously paired with vernier alignment stimuli. The vernier lines were aligned for 19 trials and misaligned for 5 trials. The dot stimuli were presented to each visual field locus in the following manner: there were four presentations to the central field, and five presentations to each of the other 4 loci (far and near left, and far and near right). The 24 stimuli were presented in random order with each stimulus of a particular shape or number of dots, in a particular field position, or a vernier misalignment, not occuring more than twice in consecutive order.

Experimental task. A total of 468 trials was administered to each subject for both tasks: 234 trials for the shape judgement task, with 117 trials with the left hand and 117 trials with the right hand; 234 trials for the dot enumeration task, with 117 trials with the left and 117 trials with the right hand. Nine different experimental test stimuli were presented twice (total = 18) for each field locus/hand/task combination. Of these 18 stimuli, there were 6 of each of 3 shapes or each of 3 numbers of dots. The presentation of a particular shape/number of dots was random, though not more than two of the same type could occur in consecutive order.

For each responding hand, there were a total of 90 experimental test trials (18 stimuli X 5 visual field loci). These 90 stimuli were divided into three sets of 30 each. The parameters of shape or numbers of dots were randomly placed within the 30 trial set so that a particular shape or number of dots did not occur consecutively more than twice. These three sets (total = 90 trials) were administered four times for each subject - for each of the 2 hand conditions for each of the 2 tasks - for a total of 360 trials.

There were 180 experimental test trials for each task (90 stimuli X 2 hands = 180), and, therefore, six sets (three sets presented twice) of 30 stimuli for each task. These six sets were presented in block random order with the constraint that not more than two sets of the same stimuli could be presented sequentially.

Overall, each subject was presented with 360 experimental test trials (180 stimuli X 2 tasks = 360), 180 stimuli per task, 90 stimuli per hand, and 18 stimuli per visual field locus, with 6 of each type of shape/number of dots.

In addition to the experimental test stimuli, 3 "practice" stimuli were added to the beginning of each set of 30 stimuli, for a total of 33 trials. These stimuli were duplicates of the experimental test stimuli and were randomly chosen from the other stimuli found in the sets.

Vernier alignment task within the experimental task. All of the 360 experimental test trials and 36 practice trials were presented with aligned vernier comparison lines at 0.0°. There were an additional 72 dot stimuli (36 per task, 18 per hand, 6 per set of stimuli) which were presented with misaligned vernier comparison lines. Three of the 6 per set of stimuli were misaligned to the left of the standard and 3 to the right of the standard. The pairing of a particular shape or number of dots with a misaligned vernier line was randomized. The sequence in which these 6 pairings were interspersed among the aligned pairings was also randomized. Thus, a total of 39 stimuli (30 experimental test stimuli, 3 practice stimuli, and 6 misaligned vernier comparisons with experimental dot stimuli) constituted a full set of stimuli.

Overall, a total of 528 trials was administered to each subject: 60 practice task stimuli, of which 12 were vernier alignment stimuli without dots and 48 were vernier alignment stimuli with dots; 360 experimental test stimuli and 36 practice stimuli, all with aligned vernier comparison lines, and 72 misaligned vernier comparison lines with dot stimuli.

All stimuli were presented in the following manner: For both practice and experimental tasks, a trial began with a 1 s computer generated tone. The fixation (standard) line was then shown for 2 s. Test stimulus (dot stimulus with vernier comparison line) presentation immediately followed the offset of the standard fixation line and lasted for 150 ms. The subject's key press response then signaled the next trial. The intertrial interval was 3 s. The data from those trials on which the subject's reaction time was greater than 3 s were discarded, and the trials were readministered at the end of the 30 practice trials and 39 experimental trials. For each trial, the subject was to respond vocally with "yes" if he judged the standard (vernier fixation line) and comparison lines to be "misaligned".

The total testing time for both sessions (shape judgement, dot enumeration judgement) was approximately 2 hr. The first session, lasting approximately 1 hr 10 min, included 20 min for the qualifying tests (visual acuity, hand preference test, report of parental hand preference), instructions, samples, dark adaptation, and 50 min for the practice and experimental tasks. The second session lasted approximately 50 min and included instructions, samples, dark adaptation, and administration of the practice and experimental tasks.

Design

The 2 X 2 X 2 X 5 mixed design of the experiment was aimed at the examination of the separate and interrelated effects of task (n = 2), hand (n = 2), and visual field position (n = 5) on reaction time and accuracy of judgement. The order of presentation of the tasks (n = 2) was an additional (control) variable.

Two tasks - shape judgement and dot enumeration judgement - responding hand - left and right - and visual field position - far left, near left, central, near right, and far right - were investigated as within subjects variables. The order of administation of the two tasks was a between subjects variable.

The order of tasks was counterbalanced between subjects, with 8 of the 16 subjects receiving the shape judgement task followed by the dot enumeration task, and the remaining 8 receiving the dot enumeration task followed by the shape judgement task. Each subject had to perform each task with the left and right hands. A particular hand was assigned to a set of 39 trials via block randomization, with the constraint that the left or right hand could not be used for more than two consecutive sets. The subject was instructed to depress the appropriate keypad to identify the shape (square, rectangle, or rhombus) or the number of dots (4, 5, or 6) with either the left or right index finger. An additional factor was the location of the stimulus within the visual field - at the far left, near left, central, near right, or far right. The statistical design was therefore a 2 X (2 X 2 X 5) with independent measures on the first (task order) and repeated measures on the 3 other variables (task, hand, visual field locus).

Procedure: Testing conditions and protocol

Each subject was tested in the New Science Building at Queens College. The subject was seated at a table where he was asked to read and sign the consent form. The subject was then given the handedness test, questions of parental handedness, and visual acuity test in random order.

The following protocol was followed for both testing sessions (one task completed per session). The subject was seated at the apparatus where height adjustments of the seat and chin rest were made so that the subject was comfortable and at eye level with central fixation (horizontal and vertical meridians) on the screen. The subject was given a page of instructions (see Appendix C) which the experimenter read along with him. Any questions were answered.

Examples of the stimuli were tachistoscopically presented under free viewing conditions. The subject was shown the fixation (standard vernier) line and was instructed to maintain his focus at the bottom of this line as his accuracy in judgement of vernier alignment would be greatest when this was followed. Accuracy and speed of response were emphasized. The subject was presented with the vernier comparison line (one aligned with the standard, one misaligned to the left, one misaligned to the right) to acqaint him with "aligned" and "misaligned" comparison vernier stimuli. Two of each type of dot stimulus (two squares, two 4 dot stimuli, etc.) were then shown, and the subject was asked to identify the stimulus by pressing the key corresponding to the shape or the number of dots on the screen. The subject was told to keep his index finger on the finger rest pad at all times except when responding to the stimulus. Further instruction was given to clarify the task, if necessary. The room was then darkened for the remainder of the session, and a 10 min period prior to testing was alloted for dark adaptation. The 30 practice trials followed by the 234 experimental trials were then administered.

Practice. For the first 6 (vernier only) trials of the practice task the subject was told that he would only be seeing the standard line followed by the comparison line. He was told to focus on the bottom of the standard line and to maintain this focus during its presentation and during the presentation of the subsequent comparison line. He was instructed to press one of the keys in a left to right order (to terminate the trial) and to say "yes" if the comparison line was misaligned and to remain silent if the standard and comparison lines were deemed aligned. After the sixth (vernier alignment only) trial and prior to the seventh (stimulus) trial, the subject was informed that the dot stimuli would now be presented along with the vernier alignment stimuli. The instructions (see Appendix C) for these 24 trials of the practice task (and for all 468 experimental task trials) were 1) to focus on the bottom of the standard vernier line and maintain this focus during its presentation and during the subsequent presentation of the comparison line, 2) to identify either the shape of the stimulus or the number of dots by counting them, as quickly and accurately as possible, 3) to indicate his decision as to the shape or number of dots by pressing the appropriate key, and then 4) to indicate whether the comparison line was misplaced to the left or the right by saying "yes".

If the subject erred by saying "yes" when the lines were aligned, or failed to respond with a "yes" when the lines were misaligned, the trial was rerun at the end of the 30 trials. Trials on which there were errors in the judgement of alignment were readministered until the subject achieved an overall accuracy rate of at least 90%.

Experimental testing. Following the practice task the 234 experimental task trials were administered in 6 sets of 39 trials. Prior to each set, the subject was told which hand/index finger he would be using. He was also reminded to maintain focus on the bottom of the standard vernier line, and to identify the stimulus as accurately as possible by pressing the appropriate key as quickly as possible. The subject was also asked to respond to the vernier alignment task with a "yes" response whenever he judged the standard and comparison lines to be misaligned. No response was required if the vernier lines were judged to be aligned.

Errors on the alignment task for both aligned and misaligned stimuli were used to assess the subject's skill at the fixation task. The data (reaction time and accuracy of stimulus identification) from those trials on which there were errors in vernier alignment judgments were discarded and the trials were readministered once at the end of the 39 trial set.

Response measures. There were 2 response measures: (1) accuracy of judgement (shape and number of dots), and (2) reaction time to make the judgments. Both the accuracy and reaction time data were obtained only from those trials in which the vernier stimuli were correctly judged as aligned.

Data Analysis

The mean reaction time scores for each task, hand, and field location combination were calculated from each subject's median reaction time score for that combination. For the accuracy measure, the percentages of correct judgments were calculated for each subject, and the mean percentages were calculated for each task, hand, and visual field position combination.

To directly address the major questions posed in this experiment, three levels of statistical analyses (ANOVAs) were done, as follows:

Level A. 2(Order) X 2(Task) X 2(Hand) X 5 (Field Locus)

The purpose of the overall analysis was to compare the data from the central visual field (CVF) with those from the (4) non-central loci.

Level B. 2(Order) X 2(Task) X 2(Hand) X 2(Field: RVF, LVF) X 2(Locus: Far, Near)

This analysis was aimed at direct assessment of the main effects of visual field, locus, and hand, and their interactions, for the two tasks combined.

Level C. 2(Order) X 2(Hand) X 2(Field) X 2(Locus)

In this analysis, the data from the shape judgment and dot enumeration tasks were analyzed separately (2 ANOVAs).

Each of the above (four) ANOVAs was performed on the accuracy data and on the reaction time data, for a total of eight ANOVA tests. Differences between means were considered statistically significant if they reached or exceeded the .05 level of significance.

To ascertain the relationship between reaction time and accuracy, two Pearson product moment correlations (of median reaction time and percentage correct judgments) were performed, one for the shape judgment task and one for the dot enumeration task.

Results

Accuracy

The percentage of correct responses was calculated for each order, task, visual field location, and response hand combination for each subject. These percentages (means and standard deviations) are presented in Table 1. The mean percentages for order (2), task (2), hand (2) and visual field locus (5) were entered into a (Level A) Analysis of Variance (ANOVA).

There was a significant effect of visual field location on subjects' accuracy of response ($F(4, 42)=21.27$, $p<0.001$). Planned comparisons calculated with the multiple F test procedure (Weiss, 1990) showed that responses to stimuli at the CVF locus ($\overline{X}=81\%$) were significantly more acccurate than those to each of the other loci (FLVF: $\overline{X}=65\%$, NLVF: $\overline{X}=67\%$, NRVF: $\overline{X}=69\%$, FRVF: $\overline{X}=64\%$) (CD=11.67, $p=0.01$).

For further analyses of accuracy, the data from the CVF stimulus were omitted. A (Level B) ANOVA was performed for the variables of order (2), task (2), field (2: LVF and RVF), locus (2: far and near visual hemifields), and hand (2) (see Tables 2 and 3).

A difference in accuracy between the two tasks was found, with responses to the shape judgment task ($\overline{X}=82\%$) being significantly more accurate than

Table 1

Mean Percentage Correct With Corresponding Standard Deviations (Level A)

Dot Enumeration Task

	FLVF	NLVF	CVF	NRVF	FRVF
Left Hand					
Order A	49 (12)	48 (11)	78 (21)	52 (11)	51 (14)
Order B	54 (16)	55 (21)	70 (15)	48 (12)	43 (9)
Right Hand					
Order A	50 (12)	53 (13)	83 (13)	46 (13)	48 (16)
Order B	50 (10)	56 (15)	71 (16)	58 (15)	44 (7)

Shape Judgment Task

	FLVF	NLVF	CVF	NRVF	FRVF
Left Hand					
Order A	82 (8)	82 (11)	85 (7)	85 (10)	72 (16)
Order B	79 (6)	79 (11)	90 (12)	92 (7)	88 (8)
Right Hand					
Order A	78 (8)	85 (11)	86 (13)	85 (10)	81 (10)
Order B	76 (5)	76 (13)	90 (9)	89 (7)	82 (10)

Table 2
Mean Percentage Correct With Corresponding Standard Deviations for Combined Near and Far Loci (Levels B and C)

Dot Enumeration Task

	Left Visual Field	Right Visual Field
Left Hand		
Order A	49 (12)	51 (13)
Order B	55 (18)	46 (11)
Right Hand		
Order A	51 (12)	47 (14)
Order B	53 (13)	51 (11)

Shape Judgment Task

	Left Visual Field	Right Visual Field
Left Hand		
Order A	82 (10)	79 (13)
Order B	79 (9)	90 (8)
Right Hand		
Order A	82 (9)	83 (10)
Order B	76 (9)	85 (9)

Table 3

Mean Percentage Correct With Corresponding Standard Deviations for Combined Right and Left Visual Fields (Levels B and C)

Dot Enumeration Task

	Near Visual Field	Far Visual Field
Left Hand		
Order A	50 (11)	50 (13)
Order B	52 (16)	49 (13)
Right Hand		
Order A	49 (13)	49 (14)
Order B	57 (15)	47 (7)

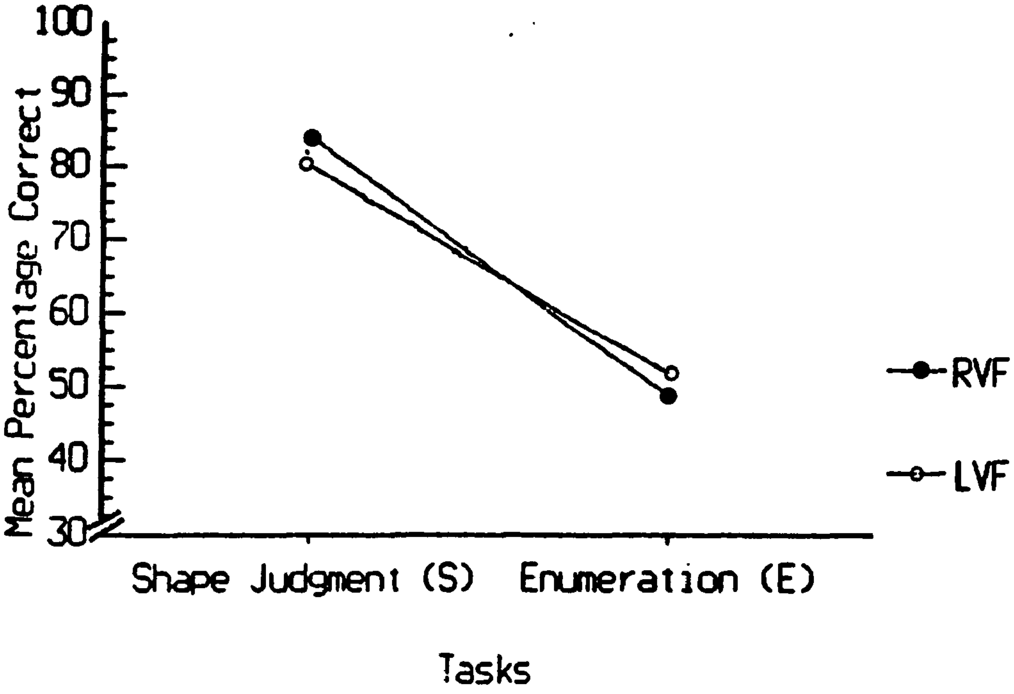
Shape Judgment Task

	Near Visual Field	Far Visual Field
Left Hand		
Order A	84 (11)	77 (12)
Order B	85 (9)	84 (7)
Right Hand		
Order A	85 (11)	80 (9)
Order B	82 (10)	79 (7)

responses to the dot enumeration task ($\bar{X}=52\%$), $F(1, 14)=215.83$, $p<0.0001$. There was also a difference in accuracy between the two loci (near vs. far visual hemifields). Responses to dot patterns in the near fields ($\bar{X}=68\%$) were significantly more accurate than to those in the far fields ($\bar{X}=65\%$), $F(1, 14)=9.07$, $p<0.01$. Overall accuracy differences between the LVF ($\bar{X}=66\%$) and RVF ($\bar{X}=67\%$) stimuli, and between the left and right hands ($\bar{X}=66\%$ and $\bar{X}=66\%$, respectively) were not significant ($F(1,14)=0.20$, $p<0.67$, $F(1,14)=0.03$, $p<0.86$ for visual field and hand, respectively). In addition, there was no evidence of an effect of task order (Order A: shape judgment followed by dot enumeration, $\bar{X}=65\%$, Order B: dot enumeration followed by shape judgment, $\bar{X}=66\%$) on accuracy of response ($F(1,14)=0.27$, $p<0.61$).

Response accuracy depended on the relationship between task and visual field of stimulus presentation. This interaction between task and visual field was statistically significant ($F(1, 14)=4.66$, $p=0.05$) and showed that the accuracy difference between the LVF ($\bar{X}=80\%$) and the RVF ($\bar{X}=84\%$) for shape judgments was significantly different from the difference between the LVF ($\bar{X}=52\%$) and the RVF ($\bar{X}=49\%$) for dot enumerations. As may be seen in Figure 4, for shape judgments, overall accuracy was greater for RVF than for LVF

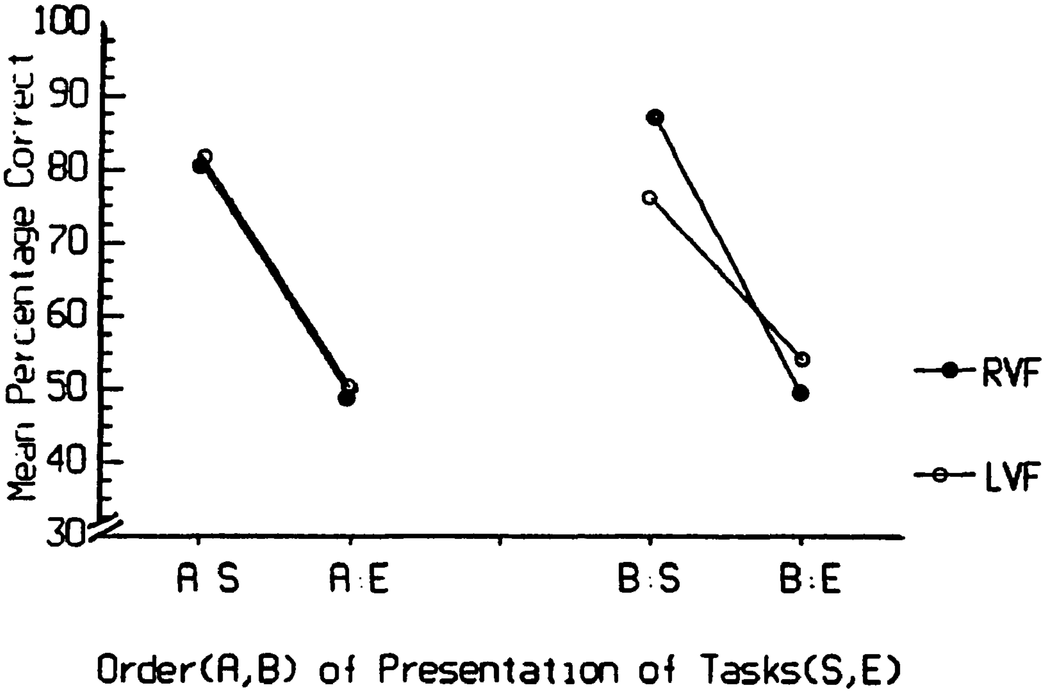
Figure 4. Mean percentage correct as a function of the task and the visual field of stimulus presentation (LVF = left visual field; RVF = right visual field).


100
90
80
70
60
50
40
30
Mean Percentage Correct
Shape Judgment (S)
Enumeration (E)
Tasks
RVF
LVF

presentations. In contrast, for dot enumerations, overall accuracy was slightly greater for responses made to stimuli presented to the LVF than to those presented to the RVF. However, multiple F planned comparison followup tests yielded no statistically significant differences in accuracy between the LVF and the RVF for either task.

Differences in accuracy were found when the interaction between order, task and field ($F(1,14)=4.48$, $p=0.05$) was evaluated. The difference between the LVF (shape judgments: $\bar{X}=82\%$; dot enumerations: $\bar{X}=50\%$) and the RVF (shape judgments: $\bar{X}=81\%$; dot enumerations: $\bar{X}=49\%$) for each task in Order A was significantly different from the difference between the LVF (shape judgments: $\bar{X}=76\%$; dot enumerations: $\bar{X}=54\%$) and the RVF (shape judgments: $\bar{X}=88\%$; dot enumerations: $\bar{X}=49\%$) for each task in Order B. As may be seen in Figure 5, overall accuracy of both shape judgments and dot enumerations in Order A was virtually identical for the LVF and RVF. For Order B, overall greater accuracy was found to RVF than to LVF presentations for shape judgments, whereas, in the case of dot enumerations, overall greater accuracy was found to stimuli presented to the LVF than to the RVF. The results of the significant interaction between task

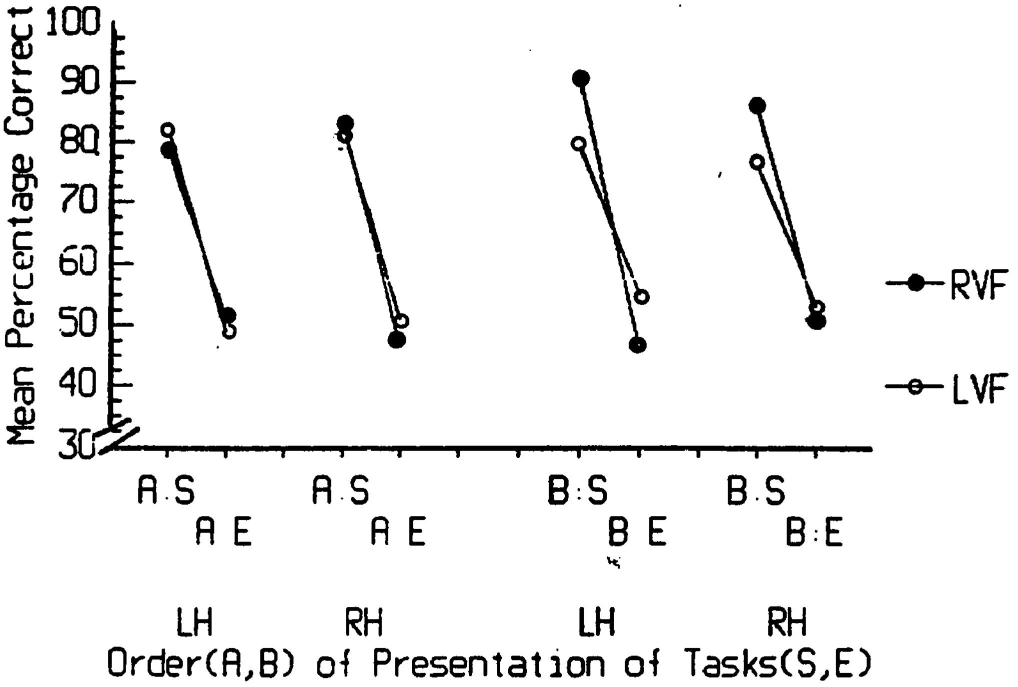
Figure 5. Mean percentage correct as a function of the task, the visual field of stimulus presentation and task order (A = shape judgments (S) followed by dot enumerations (E); B = dot enumerations followed by shape judgments; LVF = left visual field; RVF = right visual field).


Mean Percentage Correct
100
90
80
70
60
50
40
30
A S
A:E
B:S
B:E
Order(A,B) of Presentation of Tasks(S,E)
RVF
LVF

and field (see above) were thus a function of task order, with the hemifield differences being seen only in Order B.

Differences in accuracy were obtained when the interaction between order, task, field and hand was evaluated ($F(1,14)=7.45$, $p<0.01$). This interaction showed that the difference between the LVF (shape judgments: Order A - $\bar{X}=82\%$, Order B - $\bar{X}=79\%$; dot enumerations: Order A - $\bar{X}=49\%$, Order B - $\bar{X}=55\%$) and the RVF (shape judgments: Order A - $\bar{X}=79\%$, Order B - $\bar{X}=90\%$; dot enumerations: Order A - $\bar{X}=51\%$, Order B - $\bar{X}=46\%$) for each task for each order when responding with the left hand was significantly different from the difference between the LVF (shape judgments: Order A - $\bar{X}=82\%$; Order B - $\bar{X}=76\%$; dot enumerations: Order A - $\bar{X}=51\%$, Order B - $\bar{X}=53\%$) and RVF (shape judgments: Order A - $\bar{X}=83\%$, Order B - $\bar{X}=85\%$; dot enumerations: Order A - $\bar{X}=47\%$, Order B - $\bar{X}=51\%$) for each task for each order when responding with the right hand. This four-way interaction is depicted in Figure 6. As with the interaction between task and field, and between task, field and order, the greater accuracy of response to RVF presentations for shape judgments and to LVF presentations for dot enumerations was found for both the left and right hands, but only for Order B.

Figure 6. Mean percentage correct as a function of the task, the visual field of stimulus presentation, responding hand and task order (A = shape judgments (S) followed by dot enumerations (E); B = dot enumerations followed by shape judgments; LVF = left visual field; RVF = right visual field; LH = left hand; RH = right hand).


Mean Percentage Correct
100
90
80
70
60
50
40
30
A S
A E
A S
A E
B S
B E
B S
B E
LH
RH
LH
RH
Order(A,B) of Presentation of Tasks(S,E)
RVF
LVF

There was no evidence of any other significant two-way interactions (Task X Locus, $F(1,14)=0.07$, $p<0.80$; Task X Hand, $F(1,14)=0.35$, $p<0.60$; Field X Locus, $F(1,14)=2.09$, $p<0.17$; Field X Hand, $F(1,14)=0.13$, $p<0.73$; Locus X Hand, $F(1,14)=0.64$, $p<0.44$; Order X Task, $F(1,14)=0.02$, $p<0.90$; Order X Field, $F(1,14)=0.74$, $p<0.40$; Order X Locus, $F(1,14)=0.48$, $p<0.50$; Order X Hand, $F(1,14)=0.35$, $p<0.57$). Also, none of the other three-way interactions were significant (Task X Field X Locus, $F(1,14)=0.42$, $p<0.53$; Task X Hand X Field, $F(1,14)=0.29$, $p<0.60$; Task X Hand X Locus, $F(1,14)=1.05$, $p<0.33$; Field X Locus X Hand, $F(1,14)=0.55$, $p<0.47$; Order X Task X Locus, $F(1,14)=2.63$, $p<0.13$; Order X Field X Locus, $F(1,14)=0.50$, $p<0.50$; Order X Hand X Field, $F(1,14)=1.12$, $p<0.31$; Order X Hand X Locus, $F(1,14)=0.89$, $p<0.37$; Order by Task by Hand, $F(1,14)=2.64$, $p<0.13$). Lastly, none of the other four-way interactions were significant (Order X Task X Field X Locus, $F(1,14)=1.06$, $p<0.33$; Order X Task X Locus X Hand, $F(1,14)=0.17$, $p<0.69$; Order X Field X Locus X Hand, $F(1,14)=2.67$, $p<0.13$). The five-way interaction (Order X Task X Field X Locus X Hand) was also not statistically significant ($F(1,14)=0.16$,

$p<0.70$).

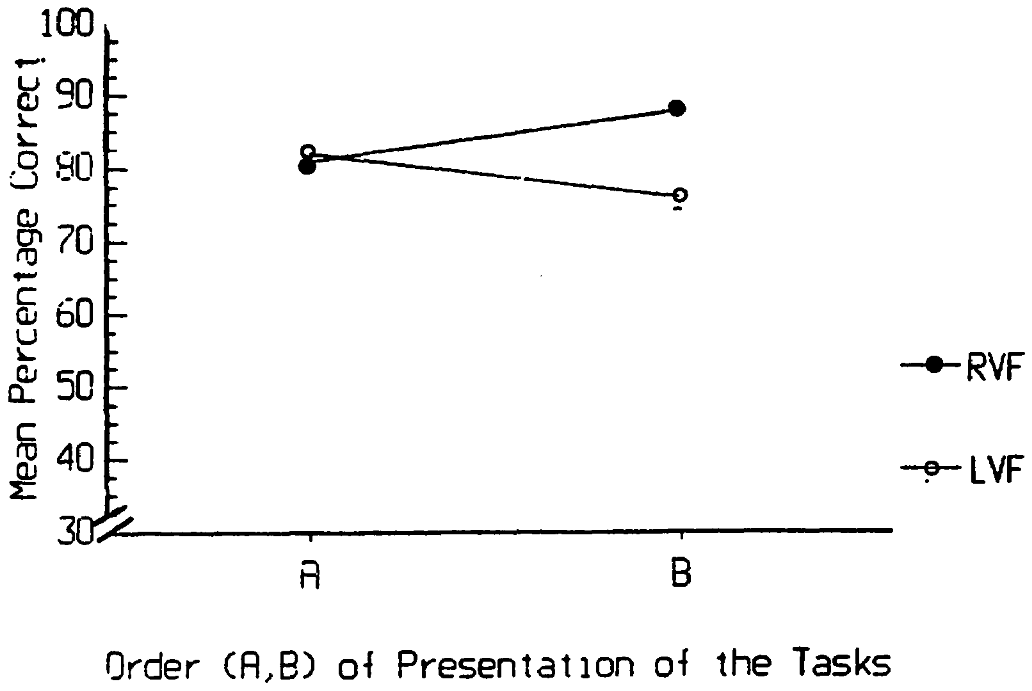
The accuracy data were then analyzed separately for each of the two tasks (Level C analyses).

Shape Judgment Task. The mean percentages of correct judgments of shape (see Tables 2 and 3) were entered into an ANOVA for the variables of order (2), field (2), locus (2), and hand (2).

A significantly greater accuracy of shape judgments to RVF presentations ($\bar{X}=84\%$) than to LVF presentations ($\bar{X}=80\%$) was found ($F(1,14)=5.43$, $p<0.04$). In addition, responses to stimuli at the near visual field loci ($\bar{X}=84\%$) were significantly more accurate than responses to stimuli at the far visual field loci ($\bar{X}=80\%$) ($F(1,14)=5.39$, $p<0.04$). No differences in accuracy of shape judgments were found between the left ($\bar{X}=82\%$) and right ($\bar{X}=81\%$) hands ($F(1,14)=0.53$, $p<0.48$), nor between the two task orders (Order A: $\bar{X}=81\%$; Order B: $\bar{X}=82\%$) ($F(1,14)=0.21$, $p<0.66$).

There was a statistically significant interaction between visual field and task order ($F(1,14)=7.13$, $p<0.02$). This relationship may be seen in Figure 7. The difference in accuracy between the LVF ($\bar{X}=82\%$) and RVF ($\bar{X}=81\%$) in Order A (shape judgment followed by dot enumeration) was significantly different from the difference between the LVF ($\bar{X}=76\%$) and RVF ($\bar{X}=88\%$) in Order B (dot enumeration followed by shape judgment).

Figure 7. Mean percentage of correct shape judgments as a function of visual field of stimulus presentation and task order (A = shape judgments followed by dot enumerations; B = dot enumerations followed by shape judgments).


Mean Percentage Correct
100
90
80
70
60
50
40
30
A
B
Order (A,B) of Presentation of the Tasks
RVF
LVF

None of the other two-way and none of the three-way interactions or four-way interaction were found to be statistically significant (Field X Locus, $F(1,14)=3.67$, $p<0.08$; Field X Hand, $F(1,14)=0.35$, $p<0.57$; Hand X Locus, $F(1,14)=0.00$, $p<1.00$; Order X Locus, $F(1,14)=0.73$, $p<0.41$; Order X Hand, $F(1,14)=4.25$, $p<0.06$; Field X Locus X Hand, $F(1,14)=0.76$, $p<0.40$; Order X Field X Locus, $F(1,14)=0.01$, $p<0.92$; Order X Hand X Field, $F(1,14)=0.94$, $p<0.35$; Order X Hand X Locus, $F(1,14)=0.20$, $p<0.66$; Order X Field X Locus X Hand, $F(1,14)=1.86$, $p<0.20$).

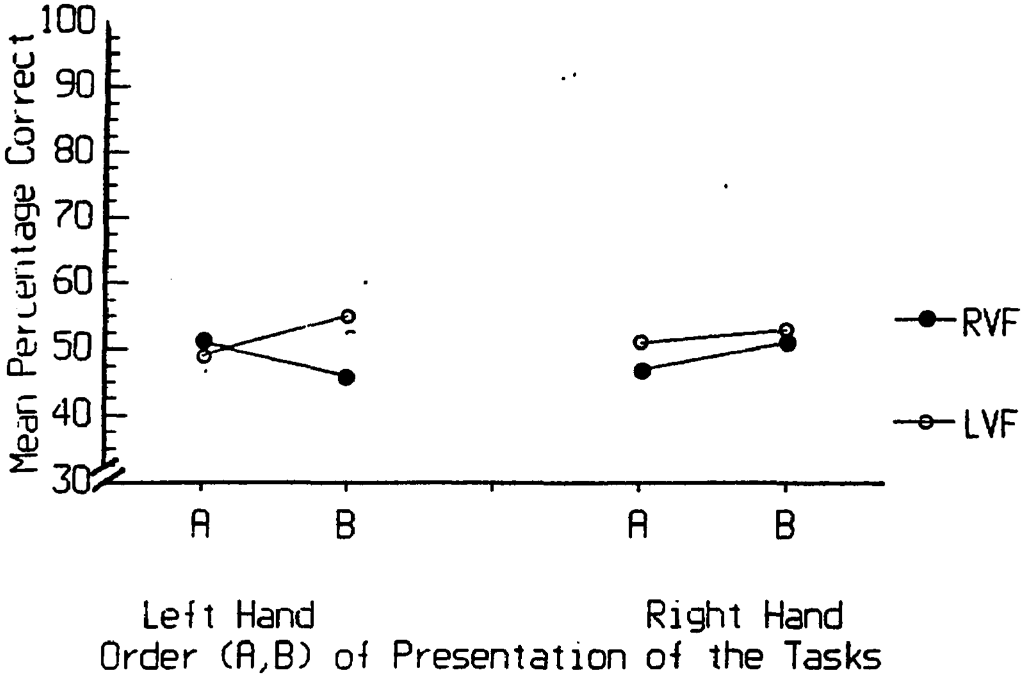
Dot Enumeration Task. As for shape judgments, the mean percentages of correct dot enumerations (see Tables 2 and 3) were entered into a (Level C) ANOVA.

Accuracy of dot enumeration was similiar for the LVF ($\bar{X}=52\%$) and RVF ($\bar{X}=49\%$) ($F(1,14)=1.03$, $p<0.33$). No statistically significant differences in accuracy emerged between stimuli at the near ($\bar{X}=52\%$) and far ($\bar{X}=49\%$) loci ($F(1,14)=2.64$, $p<0.13$), between the left ($\bar{X}=50\%$) and right ($\bar{X}=51\%$) hands ($F(1,14)=0.53$, $p<0.81$), or between the two task orders (Order A: $\bar{X}=49\%$; Order B: $\bar{X}=50\%$) ($F(1,14)=0.15$, $p<0.71$).

Differences in accuracy of dot enumeration were found when the interaction between order, hand and field ($F(1,14)=8.05$, $p<0.01$) was evaluated. The difference in accuracy between the LVF (Order A: $\bar{X}=49\%$; Order B: $\bar{X}=55\%$) and the RVF (Order A: $\bar{X}=51\%$; Order B: $\bar{X}=46\%$) for each task order for the left hand was significantly different from the difference between the LVF (Order A: $\bar{X}=51\%$; Order B: $\bar{X}=53\%$) and RVF (Order A: $\bar{X}=47\%$; Order B: $\bar{X}=51\%$) for each task order for the right hand. This three-way interaction is depicted graphically in Figure 8. As is suggested by the figure, greater accuracy was found to LVF presentations for both task orders when responding with the right hand, but to LVF presentations when using the left hand only in Order B.

None of the two-way and other three-way interactions or four-way interaction were statistically significant (Field X Locus, $F(1,14)=0.40$, $p<0.54$; Field X Hand, $F(1,14)=0.01$, $p<0.93$; Locus X Hand, $F(1,14)=1.97$, $p<0.19$; Order X Field, $F(1,14)=0.55$, $p<0.48$; Order X Locus, $F(1,14)=2.49$, $p<0.14$; Order X Hand, $F(1,14)=0.42$, $p<0.53$; Hand X Field X Locus, $F(1,14)=0.02$, $p<0.89$; Order X Field X Locus, $F(1,14)=1.04$, $p<0.33$; Order X Hand X Locus, $F(1,14)=1.22$, $p<0.29$; Order X Hand X Field X Locus, $F(1,14)=0.87$, $p<0.37$).

Figure 8. Mean percentage of correct dot enumerations as a function of visual field of stimulus presentation, responding hand and task order (LVF = left visual field; RVF = right visual field; A = dot enumeration as the second task that was completed; B = dot enumeration as the first task that was completed).


Mean Percentage Correct
100
90
80
70
60
50
40
30
A
B
A
B
RVF
LVF
Left Hand
Right Hand
Order (A,B) of Presentation of the Tasks

Reaction Time

Each subject's median reaction times for correct responses were calculated for each order, task, visual field location, and response hand combination. The group/condition mean reaction times and standard deviations are presented in Table 4. The reaction time scores for order (2), task (2), hand (2) and visual field locus (5) were entered into a (Level A) ANOVA.

As was the case for the accuracy measure (see p. 78), there was a statistically significant effect of visual field location on reaction time ($F(4,42)=6.48$, $p<0.001$). Followup planned comparison multiple F tests (Weiss, 1990) indicated that reaction time to the CVF ($\bar{X}=1052$ ms) dot pattern was significantly faster than reaction time to the FLVF pattern ($\bar{X}=1133$ ms) (CD=79.24, $p=0.05$), and slightly but not significantly faster than reaction times to stimuli in the NLVF ($\bar{X}=1117$ ms), the NRVF ($\bar{X}=1061$ ms), and the FRVF ($\bar{X}=1107$ ms).

The reaction time scores were then analyzed with the data from the CVF omitted. A (Level B) ANOVA was performed for the variables of order (2), task (2), field (2: LVF and RVF), locus (2: near and far visual hemifields), and hand (2) (see Tables 5 and 6).

As the data in Tables 5 and 6 show, reaction time

Table 4

Mean Reaction Time (ms) With Corresponding Standard Deviations (Level A)

Dot Enumeration Task

	FLVF	NLVF	CVF	NRVF	FRVF
Left Hand					
Order A	1326(232)	1241(263)	1169(231)	1128(211.83)	1182(147)
Order B	1106(201)	1159(207)	1060(265)	1046 (169)	1093 (177)
Right Hand					
Order A	1233(247)	1209(214)	1109(203)	1083(159)	1143(202)
Order B	1132(233)	1100(218)	1048(171)	1105(136)	1192(220)

Shape Judgment Task

	FLVF	NLVF	CVF	NRVF	FRVF
Left Hand					
Order A	1151(273)	1191(228)	1121(255)	1088(240)	1127(228)
Order B	1000(174)	963(172)	919(177)	947(132)	991(228)
Right Hand					
Order A	1132(226)	1099(290)	1031(175)	1046(234)	1081(173)
Order B	986(137)	976(173)	957(166)	953(142)	1041(153)

Table 5

Mean Reaction Time (ms) With Corresponding Standard Deviations for Combined Near and Far Loci (Levels B and C)

Dot Enumeration Task

	Left Visual Field	Right Visual Field
Left Hand		
Order A	1284 (247)	1152 (180)
Order B	1133 (204)	1070 (173)
Right Hand		
Order A	1221 (230)	1113 (180)
Order B	1116 (225)	1149 (178)

Shape Judgment Task

	Left Visual Field	Right Visual Field
Left Hand		
Order A	1171 (251)	1108 (234)
Order B	982 (173)	969 (132)
Right Hand		
Order A	1116 (258)	1064 (204)
Order B	981 (155)	997 (148)

Table 6

Mean Reaction Time (ms) With Corresponding Standard Deviations for Combined Left and Right Visual Fields (Levels B and C)

Dot Enumeration Task

	Near Visual Field	Far Visual Field
Left Hand		
Order A	1181 (237)	1254 (189)
Order B	1103 (188)	1100 (189)
Right Hand		
Order A	1146 (187)	1188 (224)
Order B	1103 (177)	1162 (226)

Shape Judgment Task

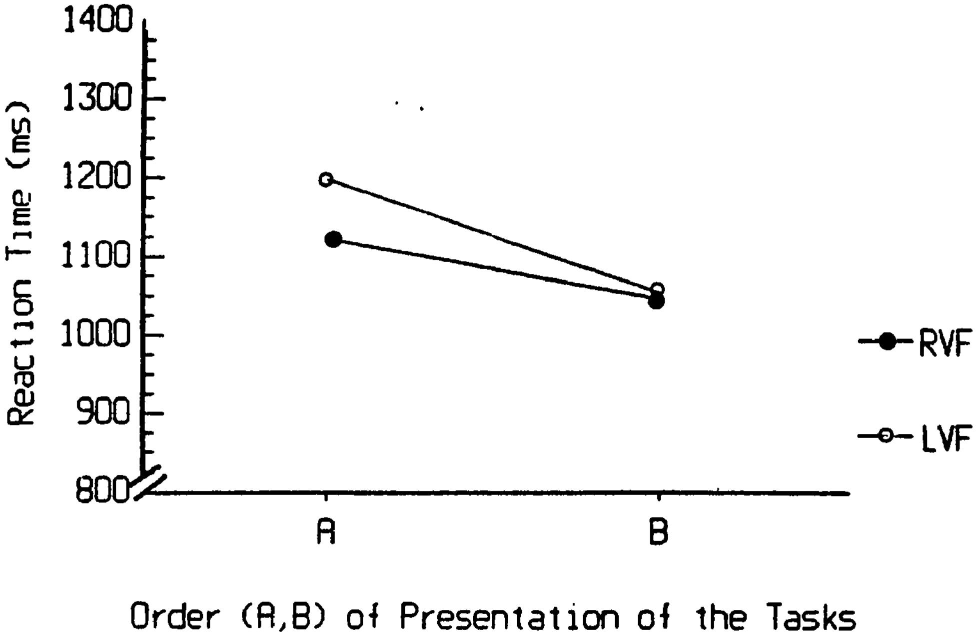
	Near Visual Field	Far Visual Field
Left Hand		
Order A	1140 (234)	1139 (251)
Order B	955 (152)	996 (152)
Right Hand		
Order A	1073 (262)	1107 (200)
Order B	965 (158)	1014 (145)

on the shape judgment task ($\bar{X}=1048$ ms) was faster than on the dot enumeration task ($\bar{X}=1160$ ms). This difference was statistically significant ($F(1,14)=9.17$, $p<0.01$). Also, responses to stimuli in the RVF ($\bar{X}=1084$ ms) were significantly faster than to those in the LVF ($\bar{X}=1125$ ms) ($F(1,14)=6.20$, $p<0.03$). Finally, reaction time to stimuli presented in the near visual fields ($\bar{X}=1089$ ms) was significantly faster than to stimuli in the far visual fields ($\bar{X}=1120$ ms) ($F(1,14)=6.20$, $p<0.03$). No differences in reaction time were found between the left ($\bar{X}=1115$ ms) and right ($\bar{X}=1094$ ms) hands ($F(1,14)=2.25$, $p<0.16$), or between the two task orders (Order A: $\bar{X}=1160$ ms; Order B: $\bar{X}=1049$ ms) ($F(1,14)=1.85$, $p<0.20$).

Differences in reaction time were seen between Order A and Order B as a function of visual field ($F(1,14)=4.63$, $p<0.05$) (see Figure 9). This interaction shows that the difference in reaction time between the LVF ($\bar{X}=1198$ ms) and the RVF ($\bar{X}=1122$ ms) in Order A (shape judgments followed by dot enumerations) was significantly differerent from the difference in reaction time between the LVF ($\bar{X}=1053$ ms) and RVF ($\bar{X}=1046$ ms) in Order B (dot enumerations followed by shape judgments).

The Order X Hand interaction was also found to be

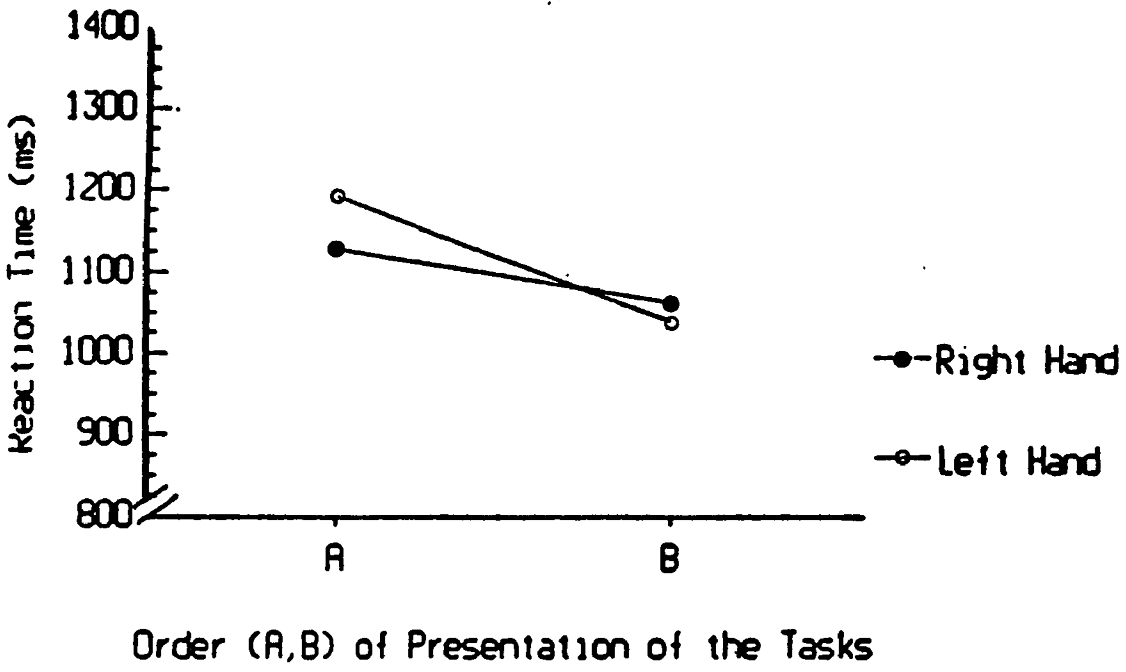
Figure 9. Reaction time as a function of visual field of stimulus presentation and task order (LVF = left visual field; RVF = right visual field; A = shape judgments followed by dot enumerations; B = dot enumerations followed by shape judgments).


1400
1300
1200
1100
1000
900
800
Reaction Time (ms)
A
B
Order (A,B) of Presentation of the Tasks
RVF
LVF

statistically significant ($F(1,14)=10.12$), $p<0.007$). The difference in reaction time between responding with the left hand ($\bar{X}=1191$) and the right hand ($\bar{X}=1128$ ms) for Order A was significantly different from the reaction time difference between the left ($\bar{X}=1038$ ms) and right ($\bar{X}=1061$ ms) hands for Order B. This relationship may be seen in Figure 10.

None of the other two-way interactions and no three-way or four-way interactions or the five-way interaction were statistically significant (Task X Field, $F(1,14)=0.76$, $p<0.40$; Task X Locus, $F(1,14)=0.00$, $p<1.00$; Field X Locus, $F(1,14)=2.40$, $p<0.15$; Task X Hand, $F(1,14)=0.01$, $p<0.93$; Field X Hand, $F(1,14)=1.06$, $p<0.33$; Locus X Hand, $F(1,14)=3.03$, $p<0.11$; Order X Task, $F(1,14)=0.35$, $p<0.57$; Order X Locus, $F(1,14)=0.24$, $p<0.64$; Task X Field X Locus, $F(1,14)=0.26$, $p<0.62$; Task X Hand X Field, $F(1,14)=0.15$, $p<0.71$; Task X Hand X Locus, $F(1,14)=0.17$, $p<0.69$; Hand X Field X Locus, $F(1,14)=0.22$, $p<0.65$; Order X Task X Field, $F(1,14)=0.11$, $p<0.75$; Order X Task X Locus, $F(1,14)=1.00$, $p<0.34$; Order X Field X Locus, $F(1,14)=2.59$, $p<0.13$; Order X Task X Hand, $F(1,14)=0.30$, $p<0.60$; Order X Hand X Field, $F(1,14)=1.68$, $p<0.22$; Order X Hand X Locus,

Figure 10. Reaction time as a function of responding hand and task order (A = shape judgments followed by dot enumerations; B = dot enumerations followed by shape judgments).



Reaction Time (ms)
1400
1300
1200
1100
1000
900
800
A
B
Order (A,B) of Presentation of the Tasks
Right Hand
Left Hand

$F(1,14)=0.06$, $p<0.82$; Task X Field X Locus X Hand, $F(1,14)=0.53$, $p<0.48$; Order X Task X Field X Locus, $F(1,14)=1.48$, $p<0.25$; Order X Field X Locus X Hand, $F(1,14)=0.06$, $p<0.82$; Order X Task X Field X Hand, $F(1,14)=1.88$, $p<0.20$; Order X Task X Locus X Hand, $F(1,14)=0.55$, $p<0.48$; Order X Task X Field X Locus X Hand, $F(1,14)=4.35$, $p=0.06$).

As with the accuracy data, reaction times for order (2), field (2), locus (2) and hand (2) factors were analyzed separately for the shape judgment task and the dot enumeration task via (Level C) ANOVAs.

Shape Judgment Task. As may be seen in Tables 5 and 6, the reaction time to near loci stimuli ($\bar{X}=1034$ ms) was faster than to far loci stimuli ($\bar{X}=1064$ ms) and this difference was statistically significant ($F(1,14)=5.83$, $p<0.03$). No difference in reaction time was found between the LVF ($\bar{X}=1064$ ms) and RVF ($\bar{X}=1035$ ms) ($F(1,14)=3.48$, $p<0.08$). As with the accuracy measure, overall reaction times did not differ between the two hands (left: $\bar{X}=1039$ ms; right: $\bar{X}=1030$ ms) ($F(1,14)=0.72$, $p<0.42$) or the two task orders (Order A: $\bar{X}=1114$ ms; Order B: $\bar{X}=982$ ms) ($F(1,14)=2.04$, $p<0.18$).

None of the two-way and three-way interactions or the four-way interaction - between field and locus ($F(1,14)=2.78$, $p<0.12$), field and hand ($F(1,14)=0.47$,

$p<0.51$), locus and hand ($F(1,14)=0.79$, $p<0.39$), order and field ($F(1,14)=3.94$, $p<0.07$), order and hand ($F(1,14)=2.20$, $p<0.16$), field, locus and hand ($F(1,14)=0.01$, $p<0.94$), order, field and locus ($F(1,14)=0.00$, $p<0.98$), order, field and hand ($F(1,14)=0.08$, $p<0.78$), order, locus and hand ($F(1,14)=0.29$, $p<0.61$), and order, field, locus and hand ($F(1,14)=2.81$, $p<0.12$) - were found to be statistically significant.

Dot Enumeration Task. As may be seen in Table 5, reaction time to stimuli in the RVF ($\bar{X}=1134$ ms) was slightly but not significantly faster than to stimuli in the LVF ($\bar{X}=1188$ ms) ($F(1,14)=3.86$, $p<0.07$). Near loci stimuli ($\bar{X}=1146$ ms) were not responded to faster than far loci stimuli ($\bar{X}=1176$ ms) ($F(1,14)=3.49$, $p<0.08$) (see Table 6). There were no differences in reaction time between the left ($\bar{X}=1172$ ms) and right ($\bar{X}=1150$ ms) hands ($F(1,14)=0.70$, $p<0.42$), or between the two task orders (Order A: $\bar{X}=1205$ ms); Order B: $\bar{X}=1117$ ms) ($F(1,14)=1.06$, $p<0.32$).

None of the two-way interactions (Field X Locus, $F(1,14)=0.22$, $p<0.65$; Field X Hand, $F(1,14)=0.94$, $p<0.35$; Locus X Hand, $F(1,14)=1.44$, $p<0.25$; Order X Field, $F(1,14)=2.02$, $p<0.18$; Order X Locus, $F(1,14)=0.01$, $p<0.90$; Order X Hand, $F(1,14)=4.12$, $p=0.07$), three-way interactions (Field X Locus X Hand, *F*(1,14)=0.39, *p*<0.55; Order X Field X Locus, *F*(1,14)=2.82, *p*<0.12; Order X Field X Hand, *F*(1,14)=2.86, *p*<0.12; Order X Locus X Hand, *F*(1,14)=0.41, *p*<0.54) or the four-way interaction (Order X Field X Locus X Hand, *F*(1,14)=1.22, *p*<0.29) were statistically significant.

Relationship between Accuracy and Reaction Time

To ascertain the relationship between accuracy of response and reaction time, two Pearson product moment correlation coefficients were computed - one for each of the two tasks. Nonsignificant correlations were obtained for both shape judgments (*r*=-0.3957) and dot enumeration judgments (*r*=-0.1816).

Summary of Results

The following main effects were found to be statistically significant: For Level A analyses, there was a significant difference in both accuracy and reaction time as a function of locus of stimulus presentation. Significantly greater accuracy of response was found to stimuli presented in the CVF than to those in the FLVF, the NLVF, the NRVF and the FRVF. The analysis of reaction time showed that responses to the CVF stimuli were significantly faster than those to the FLVF stimuli.

For the Level B analyses (shape judgment and dot enumeration tasks included), significantly more accurate and significantly faster responses were made in the shape judgment task than in the dot enumeration task. Responses to stimuli in the RVF were significantly faster than to LVF stimuli. Additionally, responses to near loci stimuli were significantly more accurate and faster than responses to far loci stimuli.

For Level C analyses of the shape judgment task, significantly greater accuracy was found for responses to RVF as compared to LVF stimuli. Near loci stimuli were responded to with significantly greater accuracy and faster reaction times than to far loci stimuli.

Analyses of the dot enumeration task (Level C) did not reveal significant (main effect) differences in accuracy for visual field, locus, hand or order.

The following interactions were found to be significant: For Level B analyses (both tasks included), visual hemifield differences were obtained for the accuracy measure as a function of task, of task, field and order, and of task, field, hand and order. As Figures 4, 5 and 6 suggest, greater accuracy of response was found for shape judgments when the stimuli were presented in the RVF, and for dot enumerations when the stimuli were presented in the

LVF. This occurred in Order B for both the left and right hands.

Furthermore, in the Level B analyses, the Order X Field interaction (see Figure 9) was significant for the reaction time data. The difference between the visual fields in Order A was significantly different than the difference between the visual fields in Order B. Also, the statistically significant Order X Hand interaction (see Figure 10) showed that the reaction time difference between the left and right hands in Order A was different than the reaction time difference between the left and right hands in Order B.

In the Level C analyses (each task analyzed separately), greater accuracy of shape judgments to RVF stimulus presentations was found to be a function of the task order: similar accuracy scores were obtained for Order A, whereas differences between the visual fields were seen in Order B (see Figure 7). In the case of dot enumeration, a significant Field X Hand X Order interaction was found. As may be seen in Figure 8, greater accuracy was obtained to stimulus presentations in the LVF for all conditions except when responding with the left hand in Order A, where greater accuracy was found to RVF stimulus presentations.

Lastly, neither of the two correlations between accuracy and reaction time, for the shape judgment and dot enumeration tasks, were statistically significant.

Discussion

The primary question addressed was whether task demand - holistic (identifying the shape of the dot pattern) vs. analytic (enumeration of the dots in the pattern) - would influence cerebral processing as evidenced by different lateral hemifield/hemispheric differences in accuracy and/or reaction time. Visual hemifield asymmetries were found for both shape judgments and dot enumerations, although not necessarily in the hypothesized direction. For the shape judgment task, greater accuracy was found to RVF/LH than to LVF/RH presentations; for the dot enumeration task, there was greater accuracy of response to LVF/RH stimuli, as evidenced in a higher level interaction (see p. 95). The obtained visual field asymmetries will be discussed in relation to the task demands, the eccentricity of the stimuli, the responding hand, and the task order.

It was hypothesized that shape judgments would be preferentially processed by the RH as evidenced by greater accuracy and faster response times to stimuli presented in the LVF. The finding of a significant RVF/LH superiority for accuracy of shape judgments was unexpected. In fact, this finding was in the opposite direction of the predicted asymmetry because making a judgment as to the identity of the configuration (square, rectangle, rhombus) was expected to elicit a gestalt closure strategy previously shown to be a process best handled by the RH (Nichelli, Manni & Maglioni, 1983). It is possible that RH advantages for the processing of complex patterned stimuli exist only when the task requirements are complex and/or difficult (Van Kleek, 1989). This possibility is supported by the finding that more frequent RH advantages occur when the local details are in conflict with the overall configuration than when they do not conflict (Martin, 1979), or, as in Sergent's (1982) experiment, where subjects were instructed trial by trial to identify the configuration or the element of the configuration.

The RVF/LH advantage in the accuracy of shape judgments found in the present experiment may reflect analytic processing. When the subjects were questioned at the end of the testing session as to what strategy they used to perform the shape judgment task, most stated that they were not using the overall configuration to make the judgment, but, rather, that they examined one of the corners of the configuration to identify the form/shape. This "non-holistic" approach to the processing of configurational material has been reported in some studies of visual hemifield differences (Duda & Adams, 1987; Magnanni, Mazzucchi &

Parma, 1984; Rapaczynski & Erlichman, 1979), resulting in either the negation of hemifield differences or the enhancement of LH processing.

Alternatively, the LH advantage for the shape judgment task might be ascribed, at least in part, to the subjects' use of verbal strategies to perform the task. For example, the test milieu (college campus laboratory) and the verbal instructions may have affected the processing strategy of these college students who have had a predominantly verbal academic background, training and experience, and led the subjects to utilize the presumably well-developed verbal skills in task performance, thereby priming the LH. Furthermore, the stimuli are verbally labelable (square, rectangle, rhombus), and were, in fact, labelled in the written instructions, which may have also increased LH involvement in the task.

Another possible explanation of the LH superiority in performance accuracy on the shape judgment task is in terms of the exposure exposure duration of the stimulus, since this factor has been shown to affect the direction of hemispheric asymmetry in the processing of visual stimuli. Most common is the finding of superior performance to stimuli presented in the LVF/RH (Gibson, Dimond & Gazzaniga, 1972; Hellige & Webster, 1979; Moscovitch, 1983) with the use of very brief exposure durations (<50 ms), and indeed, much briefer than the 150 ms duration used in this study. To examine the relationship between lateral hemifield asymmetries and stimulus duration, Sergent (1983) varied the exposure duration of letter stimuli. At 20 ms, a LVF/RH superiority for reaction time was found, but at 150 ms a RVF/LH superiority was found. Pring (1981) presented subjects with letter strings (words and nonwords) at 50, 100 and 150 ms, and found a LVF/RH advantage for reaction time at 50 ms and a RVF/LH advantage at 150 ms. Pring (1981) suggested that the RH was faster at processing stimuli at the 50 ms exposure duration due to the RH's greater facility in the processing of perceptual information, while at the 150 ms exposure duration the LH showed a relatively greater efficiency as a consequence of the greater availabilty of information to be processed analytically. Both of these sets of results are congruent with the finding in the present study of a LVF/RH advantage at the 150 ms exposure, and suggest that short exposure durations may "lock in" a perceptual matching strategy, since time is not available for the subject to develop or choose a processing strategy based upon higher cognitive functions. The results also suggest that regardless of the type of material, i.e., verbal or nonverbal, shorter exposure durations may lead to greater RH involvement in the processing of the information. In line with these findings, it has been suggested that low spatial frequencies (configurational aspects) are completely resolved within 50-100 ms, whereas high spatial frequencies (details) require 100-300 ms (Breitmeyer & Ganz, 1977; Christman, 1987; Kitterle & Corwin, 1979). Although these findings are not universal (e.g., Hatta, 1986), they do indicate that exposure duration may be an important variable to consider when assessing hemispheric asymmetries based upon perceptual characteristics. Thus, in experiments using short exposure durations, more of the allotted time may be maximally effective for the development of the percept of the overall configuration leading to superior LVF/RH performance, whereas in experiments using longer exposure durations, such as the present one, both low and high frequency information would more likely have equal access to the left and right hemispheres, and therefore have a better chance of being processed by both hemispheres. Furthermore, equal access would seem more likely to allow higher level cognitive processing to occur rather than simple perceptual processing, thereby increasing the likelihood of LH involvement. In this experiment, the exposure duration of 150 ms was chosen to allow the simultaneous completion of both the vernier alignment task and the experimental task (shape judgment or dot enumeration). The exact time course and partitioning of time to each task within the 150 ms and beyond (to 3 s) is unknown, although it would seem that the full 150 ms could not have been devoted to the alignment task, but would be somehow divided between the two tasks. In any case, the time devoted to the experimental task was probably sufficiently long enough to activate the LH and could account for the obtained RVF/LH superiority for shape judgments.

Other stimulus parameters which may account for the RVF/LH superiority on the shape judgment task include the degree of contrast between the dots and background, luminance, and blur. For each of these variables, which are not mutually exclusive, it has been found that the RH processes information at lower levels of intensity, contrast and blur than is the case for the LH, although the literature is sparse and not always consistent (Jonsson & Hellige, 1986; Keenan, Whitman & Pepe, 1989). Better RH as compared to LH processing of a stimulus of low energy, however, does not necessarily mean that cognitive processing by the RH is superior to that by the LH. It does indicate that the percept is formed with lower levels of energy and, then, that further cerebral processing may follow.

Whether this second stage is needed or related to a specific hemisphere is questionable. The reported effects of perceptual quality on functional visual asymmetries do suggest that the relationship between stimulus characteristics and preferential hemispheric processing/level of cognitive processing warrants futher investigation to clarify the reason(s) for the hemifield asymmetry.

The role of factors such as exposure duration and blur in visual hemifield asymmetries has been accounted for by the spatial frequency hypothesis (see p. 46) (Sergent, 1983; Christman, 1989), according to which low spatial frequencies are preferentially processed by the RH and high spatial frequencies by the LH. A direct test of this hypothesis was conducted in this experiment by the assigniment of two tasks, shape judgments and dot enumerations (i.e., attending to the global, low frequency aspect, and to the local, high frequency aspect, respectively) and by manipulating the eccentricity of the stimulus (2.5° and 4.5° visual angle) to the left and right of center.

When subjects were instructed to make shape judgments, they were more accurate and faster than when instructed to enumerate the number of dots. The superiority of shape judgments over enumeration judgments was significant at all five loci - FLVF, NLVF, CVF, NRVF and FRVF - and leads to the conclusion that global information, as in the case of shape judgments, is processed more easily and more readily than local information, as in dot enumeration. The greater accuracy and faster processing times of holistic information has been found by numerous other investigators (Grice, Canham & Boroughs, 1983; Kinchla, 1977; Kinchla & Wolfe, 1979; Martin, 1979; Navon & Norman, 1983; Ward, 1983), for various sizes of stimuli (Hoffman, 1975; Kinchla & Wolfe, 1979; Navon, 1977, 1981; Shultz & Eriksen, 1978) and for stimulus presentations at various eccentricities (Navon & Norman, 1983). Furthermore, the magnitude of the difference in reaction times between shape judgments and dot enumerations (approximately 100 ms) found in the present experiment is similar to that found in earlier studies comparing holistic and analytic processing of the same stimulus configuration (a large letter constructed of small letters)(Navon, 1977; Navon & Norman, 1983). Navon (1977) has suggested that the earlier (faster) processing of gestalt-like total configurations reflects the greater "availability" of this kind of information in the visual perception of a complex stimulus, which proceeds from holistic identification to analysis of the configurational details.

The predicted findings of better performance in accuracy and reaction time to stimuli in the near, as opposed to the far, visual hemifields are congruent with the results of studies (Eriksen & Shultz, 1977; Hellige, 1986; Riggs, 1965; Thomas, 1987) mapping the visual acuity gradient wherein increasing the eccentricity of the stimulus in the visual periphery leads to slower and less accurate processing of the stimulus as a result of decreasing amounts of spatial frequency components of the complex stimulus. In the current study, when the data for both tasks were combined, responses to near stimuli were significantly more accurate and faster than those to the far stimuli. When the shape judgment task was analyzed separately, significantly greater accuracy and faster responses were also found to near, as opposed to far, loci. These results suggest that the degradation of the stimulus from near to far loci adversely affected shape judgments.

The spatial frequency hypothesis also predicts that low frequency information is used more effectively by the RH and high frequency information by the LH (Christman, 1990, 1988, 1987; Jonsson & Hellige, 1986; Keenan, Whitman & Pepe, 1989; Sergent, 1982, 1983). In the present study, manipulation of spatial frequency was achieved by varying the eccentricity of the stimulus to test this hypothesis. If the finding of a RVF/LH superiority for shape judgments reflects analysis of the details of the configuration, then with increasing eccentricity in the RVF, this LH advantage should decrease. In the present experiment, although the interaction between visual hemifield and locus for accuracy of shape judgments was not statistically significant ($p<=.05$), there was a "tendency" ($p<.08$) towards greater accuracy of response to NRVF/LH stimulus presentations than to all other loci. The difference in accuracy within each visual field for shape judgments was somewhat greater between the NRVF and FRVF (a decrease in accuracy from the NRVF to the FRVF) than between the FLVF and NLVF and, interpreted in accordance with the spatial frequency hypothesis, suggests poorer use by the LH of degraded stimuli, i.e., greater loss of high frequency information at the greater eccentricity (4.5^{o}) in the RVF than in the LVF. In fact, processing of the stimulus information presented in the LVF/RH was not affected by locus (near versus far), as little change in accuracy was observed between loci in the LVF. This finding corroborates those of others' (Christman, 1990; Hellige, Corwin & Jonsson, 1986; Sergent, 1983) and indicates that dependence on the details of the configuration for performance is less affected by changes in stimulus quality in the LVF/RH than is the case in the RVF/LH. Studies assessing the effect of eccentricity on visual hemifield asymmetries, for example, McKeever and Gill (1972), Hellige, Corwin and Jonsson (1986) and Christman (1987), all found significant differences between the visual fields at their respective near eccentricities of 1.5°, 1.0°, and 3.0° but not at those loci of greater eccentricity. Christman (1988) explained his findings and those of Hellige et al. (1984) in terms of the relationship between the level of feature analysis required by the task and that provided by the input. In the present study, the decrease in the observed lateral differences from the lesser to the greater eccentricity in the RVF/LH for shape judgments may be due to the preferential use of the smaller elements/dots in the configurations which were degraded at the FRVF.

Although shape judgments showed a LH advantage, further analyses revealed that the RVF/LH superiority was evident in accuracy when it was the second task (Order B). The significant LH advantage for accuracy of shape judgments only when such judgments followed enumeration judgments might be accounted for in terms of practice, familiarity or learning. As noted above (p. 117) linguistic strategies may have played a significant role in eliciting the LH superiority.

Additionally, the increase in familiarity/practice/ learning from the first (enumeration) to the second (shape) testing session may have additionally fostered a LH analytic/linguistic strategy for making shape judgments.

Visual hemifield differences in task performance as a function of task order or sequence have been frequently noted, and the consensus is that greater LH involvement, or lesser RH involvement, in a given task occurs when that task follows another task rather than when it precedes it, even when the first is not verbal/linguistic in nature. Witelson (1974) found a left hand (RH) superiority on a nonsense shape matching task when that task was presented approximately one week prior to the presentation of a letter matching task; no hand difference was found when the nonsense shape task followed the letter matching task. Witelson suggested that the initial letter-matching task primed, or preferentially activated (Kinsbourne, 1970, cited in Witelson, 1974), the LH and thereby facilitated the processing of right hand input with a consequent increase of accuracy in right hand/LH matches that effectively "washed out" the RH superiority. She further suggested that, with practice, the left hemisphere becomes more adept at relaying the shape information to the right hemisphere for spatial analysis. However, since Witelson did not find hand asymmetries on the letter-matching task, her argument of activation/priming is weakened (somewhat). In relation to the present study, the task of dot enumeration, when first in the testing sequence, may have primed the LH, resulting in significantly greater accuracy of response to RVF/LH presentations for the subsequent (second session) shape judgment task. Analysis of performance on the dot enumeration task, however, showed greater accuracy to LVF/RH presentations in Order B (where dot enumeration was administered first) so it is difficult to say, as with Witelson, how much, if any, priming of the LH occurred. Some studies of order and/or sequencing effects on visual hemifield differences have also noted a shift in cerebral hemispheric advantage. For example, Gordon and Carmon (1976) had subjects vocally identify unfamiliar shapes constructed of dots and found a LVF/RH advantage for the initial blocks of trials and a RVF/LH superiority for the later blocks of trials.

One model that has been proposed to explain the emergence of LH advantages with greater practice over subsequent testings is that of Goldberg and Costa (1981). In this model of hemispheric functioning, each cerebral hemisphere participates in the development and implementation of a descriptive system. A descriptive system consists of discrete units of encoding or rules of transformation which can be successfully applied to the processing of a certain class of stimuli. The LH is viewed as using a "well routinized descriptive system"; for example, systems specialized for the comprehension of language and use of mathematical notation. The RH, in contrast, is viewed as mediating information for which a developed descriptive system is not available. Orientation in a novel task, i.e., linking a new stimulus or category with a preexisting category, would initially engage the RH until an association is established between the new information and the preexisting system, and the newly established association would then lead to a shift to LH processing. Evidence in support of this model has been provided by Kittler, Turkewitz and Goldberg (1989), Ross-Kossak and Turkewitz (1986) and Turkewitz and Ross (1983), who found a shift in the processing of faces and Kanji symbols from initial preferential processing by the RH to the LH as a consequence of repeated exposure to the stimuli.

Bradshaw and Sherlock (1982) have also addressed the question of sequence/order effects, suggesting that relatively larger lateral hemifield differences are found for a second task in a two task series when it is preceded by a more difficult task. This could account for the present finding of a significant LH advantage for accuracy of shape judgments when this task followed the more difficult dot enumeration task. Bradshaw and Sherlock concluded that this particular order effect may be one component of Goldberg and Costa's model.

The RVF/LH superiority for shape judgments obtained in this experiment is at least partially compatible with Goldberg and Costa's model of descriptive systems in regard to a general shift to preferential processing by the LH. In this model, Goldberg and Costa postulate a three stage process - an initial RH superiority, followed by a transitional stage of no lateral differences, and concluding with a LH superiority when the task/stimulus is associated with a descriptive system. The results of the present study provide evidence in support of the latter two stages - no hemifield differences in accuracy of shape judgments when this task was first, and a LH superiority when the task was the second in the sequence. Issues of RH involvement in the task, the nature of the transitional stage, and the stability of the LH superiority would seem to require further investigation.

Support for the hypothesis that the dot enumeration task would be preferentially processed by the LH was not obtained in the present experiment, and can only be cautiously suggested, by the finding of a nonsignificant trend ($p < .07$) towards faster reaction time to stimuli presented in the RVF than to stimuli in the LVF. This finding may indicate that the LH is somewhat better than the RH in processing the individual dots of the configuration. Presenting the dots in a configuration, rather than via a random pattern which has been shown to yield a LVF/RH advantage (Kimura, 1966; Sheehan & Smith, 1986), may decrease, somewhat, the need for spatial analysis prior to enumeration. The same reasons postulated for the RVF/LH superiority for shape judgments can be applied to the "trend" towards a RVF/LH superiority for the dot enumeration task. For example, the dot enumeration task may have required verbal strategies for optimal performance, and the relatively long exposure duration may have thereby enhanced the opportunity for the development of a verbal coding strategy.

When accuracy of dot enumeration was examined, significant hemifield differences in accuracy of dot enumeration were obtained as a function of responding hand and task order. A LVF/RH superiority emerged when responding with either hand when dot enumeration was the first task to be completed. When dot enumeration followed the shape judgment task, a LVF/RH superiority emerged when responding with the right hand, but responding with the left hand elicited a RVF/LH advantage. It would seem that this result does not support the prediction of a RVF/LH advantage. In fact, it may be that the typically found LVF/RH advantage for the task of dot enumeration was weakened in the present study by the presentation of dots in an identifiable pattern, (i.e., the preceding shape judgment task) or, perhaps, was a function of greater LH involvement as a consequence of familiarity/practice with the dot pattern. Thus, the obtained effect of task order on dot enumeration task performance could be interpreted in terms of Goldberg and Costa's model of hemispheric functioning, in that prolonged exposure to the stimulus led to a RVF/LH advantage when responding with the left hand.

When the subjects were asked to describe the strategy they used to complete the dot enumeration task, many stated that they first grouped portions of the configuration of dots (usually 3 dots) and then added the remaining dots on the periphery of this grouping. It is possible that this strategy, which seems to combine both holistic and analytic processing, may have engaged both hemispheres, thereby lessening the magnitude of the hemifield asymmetry, especially in regard to accuracy.

Interpretation of the results of dot enumeration task performance in terms of the spatial frequency hypothesis is equivocal. The obtained differences between performances on the shape judgment and dot enumeration tasks suggest that the subjects were using different aspects of the stimulus information to complete each task. The availability of stimulus information to complete each task was more conducive to making shape judgments than dot enumerations. This is what would be predicted by the spatial frequency hypothesis (Sergent, 1983; Christman, 1987). Judgments of the overall configuration (shape judgment task) would be based on the lower spatial frequencies, whereas judgments of dot enumeration would be based on the high frequency information, i.e., individual dots. As the perception of higher frequencies drops off at a greater rate than lower frequencies at greater eccentricites, the failure to find a significant difference in enumeration accuracy between near and far loci may have been due to an overall sharper decline in relevant information (individual dots) available to be processed at the near and far eccentricities used in this study. Furthermore, it can be reasoned that with stimulus presentations at a locus greater than the 4.5° visual angle used in this study, larger differences in accuracy and reaction time would be seen between loci, as a further decline in the quality of the information would be found at the greater eccentricities (Sergent, 1983).

In the present study, subjects performed both tasks with both the left and right hands. One reason for including responding hand as a variable was to determine whether there are manual differences in performance (accuracy, reaction time, or both) on either or both tasks. Since no hand differences were found for either task, for either the accuracy or reaction time measure, it is clear that the right (preferred) hand does not differ from the left (nonpreferred) hand in making shape identifications or dot enumerations.

A second reason for requiring both left and right hands to perform the tasks was to enable examination of the question of stimulus - response compatibility, i.e., whether preferential hemispheric processing of LVF and RVF stimuli could be elicited to a greater extent with the contralateral than with the ipsilateral hand (Berlucci, Heron, Hyman, Rizzolatti & Umilta, 1971; Bowers, Heilman & Van Den Abell, 1982; Heister & Schroeder-Heister, 1987). The only findings of a relationship between responding hand and visual hemifield were suggested by higher level interactions. The interactions were primarily due to the inconsistency of the left hand response as a consequence of either order, task, or field. This inconsistency is not easily explained by stimulus-response compatibility. For example, in relation to the Task X Field X Hand X Order interaction (Level B), accuracy of left hand responses in Order A was in the predicted direction - dot enumerations were more accurate to stimuli presented in the RVF and shape judgments were more accurate to stimuli presented in the LVF - as compared to accuracy of response under other combinations of field, hand and order for each task. This result suggests lability of left hand responding for the shape judgment task when it is the first task and for dot enumeration when it is the second task for each sequence. No significant interactions were found when the shape judgment task was analyzed separately. For the dot enumeration task, the significant Order X Field X Hand interaction (discussed above) showed greater accuracy to RVF presentations when responding with the left hand, whereas responding with the right hand showed consistently greater accuracy of response to stimuli presented in the LVF. Additionally, the highly significant Order X Hand (Level B) interaction suggests that the relatively unskilled left hand differs in reaction time depending on the sequence of tasks, with slower responding when the shape judgment task is administered first (Order A), and somewhat faster responding when the dot enumeration task is given first (Order B), both as compared to right hand responding. These findings may signify the lability of the nondominant, left hand on the keypress apparatus used in this study rather than lability in hemispheric advantage as evidenced through the responding hand.

The results obtained from analysis of response accuracy and reaction time to presentation of stimuli in the CVF indicate that the purpose of these presentations - to ensure, or at least optimize, the maintenance of central fixation - was accomplished. This was evident by the finding of significantly greater accuracy and faster reaction times to CVF dot patterns than to dot patterns presented at the far and near, left and right visual fields. These results, for both accuracy and reaction time, strongly suggest that the stimuli presented in the LVF and RVF were indeed projected to the contralateral cerebral hemispheres (Hellige, 1976; Hellige, Cox & Litvac, 1979; Lamb & Robertson, 1988; Sergent, 1985).

Lastly, there was no evidence of a systematic relationship between reaction time and accuracy of judgment for either the shape judgment or the dot enumeration task. The correlations between reaction time and accuracy were not significant for either the shape judgment task or the dot enumeration task. It can therefore be concluded that there was no speed/accuracy tradeoff in the present experiment, which tradeoff has occassionally been reported (Kroll & Hershenson, 1980; Measso & Zaidel, 1990). Furthermore, reaction time and accuracy may be considered independent response measures, although each may be measuring the same/different aspects of performance and cerebral processing of the stimuli (Hellige & Sergent, 1986).

In conclusion, some support for the analytic/holistic distinction in the lateralized processing of visual information was obtained in the present experiment. An analytic/LH strategy seemed to be used for the processing of shape judgments, whereas the processing of dot enumerations seemed to elicit a more holistic/RH advantage. It can be said that perceptual characteristics and cognitive processing interact in complex ways that cannot be ascribed simply to the nature of the physical characteristics of the stimuli or the supposed "ideal" cognitive operations that should be performed on the material, especially when higher cognitive operations may be involved. Each task was found to preferentially activate the left and the right cerebral hemispheres. The interrelationships between the task order and hemifield asymmetry yielded more pronounced hemifield differences for the shape judgment task as a consequence of its following the dot enumeration task, whereas a less consistent hemifield advantage was found when the dot enumeration task followed the shape judgment task. The sequence effects for the tasks seem to be best accounted for by the model of Goldberg and Costa (1981), which suggests that initial RH or no hemispheric advantages may, with increasing exposure, familiarity and practice, be brought into an existing or a new descriptive system used by the LH. Locus within each visual hemifield was not seen to be a significant factor for either accuracy of response or reaction time, although for shape judgments, there was a suggestion that stimulus parameters such as clarity and contrast may be important for LH functioning and, perhaps more so than for RH functioning.

Appendix A

QUEENS COLLEGE
of the CITY UNIVERSITY OF NEW YORK
Department of Psychology

CONSENT FORM

Subject's Name

I understand the following:

1. that this study is being conducted by Bill Matos, a doctoral student in the Ph.D. Neuropsychology Subprogram at Queens College of the City University of New York, under the direct faculty supervision of Tina Moreau, Ph.D.;
2. that I have been fully informed of the nature of the proposed study including its purposes, procedures, time requirements, and my rights as a subject. Furthermore, I have been assured as to Bill Matos' availability to answer any questions that may arise;
3. that this study will involve a visual acuity test, a hand preference test, and informing as to my parent's hand preference. In addition, I will be sitting in a quiet room where I will be asked to look at a screen on which will be presented dots in three geometric shapes (square, rectangle, and rhombus). My task is simply to indicate either the shape or the number of dots presented and whether the fixation line moved.
4. that this study will not be physically or psychologically harmful to me;
5. that my participation is VOLUNTARY and my refusal to participate or to discontinue participation at any time will incur NO PENALTY;
6. that my Anonymity and Confidentiality will be guaranteed. All data will be coded by number and not by name;
7. that, although the information obtained may not be directly beneficial to me, it will contribute to the understanding of information processing;
8. that I am free to withdraw this consent and discontinue participation at any time. I have received a copy of this form.

Signature of Subject Date

Witness Date

Appendix B

Subject ID Number:

Date:

Handedness Questionnaire

1.	Hand used to write -	R	B	L
2.	Hand used to throw a ball -	R	B	L
3.	Hand used to manipulate scissors	R	B	L
4.	Hand used to draw a picture	R	B	L
5.	Hand used to brush teeth	R	B	L

Parental Handedness

Mother	R	B	L
Father	R	B	L

Best Visual Acuity

Right Eye

Left Eye

Appendix C

INSTRUCTIONS TO PARTICIPANTS

In this study you will be asked to place your chin on the chin rest and view pictures presented on the screen in front of you. The first picture is a vertical line which is also called the fixation line. You are asked to focus on this line and to not look elsewhere. You will then see another picture with another vertical line and dots on either side of the vertical line. Even while viewing this second picture you should maintain your focus on the vertical line. Your participation requires that you view the material and that you make judgements of each picture along the following criteria :

1. If asked to make a shape judgement for a series of pictures, you should identify the picture, as either a square, rectangle, or rhombus, by pressing the appropriate key.
2. If asked to make a number judgement for a series of pictures, you should identify the number of dots in the picture, either 4, 5, or 6, by pressing the appropriate key.
3. You will be asked to use either your right or left index finger to press the key and will be told in advance which finger to use.
4. For each picture that is presented you will also be asked to say "YES" (after you identify the picture according to its shape or number of dots) if you saw the vertical line in the middle of the screen move either to the left or right in relation to the fixation line. If you did not see it move DO NOT SAY ANYTHING!
5. You are asked to make your decisions as QUICKLY and as ACCURATELY as possible. You will only have three seconds in which to respond. If you are unsure of the kind of shape or number of dots, please make your best guess. Remember, only say "YES" if you saw the second vertical line move in relation to the first.

You will be given practice at the beginning to familiarize yourself with the pictures and response keys and to ask questions about the procedure.

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