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HEMISPHERIC INVOLVEMENT IN FACE RECOGNITION AS A FUNCTION OF STIMULUS ORIENTATION AND FIELD ARTICULATION

by

Wanda G. Rapaczynski

A dissertation submitted to the Graduate Faculty in Psychology
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Chapter 1

INTRODUCTION

Past years have witnessed an upsurge of interest in cognitive processes, with growing emphasis being placed on the individual as an epistemologically active agent. Various domains of so-called "private events" such as thinking, problem solving, perceiving, remembering, imagining, daydreaming, and creating are being investigated. The point of view adopted in this dissertation is that in order for a theory of cognition to be truly comprehensive, systematic individual differences in cognition must be considered. Thus, the necessary prerequisite for success in the search for predictive power in the study of cognition is a theory of individual differences which would specify how different subjects approach various cognitive tasks. Such a theory should be based on descriptions of individuals in terms of cognitive style rather than in terms of cognitive skills alone--the latter defining efficiency of performance, whereas the former affects the subject's choice of strategy without necessarily influencing the level of performance.

Over the years there has been an increasing concern about the neural substrata of thought and attempts have been made to link higher cognitive functions to brain mechanisms. A recent example of such an attempt is investigation of hemispheric asymmetry as related to different modes of information processing in the brain. The present study investigates the relationship between a cognitive process (memory of faces) and its neural substratum (hemispheric asymmetry) as related to individual differences in cognitive style, *in a common conceptual framework*. The purpose of the work is to explicate further the relationship between (1) memory for pictorial stimuli, (2) hemispheric asymmetry, and (3) individual differences in cognition.

Hemispheric Asymmetry

The left hemisphere is superior in tasks involving recognition and learning of verbal material; the right hemisphere is dominant on a variety of non-verbal, visuospatial tasks. This general principle is documented by a vast number of clinical studies involving patients with unilateral brain lesions (e.g. Butters et al., 1970; DeRenzi, 1968; DeRenzi and Spinnler, 1966; Lansdell, 1968, 1970; Milner, 1958, 1963, 1965, 1967, 1968, 1970; Milner and Teuber, 1968; Newcombe, 1974; Parsons et al., 1969; Teuber, 1964; and many others) and patients with severed cerebral commisures (Bogen, 1969a, b, c; Gazzaniga, 1970; Sperry, 1968); similar conclusions are also drawn from studies employing pharmacological or electrical means to temporarily depress one hemisphere (Bogen and Gordon, 1971; Cohen, 1968; Terzian, 1965). These findings are further corroborated by non-clinical studies, employing subjects with intact brains. Essentially, there are three techniques allowing investigation of hemispheric asymmetry in normal subjects.

(1) *Dichotic listening*: subjects are exposed to two sources of auditory stimulation simultaneously, each coming through a different channel (ear) of the headphones. The subjects' task is to report what they have heard. When both channels contain speech messages, there is a right ear advantage (REA); ie., the material coming through the right

ear is reported faster and more accurately. When both messages are non-speech (music, environmental sounds, and the like), there is a left ear advantage (LEA); finally, when a speech stimulus is paired with a non-speech one, both ears perform equally well--or equally poorly (Curry, 1967; Kimura, 1961, 1964, 1967; Shakweiler and Studdart-Kennedy, 1967). Since it is assumed that contralateral pathways connecting the left ear with the right hemisphere and the right ear with the left hemisphere are prepotent over ipsilateral connections, REA is interpreted as reflecting the left hemisphere superiority for the given task and LEA as reflecting the right hemisphere superiority (Kimura, 1964).

(2) Tachistoscopic projections to visual hemifields: this technique can be thought of as a visual equivalent of the dichotic listening situation. Since the left and right visual fields project exclusively to the contralateral hemisphere, a stimulus can be presented to the left or the right hemisphere by displaying it briefly to the left or to the right of visual fixation point. Brief exposure is designed to prevent initial stimulation of ipsilateral cortex (Filbey and Gazzaniga, 1969; Sperry, 1968). Verbal materials are recognized faster and more accurately when presented to the right visual field (RVF) than to the left visual field (LVF); the opposite is true for non-verbal shapes, patterns, and nonsense figures (Dee and Fontenot, 1973; Dixon and Henley, 1974; Ellis and Shepherd, 1973, 1975; Fontenot and Benton, 1972; Geffen and Bradshaw, 1972; Geffen et al., 1971, 1972; Gross, 1972; Hilliard, 1973; Kimura, 1966; Kimura and Durnford, 1974; McGlone and Davidson, 1973; McKeever and Huling, 1970; McKeever et al., 1972; Rizzolatti et al., 1971; Schell and Satz, 1970; White, 1969). When

subjects are required to match stimuli on the basis of physical attributes, they respond faster if information is presented to the right hemisphere (Cohen, 1972; Geffen et al., 1971; Metzger and Antes, 1975; Posner, 1969). Also, familiar visual stimuli, such as faces, are responded to more quickly when presented in the right visual field than when in the left visual field; this relationship is reversed for unfamiliar stimuli. Extreme familiarity obliterates the asymmetry effect altogether (Berlucchi, personal communication).

(3) Measurement of electrical activity of the brain: there have been several reports that both evoked response asymmetry and bilateral alpha wave ratios are related to lateral specialization. For average evoked responses, waveforms differ laterally depending on the nature of the stimulus (verbal or not) or the dimension of the stimulus (linguistic or not) to which the subject is attending (Buchsbaum and Fedio, 1969, 1970; Teyler, Roemer, and Thompson, 1973; Wood, Goff, and Day, 1971). Using EEG alpha activity it has been reported that when a subject is involved in a verbal task, there is relatively more alpha over the right hemisphere; when a subject is working on a spatial, musical, or facial memory task, there is more alpha activity over the left hemisphere (Doyle, Galin, and Ornstein, 1974; Dumas and Morgan, 1975; Galin and Ellis, 1975; Galin and Ornstein, 1972; McKee, Humphrey, and McAdam, 1973; Morgan et al., 1971; Robbins and McAdam, 1975; Schwartz et al., 1973; Warren et al., 1976). The assumption underlying these studies is that blocking of alpha activity reflects cerebral activation; since this blocking is found to be asymmetrical, it lends itself to interpretations in terms of hemispheric specialization for different functions.

On the basis of these findings the two cerebral hemispheres could be considered to be, at least partially, independent channels of information processing. Many recent investigations are concerned with the issue of the mechanism of hemispheric specialization in an attempt to clarify the nature of hemispheric commitment to different tasks. In the light of these studies the simple verbal vs. visuo-spatial dichotomy is no longer tenable. A more fundamental dichotomy may underlie hemispheric function.

To begin with, one cannot characterize hemispheric functioning by stimulus properties alone. The relationship between the type of stimulus and the hemisphere which will process it is not invariant. It is possible to obtain left visual hemifield superiority for letters if they are script-like (Bryden, 1976), for words when the stimuli are short and their exposure brief (Gibson et al., 1972; Gill and McKeever, 1974), or when the task calls for pictorial encoding (Moscovitch, 1976), and no asymmetry altogether when the stimuli are strings of letters not forming words (Leiber, 1976). Word recognition seems to be a multi-stage process and not all the stages of analysis are performed better by the left hemisphere. It is possible that when stimuli are presented visually, all the initial processing is done by the right hemisphere, which "perceives" the visual stimulus first. A task structured so that the verbal stimuli (letters) would be processed as visual forms and pictorial stimuli as names yields visual field advantages opposite to those usually associated with the verbal vs. non-verbal dichotomy

(Klatzky and Atkinson, 1971). Similarly, in the auditory mode, ear advantage in the dichotic listening task depends on the dimension of the stimulus to which the subject is attending. Using the same stimuli, it is possible to obtain LEA for non-linguistic and REA for linguistic dimension (Bartholmeus, 1974; Haggard and Parkinson, 1971; Wood et al., 1971).

Thus, the nature of the stimulus does not fully determine which hemisphere will be involved in the task. In predicting hemisphere activation in a task various other variables such as tasks constraints, process variables, and individual differences in the mode of information processing have to be taken into account. This point is well illustrated in a series of experiments by Seamon (Seamon, 1972, 1974; Seamon and Gazzaniga, 1973; Modigliani and Seamon, 1974). A significant interaction of coding strategy and visual field effect was found: probes presented to the right hemisphere yielded faster reaction times than those presented to the left hemisphere when imaginal coding strategy was employed by the subjects; when verbal rehearsal was used, the reverse was true. It was also shown that coding strategies affect retrieval processes. When information was unified (as with the use of relational imagery coding), the RT functions were flat, indicating a parallel comparison process; when information was disjointed, RT functions increased linearly with increase in memory set size, implicating a serial comparison process. Seamon notes that the use of pictorial coding strategy does not have to be equivalent with the experience of mental imagery; however, recent findings of Shephard and his co-workers (cf. for example Cooper, 1975) suggest that in fact it is by demonstrating the reality of mental representations. It is possible that persistence of such mental representations might be the common process underlying all the right hemisphere functions (Bever and Chiarello, 1974; Cohen, 1972; Compton and Bradhsaw, 1975; Davis and Schmit, 1973; Geffen et al., 1972; Patterson and Bradshaw, 1975; Smith and Nielsen, 1970). Thus, for the same stimulus material, retrieval processes might involve either of the hemispheres, depending on the coding strategy used.

It appears that in order to understand the nature of hemispheric specialization one must examine the nature of the processes characteristic of the two half-brains. The two hemispheres appear to be specialized for different modes or strategies of information processing. Neisser (1967) wrote that psychology has long recognized the existence of two different modes of mental organization. This distinction has been given various names--rational vs. intuitive, convergent vs. divergent, Type A and Type B thinking, verbal vs. imaginal, verbal vs. pictorial memory system (the two operating on different principles, and possessing different storage capacities) (Bower, 1970, 1972; Haber, 1970; Paivio, 1969, 1971; Richardson, 1967; Shepard, 1967). Some researchers have recently suggested that the dichotomy of thought is associated with different hemispheric functions and is best described in terms of analytic vs. holistic-Gestalt-synethetic modes of information processing. Levy-Agresti and Sperry (1968) theorized that the left hemisphere is specialized for sequential, feature analytic processing of information, and the right hemisphere is specialized for Gestalt, holistic processing. Bogen (1969a, b, c) described hemispheric asymmetry in terms of propositional vs. appositional thought dichotomy, implying that the left hemisphere is specialized for sequential symbolic thought and the right hemisphere for apposing--or simultaneous comparisons--of perceptions, schemas, engrams, etc. Depending on which mode of processing is more appropriate for the given task or constitutes the preferred strategy of the given subjects, the right or left hemisphere superiority will obtain. It should be stressed that in this model of hemispheric specialization the stimulus and the process dimensions might be considered to be orthogonal in principle. Empirical evidence supporting this model has been reported in a number of recent investigations (cf. for example Bever, 1975; Patterson and Bradhsaw, 1975; Tucker, 1976).

Face Recognition

This hypothesis of the analytic vs. Gestalt processing underlying hemispheric involvement in various tasks is further investigated in this dissertation, using human faces as stimuli. Human faces seem to be particularly well suited to investigation of hemispheric asymmetry for a number of reasons.

Face recognition has been investigated extensively both (1) as a facet of general pictorial, non-verbal memory, and (2) as a function which might be independent of other picture memory systems. A number of studies emphasize the surprisingly large storage capacity of human memory for faces and the easy discriminability of faces in spite of their great objective similarity (Haber, 1970; Nickerson, 1965, 1968; Shepard, 1967). This storage capacity has been interpreted as reflecting the generally larger storage capacity of non-verbal memory by Shepard (1967), or as unique for facial stimuli by Goldstein and Chance (1970). These latter authors found that recognition accuracy and rates of memory decay for faces and other complex visual patterns of low codeability were reliably different.

The problem of specificity of face recognition vis-à-vis other forms of pictorial memory can be investigated as outlined by Attneave (1967) in a discussion of the relationship between invariance of response and the concept of visual form. This problem can be redefined in the following way. How does face recognition relate to the problem of meaning, i.e. to ascription of a unique label to a stimulus? The solution to this problem may be provided by testing the limits of response invariance; that is, by finding out what kinds of transformations affect the level of recognition, since, according to Attneave, an adequate theory of form perception must take into account decrements in performance caused by such stimulus transformations.

After seeing a photograph of a face only once, we are still able to recognize the face even when the emotional expression, surroundings, angle of view, or angle of illumination are different (Saltz and Siegel, 1967). For familiar faces, an extremely degraded stimulus which leaves only gross contour information intact can support recognition (Harmon, 1973). On the other hand, recognition of faces is affected by reversal of brightness relationships (Galper, 1970; Galper and Hochberg, 1971; but see also Bradshaw and Wallace, 1971 for evidence to the contrary) and by spatial inversion (Hochberg and Galper, 1967; Yin, 1968). Both of these operations, it should be noted, reduce recognizability of faces without affecting pattern configuration. Interestingly enough, the information stored during upside-down viewing is not strongly tied to orientation, whereas that stored during normal, upright viewing, is (Hochberg and Galper, 1967). The effect of spatial inversion is greater for faces than for other typically mono-oriented complex stimuli such as houses, airplanes, and figures of men in motion (Yin, 1968). In addition, an interesting fact was revealed in post-experimental discussions with the subjects in Yin's study: upright faces are processed in a holistic manner; in the inverted face task subjects are unable to use this strategy efficiently. With practice, performance on inverted faces improves, whereas there is no such effect for upright faces (Bradshaw and Wallace, 1971). This is probably due to a ceiling effect already imposed by earlier learning of such stimuli; upright faces are an overlearned pattern, a well entrenched "schema," in order to deal with the novelty of inverted faces, subjects must work out a new, different strategy. Presumably, the new strategy which subjects learn to deal with inverted faces is different from that which they use for processing of upright faces.

Certain developmental trends have been observed with respect to the effect of inversion on recognition of faces. Brooks and Goldstein (1963) found that accuracy of recognition of inverted faces increases with age in children aged between 3 and 14 years; they interpreted this finding as reflecting increasing ability to identify wholes from parts. On the other hand, Diamond and Carey (1975) and Carey et al. (1975) found that in younger children (below age 10) performance is relatively unaffected by spatial inversion of the stimulus, whereas changes in emotional expression and accessories are potential sources of error. This suggests that young children represent faces in terms of relatively isolated aspects, including even background factors (hairdo, clothing), unrelated to the face itself. Around the age of 10 years a qualitative change takes place: children begin to encode configurational (Gestalt) information and develop a generalized face schema.

The data reviewed so far suggest that faces are not coded and stored simply on the basis of their pattern characteristics. Something else in addition to pattern storage and pattern recognition is operating in the recognition of faces. One possibility is that there is a "meaning" inherent in facial configuration which allows recognition of a face not only as a member of the given class, but also qua individual. The fact that both reversal of brightness relationships and spatial inversion affect recognition accuracy could be interpreted to mean that spatial orientation and brightness relationships are somehow related to the "meaning" (ascription of an individual label) of a face, and that the two transformations obliterate it. Furthermore, the mode of information processing employed by the subjects may depend on the presence or absence of this "meaning."

There is evidence for considerable right hemisphere commitment to face recognition under normal viewing conditions. Patients with lesions in the right hemisphere perform poorly on tasks involving recognition of faces (De Renzi and Spinnler, 1966; Lansdell, 1968; Milner, 1968; Newcombe, 1974; Tzavaras et al., 1970). In everyday life, patients with right hemisphere lesions are more likely than patients with left hemisphere lesions to display a syndrome termed prosopagnosia. It consists of an inability to recognize even very familiar faces (e.g. member of patient's family) without recourse to significant features such as moustache, scars, glasses, hairdos, and the like, all of which are amenable to verbal mediation (Hecaen and Angelgergues, 1962).

Capitalizing on the phenomenon of visual completions of stimuli presented in the midline to commissuratomy patients, Levy and others (Levy et al., 1972; Levy, 1974) investigated hemispheric dominance for face recognition using chimeric stimuli. In such stimuli, the left and the right half of the photograph do not come from the same person. They found that, irrespective of which hand was used for pointing, the subjects overwhelmingly selected the face seen by the right hemisphere. The left hemisphere percept, if it existed at all, exercised practically no control over behavior. In addition, the overall form of a face could not be remembered by the left hemisphere. Thus, in the vast majority of dextrals, face recognition depends on memory images available only to the right hemisphere. Using a variation of the above procedure, i.e., composite faces,[1] Gilbert and Baken (1973) have shown that normal subjects also tend to select the composite made of the right side of the model's face. Since, on the assumption that central fixation is maintained, the right side of a face lies in the observer's left visual field which, in turn, projects to the right hemisphere, this finding is interpreted as lending support to the notion of right hemisphere superiority for face recognition.

Facial stimuli are responded to more quickly and more accurately when projected to the left visual field than when they appear in the right visual field (Ellis and Shephard, 1973, 1975; Geffen et al., 1971; Hilliard, 1973; Rizzolatti et al., 1971), while the reverse is true for verbal material (Rizzolatti et al., 1971). Finally, the right hemisphere alpha activity is suppressed during a facial memory task (Dumas and Morgan, 1975).

Although the evidence in favor of the right hemisphere commitment to face recognition is fairly conclusive, it lends itself to different interpretations. We need to know whether the right hemisphere commitment to face recognition reflects this hemisphere's specialization for processing of visual stimuli in general, or whether there is something specific in facial stimuli which facilitates Gestalt processing of these stimuli. Unfortunately, there is no clear-cut answer to this question; in fact, experimental data bearing on the issue are contradictory. On one hand, low frequency of prosopagnosia in patients with right hemisphere lesions might be explained if only a small and specific region of the right hemisphere is involved in face recognition (Levy, 1974). Newcombe's (1974) data support this contention. She found no overlap in scores between patients most impaired on a face recognition task and those most impaired on another visuospatial task (mazes). Moreover, these two groups could be distinguished on the basis of the anatomical location of the lesion. Men with a deficit in face recognition task had lesions on the right temporal lobe, while those with a deficit in mazes tended to have lesions in the parietal or parietal-occipital region.[2] The two tasks were correlated negatively in the right hemisphere lesion group. Tzavaras et al. (1970) found no correlation between tests of face recognition and recognition of other complex but meaningful patterns. On the other hand, Warrington and James (1967) argued that only the deficit involved in prosopagnosia (i.e. recognition of long-familiar faces) might have any degree of specificity; the impairment on previously unknown faces (a design typically employed in experimental studies of face recognition) seems to be related to the more general impairment that the patients with right hemisphere lesions exhibit in tasks involving visual recognition of perceptually complex form. A positive correlation between face recognition and other visual recognition tasks has been reported by DeRenzi and Spinnler (1966a, 1966b). Levy (1974) interpreted her data as offering no support for the idea that face recognition is a special ability separate from general Gestalt perception but, rather, as being in keeping with Milner's (1968) conclusion that the right hemisphere is dominant for non-nameable visual stimuli. It is, furthermore, possible that the right hemisphere commitment to face recognition might be related to the mode of processing of faces. Generally speaking, faces are processed as Gestalten; since the right hemisphere specialized in Gestalt processing, right hemisphere superiority is expected. We have seen previously that modes of information processing of the same verbal stimuli differ along the hemispheric lines. The same holds true for facial stimuli. Patterson and Bradshaw, using schematic faces (1975) reported a significant interaction of mode of processing (feature analytic vs. Gestalt) and visual hemifield. Gestalt processing (which, presumably, underlies judgments of "same") was performed better by the right hemisphere; when feature analytic processing was favored by task constraints (i.e. fine discriminations between stimuli were reported), the left hemisphere was found to be superior.

How can we disentangle these different possible reasons for the right hemisphere commitment to face recognition? One way involves spatial rotation of the stimulus, discussed previously. As suggested by Yin's (1968) study, spatial inversion affects "meaning" of the face, without changing the configuration or the complexity of the pattern. Both an upright and an inverted face are complex visual patterns; but only the upright face possesses the unique "meaning" which is strongly tied to stimulus orientation. If (1) face recognition is a facet of general pictorial memory, processing of upright and inverted faces should not differ along the hemispheric lines. If, however, (2) the right hemisphere is committed to face recognition because of the unique Gestalt property (the "meaning"), hemispheric asymmetry for processing of faces should depend on stimulus orientation such that upright faces are processed by the right hemisphere and the inverted faces by the left hemisphere.

In the first case, the difference between the upright and the inverted stimuli should be in the level of recognition and, possibly, in the extent to which the two tasks will differentially benefit from practice (inverted faces, being relatively novel stimuli, should benefit more). In the second case, it is assumed that, in addition, the mode of information processing will change. Rotation of the stimulus to an inverted position should eliminate the unique Gestalt property; stripped of it, a face is no longer amenable to holistic processing by the right hemisphere; feature analytic processing by the left hemisphere should prove to be more suitable.

There are two pieces of evidence directly bearing on the issue just discussed. Unfortunately, the conclusions that can be drawn from these two studies conflict. Yin (1970) tested a group of subjects with unilateral brain lesions on a facial recognition task, using both upright and inverted stimuli. In addition, upright and inverted photographs of houses were also employed. In accordance with the expectations based on a previous study (Yin, 1968), patients with right cerebral injuries showed lower recognition of upright faces than patients with lesions on the left side of the brain. However, on a task involving recognition of inverted faces patients with right-sided injuries were actually superior to subjects with left-sided injuries. Incidentally, this relationship did not obtain for houses--also familiar, complex, and typically mono-oriented stimuli. Thus, the right hemisphere is superior for upright faces, and the left hemisphere for inverted faces.

In an attempt to replicate Yin's (1970)findings on normal subjects, Ellis and Shepherd (1975) presented photographs of upright and inverted faces either in the left or in the right visual field. The subject's task was to judge whether the pairs of stimuli were the same or different. From Yin's study it might be expected that upright faces will result in shorter response latencies in the left visual hemifield; for inverted faces response latencies should be shorter in the right visual field. Contrary to this expectation, right hemisphere superiority was found for both types of stimuli. However, the authors failed to obtain a decrease in performance for inverted faces; in their experiment, the two types of stimuli fared identically. The very brief duration of probe exposure (15 msec.) used by these authors could be responsible for the failure,for one could argue that such a short time limit precludes all but the most rudimentary processing of the stimulus. Such rudimentary processing might always be visual in nature, even when the stimulus is verbal (Gazzaniga and Hilyard, 1972; Posner et al., 1969).[3]

Individual Differences

A finding of individual differences in hemispheric functioning has been reported in a number of recent studies. Basically, two models of consistent individual differences have been offered.

The first one can be termed the bias model. It postulates that individuals differ in the extent to which they depend on utilization of one or the other hemisphere function, and that a preference for the left or the right hemisphere functions can be defined. Some support for the bias model comes from lateral eye movement studies (Bakan, 1969, 1970; Day, 1967; Duke, 1968; Singer and Singer, 1972). In particular, Bakan (1969, 1970) interpreted the differences in the direction of the initial gaze shifts as reflecting differential reliance on the left or right hemisphere (i.e. the one which is contralateral to the usual direction of gaze shifts). Bogen et al. (1974) suggest that such differences exist not only between individuals, but also between societies (_nota bena_, differing primarily in the degree of literacy). Such descriptions of hemispheric functioning seem to be based upon rather global generalizations about asymmetry of the brain, going far beyond empirical evidence. As such, the bias model allows us to make interesting speculations about the nature of human consciousness, Eastern and Western thought, and the like, but these speculations are best treated as metaphors rather than factual descriptions of what goes on in the brain. It should be mentioned, in passing, that there is a more limited version of the model which, unlike the above, is amenable to empirical testing. This limited version's claim is that--since there is some basic incompatibility in the modes of information processing in the two hemispheres--their development is reciprocal; thus it is possible for one hemisphere to overdevelop to the detriment of the other. There is some anecdotal evidence that this is, in fact, possible. For example, Luria's Shereshevskii (Luria, 1968) may be considered a case of overdeveloped right hemisphere (hence the use of the imaginal coding strategies, capacity for synesthesias, impressive visual memory storage) at the expense of the left hemisphere (no abstract ability whatsoever). However, it must be realized that a model, based on descriptions of this and similar unusual cases, is not useful in describing people in general. In the population at large abilities exist in a positive manifold, meaning that there is always some positive correlation between different pairs of mental skills, whereas a negative correlation between visuospatial-artistic abilities and verbal-logical-mathematical abilities would be predicted from the bias model. The foregoing argument requires one qualification: to say that abilities exist in a positive manifold is to state a nomothetic principle; it is not necessarily true as an idiographic principle. It is possible that in the case of an individual, to use an analogy of the game theory, there is a zero sum competition between various abilities for the contribution to the overall IQ or g factor. In other words, there might, in fact, be an inverse relationship between various classes of abilities such that the more one class contributes to the overall IQ, the less will the other class of abilities contribute. The positive manifold may then reflect other factors in abilities measurement than individual patterning of mental skills.

The second model is best termed the <u>lateralization</u> or <u>differentiation</u> model. It postulates that individuals differ in the extent of segregation of different functions between the two hemispheres, i.e. in the degree of cerebral asymmetry. Levy (1969) has suggested that the segregation into different hemispheres of the two aspects of intellectual functioning evolved because of a fundamental incompatibility between the two modes of information processing. Individuals in whom verbal and visuospatial tasks are carried out within the same hemisphere should, then, be deficient in one or the other type of process when compared to more completely lateralized individuals.

Essentially, three correlates of this dimension of lateralization have been suggested:

(1) Handedness: It appears from clinical studies that non-right handed individuals are more likely to have some language representation in both cerebral hemispheres than are right handers (Branch, Miller, and Rasmussen, 1964; Goodglass and Quadfasel, 1954; Hecaen and Piercy, 1956). According to Levy (Levy and Sperry, 1968; Levy, 1969, 1974), people with bilateral speech representation (two left hemispheres, as it were) are inferior on visuospatial skills since, due to the incompatibility of information processing modes, the right hemisphere component of linguistic ability interferes with the right hemisphere visuospatial processing. These people have been variously described as left-handers in general, weak left-handers, strong left-handers, familial left-handers, or right-handers with close left-handed family. Levy's hypothesis (cf. Levy, 1974) implies that strong degree of lateralization confers the advantage of superior performance on both linguistic and visuospatial tasks, whereas weak lateralization means specialization in one type of information processing, usually the left hemisphere one, for it is the right hemisphere function which is usually sacrificed.

(2) Sex: The finding of sex differences on verbal vs. spatial tasks has been reported in a great number of investigations. Women and

girls perform consistently less well on spatial tasks than men and boys (Anastasi, 1958; Fruchter, 1954; Maccoby, 1966; Sandstrom, 1953; Tyler, 1965). Recently, Witelson (1976) suggested that this difference is due to different courses of hemispheric lateralization in men and women. Using tactile spatial tasks with boys and girls aged 6 to 13 years, she found that in boys the right hemisphere is specialized for spatial tasks as early as at 6 years, but that in girls bilateral representation exists till age 13, the oldest age she studied. These results are consistent with those reports in which the sexes were studied separately for lateralization of spatial processing (e.g. Bogen et al., 1972; Kimura, 1969; Lansdell, 1962, 1968; McGlone and Davidson, 1973; Rudel et al., 1974). Similar results have been obtained with rhesus monkeys (Goldman et al., 1974). All these studies suggest greater participation of the left hemisphere in spatial tasks in females than in males.

Witelson (1976) suggests also that since the right hemisphere in girls is not specialized for a particular cognitive function, the brain of young females, particularly the right hemisphere, may have greater plasticity for a longer period than that of males. In fact, women show less impairment than men on verbal tasks after injury or lesion to left hemisphere (Lansdell, 1961, 1973).

Buffery and Gray (1972) proposed the exact opposite hypothesis. They suggest that hemispheric specialization develops earlier in females. This conclusion is based on the finding that in women the left hemisphere is earlier specialized for linguistic processing (Kimura, 1967). As a result of this earlier specialization of the left hemisphere for language, the non-dominant (right) hemisphere of the female will have more unoccupied channel space to subserve non-verbal functions, whereas in males there is more of a bilateral representation of visuospatial function. In contrast to Levy (1969), Buffery and Gray believe that most forms of spatial function benefit from such bilateral representation, hence the male superiority on spatial tasks.

(3) Field Articulation: Many authors have characterized the cognitive processes of the left and right hemisphere in terms similar to Witkin's concept of psychological differentiation as manifested in analytic vs. global field approach.

The concept of differentiation has a venerable tradition in psychology. It refers to the complexity of structure of a psychological system. A less differentiated system is in a relatively homogeneous structural state; in Lewinian parlance, the regions are few and the boundaries between them weak. A more differentiated system is in a relatively more heterogeneous state, with many regions separated by firm boundaries. This description of a system as more or less differentiated carries definite implications about how it functions: highly differentiated systems are also highly specialized. This means that the subsystems which are present within the general system are capable of mediating specific functions which, in a relatively undifferentiated state, are not possible at all or are performed in a more rudimentary way by the system as a whole. In terms of a psychological system, differentiation means a degree of specialization of psychological areas and specificity in manner of functioning within an area.

Witkin et al. (1954;1962) postulated that progress toward increased differentiation is expressed through increased articulation (i.e. analysis and structuring) of experience. Individual differences in the articulation of experience are measured by a variety of perceptual tasks such as the Embedded Figures Test, Rod-and-Frame Test, Body Adjustment Test, and Room Adjustment Test (Witkin et al., 1954). Subjects scoring on the field-independent (articulated)[4] end of the continuum are described as experiencing their surroundings analytically, with objects experienced as distinguished from their backgrounds; this mode of perception is said to reflect the ability to overcome the influence of an embedding contest, that is, to restructure it. Field-dependent subjects are said to see their environment in a relatively global fashion, fusing objects with their backgrounds; such subjects are easily influenced by the context (the field). It has been demonstrated that this dimension of individual differences is quite pervasive; it pertains to other forms of cognitive functioning such as, for example, learning and memory, and it affects other, psychological and non-psychological domains as well (Goodenough, 1975; Witkin et al., 1962; Witkin and Goodenough, 1976). This trait is particularly salient in interpersonal behavior where it manifests itself as self-nonself segregation, resulting in a tendency to rely on internal or external referents (Witkin and Goodenough, 1976). In studies of face recognition, field-dependent subjects do better in incidental learning paradigms (Messick and Damarin, 1964), whereas field-independent persons do better in task-oriented situations (Goodenough, 1975). Apparently, when field dependent subjects are superior, it is because they attend more closely to socially relevant cues.

Both of the two extremes of field-articulation dimension and the modes of functioning of the two cerebral hemispheres have been described in terms of global vs. analytic dichotomy. In fact, the possibility of a connection between the dimension of field articulation and hemispheric asymmetry has often been suggested (Berent, 1974; Berent and Silverman, 1973; Oltman and Capobianco, 1973; Oltman, Ehrlichman and Cox, 1976; Pizzamiglio, 1974; Witkin and Oltman, 1967); however, there is little agreement as to the direction of the relationship. Three types of the relationship are possible:

1. Analytic field approach is associated with left hemisphere function. This type of relationship is suggested by semantic analogies (Bogen, 1969c; Levy and Sperry, 1968; Levy, 1969, 1974); the empirical evidence in favor comes from studies by Berent (Berent, 1974; Berent and Silverman, 1973) linking field independence with superior performance on tasks presumed to involve the left hemisphere, and from a study by Cohen et al. (1973) in which a direct association between performance on the Rod-and-Frame Test (measuring field articulation) and hemisphere activation has been demonstrated. In this study, a single electroconvulsive treatment (ECT) was administered to either the left or the right cerebral hemisphere of female patients treated for depression. Field-articulation scores were obtained before and shortly after the administration of the shock treatment. All 12 left ECT patients showed a shift toward the field-dependent end of the continuum; all of the 12 right ECT patients showed a shift away from the field-dependent end (i.e. they had smaller position errors) as compared to the pre-treatment field articulation scores. In other words, a temporary suspension of the left hemisphere functions resulted in the subjects' functioning in a more global way; a temporary suspension of the right hemisphere caused a shift toward a more analytic

functioning. Finally, an argument in favor of this view can be also extracted from two neurological studies in which patients with left hemisphere damage were impaired on a visually presented task requiring the perception of an embedded figure (Russo and Vignolo, 1967; Teuber and Weinstein, 1956).

2. Analytic field approach is associated with right hemisphere function. This postulate is suggested by some evidence of shared variance between tests of analytic field approach and performance on tasks sampling right hemisphere functions, i.e. various visuospatial tasks.

It has been reported (Witkin et al., 1962) that nonverbal subtests of the WISC such as Block Design, Picture Completion, and Object Assembly load on the same factor of analytic vs. global field functioning as scores of the perceptual index tests (Embedded Figures, Body and Room Adjustment). The authors suggest a reason, namely, that all the WISC subtests listed above involve disembedding or restructuring. For example, in the case of Block Design, the organization of the reference design has to be "broken up" into component blocks if it is to be reproduced. Also, Block Design loads highly on the factor of flexibility of closure (Thurstone, 1944) which, according to Witkin, is practically identical with his dimension of analytic vs. global field approach. Mazes (WISC) correlate with field-independence as well (at the age of 12, but not at 10 years). All of these tests are visuospatial in nature and, as such, should sample the right hemisphere function. In fact, superior recognition of Block Design patterns in the left visual field (and thus by the right hemisphere) has been found (Schell and Satz, 1970), and damage to the right hemisphere causes an impairment of performance on Kohs Block Design (Parsons et al., 1969) and Mazes (Newcombe, 1974).

One way to explain the apparent contraction of (1) and (2) is the following: Most of the tests employed to assess field articulation are spatial in nature; they require good spatial orientation in a confusing environment; EFT is also visuospatial in nature and it requires skills not unlike those called for by Block Design.[5] Thus, the spatio-visual variance shared by both the measures of field articulation and the non-verbal subtests of the WISC might contribute to the reported relationship of field independence with the right hemisphere. However, possibly, the part of field articulation variance which is associated with the ability to restructure and to think analytically may contribute to the association of field articulation with the left hemisphere functioning. It is further possible that different measures of field articulation sample the two portions of field articulation variance to different extents. The relatively low correlations between these different measures of field approach reported in the literature are symptomatic of their factorial impurity and could be interpreted as meaning that in addition to the construct of field articulation, common to all, they measure different constructs.[6] The Embedded Figures Test, in particular, is suspected to possess a significant contribution from the dimension of spatial ability. EFT and Block Design correlate more highly than RFT and Block Design (.80 vs. .65) (from Witkin et al., 1962); Vernon reported that EFT correlates with spatial tests such as Block Design and Concealed Figures more highly than it correlates with RFT (.51 and .61 vs. .36) (Vernon, 1972). The EFT loading on Witkin's Factor III (analytical field approach) is smaller than that of RFT (.50 and .68, respectively) (Witkin et al., 1962).

However, there are further contradictions which need to be dealt with. Take the example of the factor of speed of closure. This factor is most clearly defined by tasks which require immediate, spontaneous identification of an impoverished (incomplete) figure; the Street Gestalt Completion Test and Mooney's Closure Test are good examples of such tasks. Thus defined, the factor seems to tap the capacity to think in global, Gestalt terms--a capacity associated with the field-dependent end of the field articulation continuum. However, no such relationship was found by Witkin et al. (1962). On the other hand, Goodman (1960) found a significant correlation between scores on Mooney's Closure Faces and field independence. Similarly, Ehrlichman (personal communication) found a substantial correlation between Gestalt closure and scores on Embedded Figures Test.[7] In a recent revision of the theory of field independence Witkin and Goodenough (1976) in fact suggest that Gestalt Completion is a restructuring task at the same level as the Embedded Figures Test.

One way of resolving this difficulty is to propose a third type of relationship between hemisphere functioning and field articulation:

3. Analytic field approach is associated with greater lateralization of cognitive functions between the two hemispheres. The concept of differentiation underlies this postulate. Although no basic identity between the concept of differentiation as espoused by Witkin and that contained in Levy's (1969, 1974) postulates concerning individual differences in the degree of lateralization of cerebral functions is necessarily implied, the model suggests a possible neurological

correlate of cognitive differentiation. In support of this postulate, Silverman et al. (1966) found that left-handed subjects were more field dependent than right-handed ones, a finding consistent with Levy's hypothesis that left-handed subjects are less differentiated. Also, subjects with mixed eye dominance are more field-dependent than subjects with clearly established eye dominance (Goodenough et al., 1971; Oltman and Capobianco, 1967). Pizzamiglio and Cecchini (1971) found a significant correlation between the degree of acoustic lateralization (as measured by dichotic listening) and the degree of field-dependence. In the same vein, Pizzamiglio (1974) found that right-handed subjects and those with strong ear preference in dichotic listening tasks were more field-independent than the ambidextrous or the mixed-ear-preferent ones, respectively. Also, a finding by Oltman, Ehrlichman and Cox (1976) supports this model. They found that relatively more field-independent subjects showed a stronger visual field effect for perception of faces in a composite face task. This bias was not significant in the sample as a whole. The authors interpret the finding as showing that subjects with analytic field approach and those with global field approach differ in the extent of lateralization of face perception. In direct support of the model, Zoccolotti and Oltman (1976) reported that field-independent subjects showed a significant right visual hemifield advantage in reaction time in a letter discrimination task and field dependent subjects did not show a significant hemifield difference. Moreover, field-independent subjects showed a significant left visual hemifield superiority in tachistoscopic face discrimination, while field-dependent subjects did not.

It is thus possible that field-dependent individuals, whose behavior in many situations has been described as less differentiated, are less differentiated at the neurophysiological level as well, and show greater equipotentiality between the two cerebral hemispheres. Thus, field-dependent subjects are expected to show less asymmetry than field-independent subjects on tasks possessing hemispheric specificity.

In fact, such an hypothesis was recently proposed by Witkin and Goodenough (1976) in a revision of the theory of field independence. They write:

> . . . differentiation theory leads to the expectation that people who are field independent, compared to field dependent people, will show greater lateralization of verbal processing in the left hemisphere, where such processing is usually found, and of processing of configurational material in the right hemisphere, the common locus of this kind of processing. We designate this expectation the "localization hypothesis." The emphasis, it should be noted, is on degree of lateralization of particular functions in each of the two hemispheres rather than on overall dominance of one hemisphere or the other.

And, upon reviewing available empirical studies bearing on the issue, Witkin and Goodenough conclude: ". . . With a high degree of consistency, the evidence that has been reviewed favors the cerebral localization hypothesis, thereby lending support to the segregation-of-neurophysiological-functions concept from which that hypothesis was derived." (Witkin and Goodenough, 1976).

Propositions: Focus of the Study

The following propositions can be drawn from the foregoing discussion:

(1) Hemisphere involvement in a task might be a function of the mode of information processing which is being called for, rather than of the nature of stimulus being processed. Sequential, feature-analytic processing, and processing involving name matching depend on the left hemisphere; Gestalt, synthetic processing and processing based on physical matches involves the right hemisphere.

(2) Face recognition involves the right hemisphere process under normal viewing conditions (i.e., when the stimulus is upright); however, the two hemispheres can be involved differentially depending on stimulus orientation. The right hemisphere commitment to face recognition might be due to the unique Gestalt quality of upright faces, favoring holistic processing. When the stimulus is rotated in space, this unique face-specific attribute is obliterated although pattern configuration remains the same. An upside-down face may be more amenable to feature-by-feature rather than Gestalt processing; a shift in the mode of processing may be associated with a change of hemispheric involvement.

(3) There are systematic individual differences in the degree of hemispheric asymmetry, differences specified by the extent to which particular functions are segregated to the two half-brains. Such individual differences in lateralization seem to be associated with the degree of field articulation. This dimension is defined as restructuring ability and is manifested in cognitive and interpersonal functioning.

Thus, the general claim to be tested in this work is that hemispheric specialization for face recognition is a joint function of stimulus orientation and field articulation. This claim will be evaluated using two methodological approaches, viz. tachistoscopic presentations of stimuli to vision hemifields and EEG recording of bilateral alpha activity. Two specific hypotheses, derived from this general claim, will be tested.

Hypothesis 1: Upright faces will be processed by the right hemisphere; inverted faces by the left hemisphere. Thus, an interaction of asymmetry with stimulus orientation is predicted.

(a) In the tachistoscopic part it means that a left visual hemifield superiority for inverted faces will be found.

(b) In the EEG part it is expected that there will be relatively more alpha blocking in the right hemisphere than in the left hemisphere for upright faces. For inverted faces, the reverse should hold; more alpha blocking is expected in the left than in the right hemisphere.

Hypothesis 2: Field-independent subjects will show greater extent of lateralization than field-dependent subjects.

(a) Specifically, when stimuli are presented hemiretinally, the shift from the left visual hemifield superiority to right visual hemifield superiority due to rotation of the stimulus should be greater for field-independent than for field-dependent subjects.

(b) When EEG alpha is recorded, the difference between left-minus-right index for upright faces and that for inverted faces will be more sizable for field-independent than for field-dependent subjects.

(c) The same should hold true for processing of upright faces as compared to processing of words--the asymmetry effect is ecpected to be more sizable for field-independent than for field-dependent subjects.

In addition, a number of specific hypotheses with regard to involvement in processing of words, faces, and chairs with regard to differential effect of inversion on faces and on chairs will be tested in the EEG study. These expectations are discussed separately in the Method Chapter which follows.

Chapter 2

METHOD

Two measures of hemispheric asymmetry were employed to test these hypotheses. The first method of assessing hemispheric invovement in processing of stimuli presented visually is tachistoscopic projection of stimuli onto the hemiretinae. The second method is EEG recording of bilateral integrated alpha potentials. A supportive body of experimental evidence has been accumulated with regard to the validity of these two measures of lateral task specificity. Furthermore, these two measurement techniques seem reliable enough to warrant their use for the measurement of consistent individual differences (Ehrlichman and Wiener, 1977; Zurif and Bryden, 1969).

The proposed joint use of these two methods on the same sample of subjects in the present investigation constitutes a converging operation, i.e. an attempt to demonstrate that, in spite of the fact that each of these techniques possesses its own method variance, they both aim at the same construct. Consequently, they should produce comparable results. On the one hand, a demonstration of such convergence would be a valuable finding in its own right. A failure to demonstrate such convergence, on the other hand, should lead us to question the assumption that these two methods can be directly compared as measures of hemispheric asymmetry.

1. SUBJECTS

Twenty-four women participated in the study. The subjects were selected from a large group of women pretested on the Rod-and-Frame Test (RFT). Only those subjects scoring either in the lower third or the upper third of the distribution were asked to participate.[8] Two groups, each containing 12 subjects, were formed. The mean RFT score for the field dependent group was 80.7; the mean for the field-independent group was 18.7. The difference between these two means is significant ($t = 11.6$; $df = 22$; $p < .001$).

The use of only one sex has been dictated by considerations with respect to the complexity of the design. Since there are good reasons to suspect sex differences on many of the tasks and since sex affects field articulation scores, the data would have to have been analyzed separately for sexes, thus requiring larger Ns to produce sufficient cell frequencies. This was not possible in the present study due to financial constraints. The decision to use women rather than men only stemmed from the fact that it is generally easier to obtain a wider range of field articulation scores from women than from men; men's scores tend toward the upper end of the distribution whereas women's scores are more evenly distributed.

All of the subjects were right-handed since left-handed subjects show a much greater variability in hemispheric speech localization than right-handed subjects thus making it difficult to draw conclusions with respect to lateral specificity of tasks.

Subjects were paid for their participation in the study. Subjects were tested individually in two separate two-hour sessions. There was an interval of at least a week between the two sessions.

Part I. TACHISTOSCOPIC STUDY

This part of the study involves acquisition of a memory set, and then a recognition procedure where subjects have to decide whether the given memory probe presented tachistoscopically, is or is not a member of the memory set.

Rationale. When stimuli are presented briefly either to the right or to the left off center and steady fixation is maintained, stimuli to the left off center are perceived by the left visual hemifield (LVHF) which, in turn, projects to the right hemisphere. Stimuli to the right off center are perceived by the right visual hemifield (RVHF) which projects to the left hemisphere. When the same stimulus is shown in the right visual hemifield on some trials, and in the left visual hemifield on other trials, response latencies and/or accuracy scores from these two conditions can be compared to assess which hemisphere deals with the given task more effectively.

Design. Since upright and inverted faces may be encoded differently, two sets of memory faces were used, one upright and one inverted. A set of memory probes for each memory set was constructed, with no overlap between sets. In each set of probes half of the faces were upright and half inverted; half were shown in the left visual hemifield and half in the right visual hemifield; half were positives and half negatives (not members of the original memory set). This yields a group x orientation of memory set x orientation of probe x visual hemifield x response -- 2 x 2 x 2 x 2 x 2 design.

The use of upright and memory probes constitutes an attempt to tap hemispheric differences associated with the retrieval aspect of the memory process. It should allow us to answer the question of what happens (which hemisphere will be involved) when an inverted probe needs to be matched to the upright memory set as compared to the more usual situation in which an upright probe is matched to an upright memory set. Since, as discussed in the Introduction, different information processing strategies appear to be involved in these two situations, namely, matching of Gestalten in the case of the upright probe and matching on the basis of features in the case of inverted probes, this aspect of the design should provide fairly direct answers concerning the relationship between the nature of cognitive process and hemispheric activation. Since there is a distinct possibility (Hochberg and Galper, 1967; Yin, 1968) that upright and inverted faces are also encoded differently, two memory sets--one upright and one inverted--were used. The use of these two memory sets completes the fourfold design in which the encoding and the retrieval processes can be evaluated separately and which also allows for evaluation of their interaction, viz. the effect of match vs. mismatch of memory set and memory probe for orientation.

Stimuli. Stimuli were trimmed photographs of faces mounted on white index cards. All the photographs were taken from an old high school yearbook and all were photographs of women relatively uniform with respect to clothing, hairdo and angle from which the face was photographed. The memory set faces were mounted centrally on 3x5 cards. There were two memory sets, each containing seven faces, with no overlap of items between the two sets. In order to control for the possible differences in distinctiveness of faces (Cohen and Carr, 1975), the order and orientation of memory sets were randomized. Each of the two sets was used in both orientations. Half of the subjects got Set I upright and Set II inverted; the other half got Set II upright and Set I inverted.

The memory probes were trimmed photographs of faces mounted on 5x7 index cards either to the left or to the right of a central fixation point, subtending visual angle of about 3^o. Fifty-six probes were constructed for each memory set. In addition to the photograph of a face each stimulus card contained a central digit, aligned with the fixation point.

Apparatus. A three field Scientific Prototype tachistoscope with automatic control of projection time and luminance for each element of the sequence was used. The three fields were shown in the following sequence: fixation dot, stimulus card, black post-exposure field. The distance between the viewer and the stimulus card was about 1 m.

Procedure. The memory set design used in this part of the investigation consisted of two stages: the acquisition stage and the recognition stage. In the acquisition stage the subject was first given a set of 7 faces and was asked to learn all the faces by going through the deck at a preferred rate, spending about five (or more) minutes on the entire deck. The subject was asked to view the photographs in the orientation in which they were handed to her. After the subject said she had learned the faces, recognition was checked by asking the subject to pick out these seven faces from a deck of fourteen cards, half of which were negatives, i.e., not member of the original memory set. If the subject made any errors, she was asked to look at the cards a little more; and recognition was checked again. All the subjects were brought to a common criterion of 100% correct. Time spent learning memory set faces was recorded. Subjects were informed that memory for the photographs would be tested.

In the recognition stage of the experiment sets of memory probes were presented tachistoscopically. At the beginning of each trial the experimenter said "ready," then the fixation dot was shown for 5 seconds, followed by the stimulus face shown for 250 milliseconds. The use of 250 milliseconds exposure time was based on results of a pilot study in which this interval was found to be optimal with respect to accuracy. The stimulus card was followed by a black post-exposure field till the beginning of the next trial. The subject's task was to judge whether a given stimulus was a member of the memory set (positives) or not a member of the set (negatives). She was to indicate her answer by pressing one of the two switches--yes or no--using the index (yes) and the middle (no) fingers of the right hand. Next, the subject was asked to report the central digit.

After the subject familiarized herself with the experimental set-up, she was given ten practice trials. Care was taken in instructing subjects to main steady central fixation.

The set of 56 probes was shown twice. In the second run the yes/no switches were reversed to guard against the possibility of different response latencies associated with the use of the index and middle finger. Thus, 112 probes were shown for each memory set. On each trial the reaction time, response, and the digit were recorded by the experimenter.

Both steps (acquisition and recognition) were repeated for the second memory set. For half of the subjects the upright memory set was first and the inverted second; the rest of the subjects learned the inverted set first and the upright second. The randomization of the yes response over the two switches for the four blocks of trials was of the abba order (index-middle-middle-index). Within each set of 56 trials, probes were presented in alternating blocks of 4 upright and 4 inverted. They were randomized with respect to visual hemifield of presentation and type of response required.

Part II. EEG STUDY

Rationale. It has been shown that disruption of the alpha wave and its replacement by a low amplitude, irregular, fast rhythm is symptomatic of a cortical involvement in the ongoing task. It has also been shown that the two hemispheres differ in the extent of such disruption of alpha activity; depending on the nature of task, one hemisphere will become more active than the other.

Continuous recognition tasks were employed in this part of the investigation.[9] In this procedure the subject views a large number of stimuli presented centrally one at a time. The subject's task is to respond whenever any stimulus reoccurs. Three types of stimuli were used; faces, chairs, and words.

Stimuli

Face Tasks. Since, as discussed previously, upright and inverted faces are amenable to different information processing strategies and hence, according to the concept of analytic vs. global dichotomy, should produce differential hemisphere involvement, both upright and inverted facial stimuli were used. It was hypothesized that processing of upright faces will result in a relative right hemisphere activation and of inverted faces in a relative left hemisphere activation. It was also expected that this asymmetry effect will interact with field independence, specifically, that it will be greater for field-independent than for field-dependent subjects.

Stimuli were trimmed photographs of faces mounted centrally on 3x5 inch white index cards. All the stimuli were photographs of men taken from an old high school yearbook; they were uniform with respect to clothing, hairdo, and angle from which the face was photographed. Two decks, each containing 60 photographs, were constructed. One deck consisted of all upright faces, and the other of all inverted faces. The two decks were independent: there was no overlap of stimuli between them. Within each deck, 20 stimuli occur only once, and 20 twice. Thus, the number of correct positives (hits) is 20 for each set. All cards were photographed and made into transparencies.

<u>Chair Tasks</u>. Chairs, like faces, are typically mon-oriented pictorial stimuli which, however, do not possess the unique Gestalt meaning which is inherent in faces. Consequently, they should tap less of the right hemisphere variance than faces. It was therefore expected that relative right hemisphere involvement will be greater for upright faces than for upright chairs. Moreover, because of the lack of the unique Gestalt property in chairs, the effect of inversion which, in the case of faces reflects obliteration of this meaning, should be different for chairs than for

faces. It was predicted that the effect of inversion or asymmetry scores will be significantly smaller for chairs than for faces.

In order to test these hypotheses, two sets of cards containing photographs of chairs were constructed, one containing upright chairs, and the other inverted. The stimuli were photographs of antique chairs from the Victoria and Albert Museum in London. The two decks were constructed analogously to the two decks for Face Tasks. Probability of hit was again 1/3.

Word Tasks. Since processing of words is highly left-hemisphere specific, word tasks were employed to provide a left hemisphere reference point to which other asymmetry scores could be compared. The use of two word tasks was dictated by the considerations of the possibility of a confounding factor in the face and chair tasks, viz. task difficulty. It is possible that inverted stimuli are simply more difficult to process than upright stimuli, possibly because they might require a more in-depth processing. Therefore, in order to complete the design and allow for the evaluation of the effect of difficulty in verbal tasks, as compared to visuospatial tasks, two verbal tasks were used, of which one was considered to be easy (Matching Words) and the other difficult (Synonyms). If the hemispheric asymmetry effect present in the face and chair tasks reflects differences in task difficult rather than differences in strategies employed, then, analogously, the asymmetry scores for the two verbal tasks should be different, the difficult task engaging the left hemisphere to a greater extent than the easy task. No such difference was expected.

The stimuli were short words selected on the basis of medium to high frequency of occurrence in the English language from the Thorndike-Lorge list. The words were typed on 3x5 inch index cards, one word to a card. There were two sets of words, each set containing sixty stimuli. In Matching Words set, 20 words occur only one and another 20 are repeated twice. In Synonyms Task, 20 words are synonyms of another 20 words presented earlier. Again, the cards were photographed and made into transparencies.

(4) For the *Composite Faces* task, the stimuli were 14 photographic slides. Each slide consisted of a frontal picture of a human face in the upper center, and two composite pictures, one at the lower left and one at the lower right. One composite was constructed of the right half of the original face and its mirror image, and the other of the left half of its mirror image. The location of the composites on the slide was randomized.

Apparatus: An EEG machine was used to amplify, integrate and record bilateral alpha in 8-12 Hz band width. Three disk scalp electrodes were attached: a central vertex common reference electrode and one on each hemisphere in average temporal-parietal region (P_3-T_3 and P_4- T_4). An additional ground electrode was placed on the subject's forehead. The integrator processed each temporal-parietal channel to the vertex channel of alpha independently. The input was filtered through analog (6-15 Hz) and digital (8-12 Hz) filters, and integrated in 30 second epochs for all tasks except Composite Faces, in which epoch length was 3 seconds. Numerical output consisted of cumulative integrated amplitude per epoch within the designated passband for each channel. Integration rate was calibrated at 800 units per epoch ('o for Composite Faces). Preamp output was monitored on an oscilloscope for artifacts. All the epochs containing artifacts lasting longer than 5 seconds were discarded.

A Kodak Carousel slide projector with automatic timer was used to present stimuli in all the tasks. The slides were projected onto a white screen situated about 2 meters in front of the subject.

Procedure. At the beginning of Part II, the nature of the EEG experiment was explained to the subject. Next, the electrodes were attached, and after a brief resting period (allowed in order for the recordings to stabilize), the testing began.

A. First, the following tests were administered to the subject:

(1) Group Embedded Figures TEST (GEFT). This is a paper and pencil, group administration version of the Embedeed Figures Test (Oltman et al., 1971). It measures the subject's standing on the dimension of field articulation. The task is to find simple forms hidden within more complex patterns and to trace their outlines directly over the lines of complex figures. The score on the test is the number of correctly traced simple figures.

(2) Gestalt Completion Test. This is test C_s-1 in the Kit of Reference Tests for Cognitive Factors (French et al., 1963). The task is to decide what objects are depicted in a number of incomplete drawings. The subject responds by writing the names of the object underneath the drawing. The score on the test is the number of correctly identified drawings. This test is a measure of the Speed of Closure factor.

(3) Extended Range Vocabulary Test. The test used was V3 from the French Kit (French et al., 1963). This is a 5-choice synonym test containing items of varied difficulty. The score on the test is

the number of correct answers minus a fraction (.25) of incorrect answers. The score reflects the subject's standing on the factor of Verbal Comprehension, the ability to understand the English language.

B. Second, each subject was given all of the continuous recognition tasks in the following order: Upright Faces, Inverted Chairs, Matching Words, Inverted Faces, Synonyms, Upright Chairs. The order was the same for all the subjects. Short breaks were given between tasks. Before each task standard instructions explaining the task were read to the subject. Each slide was shown for 5 seconds. The subject's task was to indicate positives (re-occurring stimuli) by turning a switch. All the responses were recorded.

C. Finally, the Composite Face task was administered. In this task exposure time was 6 seconds. This time interval was judged to be short enough to insure that subjects will have based their judgments on first impression rather than detailed scanning. The subject was asked to judge which of the composites more resembled the standard. Subjects responded verbally saying "left" if they thought the composite photograph to the left off center was a better resemblance of the original face than the one to the right. They said "right" if they thought that the composite to the right of center was a better resemblance.

The experimenter recorded alpha values for the two channels (the right and left hemisphere) and subjects' responses on protocol sheets.

Chapter 3

RESULTS

Results from the two parts of the investigation are reported below. First, findings from the tachistoscopic study are presented. They are followed by a presentation of results from the EEG study. Finally, the results from the two studies are compared.

Part I: Tachistoscopic study.

All of the trials on which the central digit was reported incorrectly (3% of all trials) were discarded from all subsequent analyses.

There were two dependent variables in this part of the investigation--reaction time and accuracy. They were analyzed in two separate 5-way analyses of variance (ANOVA).

1. Reaction time analysis

Two ANOVAs were run on the reaction time data. In the first analysis only correct trials were included (84% of the remaining trials). In the second analysis both correct and incorrect trials were used. The results from these two ANOVAs were virtually identical. Therefore, only the second analysis of variance including all trials will be discussed here. The results of this analysis are displayed in Table 1.

As expected, there were, overall, longer reaction times associated with inverted faces than with upright faces. Orientation of probe and orientation of memory set were both significant main effects, both due to longer reaction times to upside-down faces. In addition, the interaction

Table 1

TABLE Analysis of Variance of Reaction Times *

	SS	df	F	P
Group (Field dependent, Field independent	1064768.0	1	.61	NS
Orientation of set	1094481.0	1	6.97	<.01*
Orientation of set x group	566440.0	1.	3.61	NS
Orientation of probe	345548.75	1	15.34	<.001*
Orientation of probe x group	74988.94	1	3.33	NS
Orientation of memory set orientation of probe	1786683.0	1	32.51	<.001*
Orientation of set x probe x group	12985.0	1	.23	NS
Visiaul hemifield	106.81	1	.009	NS
Visual hemifield x group	20946.62	1	1.81	NS
Orientation of memory set x visual hemifield	59.87	1	.006	NS
Orientation of memory set x visual hemifield x group	7733.44	1	.84	NS
Orientation of probe x visual hemifield	569.19	1	.067	NS
Orientation of probe x visual hemifield x group	79358.44	1	9.46	<.01
Orientation of set x orientation of probe x visual hemifield	37981.19	1	2.38	NS
Orientation of set x orientation of probe x VHF x group	1891.37	1	.12	NS
Response (yes or no)	94423.19	1.	3.52	NS
Response x group	15284.5	1	.57	NS
Orientation of memory set x response	2022.25	1	.086	NS
Orientation of memory set x response x group	834.25	1	.03	NS
Orientation of probe x response	16890.87	1	.39	NS
Orientation of probe x response x group	16145.94	1	.38	NS
Orientation of set x probe x response	204846.37	1	10.13	<.01*
Orientation of set x probe x response x group	5882.25	1	.29	NS
Visual hemifield x response	370786.0	1	20.19	<.001*
Visual hemifield x response x group	9913.62	1	.54	NS
Orientation of set x VHF x response	2763.75	1	.39	NS
Orientation of set x VHF x response x group	2548.62	1	.35	NS
Orientation of probe x VHF x response	158414.37	1	7.71	<.01*
Orientation of probe x VHF x response x group	19233.56	1	.94	NS
Orientation of set x probe x VHF x response	28690.00	1	2.48	NS
Orientation of set x probe x VHF x response x group	827.62	1	.07	NS

*** The BMD Statistical Package was employed in the statistical analyses. For this, and all the subsequent analyses of variance, BMDP2V program for analysis of variance with repeated measures was used.**

of orientation of memory set and orientation of probe was significant. These results are presented in Table 2. It appears that the significance of the interaction is attributable to greater task difficulty on trials where memory set and probe were mismatched for orientation compared to those where the set and probe were matched for orientation.

There was no significant main effect for visual hemifield. Response latencies in the RVHF and the LVHF are comparable in magnitude when we collapse across various conditions of the experiment. The two means are 1507.6 for RVHF and 1506.6 for LVHF. In other words, in the present investigation neither hemisphere was found to be dominant for facial stimuli; stimulus orientation and subjects' standing on the dimension of field independence were not considered.

In addition, when the two groups of subjects were collapsed into one, visual hemifield did not enter into any significant interactions with either the orientation of memory set, orientation of probe, or both.

Group was not a significant main effect. Although field-independent subjects show a tendency to respond faster than field-dependent subjects (mean reaction times for the two groups are 1454.41 and 1559.73, respectively), the difference is not statistically significant.

In the present framework the most important finding apparent from Table 1 is that the predicted interaction of orientation of probe x visual hemifield x group was significant ($F = 9.46$, $p < .01$). The means for this interaction are presented in Table 4; they are presented graphically in Figure 1.

When upright probes are shown, field independent subjects show shorter response latencies when the probe is in the left visual hemifield

Table 2

Mean Reaction Times (in milliseconds) as a Function of Orientation of Set and Orientation of Probe

		Memory Set		
		Upright	Inverted	Mean
PROBE	Upright	1355.5	1598.7	1477.1
	Inverted	1551.9	1522.3	1537.1
	Mean	1453.7	1560.5	-

Table 3

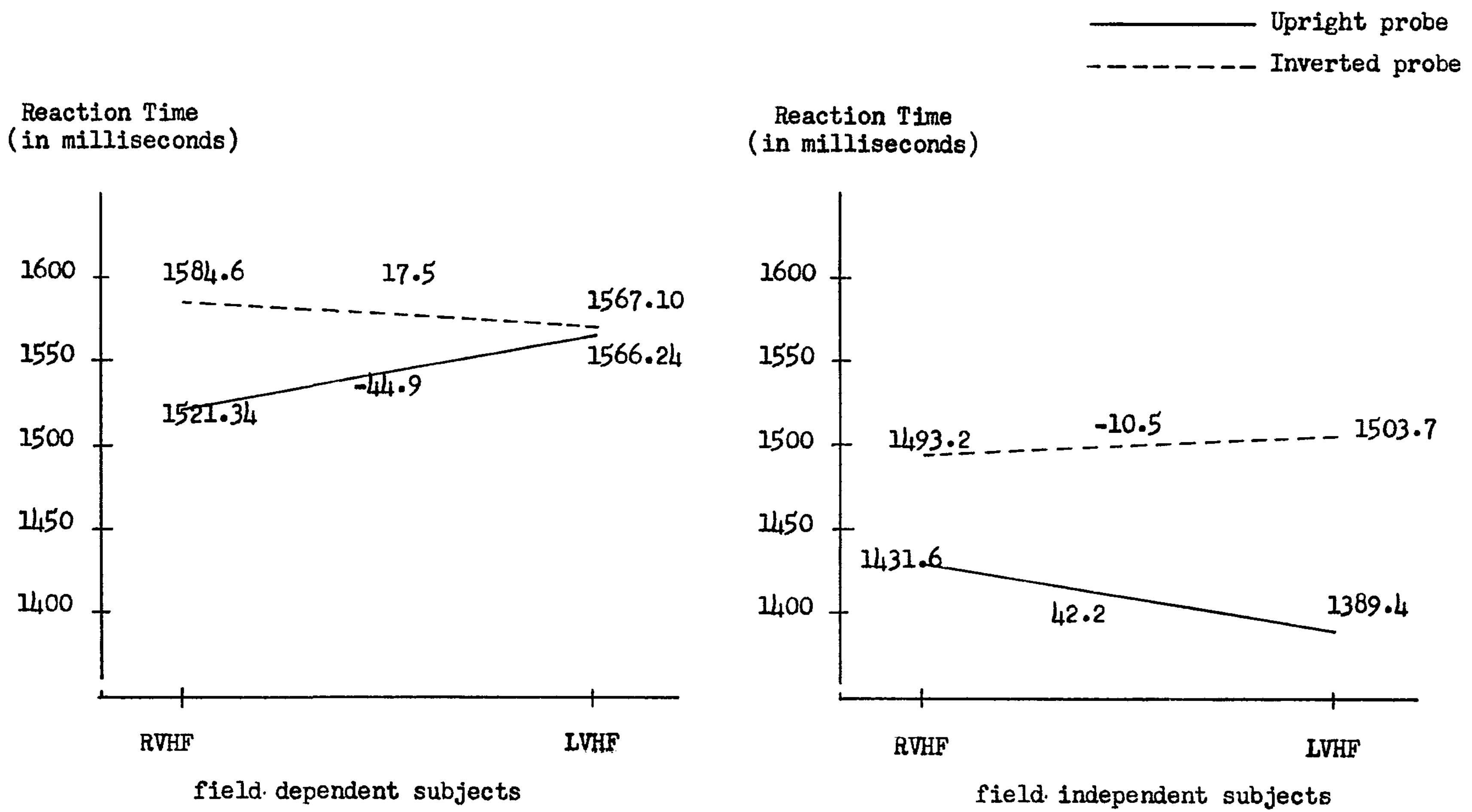
Mean Reaction Times (in milliseconds) as a Function of Visual Hemifield of Presentation and Type of Response

		Visual Hemifield		
		RVHF	LVHF	Mean
RESPONSE	Yes	1523.0	1459.8	1491.4
	No	1492.2	1553.3	1522.7
	Mean	1507.6	1506.5	

Table 4

Mean Reaction Times as a Function of Visual Hemifield Group, and Orientation of Probe

	Upright Probe		Inverted Probe	
	RVHF	LVHF	RVHF	LVHF
Field Dependent Subjects	1521.3	1566.2	1584.6	1567.1
Field Independent Subjects	1431.6	1389.4	1493.2	1503.7
Mean	1476.5	1477.8	1538.9	1535.4



N = 24.

<u>Figure 1</u>. Reaction Time as a Function of Group, Visual Hemisphere, and Orientation of Probe.

than when the probe is in the right visual hemifield. The mean difference in reaction times in the two visual hemifields is -42.2 milliseconds. This difference is significant ($t = 2.32$, $df = 11$; $p < .05$).[10]

When inverted probes are presented, field-independent subjects show slightly shorter latencies to probes presented in the right visual field than to those presented in the left visual field. The difference between these two conditions is 10.5 milliseconds; it is, however, not significant.

The pattern of reaction times is different for field-dependent subjects. To begin with, when upright probes are presented these subjects show shorter latencies when the probe is in the right visual field than when it is in the left visual hemifield--a trend opposite to that which is usually expected with upright faces. The mean difference between the two conditions is 44.9 milliseconds. This difference between means is significant ($t = 3.18$, $df = 11$, $p < .05$). The magnitude of the difference is comparable to that for field-independent subjects; however, it is in the opposite direction. When inverted faces are presented, field-dependent subjects show a tendency to react more quickly when probes are shown in the left visual hemifield than when probes are shown in the right visual hemifield. The difference between the two conditions is -17.5 milliseconds and it is not significant. Again, the mean difference is of a magnitude comparable to that for field-dependent subjects, but again, it goes in the opposite direction.

Comparisons were also made between reaction times to upright and inverted probes in each visual hemifield.

For field dependent subjects, when stimuli are presented in the right visual hemifield, the presentations of upright probes results in shorter response latencies than for inverted probes ($t = 2.47$, $df = 11$, $p < .05$). There is no difference between the two types of stimuli in the left visual field ($t = 2.21$) and a significant difference between upright and inverted probes presented in the left visual hemifield ($t = 5.29$, $p < .001$). In both cases reaction times to upright probes are shorter than to inverted probes.

The difference between reaction times of field-dependent and field-independent subjects in the four conditions of the design (upright probe shown in the RVHF, upright probe shown in the LVHF, inverted probe to RVHF, and inverted probe to LVHF) were evaluated for significance. It is important to note that in no case was the difference significant.

Overall, field-independent subjects show the predicted pattern of reaction times and field dependent subjects do not. It should be remembered that the main effects for group and visual hemifield were not significant. Therefore, the significance of the interaction is attributable to different patterns of response to probes in the left and right visual hemifields by the field-dependent and field-independent subjects. In fact, from inspection of Figure 1, it is possible to conclude that the reason for the non-significance of these two main effects, as well as the non-significance of the interaction of visual hemifield x orientation of probe, is that the two groups show opposite patterns of response and therefore obliterate each other's effect.

Incidentally, the type of response--positive or negative--also made a difference. Although the main effect for response was not significant, this variable entered into a number of significant interactions with orientation of probe, orientation of memory set and visual hemifield. (Cf. Table 3).

II. Error Analysis

Since accuracy has been used interchangeably with reaction time as a measure of hemispheric asymmetry (Gross, 1972), the question arose to what extent the two measures--response latency and number of errors--are comparable. The question seems particularly worth asking in view of the evidence that reaction time is more sensitive to hemispheric asymmetry effects (Gross, 1972; Springer, 1976). In order to answer this question in the present context, it was decided to analyze errors in an analysis of variance analogous to that for reaction times. A considerable overall percentage of error (16%) was considered high enough to warrant such procedure. The dependent variable in this analysis was mean number of errors.

Results of this ANOVA are presented in Table 5. It will be observed that (1) all of the findings of reaction time ANOVA were replicated by this analysis; and (2) in addition, several other main effects and interactions were significant.

In the present analysis group was a significant main effect ($p < .05$) with field-dependent subjects making more errors than field-independent subjects (mean numbers of errors are 2.58 and 1.88, respectively). Orientation of memory set was a significant main effect ($p < .001$)--a greater number of errors was associated with inverted as opposed to upright memory set (2.78 and 1.67, respectively). Also, subjects made more errors in responding to inverted memory probe faces than to upright probes (the means are 2.65 and 1.80; the effect is significant at $p < .001$). The interaction of orientation of memory set and orientation of probe was

Table 5

Analysis of Variance: of Error Scores

Effect	Sum of Squares	df	F	P
Total				
Group	47.46	1,22	4.94	.05
Orientation of set	118.15	1,22	30.26	.0011
Orientation of set x group	1.14	1,22	.29	NS
Orientation of probe	69.19	1,22	20.92	.001
Orientation of probe x group	16.25	1,22	4.91	.05
Orientation of set x orientation of probe	115.94	1,222	35.59	.001
Orientation of set x probe x group	2.84	1,22	.87	NS
Visual hemifield	15.44	1,22	10.81	.01
Visual hemifield x group	3.56	1,22	2.49	NS
Orientation of set x visual hemifield	.44	1,22	.44	NS
Orientation of set x visual hemifield x group	.06	1,22	.04	NS
Orientation of probe x visual hemifield	9.69	1,22	6.96	.01
Orientation of probe x visual hemifield x group	7.87	1,22	5.66	.05
Orientation of probe x set x visual hemifield	.75	1,22	.45	NS
Orientation of probe x set x visual hemifield x group	9.69	1,22	5.84	.05
Response	5.27	1,22	.8	NS
Response x group	30.94	1,22	4.86	.05
Orientation of set x response	5.75	1,22	1.41	NS
Orientation of set x response x group	10.34	1,22	2.53	NS
Orientation of probe x response	217.50	1,22	42.85	.001
Orientation of probe x response x group	5.27	1,22	1.04	NS
Orientation of probe x orientation of set x response	180.13	1,22	27.71	.001
Orientation of probe x orientation of response x group	9.06	1,22	1.39	NS
Visual hemifield x response	13.13	1,22	9.72	.01
Visual hemifield x response x group	1.37	1,22	1.02	NS
Orientation of set x visual hemifield x response	2.83	1,22	2.02	NS
Orientation of set x visual hemifield x response x group	.75	1,22	.54	NS
Orientation of probe x visual hemifield x response	5.75	1,22	3.98	.05
Orientation of probe x visual hemifield x response x group	.44	1,22	.30	NS
set x probe x visual hemifield x response	.94	1,22	.74	NS
set x probe x visual hemifield x group	1.37	1,22	1.08	NS

significant beyond the .001 level. The means for the interaction are presented in Table 6. It appears that the interaction is due to a considerably lower number of errors for matching upright probes to upright memory set faces compared to the other three conditions in which the means are comparable in size.

Visual hemifield was another significant main effect ($p < .01$). Overall, subjects make more errors when probes are presented in left visual field (mean = 2.45) than when they are presented in the right visual field (mean = 2.03). Visual hemifield interacts significantly with orientation of probe ($p < .01$).

When probes are upright, there is no difference between the number of errors associated with the right visual hemifield presentations and the mean number of errors associated with the right visual hemifield presentations. When probes are inverted, subjects make more errors when probes are shown in the left visual hemifield than when they are shown in the right visual hemifield. This finding only partially supports the hypothesized interaction of visual hemifield with orientation of probe. Inspection of means in the significant interaction of orientation of probe x visual hemifield x group further explicates this finding. These means [illegible] presented in Table 8. The interaction is presented graphically in Figure 2. The graph is comparable to the interaction of visual hemifield by orientation of probe by group which emerged in analysis of reaction times. Again it is clear that the patterns of response for field-dependent subjects are different from those of field-independent subjects. When probes are upright, field-dependent subjects make more errors in the left visual hemifield than

Table 6

Mean Number of Errors as a Function of Orientation of Memory Set and Orientation of Probe

Memory Set

		Upright	Inverted	Mean
PROBE	Upright	.69	2.91	1.80
	Inverted	2.65	2.65	2.65
	Mean	1.67	2.78	2.23

Table 7

Mean Number of Errors as a Function of Group and Orientation of Probe

Probe

		Upright	Inverted	Mean
SUBJECTS	Field Dependent Subjects	1.95	3.21	2.58
	Field Independent Subjects	1.65	2.09	1.87
	Mean	1.80	2.65	2.23

Table 8

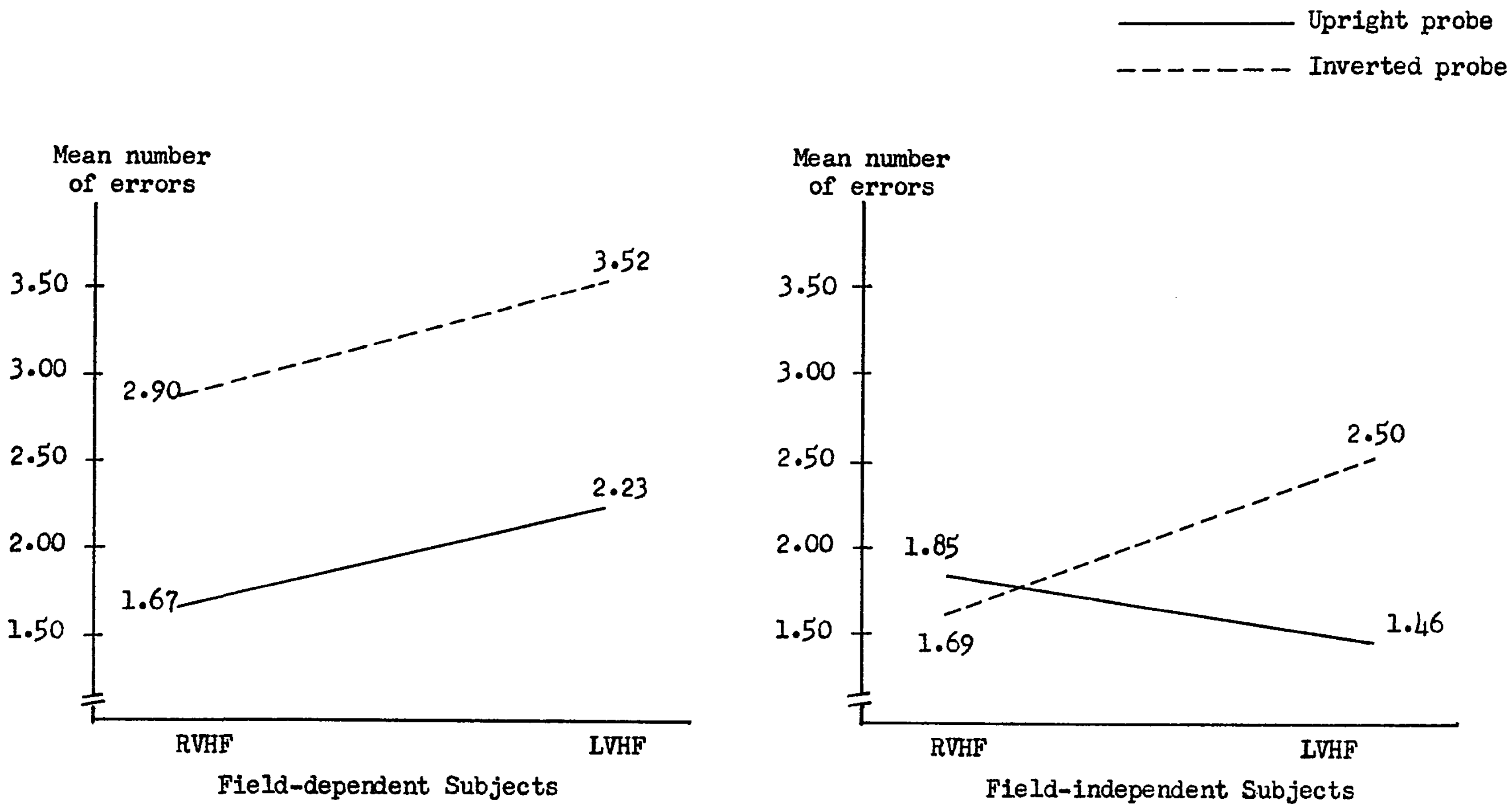
Mean Number of Errors as a Function of Group, Visual Hemifield, and Orientation of Probe

	Upright probe		Inverted probe		Mean
	RVHF	LVHF	RVHF	LVHF	
Field Dependent Subjects	1.67	2.23	2.90	3.52	2.58
Field Independent Subjects	1.85	1.46	1.69	2.50	1.88
Mean	1.76	1.85	2.30	3.01	2.23

Table 9

Mean Number of Errors as a Function of Group and Response

	Misses	False Alarms	Mean
Field Dependent Subjects	2.18	2.98	2.58
Field Independent Subjects	2.04	1.71	1.87
Mean	2.66	2.34	



N = 24

Figure 2. Number of Errors as a Function of Group, Visual Hemifield of Presentation and Orientation of Probe.

in the right visual hemifield (means are 2.23 and 1.67, and the difference between the means is not significant). They also make more errors in the left than in the right visual hemifield when the probes are inverted (2.90 vs. 3.52, $df = 11$, $t = 2.55$, $p < .05$). Field-independent subjects make more errors in response to upright probes shown in the right visual hemifield than in the left visual hemifield (1.85 vs. 1.76, $t = 2.28$, $df = 11$, $p < .05$). Conversely, they make more errors in the left visual field than in the right visual field in response to inverted faces (2.50 vs. 1.69, $t = 3.35$, $df = 11$, $p < 01$). Thus in terms of mean number of errors, there is a double dissociation of orientation of face and hemispheric involvement for the field independent subjects.

When probes are shown in the right visual hemifield, field-dependent subjects make more errors in response to inverted as opposed to upright faces (2.90 vs. 1.67, $t = 4.37$, $df = 11$, $p < .001$). The same holds when the probes are presented in the left visual hemifield--more errors are associated with inverted than with upright faces (3.52 vs. 2.23, $t = 3.74$, $df = 11$, $p < .01$). For field-independent subjects there is no significant difference between upright and inverted faces presented in the right visual hemifield (1.85 vs. 1.69, $t = 1.10$, NS). When, however, the probes are shown in the left visual hemifield, these subjects make significantly more errors in response to inverted than in response to upright faces (2.5 vs. 1.46, $t = 2.80$, $df = 11$, $p < .01$).

When error scores of field-dependent and field-independent subjects are compared in various conditions, the following mean differences are significant: When upright probes are presented in the right visual hemifield, field-dependent subjects make more effors than field-independent subjects ($t = 2.07$, df = 22, $p < .05$). Field-dependent subjects also make more errors when inverted probes are presented in the right visual hemifield ($t = 3.48$, df = 22, $p < .01$), and when inverted faces are presented in the left visual hemifield ($t = 2.24$, $p \angle .05$). There is no difference between these two groups when upright probes are presented in the right visual hemifield. Thus, with the forementioned exception, field-dependent subjects are, overall, less accurate than field-independent subjects.

As hypothesized, only the pattern of errors of field-independent subjects is in the same direction as predicted from the global-analytic dichotomy model; field-dependent subjects do not show this predicted pattern. These latter subjects make more errors when probes are shown in the visual hemifield than when they are shown in the right visual hemifield regardless of orientation of probe. In sum, the main hypothesis of Part I, predicting an interaction of orientation of probe by visual hemifield by field articulation was borne out. The two analyses of variance yielded similar patterns of interaction of orientation of probe x visual hemifield x group. In both cases, the field-independent subjects show right hemisphere superiority for upright faces and left hemisphere superiority for inverted faces; field-dependent subjects do not show this effect. There are two other points of interest in these findings: (1) Field-dependent subjects show a <u>left</u> hemisphere superiority for upright faces. This is true both in terms of reaction time scores and in terms of accuracy scores. These subjects respond faster and more accurately when upright probes are presented in the right visual hemifield. (2) When inverted faces are presented, field-dependent subjects now show shorter response latencies in the left visual hemifield, but, at the same time, they are less accurate when probes are shown in the left visual hemifield than when they are shown in the right visual hemifield.

The interaction between orientation of probe and group was also significant ($p < .05$). The means are presented in Table 7. Clearly, the effect of inversion is greater for field-dependent than for field-independent subjects, whose performance suffers only slightly when probes are shown upside down.

As in the case of reaction time analysis, the type of response made a difference. Although the main effect for the type of response ("miss" or "false alarm") was not significant, it did enter into a number of significant interactions with the group, with orientation of memory set, with orientation of probe, and with visual hemifield.

To begin with, the interaction of type of response with field independence was significant beyond the .05 level. Field-dependent subjects make more false alarms than incorrect rejections; field-dependent subjects make more incorrect rejections than false alarms. The means for the interaction are presented in Table 9. Thus, subjects' standing on the dimension of field independence determines not only the overall level of accuracy, but also influences the decision about setting the criterion level.

In addition, type of response interacts significantly with visual hemifield ($p. < 01$). When stimuli are shown to the right visual hemifield (the left hemisphere) subjects tend to make more incorrect rejections than false alarms; when stimuli are shown to the left visual hemifield (the right hemisphere), subjects make more false alarms than incorrect rejections. The means for this interaction are presented in Table 10. Inspection of means in Table 10 representing the significant interaction of type of response with visual hemifield and with orientation of probe reveals that a given hemisphere's preference for the type of error--false positive or false negative--is also a function of stimulus orientation. In both hemispheres more misses than false alarms are associated with presentation of upright stimuli and more false alarms than misses are associated with presentation of inverted stimuli. A sharp rise in the number of false positives in case of presentation of inverted stimulus to the right hemisphere seems to be responsible for the significance of the triple interaction.

Thirdly, the interaction of type of response with orientation of probe is significant at the .001 level. When the probe is upright, subjects make more incorrect rejections than false alarms; when the probe is inverted subjects make more false alarms than incorrect rejections. The relationship is further complicated by the significant triple interaction of orientation of probe, orientation of set, and type of response ($p < .001$).

Furthermore, there is a triple interaction of type of response with visual hemifield and with orientation of probe. This interaction is significant at the .05 level. The means for these interactions are presented in Table 11.

Since the two analyses--that of reaction times and that of error scores--yielded comparable results, the question arose whether there is a significant association between the extent of hemispheric asymmetry as measured both by response latency and accuracy. In an attempt to answer

Table 10

Mean Number of Errors as a Function of Visual Hemifield, Orientation of Memory Probe and Response

	RVHF		LVHF		
	Misses	False Alarms	Misses	False Alarms	Mean
Upright	2.46	1.06	2.41	1.27	1.80
Inverted	1.73	2.86	1.83	4.19	2.65
Mean	2.10	1.96	2.12	2.73	2.23
	(2.03)		(2.43)		

Table 11

Mean Number of Errors as a Function of Orientation of Set, Orientation of Probe and Type of Response

	Upright Set	Inverted Set	Mean	
Upright Probe:				
Misses	.771	4.104	2.44	
False Alarms	.625	1.708	1.17	1.81
Inverted Probe:				
Misses	2.584	.979	1.78	
False Alarms	2.708	4.333	3.52	2.65
Mean	1.67	2.78		2.23

this question, correlation coefficients were computed for RT asymmetry and the error asymmetry. The correlation matrix is presented in Table 12. Interestingly, all the pairwise correlations between RT asymmetry scores are low and non-significant; in addition, all the correlations between error asymmetry scores are low and non-significant. On the other hand, there are a few significant correlations between RT and error. However, if we look for correlation coefficients reflecting the four cells of the original design, i.e. matching upright probe to upright set, matching inverted probe to upright set, matching upright probe to inverted set and matching inverted probe to upright set, none of these correlations are significant. It appears, therefore, that there is little association between the asymmetry in the speed of responding and the asymmetry in accuracy in tachistosopic recognition of faces.

Part 2: EEG Study

1. Asymmetry

EEG Alpha Scores were subjected to a number of statistical analyses.

First, all the EEG scores were transformed into ratio scores according to L-R/L+R formula. This score reflected relative asymmetry as a function of total amount of alpha produced bilaterally. Two points should be kept in mind here:

1. All the ratio scores are negative numbers because, regardless of the nature of the task, in the present group of subjects there was relatively less alpha recorded from the left hemisphere than from the right hemisphere.

Table 12

Correlations Between Asymmetry of Reaction Time and Asymmetry of Error Scores: the Tachistoscopic Experiment

	1	2	3	4	5	6	7	8
1.	1							
2.	.06	1						
3.	.15	.17	1					
4.	.11	-.15	-.29	1				
5.	*.16*	-.07	.22	.24	1			
6.	.03	*-.07*	.47*	-.49*	.03	1		
7.	.28	-.14	*.39*	-.43*	.02	.10	1	
8.	.15	.16	-.30	*.02*	-.08	-.09	-.27	1

Note: Italicized correlations are crucial.

* = Significant beyond .05 level.

1. mean RT upright probe, upright set.
2. mean RT inverted probe, upright set.
3. mean RT upright probe, inverted set.
4. mean RT inverted probe, inverted set
5. mean number of errors, upright probe, upright set
6. mean number of errors, inverted probe, inverted set.
7. mean number of errors, upright probe, inverted set.
8. mean number of errors, inverted probe, inverted set.

2. On the assumption that the blocking of alpha reflects cortical activation, the more negative scores reflect greater involvement of the left hemisphere in the given task; a shift to the right hemisphere function is reflected in less negative ratio scores.

Ratio scores from the two face tasks, the two chairs tasks, and the two words tasks were analyzed in a number of analyses of variance. All the results presented below are based on data from 23 subjects. Subject 21 was discarded from all analyses due to a procedural error. Thus, the field-independent group consisted now of 11 subjects.

Means of EEG asymmetry scores are displayed in Table 13. It is apparent from this table that, if words are considered to be a left hemisphere anchor task, then there is an appreciable difference in hemispheric involvement between face and word tasks, whereas chairs fall in between. The data were subjected to a number of analyses of variance. These analyses are summarized in Table 14. The following results were obtained:

In this part of the investigation the hypothesis predicting an interaction of orientation of face x hemisphere x group was not borne out. The ratio scores associated with processing of upright faces were compared to those associated with the processing of inverted faces in a 2 x 2 analysis of variance. Neither of the main effects (orientation of stimulus and group) is significant, nor is the interaction of orientation x group significant. However, comparison of means shows a trend in the predicted direction. Overall, when inverted faces are shown, there is a shift to relatively greater left hemisphere function (the mean asymmetry score for upright faces is -.157 and for inverted faces -.189). This effect is stronger for field-independent subjects

Table 13

Asymmetry in EEG Tasks: Mean Ratio Scores

	Field Dependent Subjects	Field Independent Subjects	Total
Upright Faces	-.144	-.172	-.157
Inverted Faces	-.163	-.219	-.189
Total Faces	-.153	-.195	-.173
Upright Chairs	-.192	-.235	-.212
Inverted Chairs	-.186	-.175	-.181
Total Chairs	-.189	-.205	-.196
Matching Words	-.187	-.259	-.222
Synonyms	-.199	-.253	-.225
Total Words	-.193	-.256	-.223
Total	-.178	-.218	-.197

than for field-dependent subjects (the means are −.172 vs. −.219 and −.144 vs. −.163, respectively).

The prediction that inversion will have a different effect on processing of chairs than on processing of faces was supported. When faces were compared to chairs in a 2 x 2 x 2 ANOVA, the main effect for the type of stimulus was not significant ($F = 2.35$, $p < .05$). There was, however, a significant interaction between the type of stimulus and orientation ($F = 4.96$, $df = 1$, $p < .05$). This interaction is presented in Figure 3. When faces were rotated to the inverted position, there was a shift from relative right hemisphere activation to relative left hemisphere activation. The difference between the mean ratio scores for these two conditions is −.032. When chairs were shown upside down, there was a shift towards a greater involvement of the right hemisphere. The difference between the two means is .031.

The hypothesis predicting different patterns of hemispheric involvement in field-independent and field-dependent subjects obtained little support in this part of the study. The interaction of the type of stimulus with group reached significance in only one case: When words were compared to chairs, both the main effect for the type of stimulus and the interaction of the type of stimulus by group were significant (cf. Table 14). Predictably, word tasks engage the left hemisphere to a greater extent than chair tasks. The means are −.225 and −.197, respectively. However, here the patterns of asymmetry are different for the two groups of subjects. This interaction is presented in Figure 4. For field dependent subjects, the asymmetry scores in the

Table 14

Analysis of Variance of EEG Asymmetry Scores

	Sum of squares	df	F	p
Face Orientation by Group				
Group	.02	1,21	<1	NS
Orientation	.01	1,21	2.81	NS
Group x orientation	.00	1,21	<1	NS
Stimulus (faces,chairs) x Orientation by Group				
Group	.02	1,21	<1	NS
Stimulus	.01	1,21	2.35	NS
Stimulus x group	.00	1,21	<1	NS
Orientation	.00	1,21	<1	NS
Orientation x group	.00	1,21	<1	NS
Stimulus x orientation	.02	1,21	4.96	.05
Stimulus x orientation x group	.11	1,21	1.94	NS
Stimulus (words,chairs) x difficulty x group				
Group	.04	1,21	<1	NS
Stimulus	.02	1,21	7.67	.01
Stimulus x group	.012	1,21	5.42	.05
Orientation	.00	1,21	1.96	NS
Orientation x group	.00	1,21	2.91	NS
Stimulus x orientation	.00	1,21	2.67	NS
Stimulus x orientation x group	.00	1,21	<1	NS
Stimulus (words,faces) x difficulty x group				
Group	.06	1,21	<1	NS
Stimulus	.06	1,21	9.06	.01
Stimulus x group	.00	1,21	<1	NS
Orientation	.01	1,21	2.13	NS
Orientation x group	.00	1,21	<1	NS
Stimulus x orientation	.00	1,21	1.41	NS
Stimulus x orientation x group	.00	1,21	<1	NS

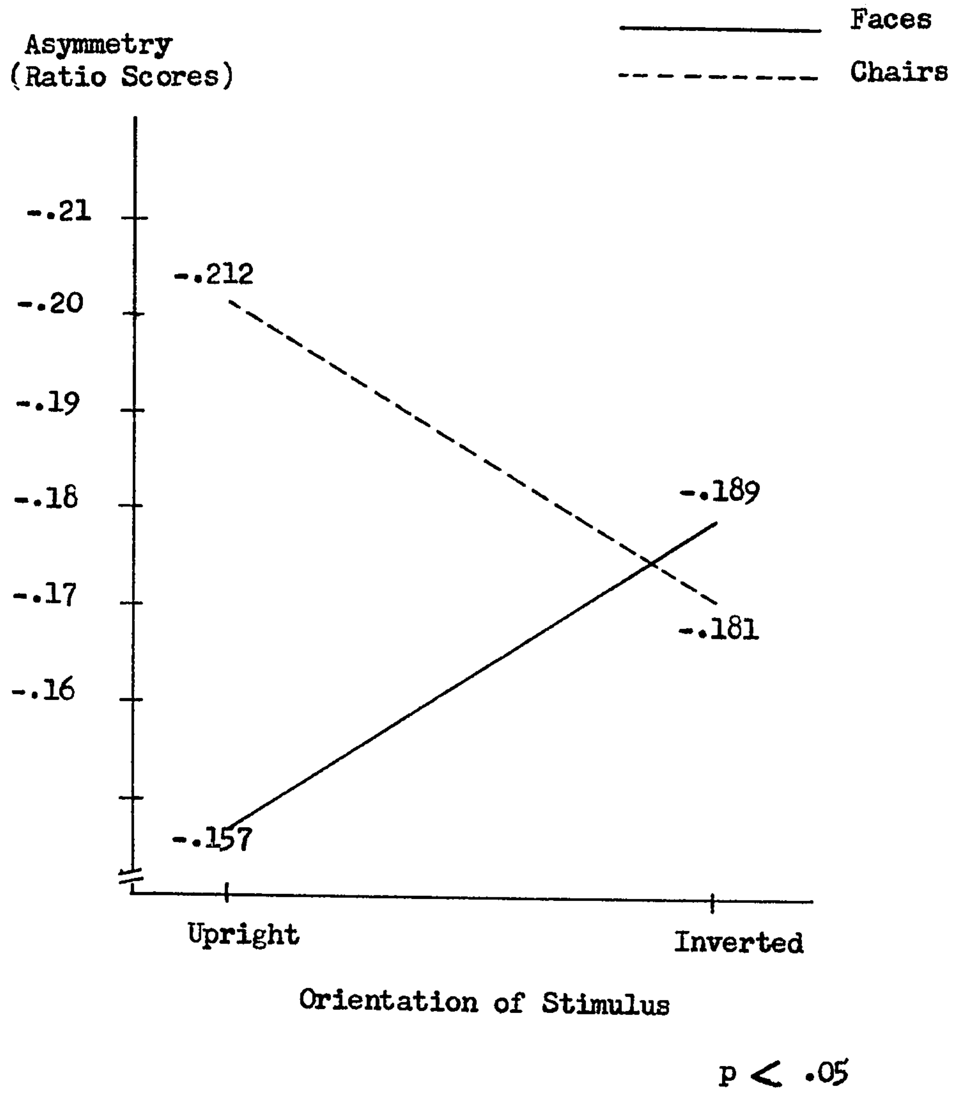


Figure 3. The Effect of Inversion on Asymmetry in Face and Chair Tasks

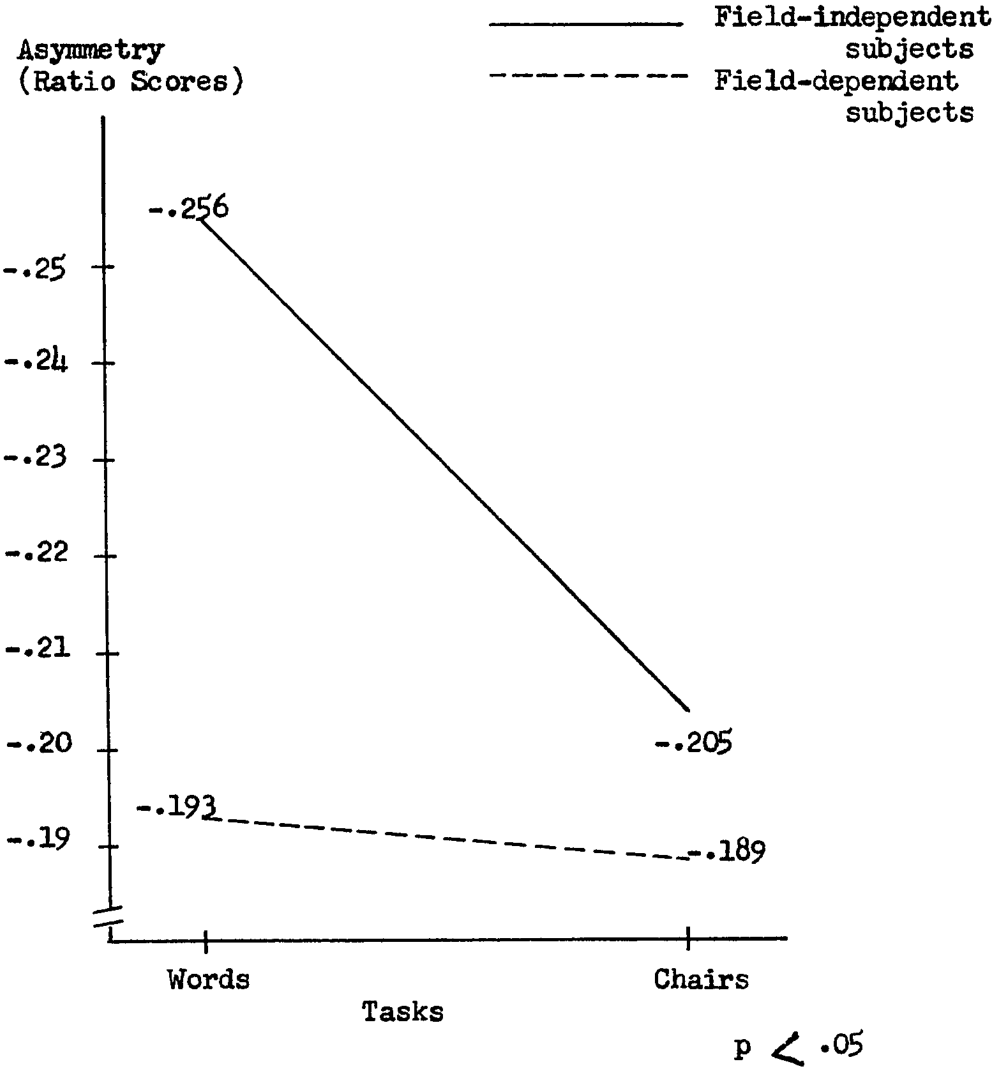


Figure 4. Asymmetry on Chair and Word Tasks as a Function of Field Articulation

word tasks and the chair tasks (pooled) were virtually identical. For field-independent subjects, on the other hand, there was an appreciable difference between the asymmetry socres in these two types of tasks. When these subjects processed verbal stimuli, they showed much greater left hemisphere involvement than when processing chairs (the means are, respectively, -.256 and -.205). Contrary to what was hypothesized, the interaction of type of stimulus with group was not significant in the analysis in which words were compared to faces. However, the inspection of means reveals that the effect is slightly stronger for field-independent subjects (the mean difference between asymmetry scores -.06) than for the field-dependent subjects (-.04). The situation is similar in the case of comparison of faces and chairs. Here, again, the main effect of group was not significant; nor did it enter into any significant interactions with the type of stimulus or orientation. However, inspection of the means presented in Table 13 reveals that the predicted effect was slightly stronger in field-independent subjects' pattern of response. The difference between the score for upright faces and for inverted faces is .147 for field-independent subjects and .018 for field-dependent subjects. Similarly, the mean difference between upright and inverted chairs is .059 for field-dependent subjects and only .006 for field-dependent subjects.

As expected, there was no significant difference in the ratio scores for the two word tasks. The mean asymmetry scores for the Matching Words and Synonyms are virtually identical (-.222 and -.225, respectively).

Finally, asymmetry scores for word tasks were significantly different from those for chair tasks and those for face tasks, collapsed across orientation. There is no significant difference between faces and chairs. Words engage the left hemisphere to the largest extent; faces engage it to the least extent, and chairs fall in between the two and are not significantly different from faces.

In order to assess separately hemispheric involvement in processing of upright and inverted faces as compared to words, two additional small analyses of variance were conducted. Since the asymmetry scores in the two word tasks are virtually identical, the scores were combined.

In the first ANOVA, upright faces were compared to combined words. The main effect for stimulus was significant ($F = 8.55$, $p < .01$). Predictably, words engage the left hemisphere to a greater extent than upright faces (-.223 and -.157, respectively). Group was not a significant effect nor was the interaction of group with stimulus.

In the second analysis, inverted faces were compared to combined words. Again, the main effect of stimulus was significant (the means were -1.189 and -.223, $F = 4.93$, $p < .05$). Thus, although there is a trend toward relatively greater left hemisphere involvement in the processing of inverted faces than in the processing of upright faces, the degree of the left hemisphere involvement in such a task is still significantly smaller here than in the processing of semantic stimuli. Again, the main effect of group and the interaction of group x stimulus were both non-significant in this analysis.

Accuracy

It was considered worthwhile to analyze accuracy scores in order to assess the degree of association between hemispheric involvement and levels of performance.

Since there were two types of errors that subjects could make--false alrms and incorrect reflections--a single score reflecting both of those errors was derived in the present analysis. The formula used was

$$C = \frac{\text{Hits \%} - \text{FA \%}}{1 - \text{FA \%}} .$$

The score, then, represents an adjusted proportion of correct answers.

The accuracy scores are presented in Table 15. The scores were analyzed in a number of analyses of variance parallel to those for asymmetry. The results are presented in Table 16.

1. When upright and inverted faces are compared, there is a significant main effect for group and a significant main effect for orientation stimulus. Overall, field-dependent subjects are less accurate than field-independent subjects (means are .60 and .76, respectively; $F = 4.87$, $p < .05$). Subjects are less accurate when required to recognize inverted faces than when required to recognize upright faces (means are .55 and .81, respectively, $F = 25.7$, $p < .001$). The interaction of group x orientation is not significant ($F < 1$). Inspection of Table 15, however, suggests that the effect of inversion was slightly greater for field-dependent than for field-independent subjects.

2. When performance on face tasks and chair tasks are compared, both the main effect for type of stimulus and the main effect for

Table 15

Performance Accuracy in EEG Tasks: Adjusted Percent Correct

Task	Field-dependent Subjects	Field-Independent Subjects	Total
Upright Faces	.75	.86	.81
Inverted Faces	.45	.64	.55
Total Faces	.60	.75	.68
Upright Chairs	.87	.89	.88
Inverted Chairs	.71	.82	.76
Total Chairs	.79	.85	.82
Matching Words	.87	.91	.89
Synonyms	.33	.31	.32
Total Words	.60	.61	.60
Total	.66	.73	.70

Table 16

Analyses of Variance of EEG Accuracy Scores

	Sum of squares	F	df	p
1. Orientation of face x group				
Group	.28	4.87	1	.05
Orientation	.79	25.70	1	.001
Orientation x group	.02	1	1	NS
2. Stimulus (faces, chairs) x orientation x group				
Group	.27	1	5.41	.05
Orientation	.84	1	43.34	.001
Orientation x group	.05	1	2.53	NS
Stimulus	.49	1	20.09	.001
Group x stimulus	.05	1	2.20	NS
Stimulus x orientation	.12	1	4.79	.05
Stimulus x orientation x group	.00	1		NS
3. Stimulus (chairs,words) x difficulty x group				
Group	.03	1	1	NS
Stimulus	1.11	1	24.67	.001
Stimulus x group	.01	1	1	NS
Difficulty	2.82	1	66.70	.001
Difficulty x group	.00	1	1	NS
Stimulus x difficulty	1.23	1	37.91	.001
Stimulus x difficulty x group	.04	1	1.20	NS
4. Stimulus (faces, words) x difficulty x group				
Group	.16	1	1.77	NS
Stimulus	.13	1	2.69	NS
Stimulus x group	.12	1	2.54	NS
Difficulty	4.08		76.19	.001
Difficulty x group	.00	1		NS
Stimulus x difficulty	.58	1	15.12	.001
Stimulus x difficulty x group	.85	1	.89	NS

orientation are significant. Overall, subjects do better on chair tasks than on face tasks (.80 vs. .69, $F = 20.08$, $p < .001$). As expected, subjects do better on tasks involving recognition of upright stimuli than on tasks requiring recognition of inverted stimuli (.84 vs. .65, $F = 43.34$, $p < .001$). Furthermore, the interaction of the type of stimulus and orientation is significant ($F = 4.79$, $p < .05$). This interaction seems to be due to a much greater effect of inversion on faces than on chairs. When faces are rotated to inverted position, accuracy decreased from .81 to .55; for chairs the decrement is from .88 to .76. This interaction explains the rather puzzling finding that subjects do better on chairs than on faces. In fact, performance on upright stimuli in these two tasks is comparable and the difference between them emerges only when stimuli are inverted.

The main effect for the group is significant ($F = 5.41$, $p < .05$). Overall, field-independent subjects are again consistently more accurate than field-dependent subjects (.80 and .69). However, group does not enter into any interactions with either the type of stimulus or orientation of stimuli. Thus, the main effect for group reflects a superiority of field-independent subjects with stimuli in both orientations.

3. When accuracy scores on chair tasks and word tasks are compared, again the main effect on the type of stimulus is significant ($F = 24.67$, $p < .001$). Subjects are more accurate on pictorial stimuli (chairs) than on verbal stimuli (.82 vs. .60). The common dimension which underlies the inverted face task and the synonyms task is conceptualized here as reflecting greater task difficulty. The main effect for difficulty is significant ($F = 66.7$, $p < .001$). Predictably, accuracy

on easy tasks is higher than accuracy on difficult tasks (the means are .88 and .54, respectively).

The interaction of stimulus with task difficulty is also significant ($F = 37.91$, $p < .001$). This effect is due to a greater drop in accuracy for the difficult word task than for the difficult chair task (the means for chair tasks are .88 for upright chairs and .76 for inverted chairs; the means for word tasks are .89 for matching words and .32 for synonyms--a drop of 64%).

There were no differences in performance between groups. Group was not a significant main effect, nor did it enter into any significant interactions with the type of stimulus or difficulty.

4. Finally, comparison of accuracies on face and word tasks yielded the following results:

Overall accuracy on face tasks was <u>not</u> significantly different from that on word tasks (means .68 and .60, respectively; $F = 2.69$, $p < .05$). Difficulty was a significant main effect. Subjects are more accurate on easy than on difficult tasks (.85 vs. 43, $F = 76.2$, $p < .001$). The interaction of difficulty and type of stimulus was significant ($F = 15.12$, $p < 001$). Again, the effect of difficulty is greater for words than for faces.

In order to assess the relationship between asymmetry and performance, coefficients of correlation between accuracy and asymmetry socres in each task were computed. These correlations are presented in Table 17.

There are a few points of interest in this table. Most of the asymmetry scores inter-correlate highly and significantly. There is

Table 17

Intercorrelation Matrix of Asymmetry and Accuracy Scores in the EEG Experiment

	1	2	3	4	5	6	7	8	9	10	11	12
1.	1.0											
2.	-.63*	10										
3.	-.59*	.45*	1.0									
4.	.25	-.06	.77*	1.0								
5.	.44*	-.42*	.30	.77*	1							
6.	-.07	.37	.67*	.74*	.68*	1						
7.	-.17	.25	.25	.13	.16	.37	1					
8.	.12	-.13	-.15	-.07	.19	.09	.00	1				
9.	.02	.03	.02	.05	.06	.08	-.29	.10	1			
10.	-.15	.26	.25	.16	.20	.41	.76*	.07	.41	1		
11.	-.04	.20	.07	.04	-.06	.10	-.05	.31	.64*	.38	1	
12.	.07	.07	-.07	.02	.09	.16	-.05	.53*	.65*	.40	.64*	1

Note: Italicized correlations are critical.

* = significant beyond .05 level.

1. Upright Faces minus Inverted Faces Asymmetry.
2. Upright Chairs minus Inverted Chairs Asymmetry.
3. Combined Words minus Upright Faces Asymmetry.
4. Combined Words minus Inverted Faces Asymmetry.
5. Combined Words minus Upright Chairs Asymmetry.
6. Combined Words minus Inverted Chairs Asymmetry.
7. Upright minus Inverted Faces Accuracy.
8. Upright minus Inverted Chairs Accuracy.
9. Combined Words minus Upright Faces Accuracy.
10. Combined Words minus Inverted Faces Accuracy.
11. Combined Words minus Upright Chairs Accuracy.
12. Combined Words minus Inverted Chairs Accuracy.

also a number of significant correlations between accuracy scores on various tasks; all of these correlations are positive, meaning that some subjects are consistently more accurate than others regardless of the nature of the task. On the other hand, there are no significant correlations between asymmetry and accuracy scores on various tasks.

Cognitive Tests

Bilateral alpha was also recorded when subjects responded to the three tests of cognitive skills--the Group Embedded Figures Test, the Gestalt Completion Test, and the Vocabulary Test. Ratio scores reflecting relative alpha asymmetry in these tasks were computed. Differences between tasks and between the two groups of subjects were evaluated.

The mean ratio scores for these three tests are -.094 GEFT, -.182, GCT, and -.206 Vocabulary (cf. Table 18). Thus, the GEFT is most strongly right-hemispheric, the Vocabulary most strongly left-hemispheric, and the GC falls in between the two.

When the EEG ratio scores for the three cognitive tests were subjected to a test x group (3x2) repeated measures of analysis of variance, the following results emerged: (1) group was not a significant main effect ($F = 1$, $df = 1,21$, NS); (2) the main effect due to "tests" was significant ($F = 14.04$, $df = 2,242$, $p < .01$); (3) the interaction of group by test was not significant ($F = 1.75$ $df = 2,42$, $p < .05$). The Neuman-Keuls procedure applied to the mean ratio scores for the three tests revealed that two out of three possible contrasts were significant beyond the .05 level. Specifically, there was a

Table 18

Asymmetry in Cognitive Tests: Mean Ratio Scores

		GEFT	Gestalt Completion	Vocabulary	Overall
Field-dependent Subjects:					
	Mean	-.084	-.211	-.223	-.173
	SD	.187	.209	.191	.196
Field-independent Subjects					
	Mean	-.105	-.158	-.191	-.151
	SD	.138	.189	.189	.172
Total	Mean	-.094	-.186	-.208	-.163
	SD	.162	.197	.185	.181

significant difference between the mean ratio score for GEFT and mean for Vocabulary; there was also a significant difference between mean GEFT ratio score and mean GC score. The difference between GC and Vocabulary was not significant.

Performance scores on the three cognitive tests were also evaluated. Means and standard deviations for the two groups are presented in Table 19.

Table 19

Performance on Cognitive Tests

		GEFT	Gestalt Completion	Vocabulary
Field-dependent subjects				
	Mean	6.0	9.3	25.0
	SD	4.13	4.31	9.84
Field-independent subjects				
	Mean	13.8	16.7	36.6
	SD	4.17	3.14	5.82
		$t = 4.62$ $df = 22$ $p < .001$	$t = 3.39$ $df = 22$ $p < .01$	$t = .69$ $df = 22$ n.s.

Predictably, there were significant group differences in performance on the Group Embedded Figures Test and on Gestalt Completion Test. In both cases field-independent subjects scored higher than field-dependent subjects. There was no significant difference between the two groups in performance on the Vocabulary Test, although the field-independent subjects tended to score higher than field-dependent subjects.

Next the degree of association between asymmetry and accuracy on these tests was evaluated. The correlation coefficients are presented in Table 20.

The table shows that the correlations among asymmetry scores are very high; all of them are significant. Also, the correlations among accuracy scores are quite high; two out of three are significant. However, the correlation coefficients reflecting the strength of association between asymmetry and accuracy are negligible.

Finally, when scores for the Composite Face task are evaluated, there are no significant differences between field-dependent and field-independent subjects in either asymmetry or performance. The mean number of left choices was 6 (out of 13 possible). That is, the subjects responded on a random basis. The correlations with asymmetry scores from other face tasks (either EEG or tachistoscopic) are close to zero; none of them is significant.

Relationship between the Tachistoscopic Study and the EEG Study

A review of the results presented so far suggests that, when asymmetry effects are compared, there is little convergence between the two parts of the investigation. By and large, predicted asymmetry effects due to orientation of stimulus and due to group were found in the tachistoscopic study; only limited support for these predictions was obtained from the EEG study.

Table 20

Accuracy and Asymmetry in Cognitive Tests

	1	2	3	4	5	6
1. GEFT Accy.	1					
2. GC Accy.	.65*	1				
3. Voc. Accy.	.63*	.30	1			
4. GEFT asym.	*.16*	.03	.06	1		
5. GC Asym.	.33	*.27*	.14	.74*		
6. Voc. Asym.	.32	.24	*.11*	.81*	.94*	1

Note: *Italicized correlations are crucial*.

* = significant beyond .05 level.

GEFT = Group Embedded Figures Test

GC = Gestalt Completion Test

Voc. = Vocabulary Test

Asym = asymmetry

Accy = accuracy

In order to assess the degree of relationship in right-minus-left asymmetry between the two parts of the investigation directly, first all the asymmetry scores were transformed into difference scores reflecting relative hemispheric activation in different tasks. Thus, for example, the new upright-minus-inverted faces ratio score reflects the difference between hemispheric asymmetry effect between upright face task and inverted face task. The rationale for using such difference scores is that hemispheric asymmetry becomes more meaningful when viewed as a relative rather than an absolute measure. Next, pairwise coefficients of correlation were computed for all the different scores. The correlation matrix is presented in Table 21. There are only two (out of possible 24) significant correlations between asymmetry scores from the two parts of the investigation. The first is the significant negative correlation between the combined-words-minus-inverted chairs difference ratio score and upright-minus-inverted probes matched to inverted set reaction time difference score. The correlation means that if the subject is more left hemispheric on combined Words relative to Inverted Chairs, she will respond faster in the right hemisphere than in the left when matching upright probes to inverted set relative to matching inverted probes to inverted set. This correlation seems to reflect the pattern of responding of field-dependent subjects in the present study. The second is the significant negative correlation between the combined-words-minus-inverted-chairs difference ratio score and the error difference score for upright-minus-inverted probes matched to inverted memory set. This correlation means that if the subject is more

Table 21

Correlation Matrix of Asymmetry Scores from Two Parts of the Investigation

	1	2	3	4	5	6	7	8	9	10
1.	1									
2.	-.63*	1								
3.	-.59*	.45*	1							
4.	.25	-.06	.64*	1						
5.	.44*	-.42*	.30	.77*	1					
6.	-.07	.37	.67*	.74*	.68*	1				
7.	_.13_	_-.10_	_-.07_	_.04_	_-.16_	_-.24_	1			
8.	_-.10_	_-.13_	_-.22_	_-.36_	_-.33_	_-.44*_	-.14	1		
9.	_-.20_	_.24_	_.24_	_.10_	_.12_	_.08_	.02	-.53*	1	
10.	_.06_	_-.10_	_-.20_	_-.18_	_-.36_	_-.44*_	.22	-47*	-.08	1

Note: Italicized correlations are critical.

* = Significant beyond .05 level.

1. Upright-minus Inverted Faces Ratio/EEG.
2. Upright-minus Inverted Chairs Ratio/EEG.
3. Combined Words minus Upright Races/EEG.
4. Combined Words minus Inverted Faces/EEG.
5. Combined Words minus Upright Chairs/EEG.
6. Combined Words minus Inverted Chairs/EEG
7. Upright Minus Inverted Probes, Upright Memory Set Reaction Times.
8. Upright minus Inverted Probes, Inverted Memory Set.
9. Upright minus Inverted Probes, Upright Set, Number of Errors.
10. Upright minus Inverted Probes, Inverted Set, Number of Errors.

left hemispheric on combined words relative to inverted chairs, she will make fewer errors in the right than in the left hemisphere when matching upright probes to inverted set relative to matching inverted probes to inverted memory set.

In sum, the correlation matrix yield little support for the expectation of convergence of results using the two methods of assessment of hemispheric asymmetry effect.

Chapter 4

DISCUSSION AND CONCLUSIONS

The following conclusions can be drawn from the tachistoscopic study:

Processing of inverted faces is a more difficult task than processing of upright faces. In the present study longer reaction times and more errors were associated with inverted faces than with upright faces. This result confirms the prediction and is in agreement with the extant body of evidence (cf. for example Carey et al., 1975; Hochberg and Galper, 1967; Yin, 1968). However, it contradicts the finding of Ellis and Shepherd (1975) who did not find any decrement in performance associated with inversion of faces. In the light of evidence pointing to lower recognition for inverted than for upright faces it seems that a demonstration of such decrement in performance constitutes a necessary condition which must be fulfilled before the nature of hemispheric involvement in the processing of upright and inverted faces can be investigated. Ellis and Shepherd failed to obtain this effect; it can be argued that this failure invalidates their other findings.

Neither hemisphere was found to be dominant for recognition of facial stimuli with response latency as the measure of asymmetry: there was no significant difference between the mean reaction time in the left visual hemifield and the mean reaction time in the right hemifield. Again, this finding contrasts with that of Ellis and Shepherd (1975) who found shorter response latencies to both upright and inverted stimuli in the left visual hemifield (i.e. the right hemisphere). The possible explanation of this contradiction has been already mentioned: Ellis and Shepherd failed to obtain a decrement in recognition levels for inverted faces. This failure, it is argued here, constitutes a serious procedural error and casts doubt upon other results of the study. In addition, these authors used extremely short exposure times which, as discussed previously (cf. Note 3) probably prevented any in-depth processing of the stimuli.

The main thrust of the tachistoscopic study is the support it yielded for the hypothesized triple interaction of visual hemifield with orientation of probe and with group. As predicted, hemispheric asymmetry was a joint function of orientation of probe and subject's degree of field independence; the effect emerges only when these two variables are taken into account simultaneously. Thus, the study supports the notion of analytic vs. global dichotomy underlying hemispheric specialization for cognitive functions; it also demonstrates that this relationship is further moderated by individual differences in cognitive style of field independence. Field independent subjects react faster and more accurately to upright probe presented in the left visual field than to those presented in the right visual field. These subjects react more quickly and more accurately to inverted probes when shown in the right visual hemifield than when show in the left visual field. In other words, as predicted, field independent subjects process upright faces in the right hemisphere and inverted faces in the left hemisphere. Thus, in the case of field independent subjects the hypothesis that an analytic vs. global dichotomy underlies hemispheric functioning is supported. Since inverted faces are less amenable to global than to feature analytic processing, they involve the left hemisphere function to a greater extent than upright faces.

A different pattern of response was found for field dependent subjects. They react more quickly and more accurately to upright probes presented in the right visual hemifield than to those presented in the left visual hemifield. Thus, they tend to use the left rather than the right hemisphere to process upright faces. When inverted faces are being processed by these subjects, shorter response latencies are associated with left hemifield presentations than with right hemifield presentations. At the same time, however, these subjects make more errors in response to probes shown in the left visual hemifield than to probes shown in the right visual field. This reversal of the pattern of hemispheric dominance in field dependent subjects was not anticipated. A possible explanation of these findings is as follows: We know that there is an overlap between measures of field independence and spatial ability (Sherman, 1967; Wachtel, 1972). Field dependent subjects seem to possess fewer spatial skills than field independent subjects. This, it was argued (cf. Introduction),might result from bilateral representation of speech and may cause a lesser deployment of the right hemisphere processing capacities for visuo-spatial tasks and a tendency to rely on analytic information processing skills. Possibly, then, the field dependent women learn to encode upright faces in terms of visual features rather than in terms of visual Gestalten. In other words, the synthetic process whereby the meaning of the configuration is extracted, might not be readily available to these subjects. An analogy can be drawn from field dependent subjects, as described here, and Tucker's (Tucker,1976; Ray et al., 1973) interpretation of visuospatial functioning in women. These authors (see Ray et al., 1975) reported that when visuospatial skills are divided into those which require analytic processing (such as Gottschald figures) and those requiring synthetic processing (such as Mooney closure faces), in men these two types of processing appear to be lateralized to the opposite hemispheres; no such effect was found for women. In other words, these two functions are not incompatible in women. On the basis of present results one could hypothesize that this description fits the field dependent women particularly well.

There is, of course, another possibility. Researchers working with brain injured patients (Hecaen and Angelgergues, 1962) observe that prosopagnosiacs often need to use verbal labels in order to recognize familiar faces. Possibly, also field dependent subjects remember faces as being "Joe" or "the man with the moustache who was so kind to me at a party." To put it differently, field dependent subjects might not have a visual "schema" for faces at all, whether Gestalt or feature analytic; instead, they might employ verbal labeling to encode and decode faces and, through extensive everyday practice, they might have learned to do it well.

Unfortunately, there is no basis in the present investigation for selecting one of the two explanations suggested above; they both seem to fit the results equally well.

The finding that field dependent subjects switched to the right hemisphere function for processing of inverted faces becomes quite surprising in the light of the above theorizing and is not easily explainable, since it is not clear why feature-analytic or verbal processing should be orientation-bound. It could mean that now, because the stimulus is so novel (after all, our experience with upside-down faces is rather limited), instead of analyzing the faces by features (or using verbal mediation), the field-dependent subjects are attempting to rotate images to the upright position. Since spatial rotation is a right hemisphere function, this suggestion provides a reasponable explanation for shorter response latencies in the left visual hemifield than in the right field in response to inverted probes. There is some anectodal evidence from the study which supports the notion: First, two of the field-dependent subjects did not realize that some faces were upside down after as many as 20 inverted probes were presented. Furthermore, when reporting the central digit, field-dependent subjects occasionally reported "6" where actually "9" was shown ("6"s were not used as central digits; this fact was mentioned to the subjects in preliminary instructions). When attempting to rotate an inverted face to the upright position these subjects seem to have inadvertently rotated the digit as well. However, since rotation is not an optimal strategy for field-dependent subjects since they do not possess enough of a spatial skill to successfully rotate such a complex visual configuration as a face (cf. p. 25 above), they probably often make an incorrect decision. This might explain the apparent contradiction between the finding of shorter response latencies but more errors in the left visual hemifield than in the right visual hemifield in the case of inverted probes.

An additional finding with respect to the visual hemifield by orientation of stimulus by group interaction requires comment. As noted previously, orientation of probes emerged as a significant element of the interaction determining visual hemifield effect; orientation of the memory set, however, did not enter into this interaction. This finding can be interpreted to mean that the hemispheric effects which emerged in this study are a function of retrieval rather than encoding aspect of the memory process.

With hemiretinal projections of stimuli the field-dependent subjects make, overall, more errors. With the exception of the condition in which upright probes are presented in the right visual hemifield, the differences in accuracy between the two groups are evenly distributed across the experimental situations, although the effect is particularly strong in the case of inverted probes. Here it is apparent that, regardless of whether they process the stimuli in the left or the right hemisphere, these subjects are less accurate than field-independent subjects.

A short comment concerning the unexpected set of findings with respect to the effect of type of response is in order. It has been found that field-dependent subjects, in addition to being on the whole less accurate than field-independent subjects, also display a preference for one type of error over the other. Specifically, field-dependent subjects tend to make more false alarms than incorrect rejections; this relationship is reversed for the field-independent subjects, who make more incorrect rejections than false alarms. Using terminology of the signal detection theory, field-independent subjects not only have a higher d' (an index of sensitivity), but also set a higher criterion (an index of bias) than field-dependent subjects.

Interestingly enough, a similar relationship emerged between type of response and visual hemifield. More false alarms than incorrect rejections are associated with the right hemisphere presentations; the reverse is true for the left hemisphere presentations. Thus, per analogiam, field-dependent subjects behave like the right hemisphere and field-independent subjects act in a way which resembles the left hemisphere functioning.

Carli et al. (1973, 1974) and Zoccolotti (unpublished) report similar findings with respect to setting of criterion by field-dependent and field-independent subjects. They suggest that these differences are best interpreted in terms of different decisional strategies underlying detection performance of these two groups of subjects. According to their descriptions, field-dependent subjects use an "exploratory" strategy which emphasizes the presence of the signal unless there is an overwhelming evidence to the contrary. This strategy results in a negative criterion, reflecting an increase in false alarms and decrease in misses. Field-independent subjects use an "automatized" strategy which focuses on the absence of signal unless there is an overwhelming evidence to the contrary; it results in a positive value of criterion.

To repeat, field-independent subjects showed stronger hemispheric asymmetry effects in the predicted direction and were also more accurate than field-dependent subjects. It is therefore rather surprising that, although similar patterns of visual hemifield effects emerged in the analysis of reaction times and in the analysis of errors, only negligible correlations were found between the individual extent of asymmetry as measured by reaction time and as measured in number of errors.

The fact that despite the overall similarity of the pattern of results using reaction time and number of errors as measures of asymmetry, no correlations were obtained between the two measures is quite puzzling. It suggests the possibility that the two measures possess group reliability but not subject reliability. The argument is as follows: both response latency and number of errors might be valid and reliable indicators of hemispheric asymmetry, but they might tap different aspects of it in subjects selected on the dimension of field-independence. These different aspects of the effect need not be correlated. If so, the two measures will yield comparable patterns of results in the subsamples, but will not be correlated on individual bases, as evidenced by correlation coefficients.

There is, of course, a possibility that the low correlations obtained in the present study are artifactual. If, indeed, there are process, and not only product differences between field-dependent and field-independent subjects, then, theoretically speaking, the coefficients of correlation should have been computed separately for the two groups of subjects. Since small Ns did not warrant such procedure in the present study, subjects from the two groups were pooled. Perhaps this pooling of subjects might have affected the size of correlation coefficients.

In general, this finding raises the issue of comparability of response latency and error scores as measures of hemispheric asymmetry. Gross (1972) compared the two measures and concluded that reaction time rather than mean number of errors should be used with tachistoscopic exposures to hemiretinae, since it is the more sensitive of the two measures. Recently, Springer (1976) has argued that reaction time rather than accuracy should be the preferred asymmetry measure in all the behavioral methods of assessing hemispheric involvement. She cites ample evidence supporting the view that reaction time is both more valid and more sensitive a measure in tachistoscopic and in dichotic listening studies.

On the basis of the present study we can only conclude that it does make a difference which measure is used since they appear to reflect different aspects of hemispheric function.

The EEG portion of the study produced a mixed and complex set of results. As expected, significant differences between ratio scores for the three tests of ability--Gestalt Completion, Embedded Figures, and Vocabulary--were found.

This finding replicates an earlier finding by Ehrlichman and Weiner (unpublished), with one important difference. Although these authors also found a significant main effect due to different cognitive tests, the ordering of means in their sample was different, with Gestalt Completion (rather than Group Embedded Figures Test) being the most right hemispheric task. In fact, the present finding that the GEFT involves the right hemisphere to a greater extent than the Gestalt Completion, was unexpected. Rather, it was anticipated the GEFT will be placed between GC and Vocabulary, since it is assumed to tap both spatial ability (involving the right hemisphere) and the analytic ability to disembed and restructure (presumably involving the left hemisphere). There is a possible explanation of the difference between the two results of the two studies. Ehrlichman and Weiner (unpublished) found that the width of bandpass affecting the ordering of ratio scores for the right hemisphere tasks. In particular, they found that switching from 2-17 Hz to 8-12 Hz reverses ordering of means for certain figural tasks, including Gestalt Completion task. This finding is relevant in the present context, since 8-12 bandpass was used in the present study, as contrasted with 2-12 Hz in the Ehrlichman and Weiner study. It is then possible that the difference in the ordering of means in the two studies was associated with the different bandpass width used.

Yet another possibility has been suggested by the Ehrlichman and Weiner study (1977, unpublished). These authors used both male and female subjects and found that, in their sample, women showed a stronger tendency to rely on verbal mediation (verbal hypothesis testing) in Gestalt Completion Test. Since only women were employed in the present investigation, this tendency to use verbal hypothesis testing might have resulted in a shift of ratio scores associated with the test in the direction of relatively greater left hemisphere involvement.

Correlation coefficients were computed to see if asymmetry and performance were related to any of the tasks. None of these correlations were significant. This result corresponds to those obtained by Ehrlichman and Weiner (1977) and others who have found little relationship between EEG asymmetry and performance. (However, for an exception, see Furst, 1976.)

None of the predictions with respect to the Composite Faces task were borne out. There was no difference between field-dependent and field-independent subjects in either performance or asymmetry in this task. Thus, the present study fails to replicate the finding of Oltman, Ehrlichman, and Cox (1976), in which the very same stimuli and comparable procedures were employed, and significant differences between the two groups were found in the number of left choices (asymmetry was not studied). The only immediately apparent difference in the designs of the two studies--Oltman et al. and the present one--is the sex of the subjects. The Oltman et al. subjects were all males, as compared to all females in the present sample.

Significant and meaningful differences were also found between asymmetry scores for the continuous recognition tasks. As predicted, recognition of words was the most left-hemispheric task; recognition of upright faces the least left-hemispheric task; the other tasks were arranged in between the two. The relative hemispheric involvement in the word tasks was significantly different from that in the upright or inverted face tasks or the chair tasks. There was no significant difference between face and chair tasks (collapsed across orientation). Thus, as in the case of the cognitive tests, the EEG method successfully differentiated between various tasks calling for different information processing strategies. This conclusion supports the existing body of evidence with respect to validity of the EEG method in tapping hemispheric specificity of tasks.

As predicted, inversion had a different effect on faces than on chairs. Inversion of faces resulted in a shift from relative right hemisphere activation to relative left hemisphere activation. The opposite was true for chairs. There, the shift was toward <u>greater</u>

right hemisphere activation. This finding is in keeping with that of Yin (1968) and it can be interpreted as supporting the notion of a special attribute--the "meaning"--which is inherent in a face and is strongly tied to the orientation of the stimulus. This "meaning," it seems, determines the right-hemispheric specificity of faces. When it is obliterated by the inversion of the stimulus, the subjects tend to shift their strategy to involve more the left hemisphere. What was rather puzzling here was the finding that the upright chairs engage the left hemisphere to a greater extent than inverted chairs. Rather, it was expected that upright faces would be processed by the right hemisphere and that there would be either no shift or a slight (smaller than for faces) shift towards left hemisphere involvement for inverted chairs. Possibly, this result in the case of chair tasks can be explained in terms of novelty of stimuli. The chairs which were photographed and used in the study were antiques from a European museum. All of them were rather distinctive in terms of specific features. It is possible that subjects simply had very little experience with this type of stimulus and that they might have capitalized on the distinctiveness of the chairs to encode them in terms of features rather than Gestalt properties. This suggestion, however, still does not explain why the subjects shifted to the right hemisphere processing when chairs were presented upside down. Possibly, they might have attempted to rotate the chairs to the upright position (hence the right hemisphere involvement). This hypothesis seems unconvincing in view of the fact that feature analytic processing is, presumably, independent of stimulus orientation.

In the EEG study--in contrast to the tachistoscopic study--hemispheric involvement in the processing of faces was not a function of either orientation of the stimulus, or subject's field independence, or both. Here, the interaction of group by orientation did not reach significance. Thus, contrary to what has been predicted, the part of the design of the EEG study which most closely matches the tachistoscopic study did not yield comparable results.

Moreover, the EEG study yielded only limited support for the prediction of different patterns of lateralization (or hemisphere utilization) in the field-dependent and field-independent subjects. In fact, only one significant interaction in the predicted direction with group was found in the numerous analyses carried out on the data from the EEG study. Although there is a trend in the predicted direction (cf. Table 13), the overall effect of group is not significant. This finding is particularly puzzling in view of the fact that both the type of stimulus and orientation of stimulus did produce differences in asymmetry scores. Thus, although the EEG method successfully tapped differences in information processing between tasks, unlike the tachistoscopic method it failed to tap individual differences in information processing strategies correlated with field independence.

In the EEG study field-dependent subjects were again found to be less accurate than field independent subjects. The effect of group was significant in all the analyses with the exception of the comparison of faces vs. words. In this part of the investigation the correlations between asymmetry and accuracy scores for various tasks were, as in the case of the tachistoscopic study, negligible.

The lack of support for the hypothesis of different lateralization patterns in the two groups of subjects contrasts most sharply with results obtained in the tachistoscopic study. The lack of convergence in the results of the two parts of the investigation raises questions concerning the nature of method variance responsible for this failure of the EEG study. A suggestion of lack of validity of EEG method is not convincing in the light of extant evidence. In fact, the general conclusion which can be drawn from perusing the literature on the topic is that EEG is a valid tool for assessing task specific hemispheric involvement (cf. for example, Davidson et al., 1976; Ehrlichman and Weiner, unpublished; Galin and Ellis, 1975); indeed, there is a remarkable agreement among various studies in taxonomy of tasks involving either the left or the right hemisphere. Furthermore, there seems to be little doubt about validity of the underlying construct of hemisphere specialization for various functions. As discussed in the Introduction, the construct validity of hemispheric specialization is evidenced by considerable agreement among studies employing vastly different methodologies. Loevinger (1965), in her discussion of construct validity, argues convincingly that a measurement tool which possesses construct validity will be also reliable. In the case of hemispheric specialization this argument has obtained also some empirical support. For example, Ehrlichman and Weiner (1977) found high test-retest correlations between asymmetry scores for various tasks. Thus, the failure to replicate the results of the tachistoscopic study using EEG alpha recordings is not simply attributable to a lack of construct validity (or reliability) of the EEG method. A more subtle process must be operating here.

A number of such processes can be suggested.

1. There were procedural differences between the EEG and the tachistoscopic study. First, a memory set design was used in the TS study and a continuous recognition method in the EEG study. It is possible that the demands on various aspects of memory processes are different in these two types of recognition tasks. Second, exposure times of stimuli were different in the two parts of the investigation. In the EEG study slides were shown for 5 seconds compared to 250 milliseconds in the tachistoscopic study. Possibly, when EEG alpha is recorded, the task has to be difficult enough to push the subjects to rely on a preferred strategy. Given the 5 seconds exposure time the subjects could have switched from one strategy to another and still do very well, whereas in the tachistoscopic study, due to the more stringent time constraint, subjects have had to choose one study and rely on it consistently in order to do well at all. Switching from one recognition strategy to another would, naturally, obliterate whatever hemispheric effect was present.

Since level of processing is, at least partially,a function of stimulus exposure time (see Note 3), the two designs might have also differed in the extent to which the stimuli were processed. On the assumption that levels of processing might differ along the hemispheric lines, this might have been a confounding variable.

2. Although the possibility that the EEG method is less sensitive to individual (as opposed to task) differences that the tachiscopic

method should be considered, it does not appear to be supported by extant evidence. It is, in fact, contradicted by Ehrlichman and Weiner's (unpublished) findings on EEG reliability and by recently published studies in which differences in task effects on EGG asymmetries have been related to subject characteristics (Bennett and Trinder, 1977; Davidson and Schwartz, 1977; Doktor and Bloom, 1977; McLeon and Peacock, 1977).

3. Recent research suggests that the brains of human males and females are differentially lateralized with respect to cognitive functions (e.g. Buffery and Gray, 1972; Kimura, 1969; Knox and Kimura, 1970; Levy, 1972; Marshall, 1973; McGlone and Davidson, 1973; McGlone and Kertese, 1973; Ray et al., 1973; Tucker, 1976; Witelson, 1976). Although there is still considerable disagreement about the nature of such sex differences and the course of their development, a number of authors have presented evidence that women are less lateralized than men, at least with respect to visuospatial processing (Knox and Kimura, 1970; McGlone and Davidson, 1973; McGlone and Kertese, 1973; Witelson, 1976; but see also Buffery and Grey, 1972, who take exception from this point of view. It appears that in women bilateral representation of spatial functions persists into much older age than in men and, in fact, it is possible that it exists throughout the lifespan. It can be argued, then, that the choice of women as subjects in the present study has been an unfortunate one and it might have resulted in a restriction of range of the lateralization scores. As discussed earlier, however, there is no clear evidence for sex differences in task-related EEG asymmetry. Only two studies have been

reported such differences, and their conclusions were opposite to one another (Davidson and Schwartz, 1977; Ray et al., 1976). It is probable that sex interacts with other factors, such as the nature of the tasks, the experimental setting, perhaps even electrode placement (Tucker, 1976). In addition, since subjects are in fact not randomly samples from the general population, it is possible that sex may be an important variable in some samples but not in others. Whether sex was a relevant variable in the present study is impossible to say in the absence of male subjects. However, it is clear that across all studies of EEG asymmetry, sex has not been a variable of overwhelming importance.

The fact that the present study does not replicate the previous findings (e.g. Ellis and Shepherd, 1973, 1973; Geffen et al., 1971; Hillyard, 1973, Rizzolatti et al., 1973) of shorter response latencies to facial stimuli in the left visual hemifield than in the right visual hemifield in samples unselected on the variable of field independence merits discussion. There are two issues which must be dealt with in connection with this non-replication, namely (a) representativeness of the present sample compared to other samples in which the effect was obtained; (b) comparability of various investigations of face recognition. The two issues will be taken up in the order above.

It is possible to argue that the reason for the non-replication lies in non-representativeness of the present sample. Admittedly, the sample was rather small, and as such allowed the possibility of various biasing factors. One suggestion is that trichotomizing a group of subjects on the variable of field independence and then selecting subjects from the upper and the lower third of this distribution might give undue weight to those patterns of responding which are associated with field-dependent cotnitive style. Such a possibility is suggested in a recent paper by Ehrlichman (1976) in which he reports that the intermediate group (which was excluded from the present study) performed in a manner more similar to that of field-independent than that of field-dependent subjects. In other words, in a population as such, field-dependent subjects are, in fact, a third of the distribution whereas in the present study they constituted half of the sample (on the assumption that Ehrlichman's finding represents a pattern of responding which is fairly general across different experimental situations). However, it should be mentioned that the mean RFT score in the present sample coincided almost exactly with Oltman et al. (1971) normative mean for college population.

It is also possible to attack the issue of non-representativeness from the other end and inquire how representative are the studies which reported left visual field superiority for perception of faces of the population of studies investigating the issue, when the low level of reporting null results is kept in mind). The present study is not, in fact, the only one which failed to find the left visual hemifield effect for face recognition when field-dependent and field-independent subjects were pooled, but in which the visual field effect emerged for independent subjects. Zoccolotti and Oltman (1976) reported a set of results very similar to the present ones. They found no asymmetry effect for the pooled sample, a significant effect in the predicted direction for field-indpendent subjects, and a trend (nonsignificant) in the direction opposite to the predicted one for field-dependent subjects.

The question of comparability of various studies investigating face recognition is a more complicated one. Ellis (1975) has recently reviewed face recognition literature and concluded that the studies are practically never directly comparable, since they use vastly different methodologies and designs. Obviously, a study which studies recognition of people whom subjects have met previously (Crutchfield et al., 1954) and a study in which subjects' task is to recognize a set of just learned Photo Kit or schematic faces (Patterson and Bradshaw, 1975) tap vastly different cognitive processes. To rephrase the problem, if various studies of face recognition were factor analyzed, it is doubtful that a higher order factor for face recognition, comparable to Spearman's g for general intelligence, free of specific content, would be obtained. Thus, there is probably very little, if any, common variance underlying recognition of human faces in various experimental conditions and using various types of stimuli. It seems reasonable to speak about two dimensions on which these various studies of face recognition differ. The first dimension might be termed 'ecological validity' of the stimulus situation. It could be defined as the degree to which a given experimental design approximates face recognition in real life situations. Persual of experimental results suggests that very few studies employ situations which resemble actual recognition tasks that we face in the real life outside the laboratory; it seems that differences on this dimension could, at least partially, explain various contradictions in the results. For example, Berlucchi (personal communication) found that after subjects studied a set of photographs of faces over a number of days, the initial right hemisphere (left visual hemifield superiority) for recognition of these faces was abolished. On the other hand, clinical studies of prosopagnosia suggest strongly that the right hemisphere is, in fact, implicated in recognition of long familiar faces. Possibly, recognition of photographs of faces studied intensively for four days and recognition of faces of family members a patient has known all his life involve different processing mechanisms. Clearly, we cannot refer to <u>both</u> of these as recognition of <u>familiar</u> faces without specifying differences in methodology employed to study them. The second dimension which appears relevant in disentangling this issue is the concept of levels of processing, introduced earlier in this study. Recognition according to this point of view, is a function of level to which the stimulus was processed which in turn, is a function of time alloted for looking at the stimulus, the nature of encoding process (for example, the nature of the judgment which needs to be made about it) and the like. From the vantage point of the levels-of-processing theory comparison of recognition scores of stimuli shown tachistoscopically for 50 msec. with recognition of faces studied at length or with recognition of faces of people the subject has interacted with in the past begs the question since, by defintion, recognition scores will necessarily differ. Moreover, and very importantly in the present context, different levels of processing may process hemispheric specificity. As Cohen has argued recently (1975), hemispheric specialization might be, in fact, best described in terms of specialization for different stages of the total recognition process, from physical analysis through encoding to response--that is, specialization operates within tasks rather than between tasks. According to this point of view, it would be expected that different designs allowing the stimulus to be processed to a different level, will necessarily yield contradictory results in terms of hemispheric dominance for the given task.

From the above discussion it appears that replicability cannot be meaningfully discussed given the great variety of methodologies and procedures used in studying face recognition. Before we will be able to draw conclusions about the nature of the cognitive skills and strategies involved in face recognition, it is imperative to devise such recognition tasks which resemble those real life face recognition situations we have to deal with outside of the laboratory and which tap the same cognitive functions as the real-life tasks. Only such tasks can provide us with ecologically valid insights about hemispheric involvement in cognitive functions.

Concluding Remarks

Taken by itself, the tachistoscopic study supports the view (Witkin and Goodenough, 1976) that the extent of psychological differentiation, as reflected in the subject's field articulation score, is associated with greater segregation of neurological functions, i.e. with greater degree of hemispheric lateralization. The analytic vs. global dichotomy was found to be a good descriptor of the nature of hemispheric specialization in field-independent subjects or, to be more exact, in field-independent women. This description does not fit the field-dependent women in whom hemisphere utilization appears to be of different nature. The latter subjects seem to rely more on the left hemisphere functions for processing of complex visual patterns.

Such conclusions, on the one hand, are not fully warranted by the results of the EEG study which lends only limited support for either the notion of global vs. analytic dichotomy or the hypothesis of different lateralization patterns in field-dependent and field-independent subjects. With one exception, in the present study the EEG method failed to tap individual differences in hemispheric asymmetry associated with the dimension of field articulation and, although it discriminated successfully between verbal and visuospatial tasks, it also failed to differentiate between different visuospatial tasks. This part of the investigation did not provide clear-cut evidence bearing on the issue of association between accuracy and asymmetry.

The lack of convergence between results from the two studies is the most worrisome aspect of the investigation. It is argued here that this fact should not be interpreted as meaning that there is no common construct underlying the hemiretinal projection and the EEG methods, but rather, that it reflects different aspects of method variance involved in the two techniques. In particular, it is suggested that the EEG might be more "sensitive" to various confounding effects, such as the possible effect of sex and its interactions with other variables. It does not mean that the EEG methodology might not be as fruitful in the tachistoscopic method. However, further investigation of the method itself is in order. It is hoped that future studies using subjects of both sexes, utilizing more extensive electrode placements, and varying procedural aspects might illuminate questions which remain unanswered in the present work.

Footnotes

1. In order to obtain a composite face, a photograph of face is split lengthwise, each half is rephotographed, and two composite faces are constructed: one consisting of two left halves of the face and one of two right halves.

2. Note that these findings contradict the notion of diffuse organization of the right hemisphere, proposed by Semmes (1968).

3. Craik and Lockhart (1972) argue that the memory trace can be understood as a byproduct of perceptual analysis and that trace persistence is a positive function of the depth to which the stimulus has been analyzed. This continuous rather than discrete analysis of input proceeds through a series of sensory stages to levels associated with matching or pattern recognition and finally to semantic-associative stages of stimulus enrichment. Persistence of memory traces is a function of depth of analysis, with deeper levels of analysis associated with more elaborate, longer lasting, and stronger traces. Factors such as amount of attention devoted to a stimulus, its compatibility with the analyzing structures, and the processing time available will determine the depth to which a stimulus is processed. Thus, we know that preliminary stages of stimulus analysis are concerned with the analysis of sensory and physical features, intermediate stages with pattern recognition and extraction of meaning, and the final stages with stimulus enrichment. When exposure times are different (as in the Yin and the Ellis and Shephard studies), we might be comparing "products" picked from different points of the memory "assembly line." These different levels of processing are associated with coding of different stimulus attributes, e.g. phonetic vs. semantic (Davis and Cubbage, 1976). It is possible (Posner et al., 1967) that these different stages of information processing differ also along hemispheric lines.

4. In order to avoid a confusion in terminology, a short explanation is in order. At this point Witkin and his co-workers have adopted the term "analytical field approach" for the cognitive style involving the ready ability to overcome an embedding context and to experience items as discrete from the field in which they are contained. The term "global field approach" has been suggested to describe the style of functioning that involves submission to the dominant organization of the field and the tendency to experience items as "fused" with their backgrounds. The term "field dependence-independence" which was used at the beginning to describe the continuum, is now taken to represent its perceptual component. The terms will be used interchangeably throughout this text.

5. In fact, Witkin has been criticized for confounding the field articulation variable with spatial ability (Sherman, 1967; Wachtel, 1972).

6. For example, mean correlation between EFT and RFT for ages between 8 and 17 was .43 between RFT and BAT .37, and between EFT and BAT. 37 also (derived by r to z transformations from Witkin et al., 1962). Low correlations between the two principal measures of field articulation, EFT and RFT, are reported throughout the literature cf. for example, Adevai et al., 1968; Arbuthnot, 1972; Denmark et al., 1971; Elliot, 1961; Vernon, 1972; Wachtel, 1972).

7. Note that both Lansdell (1968) and Newcombe (1974) have demonstrated that performance on Mooney's Closure Test is associated with the right hemisphere function.

8. Although the advantages of using the full range of a variable rather than only the extremes of its distribution are fully appreciated, it is felt that the exploratory nature of the present investigation warrants the less conservative approach.

9. The memory set design used in the tachistoscopic study was deemed inappropriate when EEG is recorded because of short exposure time and randomization of hemifield presentations. It was reasoned that, in order for an asymmetry to obtain and for such an effect to stabilize, a longer involvement of the given hemisphere would be necessary.

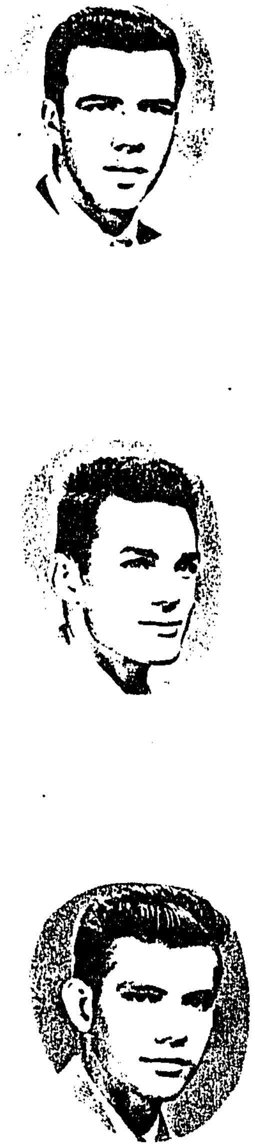
10. Since the number of degrees of freedom for all the interactions in these analyses was 1, it was impossible to further partition the number of degrees of freedom and to run multiple Neuman-Keuls tests. Instead, the differences between means were analyzed in a number of separate t-tests.

APPENDIX

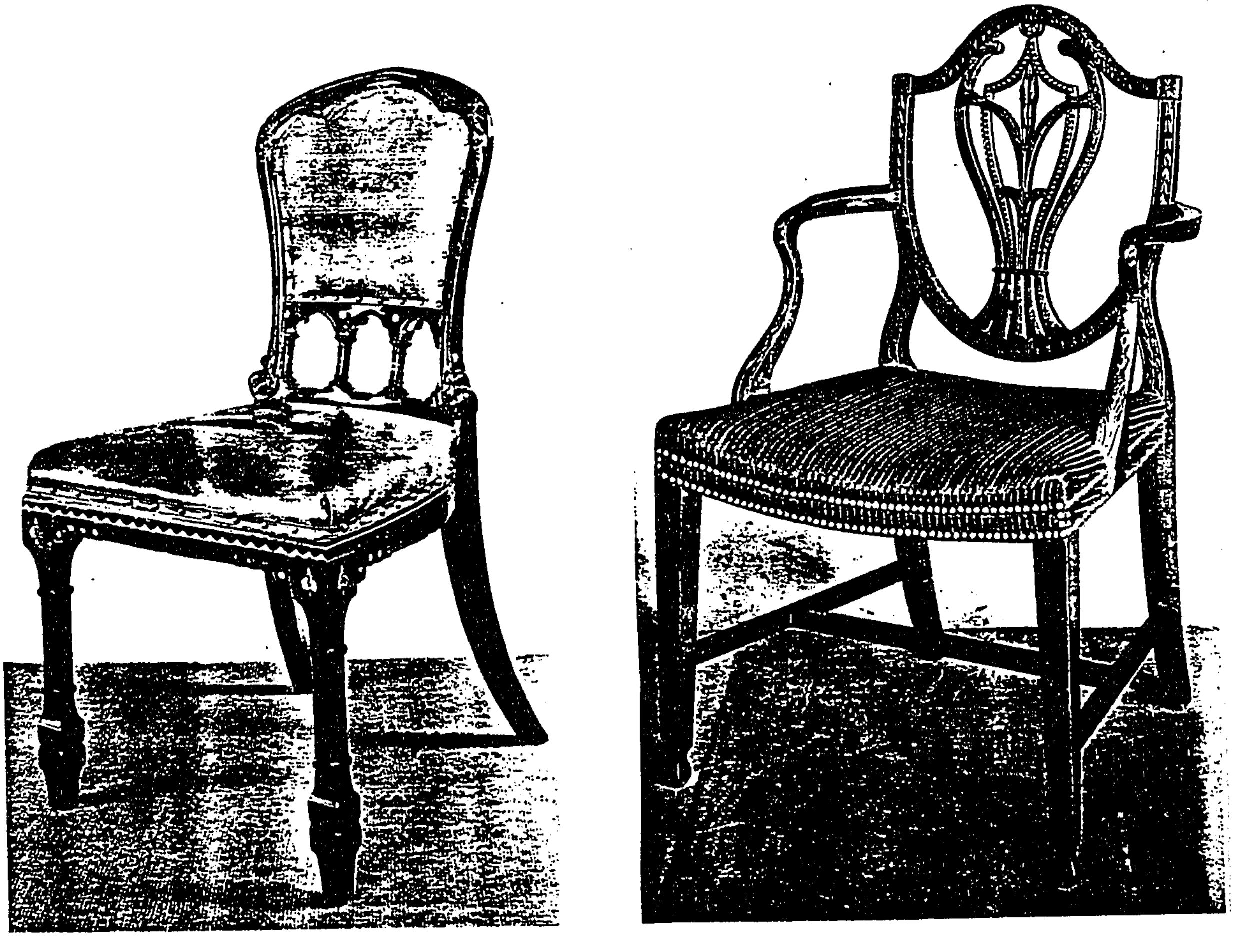
Examples of memory set faces for the tachistoscopic experiment.

1

An inverted memory probe from the tachistoscopic experiment.



Examples of facial stimuli used in the continuous recognition tasks (EEG experiment).



Examples of chair stimuli used in the EEG experiment.

Analysis of Variance of Transformed EEG Ratio Scores

All the EEG ratio scores were ipsatized through z transformations in the following manner. First, a mean of all EEG ratio scores was computed for each subject. Second, given subject's score for any task was transformed into a z score, representing deviation from this subject's mean. These transformed scores were then analyzed in a group by stimulus by "difficulty" ANOVA. The summary table is presented below:

Source of variance	Sum of squares	df	F	p
Group	1.01	1,21	1.21	NS
Stimulus	9.86	2,42	5.94	$< .01$
Stimulus x group	2.44	2,42	1.47	NS
Difficulty	.013	1,21	.03	NS
Difficulty x group	.86	1,21	1.92	NS
Stimulus x difficulty	3.36	2,42	2.22	NS
Stimulus x difficulty x group	1.43	2,42	.95	NS

Analysis of Variance of Transformed EEG Accuracy Scores

In addition, all the EEG adjusted accuracy scores were also ipsatized in the manner described above for ratio scores and subjects to an ANOVA. Below is the summary table for this analysis:

Source of variance	Sum of Squares	df	F	p
Group	.297	1,21	20.76	$<.001$
Stimulus	.011	2,42	12.63	$<.001$
Stimulus x group	.002	2,42	2.43	NS
Difficulty	.037	1,21	86.98	$<.001$
Difficulty x group	.005	1,21	11.44	$<.01$
Stimulus x difficulty	.011	2,42	16.03	$<.001$
Stimulus x difficulty x group	.0002	2,42	.38	NS

Correlations Between Accuracy and Asymmetry in EEG Tasks
Using Z-Scores Reflecting Difference Between Tasks

	1	2	3	4	5	6
1. UIF Asym.	1					
2. UIC Asym.	.25	1				
3. Com. Words Asym.	-.16	.05	1			
4. UIF Accy.	-.17*	.05	-.01	1		
5. UIC Accy.	.08	-.12*	.16	-.09	1	
6. C Words Accy.	-.23	.12	.26	-.20	-.13	1

* Significant beyond .05 level.

Note: the two word tasks were combined in this analysis.

UIF Asym. = the difference between asymmetry Z-scores for upright and inverted faces.
UIC Asym. = the difference between asymmetry Z-scores for upright and inverted chairs.
C Words Asym. = combined Z-scores for the two word tasks.

UIF Accy. = the difference between accuracy Z-scores for upright and inverted faces.
UIC Accy. = the difference between accuracy Z-scores for upright and inverted chairs.
C Words Accy. = combined accuracy Z-scores for the two word tasks.

Correlations Between Asymmetry Z-Scores in the Tachistoscopic Study and the EEG Study

		1	2	3	4	5	6	7	8
1.	UIFAS	1							
2.	UICAS	.25	1						
3.	UIRT	-.17	-.18	1					
4.	UIAC	-.18	-.07	.38	1				
5.	WMUF	.11	-.17	.04	.28	1			
6.	WMIF	-.06	.23	.18	.30	-.10	1		
7.	WMUC	-.01	.16	.27	-.08	-.35	.19	1	
8.	WMIC	.24	.34	-.32	-.21	.18	-.18	-.14	1

Note: none of the correlations was significant beyond the .05 level.

1. UIFAS = ipsatized ratio score for upright faces minus ipsatized ratio score for inverted faces (EEG).
2. UICAS = ipsatized ratio score for upright chairs minus ipsatized ratio score for inverted chairs.
3. UIRT = ipsatized mean RT for upright probes minus ipsatized mean RT for inverted probes (collapsed across memory sets) (tachistoscopic study).
4. UIAC = ipsatized mean error for upright faces minus ipsatized mean error for inverted faces (collapsed across memory sets) (tachistoscopic study).
5. WMUF = ipsatized ratio score for combined word tasks minus ipsatized ratio for upright faces (EEG).
6. WMIF = ipsatized ratio score for combined word tasks minus ipsatized ratio score for inverted faces (EEG).
7. WMUC = ipsatized ratio score for combined word tasks minus ipsatized ratio score for upright chairs (EEG).
8. WMIC = ipsatized ratio score for combined word tasks minus ipsatized ratio score for inverted chairs (EEG).

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