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Personality, Sex, and the Neuropsychology of Attention

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PERSONALITY, SEX, AND THE NEUROPSYCHOLOGY OF ATTENTION

by
Peter A. Williamson

Master of Science in Education
University of Wisconsin, Superior, 1976

A Dissertation
Submitted to the Graduate Faculty
of the
in partial fulfillment of the requirements
for the degree of
Doctor of Philosophy

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1983

Personality, Sex, and the Neuropsychology of Attention

Peter A. Williamson, Ph.D.

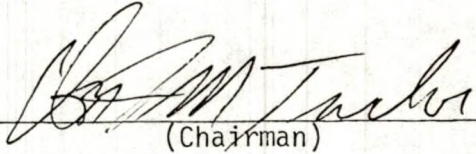
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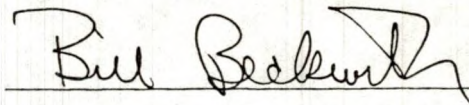
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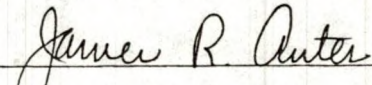
The influences of sex and personality on attentional style were examined in two neuropsychological studies in which performance and event-related potentials (ERP's) were employed. Pribram and McGuinness' (1975) conceptions of Activation and Arousal were recast in a lateralized framework in which the former was seen as characteristic of left hemisphere function while the latter was identified more closely with the right hemisphere. Four equal groups of nine subjects were selected on the basis of sex and extreme extraversion scores (I-E), while controlling for neuroticism, to participate in two lateralized attentional tasks. The first, a vigilance task designed to assess Activation modeled after Dimond and Beaumont (1973), involved responding to infrequent signals from lateralized visual stimuli. The second study, designed to assess Arousal, employed a complex reaction time task used by Heilman and Van Den Abell (1979). Four-way mixed ANOVAs were carried out for both studies on the performance and ERP data. In addition, correlations were computed between performance and ERP data. A general left hemisphere superiority was observed in the vigilance study


according to prediction. Unexpectedly, significant lateral differences and changes over time were observed for male and female introverts, but not for extraverts. Such differences are explained by a developmental model and indicate the utility of several models of hemispheric interaction. No between and within group differences in performance were observed on the complex reaction time study, failing to confirm previous findings. On both studies, consistent sex and I-E differences were observed in the topographical distribution of the ERP's. Interesting sex and I-E differences in the patterns of correlations between ERP and performance data emerged on the vigilance, but not on the complex reaction time study. Results indicate that these groups utilize different brain systems to attend. Questions also arise whether the present paradigms tap the Arousal-Activation dimension or a model based on stages of processing.

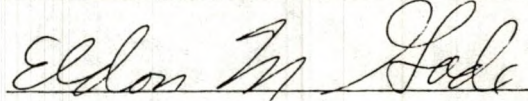
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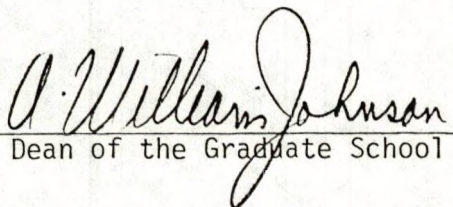








This dissertation meets the standards for appearance and conforms to the style and format requirements of the Graduate School of the University of North Dakota, and is hereby approved.

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Department Psychology

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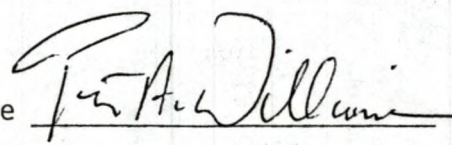
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ABSTRACT

The influences of sex and personality on attentional style were examined in two neuropsychological studies in which performance and event-related potentials (ERP's) were employed. Pribram and McGuinness' (1975) conceptions of Activation and Arousal were recast in a lateralized framework in which the former was seen as characteristic of left hemisphere function while the latter was identified more closely with the right hemisphere. Four equal groups of nine subjects were selected on the basis of sex and extreme extraversion scores (I-E), while controlling for neuroticism, to participate in two lateralized attentional tasks. The first, a vigilance task designed to assess Activation modeled after Dimond and Beaumont (1973), involved responding to infrequent signals from lateralized visual stimuli. The second study, designed to assess Arousal, employed a complex reaction time task used by Heilman and Van Den Abell (1979). Four-way mixed ANOVAs were carried out for both studies on the performance and ERP data. In addition, correlations were computed between performance and ERP data. A general left hemisphere superiority was observed in the vigilance study according to prediction. Unexpectedly, significant lateral differences and changes over time were observed for male and female introverts, but not for extraverts. Such differences are explained by a developmental model and indicate the utility of several

models of hemispheric interaction. No between and within group differences in performance were observed on the complex reaction time study, failing to confirm previous findings. On both studies, consistent sex and I-E differences were observed in the topographical distribution of the ERP's. Interesting sex and I-E differences in the patterns of correlations between ERP and performance data emerged on the vigilance, but not on the complex reaction time study. Results indicate that these groups utilize different brain systems to attend. Questions also arise whether the present paradigms tap the Arousal-Activation dimension or a model based on stages of processing.

INTRODUCTION

The study of the relationship between arousal and attention may yield valuable information about the development of cognitive style and personality. Kahneman (1973) suggests that attentional processes are composed of "intensive" and "selective" components in which the former are concerned with physiological arousal while the latter have to do with information processing strategies. Selective and intensive aspects of attention may develop interdependently since it is conceivable that the way information is processed is determined, at least in part, with respect to the individual's ability to sustain arousal and avoid fatigue. How an individual learns to modulate arousal and control attention may be crucial to the development of learning style, coping skills, and ultimately those stable characteristics of behavior which comprise personality.

This thesis first requires the demonstration that groups defined as opposites along some dimension of personality, exhibit characteristically different attentional styles. Eysenck's (1947, 1960, 1967, 1976b) construct of introversion-extraversion provides just such a framework. Briefly, this dimension is based on the conception that the ability to sustain cortical arousal is normally distributed among humans. Differences in this ability, which is thought to be genetically based, may lead to biases in the individual's choice of activity, skill development, and modes of perceiving and thinking.

Extraverts, at the low end of the continuum, who manifest a persistently low cortical arousal could be expected to manifest a pattern of behavior that is distinct from introverts, who, at the other end of the continuum, manifest a persistently high level of cortical arousal.

Thirty years of research have generally supported consistent differences in physiological response and behavioral performance between extreme introverts and extraverts. In EEG studies, extraverts exhibit higher voltage in the alpha and beta frequency ranges which is usually associated with decreased arousal (Deakin & Exley 1979; Gale, Coles, & Blayton 1969). Extraverts also show quicker habituation of the orienting response as measured by GSR (Mangan & O'Gorman 1969), heart rate and vasomotor response (Stellmack, Bourgeois, Chian, & Pickard 1979). Behaviorally, introverts exhibit a lower threshold of electrocutaneous stimulation (Edman, Schalling, & Rissler 1979), pain (Bartol & Costello 1976), and have a greater tolerance for sensory deprivation (Eysenck 1967). Extraverts, compared to introverts, show a greater "stimulus hunger" and a preference for visual complexity (Bartol & Martin 1974; Gale 1969). Introverts also exhibit a decreased tolerance for distraction during paired-associates learning and an inferior recall of serial word lists at short retention intervals (Howarth 1969; Eysenck 1967). There is a considerable research record documenting the superiority of introverts in vigilance performance (Brebner & Cooper 1974; Davies, Hockey, & Taylor 1969; Keister & McLaughlin 1972; Krupski, Raskin, & Bakan 1971; Thackery, Jones, & Touchstone 1974).

Taken as a whole, the research evidence supports the contention that introverts exhibit a lower threshold and tolerance for stimulation;

what Eysenck (1967) refers to as a "lower level of positive hedonic tone." As a result, introverts show a superior ability to sustain attention, especially under conditions of low background noise. It appears from the literature that extraverts have a difficult time sustaining attention for all but short periods of time.

Yet historically the attentional style of introverts has not been viewed as merely superior to that of extraverts, but characteristically distinct. Jung (1971), for example, describes introversion as an inward movement of interest to the subject's own psychological processes. Extraverts, in contrast, are characterized by an outward movement of interest toward objects in the environment. Jung notes that these qualitative differences are evident in Nietzsche's metaphorical dichotomy of Appollo and Dionysus. The appollonian mode of being is dreamy, oriented toward inward vision, and alienated from the external environment. The Dionysian mode is fused with the environment; the metaphor is one of "intoxication" rather than "dream." Since Jung discusses the psychophysiological differences in brain arousal as the basis for the differences in these two personality types and Eysenck (1947, 1967, 1976b) frequently cites Jung's work in his description of introversion-extraversion, it is evident that both authors are attempting to describe a similar personality dimension. In order for both perspectives to become integrated, it is necessary to demonstrate that extraverts are not merely inferior attenders, but attend in a way that is qualitatively distinct from introverts.

This requires that "attention" can take different forms. There is a considerable research history which indicates that attention can

be divided into different component parts. Several research groups have suggested, on the basis of dichotic listening studies, that different stimuli are processed by multiple channels rather than a single filter model (Deutsch & Deutsch 1963; Norman 1968; Treisman 1969). In addition several laterality models have been developed in which each hemisphere of the brain has an attentional system that serves to alert, prime, or direct cognitive processing (Levy 1980; Moscovitch 1979). Different models of hemispheric interaction have been offered to explain how different attentional systems can work in concert to provide a unity of consciousness (Allen 1983; Levy & Trevarthen 1976; Kinsbourne & Hicks 1978; Dimond 1977).

Finally the relationship between the physiological concept of brain arousal "systems" and multiple attentional "channels" has been explored. Separate but inter connected systems of brain arousal have been proposed by numerous authors (Heilman & Van Den Abell 1979; Luria 1972; Pribram & McGuinness 1975; Riklan & Levita 1969; Routtenberg 1968).

It has been proposed that different components of attention are supported by distinct neurophysiological systems. Pribram and McGuinness (1975; McGuinness & Pribram 1980) suggest, on the basis of extensive research with primates, that three such systems may be identified in the brain which they term Arousal, Activation, and Effort. Arousal is conceived as phasic response to input that is linked to noradrenergic and serotonergic circuits of the frontal cortex and amygdala complex. Activation is conceived as "a longlasting readiness to respond" and is centered on a dopaminergic system of the basal ganglia. The

third system, Effort, is conceived as coordinating the first two and is linked to the hippocampal system. While there has been some criticism of the relevance of the subcortical Effort system to attentional processes in humans (Tucker & Williamson, in press), Arousal and Activation, as separable components of attention, are directly applicable to the attentional styles of introverts and extraverts.

Arousal is conceptualized as a phasic response to input designed to orient the organism to novel stimuli. Pribram and McGuinness (1975) suggest that this type of attention is linked to the psychological operation of categorization, a "what is it?" reaction, and is the basis of the orienting response. As such, it is seen as a short-term response that quickly habituates to a stimulus upon prolonged exposure or repeated presentation. Yet this is also descriptive of the extravert's style of attention. Characteristically, they exhibit a preference for novelty and complexity, performing poorly under conditions of monotony (Bartol & Martin 1974; Eysenck 1967). They exhibit superior learning under conditions of distraction and after short retention intervals (Eysenck 1967). Extraverts are oriented to the environment and actively seek change, novelty, and stimulation.

Activation, in contrast to Arousal, describes tonic attentive states as exemplified in vigilance paradigms. Psychologically, it is tied to reasoning or, as termed by Pribram and McGuinness, a "what's to be done?" mode of cognition. Activation involves a rejection of input and a bias toward redundancy so that attention persists despite repeated stimulus presentations or prolonged exposure. The style of attention associated with introversion is clearly one of Activation.

In contrast to extraverts, they exhibit a high degree of proficiency in vigilance and experience considerable difficulty learning under conditions of background noise or after short intervals. In general, introverts are internally directed and more tonically attentive than extraverts.

Recent experiments have found significant lateral differences on attentional tasks which may have special relevance to cognitive style differences observed between introverts and extraverts. On a vigilance task, Dimond and Beaumont (1971, 1973) found that signal detection performance in the right visual field was superior to that in the left visual field. In contrast, Heilman and Van Den Abell (1979) report results of a complex reaction time experiment which at first glance appear to conflict with those of Dimond and Beaumont. They found that warning stimuli to the right hemisphere reduced reaction times of either hand more than did warning signals to the left hemisphere. While Dimond and Beaumont (1973) proposed that the left hemisphere comprises the primary vigilance system, Heilman and Van Den Abell (1979) suggest that the right hemisphere mediates cerebral "activation." This discrepancy is discussed in Tucker and Williamson (in press) and is resolved once the task used by Heilman and Van Den Abell is viewed as tapping Arousal rather than Activation. Since the dependent measure is response time and since every effort is made to reduce fatigue, it is evident that the mode of attention is phasic, not tonic, which is indicative of Arousal.

The implication is that Activation, which is the basis of vigilant attention, is related more to left hemisphere function, while

Arousal, the basis of orienting and reaction time, is more characteristic of right hemisphere function. The present problem is to find out whether such lateral differences in Arousal and Activation tasks can be related to the personality dimension of introversion-extraversion. Specifically, do introverts exhibit a superiority in vigilance that is related to left hemisphere functioning? Do extraverts exhibit a superior complex reaction-time performance that is related to the function of the right hemisphere? To date, no study has explored the relationships among these neuropsychological components of attention and the personality dimension of introversion-extraversion.

The present study is exploratory in nature and examines hemispheric differences on two "attentional" tasks between introverts and extraverts. The first task is a standard vigilance task using lateralized signals and is modeled after the one used by Dimond and Beaumont (1971, 1973). This task employs a vigilance paradigm in which performance is measured over time in terms of correct detections and number of false positive responses. Since it is a vigilance task, it is designed to assess Activation in accordance with the definition of Pribram and McGuinness (1975). The second task is designed to tap what Pribram and McGuinness have termed Arousal and is very similar to the procedure employed by Heilman and Van Del Abell (1979). Briefly, this involves a complex reaction time paradigm using an auditory stimulus to announce a trial, lateralized visual warning signals, and a centrally located reaction stimulus.

It is hypothesized that introverts will show a pattern of performance on both tasks that is distinct from extraverts. It is

hypothesized that introverts will show an initial superiority in right visual field performance on the vigilance task and that this superiority will increase over time. On the complex reaction time task, however, it is hypothesized that extraverts will exhibit superior performance (greater improvement in reaction time with a warning) and that this will be most evident for trials in which the warning signals occur in the left visual field.

While performance measures constitute the primary tests, electrophysiological measures will also be taken. Event related potentials (ERP's) will be recorded during both experiments. For both tasks amplitude measures of two components will be assessed: a negative component occurring at approximately 160 msec. and a late positive component occurring around 350 msec. There is some evidence that the former is related to functions associated with activation while the latter is associated with arousal (Picton, Campbell, Baribeau-Braun, & Proulx 1978). A final question is whether there is a relationship between the performance measures and the event related potentials.

REVIEW OF THE LITERATURE

Attention involves the selection of certain stimuli from among all the stimuli that impinge upon the senses. The factors that determine what will be attended to are varied and complex. William James (1892) noted that the complexity of attention was due to differences in objects (sensual vs. intellectual), forms of interest (immediate vs. apperceptive), and effort (voluntary vs. involuntary). Modern theorists have tended to underscore this notion of complexity. Kahneman (1973) has defined attention as an "internal" mechanism by which the significance of stimuli may be determined and stimuli-related behavior may be governed.

Much interest has been focused on those cognitive factors that influence which stimuli attention will be focused upon. Such selection appears to be determined by characteristics of both the stimuli (size, intensity, novelty, and change) and the individual (interests, expectations, attentional set) (Macworth & Morandi 1967; Biederman 1972). Such characteristics are related to what stimuli are chosen and how complex stimulus fields are searched for information.

Yet attention, as Kahneman (1973) observes, also involves the ability to engage appropriate sensory systems in such a way that information can be effectively processed. This intensive aspect has been related to the individual's level of arousal by Hebb (1955) and Berlyne (1960). Hence stimuli are seen not only as cues which function

to initiate goal directed responses, but also serve an arousing function to maintain the general alertness of the individual. Kahneman notes that such theories tie the arousing function of stimuli to the increased ability of the individual to attend. Yet he takes issue with previous theorists in that he views the intensive aspect of attention as related to effort and not mere wakefulness.

Prior to Kahneman, other authors had drawn the link between arousal and attention. Easterbrook (1959), for example, suggested that individual differences in selective attention were related to their level of arousal and that task performance varied as a quadratic function of arousal. His theory attempted to account for the effects assumed under the Yerkes-Dodson law by the hypothesis that as emotionality or arousal increases, cue utilization narrows and proficiency at first increases, then falls. The function of arousal was seen as restricting the range or focus of attention to some central task at the expense of peripheral information. M.W. Eysenck (1981), however, notes that incentives, white noise, and anxiety are all arousing but have different effects on attention. He concludes from his review that while all three increase selectivity, anxiety leads to reduced capacity. Certainly anxiety, white noise, and incentives decrease attention to subsidiary tasks. Anxiety, however, often had no effect on main task performance while incentives and white noise often enhanced main task performance.

Kahneman's theory obviates this problem since he proposes that the intensive aspect involves changes in effort or attentional capacity. As the processing demands of a primary or main task increase, there is a corresponding increase in effort. As a result, this

depletes the supply of effort and decreases spare capacity. What was of concern to Kahneman were the intrinsic factors that influenced what he termed the "allocation policy." Since the physiological capacity to sustain effort is limited, mobilization of effort is controlled by the evaluation of demands on the system. He contrasted this view against "bottleneck theory" (Deutsch & Deutsch 1963) and "filter theory" (Broadbent 1970) of attentional control, offering considerable experimental evidence for his effort model. His model, when applied to divided attention paradigms, however, is very closely related to the theory of Treisman (1969). She proposes a system of multiple analyzers in which different analyzers can operate in parallel without interference, but that processing within any one analyzer must be serial. In Kahneman's view, parallel or serial processing significantly affects the demands on capacity predicted by the effort model. This, he suggests, is apparent from studies in dichotic listening in which bias to one channel interferes with the recognition of significant targets in the other channel (Treisman & Geffen 1967; Treisman & Riley 1969). It also accounts for variations in the processing of concurrent activities, according to the demands that processing places on spare capacity. Highly demanding tasks cause an interruption of concurrent tasks while less demanding tasks may be processed in parallel. These considerations are very important when considering the application of this model to models of lateralized attentional systems.

Clearly, what concerned Kahneman was the psychological aspect of allocation: what factors affected and how they affected a limited biological capability to attend. Although, he advocates the use of

physiological measures to determine arousal and effort, he devotes very little discussion to what factors actually influence the biological capacity itself. Consequently, the physiological capacity to arouse is determined by what Kahneman describes as "miscellaneous determinants including the prevailing intensity of stimulation and the physiological effects of drugs or drive states" (p. 17). Since this is a cognitive theory and not a neurophysiological theory, there is little speculation about what systems in the brain might be involved. Since this is not a theory of individual differences, but instead a general theory, there is no conjecture about how factors such as sex and personality might interact to create "styles" of attention. Yet these are important issues to consider when applying Kahneman's model of attentional allocation to different groups of people in the real world. Specifically there is common ground between laterality models of cognitive function (i.e., Kinsbourne 1970, 1973, 1975; Kinsbourne & Hicks 1978; Levy 1980; Dimond 1977), neuropsychological theories of attention (i.e., Pribram & McGuinness 1975; McGuinness & Pribram 1980; Routtenberg 1968; Riklan & Levita 1969), as well as personality theories which focus on arousal issues (Eysenck 1967, 1981). The integration of ideas from across a number of theoretical domains can add richness to our understanding of individual differences in attentional modulation.

Laterality Models of Attentional Modulation

Typically, the primary concern expressed in the research on the asymmetrical functions of the cerebral hemispheres has been with cognition. Consequently, the left hemisphere is conceived as specialized

for verbal processes and control of purposive movement while the right hemisphere is organized to process nonverbal content (Nebes 1974; Levy 1980; Tucker 1981; Allen 1983). More recently there is research supporting the theory that there are basic differences in the way the hemispheres process information since the left hemisphere seems to process information sequentially, in an analytic mode, while the right hemisphere processes information simultaneously, in a synthetic mode (Bogen 1969; Tucker 1981; Levy 1980). These asymmetries in cognitive content and structure have also been related to perceptual asymmetries. Verbal material is perceived faster and more accurately if presented to the right sensory field, regardless of modality, while nonverbal material is more rapidly and accurately processed if presented to the left (Geffen, Bradshaw, & Nettleton 1972; Geffen, Bradshaw, & Wallace 1971; Kimura 1963; Kimura 1967). In order to account for these perceptual asymmetries, two theoretical views have emerged. The primary view is that the structural characteristics tend to support the unique functions of the hemispheres. As a result, stimuli have more direct access to the hemisphere that specializes in processing them (Klein, Moscovitch, & Vigna 1976). Verbal material visually presented is perceived more rapidly and accurately if in the right visual field than the left (Kimura 1966). Similarly, there is a long history of research documenting a right ear advantage for verbal material (i.e., Kimura 1967). In contrast, faces are better recognized when presented to the left visual field (Levy, Trevarthen, & Sperry 1972; Benton & Van Allen 1968). Yet perceptual asymmetries have also been explained as a function attentional bias (Levy 1974). Typically, this explanation

has been used to explain reaction time differences, discrimination differences, and differences in report accuracy for the right and left sensory field in relation to specific tasks (Kinsbourne 1973). Levy (1974) has suggested that attention serves an arousing or alerting function and that this accounts for the differences in discriminative reaction times between the sensory fields. This assumes that some degree of unilateral specialization holds; each cerebral hemisphere displays a greater or lesser degree of competence for specific types of information. In her view, signals sent to the less competent hemisphere must be rerouted to the more competent one via subcortical or callosal connections, and since the signals serve an arousal function, the rerouting of signals takes up additional time before the competent hemisphere can be alerted to start processing the information. In a slight variation, Moscovitch (1979) suggests that, in addition to an alerting function, attention also directs hemisphere processing. An activated hemisphere not only selectively processes information arriving at the contralateral sensory field, but also favors information compatible with the hemisphere's natural competency.

Both of these models view the allocation of attention as a necessary primary system for effective information processing. Since in these two theories, the cerebral hemispheres are viewed as specialized for different contents and modes of information processing, it stands to reason that a primary system is a necessary feature to engage the appropriate hemispheres. Yet the intricate relationship between the functions of attention and cognition need to be further delineated. Since the view of the present paper is that how one learns to modulate

arousal and control attention is related to subsequent cognitive, emotional, and social development, the developmental underpinnings need to be explored. Yet while lateral asymmetries in cognitive function have long occupied a central position in neuropsychological argument (i.e., Luria 1972), the development of such differences has only been recently explored. Although inferential, considerable evidence has amassed suggesting that lateral asymmetries in function are due to (1) morphological asymmetries present at birth, (2) innate orientation biases, (3) variations in the developmental course of lateralization.

The genetic argument is substantial. Geschwind and Levitsky (1968) reported structural asymmetries in 100 adult brains taken at autopsy in which the left temporal planum, an area recognized to be important for speech perception, was larger than on the right. Wada, Clark and Hamm (1975) suggested that since language function becomes lateralized to the left hemisphere, the left hemisphere must be morphologically predisposed for such function at the onset of life. Examination of 100 infant and 100 adult brains taken at autopsy revealed that the left temporal planum was larger in the majority (90%) of both groups. Comparative studies on the brain of other primate species (monkeys and baboons) revealed no such asymmetries indicating that this structural difference is a uniquely human phenomenon. Witelson and Pallie (1973) found similar asymmetries in the temporal planums of 14 neonates and 16 adult brains.

In addition to morphological asymmetry, there is considerable evidence for biases in orientation to the right sensory field that is present at birth. Turkewitz and his colleagues (Turkewitz 1977a;

Turkewitz 1977b; Turkewitz, Birch, & Cooper 1974; Turkewitz, Gordon, & Birch 1965) found that infant head turning toward the side of stimulation is more reliably elicited when stimulation is applied to the right side of the body or face. This right sensory field bias is not modality-specific since it is elicited by lateralized visual and auditory stimulation as well. Turkewitz (1977a) notes that while the development of this response appears to be independent of the duration of intrauterine experience, it is likely that the stability of the bias is a function of extrauterine experience. Postural bias, the tendency of infants to lie with their heads to the right, is crucial to the maintenance of the lateral response bias. That biases in posture and response are interdependent is evident from the studies (Turkewitz 1977a) in which (1) lateral differences in response bias can be eliminated by holding the neonate's (12 hours old) head in midline and (2) postural bias can be eliminated by reducing any lateral differences in sensory stimulation.

Kinsbourne (1975; Liederman & Kinsbourne 1980) has suggested that this rightward orientation bias is a uniquely human phenomenon that is related to the development of lateralized language and motor control functions. Kinsbourne (1975) notes that infants turn and withdraw depending on the reinforcement condition to the right more reliably than they do the left. Similarly this rightward bias appears to be highly related to the handedness of the parents indicating a genetic origin to the observation that the left side of the brain is predominant for motor functions. Finally Michel (1981) presents data which indicates that orientation preference, assessed during the 16

to 48 hours after birth was maintained for at least two months and predicted preferential hand use at 16 and 22 weeks. These studies support the notion that orientation biases evident from the first few hours after birth are strongly related to the lateral biases in response to reinforcement, in posture, adjustment and motor control functions.

The relationships between attention and unilateral specialization of function has also been at the heart of another developmental controversy. This concerns the hypothesis advanced by Lenneberg (1967) that language acquisition can only take place during a critical period lasting from about age two to puberty. According to the hypothesis, language cannot be learned before age two due to maturational factors and is caused by the complete lateralization of language function to the left hemisphere. Typically support for the hypothesis has come from studies of unilateral brain injury sustained during early childhood (Basser 1962; Lansdell 1969). In studies using dichotic listening tasks, Satz, Bakker, Teunnisen, Goebel, and Van der Vlugt (1975) and Bryden (1973) have provided support for the hypothesis, at least in the auditory channel. Citing evidence from studies of psychological testing Krashen (1973) concluded that language lateralization was complete by age five. Similarly, Kinsbourne and Hiscock (1980) employed a selective listening task and found a right ear advantage for all ages. Studies using task performance have provided mixed results for the hypothesis although there is some suggestion that the rate of lateralization may vary depending on the modality and type of information presented (Tomlinson-Keasey, Kelly, & Burton 1978).

A consistent finding, however, and one that appears at variance with Lenneberg's hypothesis is the wealth of electrophysiological evidence indicating a lateralization of language related responses in early infancy. Molfese, Freeman, and Palermo (1975) provide evidence that even in infants one week old the N_1 - P_2 shift in the evoked potential to speech stimuli was greatest over the left hemisphere. Larger amplitude evoked responses to nonspeech (piano chord) stimuli were found over the right hemisphere. Similar results are reported in a later paper by Molfese's group (Molfese, Nunex, Seibert, & Ramanaiah 1976). Molfese et al. (1975) have developed a plausible hypothesis and one that is consistent with the theme of the present paper. They suggest that these results occur because of attentional biases and that while such biases may be significant to the future development of function, they do not mean that information is subsequently processed more efficiently. The N_1 - P_2 component, which occurs around 100 msec. to 160 msec., is generally felt to be reflective of attention to particular stimuli among others (Picton, Campbell, Baribeau-Braun, & Proulx 1978; Hillyard, Picton, & Regan 1978; Cooper, Ossleton, & Shaw 1980). Picton et al. suggest that experimental studies support the contention that this component of the evoked potential reflects a "Stimulus set" selection process without regard to the significance of the stimuli themselves. Molfese et al. (1975) suggest that lateralized differences in evoked potential components to speech and tonal stimuli represent attention to different features. They suggest that differences in response to verbal and nonverbal auditory stimuli in the infant provides a basis for speech perception and speech itself.

These results are compatible with the structural differences observed in infant brains (Witelson & Pallie 1973) and in the orientation biases observed by Turkewitz and others (Turkewitz 1976; Liederman & Kinsbourne 1980; Michel 1981). Such results suggest that orientation or attentional biases are "wired in" at birth and provide a basis for the development of lateralized cognitive functions. This provides some measure of support for Moscovitch's (1979) contention that attention serves both an alerting function and directs hemisphere information processing.

Multiple Attentional Systems

The exploration of lateralized cognitive functions and attentional systems creates as many theoretical problems as it solves. Taken at its simplest, unilateral specialization models create the impression that the brain operates like a computer rather than like a biological system. Brain parts are seen as interconnected but still functionally independent. It is difficult to understand from popularized "right brain-left brain" notions how an integrated sense of experience is possible. Which of the subprocessors does the integrating? Do subprocessors work cooperatively or in competition with one another? How are decision rules worked out so that a unity of consciousness is achieved?

Kinsbourne (1970; 1973; Kinsbourne & Hicks 1978), using Sherrington's model of reciprocal innervation, suggests that activation of one hemisphere results in a corresponding inhibition of the opposite hemisphere. The activated hemisphere would tend to be primed and would be more receptive to stimuli than the nonactivated hemisphere.

He suggests that, in intact brains, cognitive set which activates one or the other hemisphere causes an overflow of attention to the contralateral sensory field. He suggested that interhemispheric commissures provide a negative feedback system which inhibits the activation of the opposite hemisphere. His contention, however, that orientation biases can be overcome by cognitive set has been challenged by Geffen et al. (Geffen, Bradshaw, & Nettleton 1972) and by Boles (1979), both of whom found little experimental evidence for this aspect of the hypothesis. In more recent work, Kinsbourne and Hicks (1978) have concentrated on the inhibitory interactions of neuronal systems within and between the two hemispheres of the brain.

In contrast to Kinsbourne's negative feedback model is a parallel processing model advanced by several groups (Dimond 1977; Dimond & Beaumont 1971; 1973; Moscovitch, Scullion, & Christie 1976). These groups suggest a laterality model of attention that is very close to the theory of Deutsch and Deutsch (1963). Specifically each cerebral hemisphere has its own "watchkeeper" and at a precategorical level, operate simultaneously and independently. At higher levels, however, in which the specific information handling properties of the hemispheres influence the way in which stimuli are processed, there is an integration that occurs via the corpus callosum. Dimond and Beaumont (1974) also considered and rejected a model of attention in which fatigue might cause processing to be transferred by one hemisphere to the other.

Multiple Brain Arousal Systems and Modes of Attending

The idea that arousal in the central nervous system might be related psychological function was given a firm basis thirty years ago with the discovery of the reticular formation in the brain stem (Lindsley, Bowden, & Magoun 1949). Hebb (1955) suggested that the relationships between arousal and performance efficiency closely paralleled the inverted u-shaped function predicted by the Yerkes-Dodson Law. Under or over aroused subjects performed poorly while optimal efficiency occurs in moderately aroused states. Yet Pribram (1971) has clarified that amount of arousal does not refer specifically to some amount of "excitation" but to what he terms "the configuration of expectancies of the brain state challenged by novel input" (p. 206). In other terms, the pattern of neuronal firing at the level of the brain stem either matches previous patterns. If the pattern is novel and mismatches previous information, this results in uncertainty which is characterized by desynchronization of the EEG and behavioral orienting. Sokolov (1963) found that change in any parameter of a stimulus to which an organism had habituated will cause an orienting reaction to reappear. This further suggested that the arousal response reflected a mismatch of new input to some previous pattern. Sharpless and Jasper (1956), however, suggested that there were both specific and nonspecific arousal systems in the brain in which the former proved to be more tonic, habituating slowly, while the latter was seen as phasic, habituating readily. The differences between these two systems were seen as due to distinct neurophysiological systems; the phasic system arose from the reticular formation of the brain stem and innervated the cortex

via the diffuse projections from the midline nuclei of the thalamus; the tonic system arose from specific afferent connections with differentiated nuclei at the thalamic and brain stem level.

Pribram and McGuinness (1975), however, have advanced a comprehensive theory of the neurophysiological substrates of attention. They marshalled an impressive array of studies to support a theory in which there are three component parts: arousal, defined as a "phasic response to input;" activation, considered to be "tonic, long-lasting readiness to respond;" and effort, which coordinates both arousal and activation and arousal. The coordination of activation and arousal will be considered later and so the present discussion will focus on the two attentional forms. As in previous theories (Sokolov 1963; Riklan & Levita 1969; Sharpless & Jasper 1956), the concept of arousal is one of registration when there is a mismatch with previous input. Pribram and McGuinness identify arousal closely with the orienting reaction and tie it to cognitive processes of categorization of mnemonic registration. Activation is seen as differing from arousal in maintaining a set to continue ongoing behavior and is closely related to motor operations. The tonic states of response readiness is seen as related to the attentional mode typed by vigilance and the cognitive processes involved in reasoning. While arousal responds to novel input, rejecting redundant information, activation involves a high degree of redundancy and rejects novel input.

Physiologically, the arousal system is composed of specific tracts and nuclei in the medial reticular formation and hypothalamus which are regulated by two reciprocally acting systems connecting the

amygdala and frontal lobe. The dorsolateral surface of the frontal cortex appears to exert an excitatory influence, while nuclei in the orbital area project an inhibitory influence. In contrast, the activation system is regulated by the basal ganglia of the extrapyramidal motor system.

A number of lines of evidence suggest that arousal is more characteristic of the right hemisphere's mode of attention while activation is more characteristic of the left hemisphere's mode. These approaches include (1) neurochemical and neuroanatomical differences, (2) information processing differences and their relation to activities and arousal, (3) cognitive and attentional style differences. While the first two will be considered subsequently, the third area will be explored in the next section.

Anatomical asymmetries which may have special relevance to activation and arousal modes of attention have been reported. In a review of such studies Goldberg and Costa (1981) note that hemispheric asymmetry is such that distinct, modality-specific representations are more prominent on the left. In contrast, the intermodal association areas are larger on the right. In the frontal lobes, LeMay (1976) reports similar findings, namely that the premotor zone is larger on the left while the prefrontal zone is larger on the right. LeMay (1976) also notes that typically the lateral ventricle is larger in the left hemisphere and that the right hemisphere is usually heavier. Gur, Packer, Hungerbuhler, Reivich, Obrist, Amarnek, and Sackeim (1980), however, using Xenon 133 inhalation to study local cerebral blood flow, demonstrated that the right hemisphere contained much more white matter

while the left hemisphere contained much more gray matter. The greater proportion of white matter in the right hemisphere suggests that the different areas are strongly interconnected. The greater density of gray matter on the left suggests that the connectivity within specific regions is higher than between regions. Goldberg and Costa (1981) note that these differences in organization make the right hemisphere more suited to simultaneous processing of many modes of information while the left hemisphere is more suited to tasks which require fixation upon a single modality for representation or execution. Because of this, the right hemisphere is described as "being most crucial in the processing of materials to which more of the descriptive systems pre-existing in a subject's cognitive repertoire is readily applicable" (p. 36). The right hemisphere, by this description, is more suited to the short-term processing of novel stimuli, suggesting that it may be structurally biased towards an arousal mode of attention. Almost by default, the left hemisphere, which is more focally organized for specific sensory modalities and motoric behavior, is more suited to activation.

There is also a developing argument that arousal and activation are supported by different neurotransmitter systems and further, that there are lateral biases in the distributions of the systems which underscore the different hemispheric modes of attention. This argument is largely inferential and has been examined elsewhere (Tucker & Williamson, in press). Because of this, it will be covered only briefly here. McGuinness and Pribram (1980) suggest that norepinephrine acts in a serotonergic matrix to control arousal, while

dopamine "interdigitates" a cholinergic system to control activation. The behavioral concomitants of experimental manipulations of the functioning of these neurotransmitter systems seems to support their respective roles in arousal and activation. Depletion of forebrain norepinephrine in experimental animals results in a failure to extinguish performance during nonreinforcement (Mason & Iversen 1978). Such animals exhibit impaired discrimination, fail to habituate, and are distracted by irrelevant cues (Mason & Fibiger 1979). Strains of animals with genetically high levels of norepinephrine show increased exploratory activity and poor avoidance learning (Kempf, Greilsamer, Mach, & Mandel 1974; Siegfried, Alleva, & Olivero 1980). Dopamine depletion results in impaired sequential behavior while increased dopaminergic function results in increased motoric behavior and at very high levels, results in the repetition of brief, highly stereotyped motor sequences (Iversen 1977). The relationship between dopaminergic function and motoric behavior ties it closely to activation, while the importance of norepinephrine to sensory registration seems analogous to the description of arousal. Pribram (1977), in fact, has drawn a comparison between "episodic" attention and frontal (motoric) cortical function and "participatory" attention and posterior (sensory) cortical function.

Although these modes have been delineated along an anterior-posterior dimension, there is some evidence for lateral biases in the distribution of both neurotransmitter systems, indicating possible right-left differences in attentional style. Specifically Denenberg (1980) noted that pharmacologic stimulation of the dopamine pathways in rats results in higher tendency toward right side motor functions.

Electrophysiological studies with human schizophrenics (Serafetinides 1973) and mixed psychotic patients (Gottfries, Perris, & Roos 1974) tend to support the importance of dopaminergic neurotransmission to left hemisphere attentional function. In contrast, evidence for a right lateralization bias for norepinephrine has been supported by studies on selectively lesioned animals (Pearlson & Robinson 1981) and post mortem studies on humans (Oke, Keller, Mefford, & Adams 1978).

The second line of evidence for the lateralization of arousal and activation functions concerns the differences in the ways the hemispheres process information. Goldberg and Costa (1981) suggests that the left hemisphere is designed to process information for which there is a well routinized descriptive system. In contrast, the right hemisphere is crucial to orientation in a novel task, when no descriptive system is apparent or applicable. This coordinates with a number of studies which support a left hemispheric superiority for superiority for processing matched stimuli and a right hemispheric advantage in processing unmatched stimuli (Tomlinson-Keasey et al. 1978; Bradshaw, Gates, & Patterson 1976; Moscovitch et al. 1976). This contention is closely linked to Pribram and McGuinness' (1975) suggestion that arousal systems function to monitor the environment for the unique stimuli, the neuronal representations of which do not match previous input patterns. Considering the diffuse interconnections, greater association areas, and the likelihood that there is bias toward noradrenergic neurotransmission, the right hemisphere seems more suited to more rapid, holistic processing of complex stimulus configurations. It is more suited to identifying mismatches. The left hemisphere,

however, is more able to operate logically on information presented in different modalities but matched in some important way (Tomlinson-Keasey et al. 1978). This involves a bias towards routinization and a rejection of novelty made possible by focal organization of specific modal areas.

One additional way to view possible lateral biases in attention is that the left hemisphere, activation system is geared toward information and has a low threshold for noise or uncertainty in the input channels (Pribram 1971). Uncertainty is tolerated quite well by the right hemisphere arousal-biased system since, as a simultaneous processor, noise can be accommodated as part of a complex configuration. Since activation involves the rejection of uncertainty and the sequential encoding of bits of information to fit with some scheme, the left hemisphere has less of a capacity to process complex (noisy) information. When presented with processing it is consistent with Kahneman's allocation model that the rejection of complexity and the encoding of information should involve considerable effort. This appears supported by Lacey's (1967) observation that heart rate acceleration accompanies internal cognitive operations such as mental arithmetic. That there is a left hemisphere bias is suggested by the observation that heart rate acceleration precedes verbalization (Tucker & Williamson, in press).

In conclusion, many lines of research indicate that lateral biases in information processing are present at birth and continue to develop with experience. While structural asymmetries provide the basis for such lateral specialization, biases in orientation and

perception are apparently necessary for continued cognitive differentiation. Such orientation biases are seen as directing and priming cognitive activity and are the origins of attention. Yet in addition to selective functions, attention involves the allocation of physiologic arousal necessary for information processing. The available evidence indicates that distinct arousal modulation systems develop interdependently with lateralized styles of cognition. The left hemisphere, which is focally organized for sequential cognitive processing, seems more suited to a tonic, activated mode, while the holistic, configurational processes of the right hemisphere seem more compatible with a phasic attentional set. The implications for personality theory are clear and appear especially relevant to Eysenck's dimension of introversion-extraversion.

Eysenck's Dimension of Introversion-Extraversion

There is a long historical tradition in Western philosophical and psychological thought about the relationship between human physiology and the structure of personality. Galen, writing in the second century A.D., set down what is perhaps the most enduring of these theories: the relationship between the four humors and the four temperaments (Eysenck 1967). These temperaments were based on descriptions of people that seemed to cluster together. This "clustering" was intuitively drawn from what seemed, from day to day experience, to be uniformities in the conduct of people. Galen did not invent the temperaments but merely recorded what he saw as the common wisdom of his time. What he added was a biological basis.

Immanuel Kant (1795), in his Anthropologie, carefully described the characteristics of the four temperaments. Although he did away with the notion of humors as casual agents, he nonetheless conceived of the temperaments as distinct categories. Again, the conceptualization of the temperaments was intuitive, based on one man's experience in the world. The maintenance of discrete categories, while not consistent with the realities of individual differences or human learning, is wholly consistent with a philosophical system which is predicated upon the existence of a priori categories of knowledge.

While Kant saw the temperaments as analogies for two dimensions of "character," activity and feeling, Wundt (Eysenck 1947) used them again metaphorically to distinguish the strong from the weak emotions. Hence the melancholic and choleric types were seen as strongly emotional while the sanguine and phlegmatic types were seen as much less emotional.

Jung (1971) used the terms "introversion" and "extraversion" to characterize general relationships of an enduring nature between types of people and the objects of their psychological processes. Specifically, introverts were characterized by an inward turning of interest away from objects in the external world to their own psychological domain. Extraverts tended to orient outward, showing what Jung described as more movement toward objects external to themselves. He scoffed at notions which characterized introverts as "thinking types" and extraverts as "feeling types" and provided numerous examples of philosophers, theologians and poets who fit each of these types. Jung suggested that Freud espoused an extraverted psychology while

Adler had formulated an introverted one. Eysenck (1947) notes that Jung also worked intuitively and that although he is often credited with the coinage of the terms "introversion" and "extraversion," he merely used terms that had been applied for a long time to personality types.

What Jung did that was novel was to attach the dimension of extraversion to a new biological base. He references a 1902 paper by Gross who speculated about neuronal activity in the brain and psychological processes. Specifically, Gross suggested that cerebral cells discharge tensions and that this leads to a secondary, or rebuilding process. During the time that cells are in a state of discharge or rebuilding they continue to influence psychological processes. According to Gross the "idea" that a cell represents isomorphically would then persist, leading to perseveration. Jung, in applying Gross' theory to introverts and extraverts, felt that introverts were characterized by greater psychic tension and would therefore have more intense primary discharges and prolonged secondary rebuilding processes. Extraverts seemed to be more relaxed, have weaker primary functions, and shorter secondary refractory periods. Ideation would tend to be more intense and persist longer among introverts than extraverts.

This neurophysiological basis is very similar to that of Pavlov (1957) in his theory of the psychophysiology of conditioned reflexes. In Pavlov's system the strength of the nervous system was defined by how rapidly it developed conditioned reflexes and stabilized them under a variety of stimulus situations. The term "strength" reflected the working capacity of the cerebral cells. The Pavlovian concept of

strength of the nervous system has had a strong present day advocate in Gray (1964).

Eysenck (1947, 1960) follows in the tradition of British psychology established by Galton, Kretschmer, and Burt that genetic factors are related to individual differences in personality development. He initiated a series of statistical investigations at Maudsley Hospital in the 1930s using questionnaires and psychological tests. Centroid factor analysis on the matrix of intercorrelations resulted in two orthogonal components or types: emotionality and extraversion. The resulting four groups derived from the interactions of high and low values correspond closely to the four temperaments of Galen. Repeated studies over the next thirty years using a variety of measures and factor analytic techniques have generally resulted in the reproduction of the orthogonal components of extraversion and neuroticism (Eysenck 1967). These dimensions are now generally accepted at a level of personality type. A controversy still remains, however, among various psychometricians, as to whether personality assessment is more reliable and valid at the level of trait or type (Guilford 1975, 1977; Eysenck 1977). This controversy is beyond the scope of the present discussion.

What is presently of concern is how the dimensions might be related to differences in cognitive function and might further differ in attentional styles. Briefly the research on learning and memory differences will be considered and then the psychophysiological literature will be reviewed. In addition, the effects of emotionality will only be briefly considered. This is for three reasons: (1) a

review of the literature reveals that the style of information processing depends on the factor of extraversion (M.W. Eysenck 1981), (2) anxiety appears to function as a confounding variable which differentially affects the efficiency of introverts and extraverts on a variety of tasks (Schwartz 1975; Edmunson & Nelson 1976), (3) in general, emotionality affects the working capacity for attention and memory in accordance with Eysenck's hypothesis.

Briefly, extraversion is associated with a cluster of personality traits that include sociability, impulsivity, activity, liveliness, and excitability (Eysenck 1967). Wilson (1981) reviews a number of studies which, not surprisingly, report that extraverts compared to introverts exhibit greater affiliative behavior. Research has generally found that people identified according to their position on the dimension of introversion-extraversion display the kind of social behavior expected on the basis of popular descriptions of each type. Extraverts tend to be lively, outgoing, sporty, and adventurous; introverts, by contrast, tend to be careful, controlled, quiet and withdrawn. In addition, there is an indication that extraverts are more susceptible to peer influences (Sinha & Ojha 1963), tend to be more popular (Hendrick & Brown 1971), and engage more freely and frequently in interpersonal sexual contacts (Eysenck 1976a). They also tend to become bored more easily (Organ 1975) and prefer higher levels of risk in monetary gambling (Vestewig 1977). There are some important differences in academic performance as well. Typically, introverts learn better in traditional classrooms while extraverts show superiority in less structured group settings (Wilson 1981). Wilson also notes that the academic superiority of introverts only becomes

apparent at the high school level and beyond. Anthony (1977) notes that until age 13 or 14 extraverts tend to exhibit a superior school performance, after which there is a change in favor of introverts. Anthony raises the question as to whether the change is due to the fact that introverted children can apply themselves better in individual studies more typical at higher educational levels, or whether the more academically inclined children become more introverted as they grow older.

This raises some important questions about the nature of the construct of extraversion and its measurement. Eysenck (1947, 1967) has long held that the origins of the difference between introverts and extraverts was genetically determined and biologically based. The identification of individuals along this dimension, however, is accomplished by means of a self-report questionnaire which assesses behavior at phenotypic level. Problems arise since measurement at one level does not necessarily correspond to measurement at the other level.

According to Eysenck's original theory, it was postulated that introverts were characterized by higher levels of cortical excitation and lower levels of inhibition than were extroverts (Eysenck 1947). Conceptually, Eysenck attempted to link this genetic model to the learning models of Pavlov and Hull. As Hull's star faded and as new neurophysiological systems were identified, such as the reticular formation (Lindsley, Bowden, & Magoun 1949), Eysenck revised his model although retained both the genetic component and the concept of differences in arousal. Specifically, the extroversion dimension

was linked to activity in the cortico-reticular loop, which modulates cortical activity, in which introverts were seen as chronically more aroused and extraverts as less aroused. The genetic cornerstone has been supplied through twin studies, adoption studies, and studies of the backgrounds of criminals and psychiatric populations (reviewed in Eysenck 1967).

However, Eysenck (1967) suggests that the primary traits of extraversion, such as sociability and impulsivity, arise from a confluence of a person's genotype with a variety of environmental influences. He admits that self-report measures such as the Eysenck Personality Inventory fail to be direct, unambiguous measures of genotypic status since they assess phenotypic traits. These are strongly influenced by factors such as cognitive set and social desirability. Cross-cultural comparisons have clearly shown that in American society, extraversion is more normative and desirable than in any other country examined (Lynn & Hampson 1975). As a result, it is likely that among some cultural groups, especially Americans, there may be a drift in measurement toward extraversion that would reflect the social desirability of the phenotypic cluster. This might result in the enhanced likelihood of error in selection of groups based on such self-report measures. This becomes especially critical when the outcome measures are not related to social behavior, which might be more closely related to phenotypic traits, but to electrocortical activity and performance, which, according to theory, are more genetically determined.

Such concerns might account for the fact that the hypothesis of differences between introverts and extraverts in cortical arousal

has achieved mixed experimental results. Although initial reports supported the hypothesis that introverts, on EEG measures, exhibited higher levels of cortical arousal (Eysenck 1967; Savage 1964), later reports were divided with some supportive (i.e., Gale, Coles, & Blaydon 1969) and some nonsupportive (Becker-Carus 1971). Stellmack (1981) notes that a good deal of inconsistency in these findings appears to stem from differences in recording, instrumentation, and subject selection. He suggests that the experimental results to date are equivocal and that it would be optimistic to say that, on the basis of the accumulated EEG research, introverts are more aroused than extraverts.

The few studies that have employed evoked potentials have also produced mixed results. The technique involves averaging short segments of EEG that are time-locked to the presentation of a stimulus that is repeated many times (Cooper, Ossleton, & Shaw 1980). Shagass and Schwartz (1965) reported that introverts displayed larger amplitude somatosensory evoked potential components, but an attempt to replicate the results was unsuccessful (Haseeth, Shagass, & Straumanis 1969). Friedman and Meares (1979) found that extraverts exhibited larger late components in response to visual or auditory stimulation. Although the hypothesis that introverts are more "aroused" and therefore more sensitive to stimuli was advanced by Eysenck to account for differences in vigilance performance, evoked potential studies have not thus far been supportive. Friedman and Meares (1979), in accounting for the enhanced evoked potential amplitudes found among extraverts, suggested that they were more "open" to stimulation than introverts.

What is important about the above studies is that the evoked potential was used as a measure of sensitivity to the stimulus rather than as a measure of attention. Stellmack, Achorn, and Michaud (1977), however, had subjects count the series of alternating high and low frequency tones and concomitantly measured the event related potentials. This enhanced the attentional component not present in previous studies. The results are interesting: introverts exhibited larger late component amplitudes at low levels of stimulation, but there were no differences at the high levels. Stellmack et al. (1977) argue that if introverts have enhanced cortical arousal, the difference in attentional performance would be most apparent under conditions of low stimulation. As the level of stimulation is raised, there would be a decrementing in activity among introverts but an increment among extraverts. This is consistent with the theory and findings of Zuckerman, Murtaugh and Siegel (1974) who have identified introverts as reducers of cortical activity in response to increasing stimulation and extraverts as augmenters.

Research has consistently supported the contention that introverts and extraverts differ in the way they process information. On paired associate learning tasks extraverts learn lists on fewer trials (Howarth 1969) and show fewer effects from interference (Bone 1971). Similarly extraverts are also more effective at overcoming distractors in serial list learning (Howarth 1969a). Again, extraverts show fewer effects from interference on tasks with white noise (Hamilton et al. 1972) and show less interference on the Stroop Color Word Test (Davies 1967). Overall extraverts appear to learn more quickly under

interference or in distracting conditions. Gray (1981) suggests that introverts are more susceptible to punishment effects and experience anxiety under conditions of noise. This restricts the range of cues sampled, but also reduces spare processing capacity. As a result, they cannot mobilize sufficient effort to combat the rejection demands of white noise or distraction. In other terms, introverts are more susceptible to response competition.

The differences also extend to memory and general modes of information processing. M.W. Eysenck (1981) has shown that extraverts are better at learning at short retention intervals than introverts. Howarth and Eysenck (1968) found that the number of words recalled by introverts increased at successively longer retention intervals over a 24 hour period. Extraverts showed a corresponding decrease. Eysenck and Eysenck (1979) found that introverts also take longer to access information from long term memory. M.W. Eysenck (1981) has suggested that introverts and extraverts differ in the way they integrate information. Introverts seem to add information from older schemes in long term memory to new material in a type of coding strategy. Extraverts, on the other hand, seem to use a storage strategy in which they fill short term memory to capacity and rehearse.

In considering these two hypothetical strategies, the research on learning and extraversion, and the previous discussion on activation and arousal, some connections appear likely. Since introverts show greater interference effects and more difficulty with short term processing and retrieval they exhibit an attentional style closely related to activation. In contrast extraverts appear to

manifest a short-term highly associated style much like arousal. Indeed numerous studies have shown that introverts are more successful in vigilance experiments (Davies et al. 1969; Keister & McLaughlin 1972; Thackery et al. 1974; Krupski et al. 1971). This follows from Kahneman's model since most of the experiments involve low noise and infrequent signals the attentional bias towards activation would also predict a higher level of performance on this type of task.

It appears, however, that though introverts are far superior in performance on vigilance type tasks, correlations with electrophysiology have met with equivocality. In part this may be due to the focus of most experiments which has been to establish differences in sensitivity and not attention. The one study which attempted to use an attentional paradigm (Stellmack et al. 1977) found relationships between introversion and evoked potential amplitudes at low but not high levels of stimulation. Yet the lack of research relating attentional performance to event related potentials is not limited to the literature on extraversion. Davies and Panasuraman (1977) reviewed the literature at the time and found only three studies correlating some aspect of vigilance performance with evoked potential amplitudes. This is clearly an area that invites more study.

While on the theoretical grounds reviewed above, hypotheses can be made on the lateral bias of introverts, no studies to date have explored this possibility. Similarly, while there are a number of studies which indicate that extraverts are biased towards rapid habituation of the orienting response (reviewed in Stellmack 1981), no studies have explored a possible lateral bias in their attentional

function. According to the speculations by Tucker and Williamson (in preparation) and the evidence presented in this review, extraverts might show a bias towards right hemisphere processing. Since extraverts are superior on short term, highly associated tasks and since they exhibit a higher tolerance for complexity, all of which are characteristic of right hemisphere processing, they might exhibit an attentional bias toward the left sensory field. This is in keeping with Heilman and Van Den Abell's (1979) hypothesis that warning stimuli to the left visual field will result in greater reduction in reaction times with either hand than will warning signals to the right visual field. Since extraverts habituate more rapidly and exhibit a tendency toward phasic alertness, they might be expected to excel on a reaction time task which taps this mode of attention. Forewarned reaction time tasks have been described as excellent measures of phasic alertness (Posner 1975). Since the arousal mode is thought to be more characteristic of right hemisphere processing, extraverts might be expected to exhibit the greatest improvement in reaction times for those trials in which the warning occurs in the left visual field.

Yet in conducting such research, especially with groups identified as introverts and extraverts, additional factors must be considered. The first is that, as Guilford (1975) pointed out, extraversion is composed of a variety of traits of which perhaps only one, impulsivity, is related to attention and evoked potential amplitude. This contention is supported by at least one vigilance study in which the extravert group was divided according to sociability and impulsivity subscores on the Eysenck Personality Inventory (Thackery,

Jones, & Touchstone 1974). In addition, time-of-day has been recognized as an important factor. It has long been known that extraverts perform better later in the day. Revelle, Humphreys, Simon, and Gilliland (1980) found that differences in arousal between introverts and extraverts could be eliminated by counterbalancing according to time-of-day. They also found that caffeine consumption tended to hinder groups during times of poor performance. In a related study, Keister and McLaughlin (1972) found that extraverts, given doses of caffeine (200 mgs.) did not show the performance decrement that usually occurs after 45 minutes on a vigilance task.

Event-Related Potentials

Event-related potentials have been used to study the interface between attention and brain function. The goal has been to classify the relationships between psychological constructs which have been proposed to account for attentional phenomenon (i.e., Treisman & Riley 1969; Deutsch & Deutsch 1963; Norman 1968) and specific components of the brain potentials. The focus of this type of research has been on the later-occurring, endogenous as opposed to the earlier or exogenous components.

The distinction between these two types of components warrants clarification. Donchin, Ritter, and McCallum (1978) provide a clear definition of both types. Exogenous components are short latency (the first 100 msecs.) and are invariant in amplitude and latency for any given stimulus. They occur whether the subject attends or not, is awake or asleep, aroused or relaxed. These components depend on

the neurological integrity of the pathways from receptor surface to cortex and disturbances in form can provide the basis for clinical neurological assessment. They are "exogenous" because they are evoked by sensory events external to the nervous system.

In contrast, endogenous components are long latency features that are nonobligatory in nature. Similar physical stimuli may or may not elicit the components. Moreover, the absence of an expected stimulus may elicit the component. Donichin et al. (1978) note that these components are associated with such factors as subject's expectations, prior experience, intentions and decisions. They are modulated by task parameters and experimental instructions.

Of several specific components, two will be more fully considered here for reasons described below. Of them, the N1 appears to reflect an early selective mechanism based on simple stimulus features, spatial cues, or specific modality without attribution of significance (Picton et al. 1978). Usually occurring about 90 to 110 msecs. for auditory stimuli, peaks in the visual modality occur 20 to 50 msecs. later. In fact, Hillyard, Picton, and Regan (1978) have noted a range of 130 to 180 msecs. for N1 peaks in some experiments. It is most prominent in frontal areas (Picton et al. 1978).

The P3 component is a later-occurring positive deflection with a peak latency of 275 to 600 msecs. following the delivery of task relevant information (Donichin et al. 1978). It is characterized by its scalp distribution and tends to be larger in the central and parietal areas. In contrast to the N1 component, the P3 component appears sensitive to the information content of the stimulus. The

amplitude of the P3 component is closely related to the subject's expectancy and the cognitive evaluation of the stimulus.

It has been proposed that N1 and P3 represent different stages of selection in which the former typifies a "stimulus selection set" while the latter indicates a "response selection set" (Hillyard et al. 1978). When a subject selects between signals and nonsignals which belong to the same channel (visual or auditory) the P3 wave is differentially enlarged to the signal while N1 does not differ between signals and nonsignals (Galambos, Benson, Smith, Shulman-Galambos, & Osier 1975). Shifting attention to the unattended channel will induce an enhancement of N1 with no subsequent change in P3 (Hillyard, Hink, Schwent, & Picton 1973). Pritchard (1981), however, has questioned whether P3 indexes a response set since this component correlates poorly with reaction time or any other motor response. He suggests that P3 reflects stimulus evaluation. Others (Posner 1975; Donchin et al. 1978) have also noted that the P3 wave correlates poorly with actual reaction time but depends more on the subject's ability to predict when a response should occur.

While the hypothesis has been advanced that these components reflect different stages of attention, there is also evidence that the amplitude of these components measures the degree a given stimulus is processed within a limited capacity model (Pritchard 1981). Hillyard et al. (1978) note that several factors increase the N1 amplitudes differentially between attended and nonattended channels. These include stimulus discriminability, intensity, and rate of delivery. When stimuli in an attended channel are of weak intensity, delivered

rapidly, or difficult to discriminate, more processing resources must be committed to the channel to achieve accurate perception. If the resources are limited in capacity, proportionately less would be available for the nonattended channels and the N1 wave is reduced. Also within the allocation model, the P3 wave is sensitive to the frequency and regularity of stimuli. Rare, unpredictable stimuli that are task-relevant elicit larger P3 amplitudes. The P3 amplitude appears to reflect perceptual evaluation of a stimulus; stimuli that require a greater allocation of attention for processing elicit larger amplitude P3 waves (Pritchard 1981). It is difficult to say from the outset what the amplitudes of these event-related potential components measure. The size of the amplitudes can reflect either how the subject allocates attention or how much attention the subject has to allocate.

Statement of the Problem

The problem under consideration in the present study concerns the degree to which the left and right cerebral hemispheres are biased towards specific modes of attention. In reviewing research from a variety of domains, it appears as though activation, or sustained attention, is more characteristic of the left cerebral hemisphere while arousal, or phasic alertness, is more congruent with the functions of the right cerebral hemisphere. Because of the long history of research showing the relationship between introversion-extraversion to attention and learning, this personality dimension has also been included as a between-subject's variable. It is anticipated that

introverts will show a greater superiority of left hemisphere performance on the vigilance task while extraverts will exhibit superior right hemisphere performance on the complex reaction time study. Since there is also some indication that males and females exhibit different cognitive styles (Witkin et al. 1962) and show characteristically different patterns of event related potentials (Buchsbaum, Henkin, & Christiansen 1974), this factor has also been included in the study. Aside from performance measures, event-related potentials will also be measured during this study. Although it is tempting to propose that introverts will exhibit larger amplitude ERP components denoting their greater sensitivity to rare and uncertain stimulus conditions, it is acknowledged that too little evidence exists for such a hypothesis. All that can be said at this point is that it is anticipated that ERP components will be different for the two groups although how they will differ is not known at this time. These considerations warrant the use of nondirectional tests of the hypotheses.

METHODS

Subjects

The subjects included in the study consisted of 42 students enrolled in undergraduate psychology courses at the University of North Dakota. Subjects were selected to form four equal groups of nine subjects each to account for the interaction of extraversion and sex. While thirty subjects participated in both experiments, six subjects dropped out after participating in only one experiment, necessitating the recruitment of six additional subjects. The resulting sample consisted of 22 males (age range 18-30) and 20 females (age range 18-41 years). The Eysenck Personality Inventory (Eysenck & Eysenck 1968) was used to classify individuals as either introverts or extraverts. Introverts were selected on the basis of low scores on the extraversion scale ($\bar{X} = 8.4$; $SD = 1.2$) while extraverts were selected on the basis of high scores ($\bar{X} = 14.32$; $SD = 1.66$). In addition, only those subjects were selected who had low scores on the neuroticism scale (introvert $\bar{X} = 7.4$; extravert $\bar{X} = 7.23$). Subjects were drawn from a large pool of potential participants, created by the regular screening of undergraduate psychology classes over the course of three semesters.

Screening Instrument

The screening was carried out as a collaborative recruiting effort with another doctoral candidate. To meet the needs of both

investigators, the screening instruments consisted of three scales and an additional unstandardized set of 32 questions. For the purposes of the present study only one of the instruments was used in the selection of subjects: the Eysenck Personality Inventory.

The Eysenck Personality Inventory (EPI), Form A (Eysenck & Eysenck 1968), measures two theoretically independent dimensions of extraversion and neuroticism. The Inventory consists of 57 self-descriptive statements with which the subject either agrees or disagrees. The EPI is a further development in the measurement of dimensions assessed by the Maudsely Personality Inventory (MPI) (Eysenck & Eysenck 1968). The authors in the present test manual note that improvements were chiefly in the wording of items so that they could be understood by individuals of low intelligence. In addition, the authors stated that the correlation between extraversion and neuroticism on the earlier MPI was small but marginally significant. Careful item selection on the EPI has reduced the correlation between these two scales to zero. The original MPI scales were constructed on the basis of lengthy and repeated factor analytic studies. The more recent EPI was constructed on the basis of what the authors describe as "about a dozen further" factor analytic studies, one of which included all 108 items which comprise the parallel forms (A and B) of the present scale.

Briefly, individuals who score high on the extraversion scale are seen as more outgoing, impulsive, less inhibited than low scorers. They also have more social contacts and take part in group activities. Low scorers, described as introverts, tend to be more controlled,

reserved, and distrust the momentary impulse. Individuals who score high on the neuroticism scale tend to be more reactive and emotionally labile. Such individuals have difficulty returning to a normal state after emotional experiences. Low scorers on this dimension tend to be more stable emotionally and limit their responsiveness to situations. The subject pool on which these factor analytic studies were constructed is described as exceeding 30,000 drawn from the general population of England and varying in age, sex, socio-economic class, and educational background. Norms for American college students are based on a sample of 1,003 subjects who were administered form A of the Inventory. It is interesting to note that on form A, the mean extraversion score for the American sample ($\bar{X} = 13.1$; $SD = 4.1$) is significantly greater than the mean score of the English student sample ($\bar{X} = 11.1$; $SD = 4.5$), ($t = 0.084$; $df = 1,348$, $p < .0001$).

The manual also provides the results of two test-retest reliability studies in which coefficients of .97 and .82 were obtained on samples tested after nine months and one year respectively. Split-half reliability coefficients for the parallel forms are reported to be .75 for the extraversion scale and .80 for the neuroticism scale. For the combined forms, the coefficients range from .74 to .91. Correlations between the extraversion and neuroticism scales for the American sample are reported to be $-.01$ (form A) and $-.11$ (form B). The authors report that Farley investigated the relationship between extraversion and neuroticism scores in seven separate English samples with a total sample size of 1,478 and obtained a medium r of .004.

The manual further reports factorial, construct and concurrent validity data.

Screening Procedure

During the first two semesters of the recruitment drive, subjects were obtained through a voluntary sign-up procedure. During the last semester, the investigators administered the screening instruments in individual classrooms with the permission of the course instructors. The students were told that the screening was to be carried out to create a pool of potential subjects for some additional psychological experiments. They were informed of the possibility that they might be personally contacted to participate in these experiments. Finally they were told that participation in the screening was voluntary but that such participation would be rewarded with course credit. The directions read to the students regarding the completion of the survey forms may be found in Appendix A. Completed survey forms were carefully checked to make sure that all necessary instructions were followed. The administration time lasted between 25 and 30 minutes.

Creation of a Subject Pool and Subject Selection

Over the course of the entire experiment, 381 students participated in the screening. Two of the surveys were machine-scored by the test-screening service of the University of North Dakota. For the present study, two scores on the EPI were machine derived: the Extraversion Score and the Neuroticism Score. The third score on the EPI, a lie scale, was hand scored by the experimenters. The names,

sexes, phone numbers and scale scores were compiled by an undergraduate investigator into a computer file.

The criteria for inclusion in the present study were either a high or low score on the extraversion scale as well as a low score on the neuroticism scale. In accordance with the extraversion mean score from the American normative sample as reported in the manual, it was decided to use a score of 13 as the lower limit for inclusion in the extraverted group. The introvert sample was composed of individuals who achieved scores of 9 or below, since this was approximately one standard deviation below the mean of the American sample. While subjects were selected on the basis of extreme extraversion scores, they were matched on the dimension of neuroticism. This was carried out since Stellmack (1981) reports that in all studies in which the psychometric independence of extraversion and neuroticism has been established, neuroticism has been unrelated to electrophysiological indices of cortical arousal. However, neuroticism has been related to a subject's emotional reaction to experimental situations and may therefore function as a confounding variable (Gray 1981).

Suitable subjects were then carefully chosen by the experimenter and personally contacted by phone. They were informed that, on the basis of the screening test results, they had been selected to participate in two further experiments. They were informed of the types of tasks they would be doing, the length of time each would involve, and that EEG readings would be carried out during the experiment. They were not told, however, why they had been chosen.

One point deserves special mention. Over the course of the screening it was found that subjects who displayed both an extreme

score on extraversion and a low score on neuroticism were a rarity among the population screened. Because of this it was essential that those individuals who were identified as appropriate to the present study be encouraged to participate. Every effort was made to achieve this end. They were told that their personal involvement was crucial, that they had been carefully selected on the basis of their particular test performance, and that they would be treated with respect and with attention to their comfort. They were further told that since it was important to the experiment that they perform to their capacity, the experimenter would answer any and all questions--except about the survey results and why they had been chosen. They were, however, fully debriefed at the end of the final experimental session.

In all, forty-two subjects participated in the experiment, and thirty of the first thirty-six (83%) took part in both studies. Two potential subjects refused to participate outright and four others failed to follow through on commitments to participate. Overall, then, 88% of those asked to participate in the experiment, took part in at least one of the studies.

General Subject Running Procedures

The experiments were carried out at the Neuropsychology Laboratory in the Human Nutrition Laboratory, a facility of the United States Department of Agriculture in Grand Forks, North Dakota.

Most of the actual running of subjects was carried out by two doctoral level psychology students who were naive to the group classification of the subjects.

To measure electrophysiological response, electrodes were applied to the subjects' scalp using a subset of the International 10-20 System. This consisted of frontal, mid temporal, parietal and occipital locations bilaterally placed. Linked ear lobes served as reference points and a vertex electrode served as a ground. Gold cup electrodes were applied using collodion and a compressed-air applicator. The scalp was abraded through each electrode using a Leur Stub adapter, and a conductive saline jelly was injected. Electrode impedance was then measured using a Grass Company impedance meter. All electrode impedances were kept below 5 k ohms.

At this point the subject was brought to the experimental chamber, an electrically shielded enclosure with controlled lighting and acoustics. Once the subject was seated and specific procedures explained (see Appendices for specific task instructions), they were instructed to relax, close their eyes, and the lights were turned off. A ten-second sample of EEG was then collected, a hard copy was printed and stored in a run-log. Adjustments to the electrodes, if necessary, were made, final instructions given, and the session was begun. The subjects' performance was continuously monitored both by direct visual observation through a window and by the record of responses displayed on the CRT screen of the computer terminal. At the end of the session the subject was again instructed to close eyes and relax while an additional ten-second sample of EEG was obtained.

Raw EEG signals are amplified at a .1 second calibrated time constant with an optically isolated, AC coupled amplifier powered by rechargeable batteries. The analog to digital conversion system has

a 10 bit resolution and runs at a basic rate of 128 samples per second per channel to accurately reflect the higher frequency components of the ERPs.

The raw EEG was stored magnetic tape and edited at a later date. The editing procedure involved visually scanning segments for the detection and removal of artifacts. These primarily included corneo-retinal potentials created by eye movements, electromyographic activity, and bursts of high-amplitude alpha activity. This latter artifact was problematic in records of subjects who became bored, inattentive, or fell asleep during the sessions. The good data was then transferred to an edit tape. Event Related Potentials were computed by a computer program which was a standard part of the data handling at the Neuropsychology Laboratory. For the purposes of the present study, data from the left and right frontal (F3, F4) and parietal (P5, P6) electrodes were analyzed.

Basically, the ERP wave forms constructed by this program were the arithmetic averages of each of the 128 data points over all of the one second segments of EEG. The resulting wave forms were then reviewed by the experimenter and an experienced EEG technician employed by the Neuropsychology Laboratory. Using another software program that was a standard part of the data handling system in the laboratory, the latencies and amplitudes of specific peaks and troughs were extracted from the wave forms. These included a positive peak at approximately 100 msec. (80-120 msec. range); the first major negative shift which occurred between 150 and 200 msec. (N1); the major positive peak occurring between 250 and 450 msec. (P3);

and the trough which marked the greatest negative shift after the P3. For the purposes of the present study, the amplitudes of the N1 and P3 components were further analyzed.

Vigilance

Apparatus

Two lateralized red diodes served as signal stimuli in this experiment. These diodes were mounted on a ledge at eye level and approximately 40 inches from the seated subject. Each of the lights was placed at a distance of 11.5 inches either to the right or left of a central fixation point in order to subtend 16° of visual angle. Micro-switches were mounted on both the right and left arm rests of the chair. Subjects were seated in the dark, instructed to gaze straight ahead, but able to see the two lateralized red diodes in the periphery. Signals consisted of a brightening of one of the two lights for a period of 200 msec. The brightening was achieved by increasing the voltage in the diodes from 12v to 14v. When subjects saw a brightening of the light in the right visual field, they were instructed to depress the right hand switch, depressing the switch in their left hand for signals in the left visual field.

The experimental period lasted 60 minutes. During this time fifty signals were presented, twenty-five on each side in a quasi-random sequence. Each signal was randomly allocated to a point within the fifty 72-second periods into which the experimental period was conceptually divided. Interstimulus intervals ranged from 10 seconds to 134 seconds. The randomization of signal presentation was computer generated.

Mean detection scores and the number of false positives (defined as a response occurring more than 10 seconds after the last signal at a relevant source) were recorded in each of four consecutive periods, each of which was fifteen minutes in duration. Electro-cortical activity was recorded with the onset of each signal and continued for one second. The fifty samples of EEG thus obtained were averaged over trials after editing to yield one Event Related Potential (ERP) wave form for each of the eight channels.

The data analysis for the vigilance experiment consisted of analysis of variance of both performance and ERP data. The analysis of variance of performance data was a four-factor mixed design with sex and personality as between-subject variables and laterality of signal and time period as within subject measures. For the ERPs, amplitudes of the N1 component and P3 component were analyzed for the frontal and parietal locations. This also yielded a four-factor mixed design with sex and personality crossed with ERP locations defined as anterior-posterior and right-left. Pearson product-moment correlations were also computed between each of the ERP components and the total correct detections. Separate sets of correlations were computed for the total sample, males and females, introverts and extraverts.

Complex Reaction Time

Apparatus

Two diodes that emitted a red light served as lateralized warning stimuli, and a centrally placed diode that emitted a green light

served as a reaction time stimulus. The warning stimuli were placed on a blackboard on either side of the reaction time stimulus, each at such distance necessary to subtend 16° of visual angle from the reaction time stimulus, about 11.5 inches. The times started at the onset of the green light and was stopped when the microswitch was released. The order of stimulus presentation, duration of the stimuli, and the inter-trial intervals was controlled by the computer.

Since factors such as time-of-day, caffeine consumption, and tobacco use have been shown to be confounding variables in previous research with extreme groups of introverts and extraverts, an effort was made to control for these variables. Subjects were counterbalanced in a quasi-random fashion so that half of each group was tested in the morning and half during the evening hours. The use of tobacco and caffeine was carefully recorded.

An experimental trial began with a tone, which served as a signal to depress the microswitch, fixate on the central stimulus and wait for the green light to turn on. The waiting period between the tone and the onset of the red warning light, when present, or the green light, during trials in which there were no warnings, was 12, 18, or 22 seconds. These lengthy waiting periods were used since the tone is to serve as a signal to fixate and not as a warning stimulus itself. The stimulus sequence included either a left or right red light (lateralized warning stimulus) or no warning followed by a central green light (reaction time stimulus). There was either a one or two second foreperiod between the warning stimulus and the reaction time stimulus. When the green light turned on, the subject released the

microswitch, stopping the clock and turning off both the lateralized warning stimulus and the reaction time stimulus. There was a consistent interval of 10 seconds between the termination of one trial and the next tone. Subjects were carefully trained in the task. The experiment was begun once the subject had passed three trial items in a row.

Counterbalancing and randomizing for warning stimulus, waiting period and foreperiod resulted in 90 trials for each hand. In addition, the hand used first was counterbalanced across subjects. To ensure the subjects' cooperation and make sure that they fixated and were not scanning, they were observed continuously in the manner described above.

Data Analysis

In keeping with the Heilman and Van Den Abell study, mean reduction in reaction time served as the dependent measure in the analysis of variance. For each of the four combinations of warning stimulus and foreperiod, there were 15 reaction times per hand for each subject. These fifteen times were averaged and the average time was subtracted from the average time obtained without a warning stimulus, resulting in a mean reduction of reaction time. The resulting analyses of variance had as independent variables, the between-subjects effects of personality and sex, and the within-subjects effects of laterality warning stimulus, and hand of response.

Event Related Potentials

The recording of visual ERPs began with the onset of the lateralized warning stimuli and continued for 1 sec. ERPs were recorded

for each trial yielding a total of 180. These were averaged separately for each block of trials. This yielded two averages, each based on 90 trials. Since use of hand has not been shown to influence ERPs, only the ERPs obtained during the left hand block of trials were analyzed. This was done to reduce the redundancy and size of the data set. Both amplitude of the N1 and P3 components of the averaged ERPs served as dependent measures for this portion of the analysis. The resulting analysis of variance was the same as in the vigilance study. Correlations between ERP components and the average improvement in reaction time were compiled in a manner similar to the vigilance study.

Statistical Analysis

Computer files were created for each of the studies. Performance data and the digitized values of ERPs for each of the eight channels of EEG were stored on magnetic tape. For the Vigilance Study, the performance data included the number of correct detections for each visual half-field by each of the four time periods, as well as the number of false positives for each time period. For the complex reaction time study, the stored performance data included the mean reaction time for the trials in which there was a left-side warning, a right-side warning, or no warning. Mean reaction time improvement scores were computed by subtracting the values for each of the warned conditions from the unwarned condition. The mean improvement obtained for each subject score was used for all subsequent analysis. The digitized values of both the P3 and N1 ERP components were log-transformed. This is an accepted method for reducing the extreme range of

variation and correcting the skewed distribution of the raw data (Tukey 1978).

Four-way analyses of variance were carried out on the main performance variables (correct detections and mean reaction time improvement) and the common logarithms of the ERP P3 and N1 components according to the procedure for mixed models described by Myers (1979). The Chi-Square test used to analyze the false positive data is described by Siegel (1956). The correlations computed between performance variables and the P3 and N1 components of the ERPs is described by Bruning and Kintz (1968). Finally, post-hoc analyses were carried out on these interactions which achieved significance on the analyses of variance. Duncan's Multiple Range Test (Bruning & Kintz 1968) was used to assess the significant differences between the means of independent groups. To test for significant changes within each group, Bonferroni's t-statistic (Wike 1971) was employed.

RESULTS

Vigilance

Means and standard deviations for the behavior and electrophysiological measures are presented in Table 1. The analysis of variance on the number of correct detections on the vigilance task resulted in no significant differences between groups. Significant main effects for the within-subject variable of Time Period was demonstrated ($F = 6.52$; $df = 3,96$; $p < .001$). A laterality effect was observed although this failed to achieve a suitable level of significance ($F = 3.88$; $df = 1,32$; $p > .1$, $< .05$). A significant four-way interaction was demonstrated between sex, personality, laterality and time period ($F = 5.84$; $df = 3,96$; $p < .005$). The summary table on the correct detections is presented in Table 2.

Duncan Multiple Range Tests were carried out comparing mean correct detections between groups in each time period and within each visual field. In the left field, male introverts significantly out-performed female introverts in the first time period, although the reverse was true by the third time period. In the right visual field, female introverts significantly out-performed male introverts in the first time period, but again the reverse held true for the third time period.

Bonferroni t-tests were carried out for each group, for each visual field, over time. A change over time was found for the

Table 1. Vigilance: Descriptive Statistics--Outcome Measures
by Sex and Personality

Measures	Groups							
	Male Introvert		Male Extravert		Female Introvert		Female Extravert	
	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>
Correct Detections	44.11	6.19	38.56	9.94	43.66	6.87	40.11	10.11
<u>N160</u>								
F3	-32.29*	28.86	-18.19	22.35	-43.54	37.64	-59.52	80.12
F4	-31.19	28.21	-13.42	33.65	-53.21	52.61	-51.06	93.77
P5	-50.76	58.71	-44.56	39.39	-59.09	58.56	-68.95	46.11
P6	-41.86	47.63	-47.30	45.99	-54.19	60.59	-66.91	47.21
<u>P300</u>								
F3	63.86	64.13	133.89	111.90	134.98	54.71	147.69	54.89
F4	67.48	47.75	120.84	87.36	150.98	71.23	163.59	64.74
P5	162.02	82.28	151.21	91.41	210.85	93.06	160.46	79.63
P6	217.45	89.60	160.24	77.43	224.72	89.31	192.35	70.65

*In microvolts

Table 2. Analysis of Variance Summary Table--Vigilance: Correct
 Detections by Sex and Personality with Laterality and
 Time Period

Source	SS	df	MS	F
Total	843.32	237		
Between Subjects	311.32	35		
Within Subjects	532.0	252		
Extraversion (IE)	23.35	1	23.35	2.61
Sex (MF)	.35	1	23.35	<1
IE x MF	1.12	1	1.12	<1
ERROR BS	286.50	32	8.95	
ERROR WS	415.0	224	1.85	
Laterality (RL)	5.01	1	5.01	3.88
RL x IE	2.35	1	2.35	1.82
RL x MF	.35	1	.35	<1
RL x IE x MF	.12	1	.12	<1
ERROR RL	41.29	32	1.29	
Time	16.24	3	5.41	6.52**
Time x IE	1.84	3	.61	<1
Time x MF	6.06	3	2.02	2.43
Time x IE x MF	.14	3	.05	<1
ERROR Time	79.86	96	.83	
RL x Time	4.57	3	1.52	<1
RL x Time x IE	1.96	3	.65	<1
RL x Time x MF	24.52	3	8.17	2.67
RL x Time x IE x MF	53.67	3	17.89	5.84**
ERROR RL x Time	294.02	96	3.063	

**p < .01
 ***p < .001

performance of female introverts in the right visual field in which the mean numbers of correct detections for the first two time periods were significantly higher than that found in the third period (both $p < .05$). The mean number of correct detections for each time period by the male and female introverts are presented in Figure 1.

Although the latencies of the early and late components of the ERPs were not objects of study in the present experiments, averages were computed for descriptive purposes. The early negative component had a mean latency across both experiments of 160.83 msec. (range: 142.67 to 192.90 msec.). Because of this, it will hereafter be described as the N160 component. The late positive component had a broad range from 275 msec. to 640 msec. In order to simplify labeling and to make the present results interpretable in light of the larger psychological literature on ERPs, this component will be referred to as P300.

The analysis of variance summary table for the N160 component of the ERP obtained during vigilance is presented in Table 3. No between-subjects effects were found although a significant within-subjects difference between N160s obtained from the anterior (F3, F4) and posterior (P5, P6) locations. The amplitude of the N160 was significantly larger when measured in the parietal area than in the frontal area. An interaction effect between personality and anterior-posterior location failed to achieve suitable significance.

The analysis of variance on the amplitude of the P300 component obtained during the vigilance study is summarized in Table 4. A main effect was demonstrated for sex ($F = 4.33$; $df = 1,32$; $p < .05$) in which

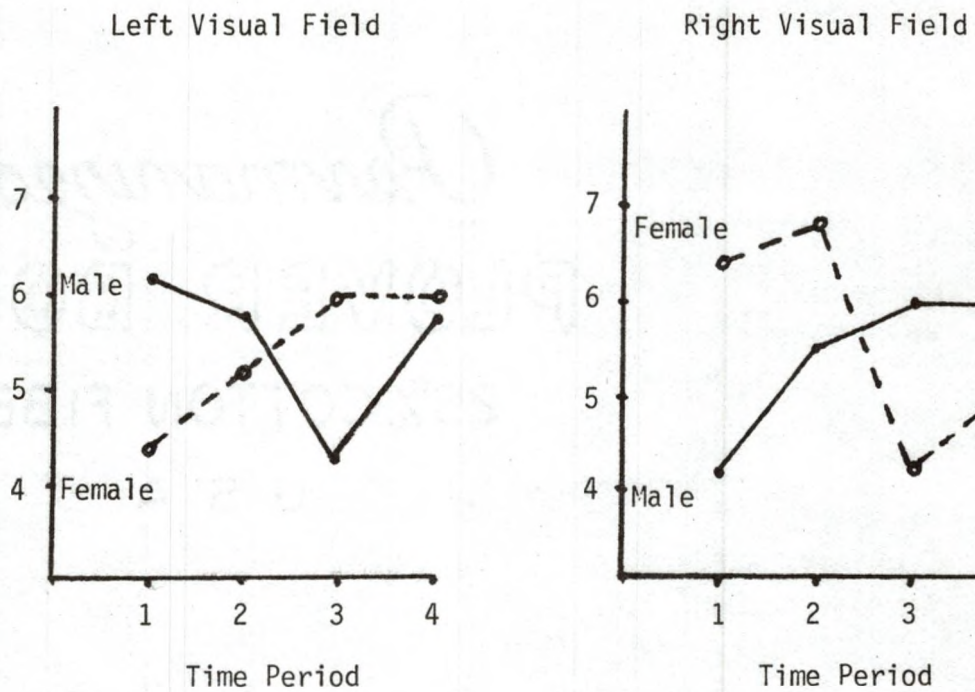


Figure 1. Mean correct detections on the vigilance task by male and female introverts for each visual half-field over time.

Table 3. Analysis of Variance Summary Table--Vigilance: N160
 Amplitude (Log Transformed Values) of ERP's by Sex and
 Personality with Anterior-Posterior and Right-Left
 Electrode Locations

Source	SS	df	MS	F
Total	12.378	143		
Between Subjects	6.333	35		
Within Subjects	6.045	108		
Extraversion (IE)	.088	1	.088	< 1
Sex (MF)	.105	1	.105	< 1
IE x MF	.00145	1	.00145	< 1
ERROR BS	6.1385	32	.192	
ERROR WS	5.13	84	.061	
Anterior-Posterior (AP)	.489	1	.489	5.26**
AP x IE	.316	1	.316	3.40
AP x MF	.010	1	.010	< 1
AP x IE x MF	.024	1	.024	< 1
ERROR AP	2.989	32	.093	
Right-Left (RL)	.009	1	.009	< 1
RL x IE	.0003	1	.0003	< 1
RL x MF	.009	1	.009	< 1
RL x IE x MF	.00025	1	.0025	< 1
ERROR RL	.8398	32	.026	
AP x RL	.0079	1	.0079	< 1
AP x RL x IE	.0079	1	.0047	< 1
AP x RL x MF	.021	1	.021	< 1
AP x RL x IE x MF	.028	1	.028	< 1
ERROR AP x RL	1.302	32		

Table 4. Analysis of Variance Summary Table--Vigilance: P300
Amplitude (Long Transformed Values) of ERP's by Sex
and Personality with Anterior-Posterior and Right-Left
Electrode Location

Source	SS	df	MS	F
Total	10.80	143		
Between Subjects	4.98	35		
Within Subjects	5.82	108		
Extraversion (IE)	.037	1	.037	<1
Sex (MF)	.576	1	.576	4.33*
IE x MF	.107	1	.107	<1
ERROR BS	4.26	32	.133	
ERROR WS	3.44	84	.041	
Anterior-Posterior (AP)	1.19	1	1.19	16.59***
AP x IE	.535	1	.535	7.46*
AP x MF	.300	1	.300	4.18*
AP x IE x MF	.155	1	.144	2.16
ERROR AP	2.2948	32	.07	
Right-Left (RL)	.0876	1	.0876	4.39*
RL x IE	.0150	1	.0150	<1
RL x MF	.0135	1	.0135	<1
RL x IE x MF	.0432	1	.0432	2.17
ERROR RL	.63815	32		
AP x RL	.005	1	.005	<1
AP x RL x IE	.035	1	.035	2.19
AP x RL x MF	.007	1	.007	<1
AP x RL x IE x MF	.003	1	.003	<1
ERROR AP x RL	.510	32	.016	

*p < .05
***p < .001

the mean P300 amplitudes were generally larger in females. The amplitude of the P300 component was also generally larger in the parietal area compared to the frontal area ($F = 16.59$; $df = 1,32$, $p < .001$) and over the right hemisphere compared to the left ($F = 4.39$; $df = 1,32$; $p < .05$). Interaction effects were demonstrated for extraversion and the anterior-posterior dimension ($F = 7.46$; $df = 1,32$; $p < .05$) and sex crossed with the anterior-posterior dimension ($F = 4.18$; $df = 1,32$; $p < .05$).

Duncan tests, carried out on the interaction between extraversion and the anterior-posterior dimension, revealed no significant interactions between groups. Bonferroni t-tests, however, revealed that introverts had significantly higher mean P300 amplitudes in the posterior regions than in the anterior ones. Extraverts showed no such differences. These results are graphically represented in Figure 2.

Duncan tests carried out on the interaction between sex and the anterior-posterior dimension demonstrated that female subjects had significantly higher mean P300 amplitudes over the anterior regions than male subjects. There were no between-group differences found for the posterior P300 amplitudes. Bonferroni tests on the male sample revealed that the mean P300 amplitudes over the parietal areas were significantly larger than those recorded over the frontal areas. Among the female sample, no such anterior-posterior differences were found.

The frequency data on false positives by each group and across the four time periods are presented in Table 5. Examination revealed that females exhibited obviously more false positives than males. Female introverts made more of these errors than female extraverts.

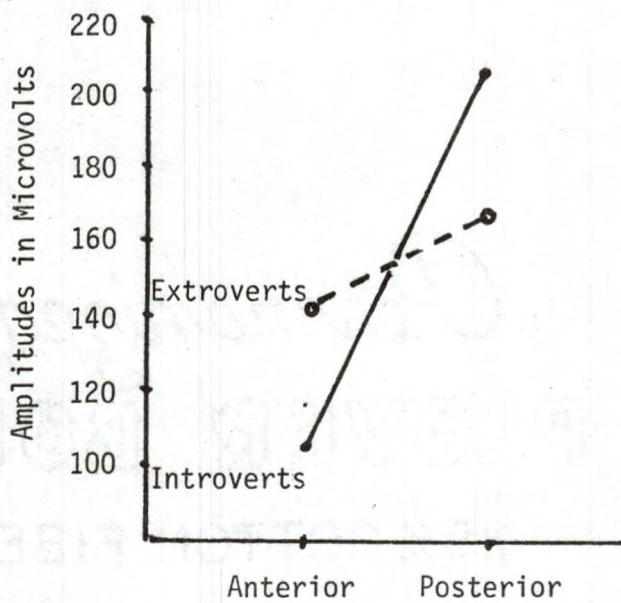


Figure 2. Mean amplitude of the P300 component according to either anterior or posterior electrode location, by personality, on the Vigilance task.

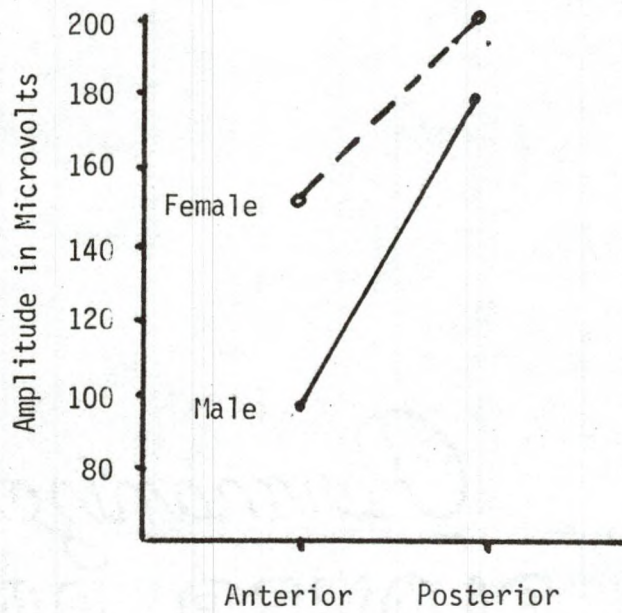


Figure 3. Mean amplitude of the P300 component according to either anterior or posterior electrode location, by sex, on the Vigilance task.

Table 5. Vigilance: Frequency of False Positives by Groups and Time Period

Group	Time Period				Total
	1	2	3	4	
Male Introverts	4	2	1	1	8
Male Extraverts	1	1	2	1	5
Female Introverts	100	7	1	1	109
Female Extraverts	35	4	4	2	45

Pearson product-moment correlations between the N160 amplitudes and the total number of correct detections are present in Table 6. Significant correlations were obtained for all subjects with the N160 amplitudes found in the parietal areas of both hemispheres. This was apparently due to a sex-related effect since significance was also obtained for the posterior locations for the male but not female sample. This was differently distributed for introverts and extraverts. Introverts showed a significant relationship between detection accuracy and the N160 component measured in the right parietal area, while extraverts showed a stronger relationship between correct detections and the N160 of the left parietal area.

Pearson product-moment correlations between the P300 amplitudes and the total number of correct detections are presented in Table 7. For the total sample, significant correlations were obtained between correct detections and the P300 amplitudes found in the parietal areas of both hemispheres. While males also exhibited this same pattern of significant correlations, females were markedly different. They exhibited significant correlations between detection accuracy and the P300 amplitudes over both frontal areas and the right parietal area. While introverts mimicked the pattern of the male response, extraverts showed a relationship between the right hemisphere amplitudes and detection accuracy.

Complex Reaction Time

Means and standard deviations for the behavioral and electrophysiological measures are presented in Table 8. The analysis of variance for the performance measures of the complex reaction time

Table 6. Pearson Product-Moment Correlations--Vigilance: Total
Correct Detections and N160 Amplitudes

	F3	EEG Channel		
		F4	P5	P6
All Subjects (N=36)	.12	.05	.42*	.47*
Males (N=18)	.21	.19	.66**	.67**
Females (N=18)	.11	-.03	.19	.31
Introverts (N=18)	.10	.02	.46	.67**
Extraverts (N=18)	.10	-.14	.54	.40

*p < .05

**p < .01

Table 7. Pearson Product-Moment Correlations--Vigilance: Total
Correct Detections and P300 Amplitudes

	EEG Channel			
	F3	F4	P5	P6
All Subjects (N=36)	.09	.26	.51	.61**
Males (N=18)	-.01	.06	.71**	.66**
Females (N=18)	.56*	.67**	.33	.56*
Introverts (N=18)	.09	.17	.73*	.63*
Extraverts (N=18)	.38	.54*	.25	.57*

*p < .05

**p < .01

Table 8. Complex Reaction Time: Descriptive Statistics--Outcome
Measures by Sex and Personality Types

Measure	Group							
	Male Introvert		Male Extravert		Female Introvert		Female Extravert	
Reaction Time	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>
RH/RW	162.22*	53.89	156.55	50.81	128.67	36.11	175.89	70.78
RH/LW	156.00	54.71	156.78	51.78	134.00	32.35	162.56	50.99
LH/RW	158.89	53.11	179.66	44.78	138.67	78.44	153.89	41.92
LH/LW	156.77	48.79	180.11	45.96	142.00	74.30	153.22	37.53
<u>N160</u>								
F3	-46.50**	27.78	-27.16	45.06	-75.81	31.83	-56.53	70.09
F4	-60.27	42.09	-29.09	64.50	-90.43	34.43	-85.50	75.69
P5	-114.81	40.22	-53.59	58.59	-80.64	39.05	-86.81	69.56
P6	-116.99	46.36	-69.55	77.79	-67.62	48.86	-98.92	52.25
<u>P300</u>								
F3	45.32	74.16	36.33	47.94	108.14	81.46	105.48	89.04
F4	58.71	67.28	26.15	44.33	94.17	72.27	102.89	105.87
P5	198.18	69.75	121.09	38.44	124.01	60.50	145.10	66.62
P6	210.29	73.70	134.46	28.54	123.35	42.78	173.52	68.48

*in msecs.

**in microvolts

are summarized in Table 9. Improvement in reaction time with a lateralized warning signal served as the dependent measure. None of the main effects or interactions demonstrated significant results. The interaction between sex, extraversion, and laterality of the warning signal approached but did not achieve significance.

The analysis of variance for the N160 component of the ERP obtained during the left hand trials of the complex reaction time task is presented in Table 10. A significant between-groups main effect was demonstrated for extraversion. Introverts showed higher mean N160 amplitudes than did extraverts ($F = 6.08$; $df = 1,28$; $p < .05$). A significant within-groups main effect was again demonstrated for the anterior-posterior dimension ($F = 8.33$; $df = 1,28$; $p < .01$). A significant interaction was found for sex and anterior-posterior location ($F = 4.59$; $df = 1,28$; $p < .05$).

Duncan tests carried out by the sex by anterior-posterior interaction showed that, over the frontal areas, female subjects had significantly higher N160 amplitudes than male subjects. No such differences were found for the parietal recordings. Bonferroni tests revealed that, among the male sample, the mean N160 amplitudes were significantly larger over the parietal compared to the frontal regions. No anterior-posterior differences were found for the female sample. These results are graphically represented in Figure 4.

The analysis of variance for the P300 component of the ERP, obtained during the Complex Reaction Time task, is summarized in Table 11. No significant between-groups effects were found. Again the main effect for the anterior-posterior dimension attained significance

Table 9. Analysis of Variance Summary Table--Complex Reaction
Time: Mean Reduction in Reaction Time by Sex and Per-
sonality with Hand and Laterality of Warning

Source	SS	df	MS	F
Total	392515.1	143		
Between Subjects	302291.3	35		
Within Subjects	90223.8	108		
Extraversion	11253.6	1	11253.6	1.28
Sex	7845.9	1	7846.9	<1
1E x MF	2232.6	1	2232.6	<1
ERROR BS	280958.6	32	8779.9	
ERROR WS	81242.1	96	846.3	
Hand	525.1	1	525.1	<1
Hand x 1E	.2	1	.2	<1
Hand x MF	1841.9	1	1841.9	<1
Hand x 1E x MF	5439.1	1	5439.1	2.45
ERROR Hand	71012.1	32	2219.1	
Warning	95	1	85	<1
Warn x 1E	105	1	105	<1
Warn x MF	3.1	1	3.1	<1
Warn x 1E x MF	564.4	1	564.4	3.48
ERROR Warn	5186.8	32	162.09	
Hand x Warn	126.6	1	126.6	<1
Hand x Warn x 1E	65.5	1	65.5	<1
Hand x Warn x MF	22.7	1	22.7	<1
Hand x Warn x 1E x MF	193.1	1	193.1	1.23
ERROR Hand x Warn	5043.3	32	157.6	

Table 10. Analysis of Variance Summary Table--Complex Reaction
Time: N160 Amplitude (Log Transformed Values) of ERP's
by Sex and Personality with Anterior-Posterior and
Right-Left Electrode Locations

Source	SS	df	MS	F
Total	12.11	127		
Between Subjects	5.66			
Within Subjects	6.45			
Extraversion (IE)	.852	1	.852	6.08*
Sex (MF)	.421	1	.421	3.02
IE x MF	.477	1	.477	3.42
ERROR BS	3.91	28	.140	
ERROR SW	4.84	84	.058	
Anterior-Posterior (AP)	.816	1	.816	8.33**
AP x IE	.085	1	.085	<1
AP x MF	.450	1	.450	4.59*
AP x IE x MF	.050	1	.050	<1
ERROR AP	2.751	28	.098	<1
Right-Left (RL)	.0045	1	.0045	<1
RL x IE	.0001	1	.0001	<1
RL x MF	.02	1	.02	<1
RL x IE x MF	.061	1	.061	1.27
ERROR RL	1.3516	28	.048	
AP x RL	.0003	1	.0003	<1
AP x RL x IE	.073	1	.073	2.81
AP x RL x MF	.055	1	.055	2.12
AP x RL x IE x MF	.017	1	.017	<1
ERROR AP x RL	.738	28	.026	

*p < .05

**p < .01

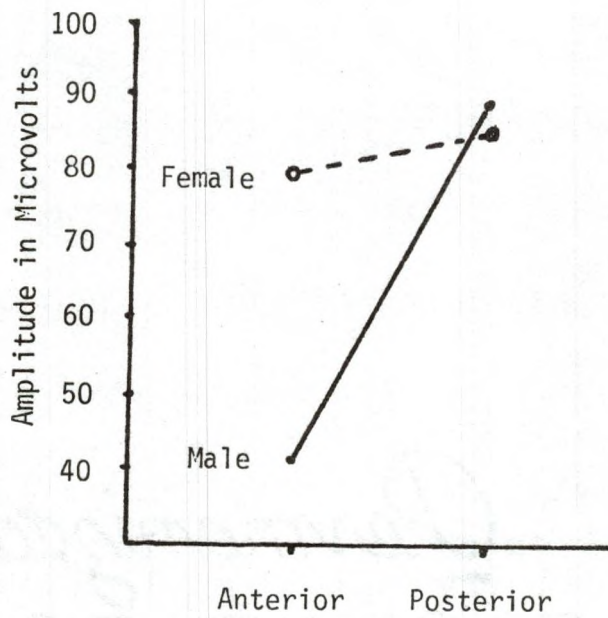


Figure 4. Mean amplitude of the N160 component according to either anterior or posterior electrode location, by sex, on the Complex Reaction Time task.

Table 11. Analysis of Variance Summary Table--Complex Reaction
Time: P300 Amplitudes (Log Transformed Values) of
ERP's by Sex and Personality with Anterior-Posterior
and Left-Right Electrode Locations

Source	SS	df	MS	F
Total	9.635	127		
Between Subjects	2.685	31		
Within Subjects	6.95	96		
Extraversion (IE)	.0042	1	.0042	<1
Sex (MF)	.234	1	.234	2.72
IE x MF	.028	1	.028	<1
ERROR BS	2.419	28	.086	
ERROR WS	4.25	84	.051	
Anterior-Posterior (AP)	1.793	1	1.793	22.70***
AP x IE	.014	1	.014	<1
AP x MF	.555	1	.555	7.03*
AP x IE x MF	.114	1	.114	1.44
ERROR AP	2.2003	28	.079	
Right-Left (RL)	.034	1	.034	<1
RL x IE	.014	1	.014	<1
RL x MF	.034	1	.034	<1
RL x IE x MF	.034	1	.034	<1
ERROR RL	1.141	28	.041	
AP x RL	.001	1	.001	<1
AP x RL x IE	.043	1	.043	1.33
AP x RL x MF	.041	1	.041	1.25
AP x RL x IE x MF	.021	1	.021	<1
ERROR AP x RL	.909	28	.03	

*p < .05

***p < .001

($F = 22.70$; $df = 1,28$; $p < .001$). The interaction between sex and anterior-posterior dimension also attained significance ($F = 7.03$; $df = 1,28$; $p < .025$).

Duncan tests carried out on the sex by anterior-posterior interaction achieved results similar to previous analyses. The mean amplitudes of the P300 recorded over the frontal areas were significantly higher in females than in males although no such differences were found in the parietal regions. Bonferroni tests also achieved results similar to those previously obtained in that the single significant difference was created by the male sample (posterior > anterior, $p < .05$). These results are graphically shown in Figure 5.

Pearson product-moment correlations between the N160 amplitudes and the mean reaction time improvement scores are presented in Table 12. Only one of these correlations achieved significance. For the male sample, there was a significant, negative relationship between the amplitude of the N160 component recorded over the right parietal area and mean reduction in the left hand reaction time.

Correlations between the P300 amplitudes and reaction time improvements are presented in Table 13. Once again the only correlation to achieve an acceptable level of significance was for the interaction noted above. Improvement in left hand reaction time for the male sample was negatively related to the amplitude of the P300 component measured over the right parietal area.

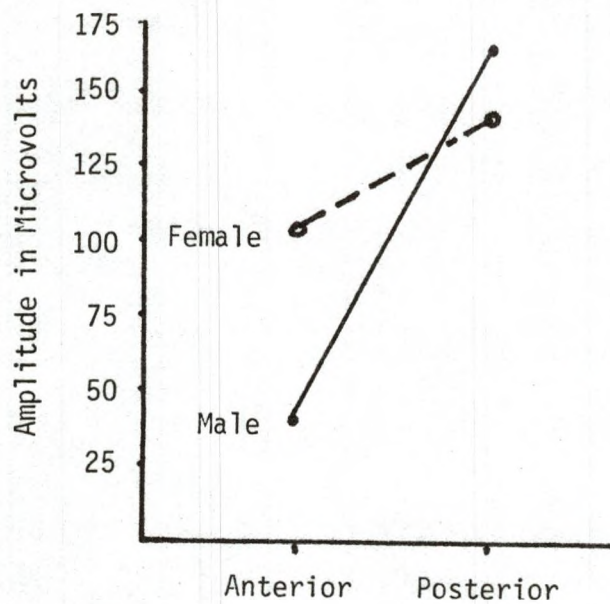


Figure 5. Amplitude of the P300 component according to either anterior or posterior electrode location, by sex, on the Complex Reaction Time task.

Table 12. Pearson Product Moment Correlations--Complex Reaction
Time: Mean Reduction in Left Hand Time and N160
Amplitudes

	EEG Channel			
	F3	F4	P5	P6
All Subjects (N=32)	-.03	-.08	-.24	-.13
Males (N=16)	-.22	-.18	-.42	-.53*
Females (N=16)	.30	.26	.10	.19
Introverts (N=16)	.25	.07	.31	.39
Extraverts (N=16)	-.16	-.12	-.15	-.19

*p < .05

Table 13. Pearson Product-Moment Correlations--Complex Reaction
Time: Mean Reduction in Left Hand Time and P300
Amplitudes

	EEG Channel			
	F3	F4	P5	P6
All Subjects (N=32)	.12	-.10	-.22	-.15
Males (N=16)	.35	-.23	-.40	-.60*
Females (N=16)	.13	.10	.15	.06
Introverts (N=16)	.10	-.18	-.17	-.07
Extraverts (N=16)	.17	.03	-.23	-.25

*p < .05

DISCUSSION

The concern of the present study was the degree of relationship between activation and arousal and lateralized brain function. It was hypothesized at the outset that these modes of attention were lateralized and that these biases would be enhanced by using extreme groups of introverts and extraverts.

The vigilance paradigm was employed to study sustained attention which inferred to be analogous to Pribram and McGuinness' (1975) concept of activation. The specific hypothesis stated that detection accuracy on a vigilance task would be superior for stimuli in the right visual field. This was indicated since the left cerebral hemisphere seemed to be more suited toward a tonic mode of attention closely related to motor readiness. It was further hypothesized that introverts would show an increased discrepancy in lateralized performance, favoring the right visual field, while extraverts would show an inferior right visual field performance. In actuality, these hypotheses were not supported by the obtained results. In both performance and electrophysiological measurements, the interaction between sex and personality variables resulted in a complex pattern of significant results.

The most often cited generalization concerning introverts and extraverts is that the former are better watch-keepers (cf. Eysenck 1967). The present results fail to provide support for that generalization. Although introverts, as a group, displayed a slight

superiority, this was far from significant. It was also noted that the variation in performance among extraverts was substantially, although not significantly, larger than that observed among introverts. Such results invite the speculation as to whether they reflect sampling error or the presence of actual trends too weak to achieve significance under the present conditions and with so few subjects. It must be reiterated, however, that time-of-day was counterbalanced across subjects in such a way that half of each group was tested at favorable and half at unfavorable times. In addition, caffeine and nicotine consumption were comparable between groups. Previous research (Revelle et al. 1980) has found that once factors such as time-of-day, caffeine consumption, and nicotine use are controlled, significant vigilance performance differences between introverts and extraverts may disappear.

The first major hypothesis that there would be a general right visual superiority in vigilance performance was not supported by a significant F , but the obtained F narrowly missed significance at the .05 level. To underscore how close the obtained results were to 95% confidence, significance would have been achieved if there was a change in visual field of only one of the correct detections. The hypothesis of a general right visual field superiority vigilance performance deserves continued study.

The most striking and unexpected finding was the interaction of sex, personality, and laterality in vigilance performance over the four time periods. While extraverts showed little difference in visual field performance, the introverts showed distinct patterns.

In general, introverts displayed a high initial mean detection accuracy in one visual field and a low mean detection accuracy in the other. For this discussion, the initially accurate field will be referred to as the primary system and the other field will be referred to as the secondary system following the descriptions of Dimond and Beaumont (1973). Over time, however, there is a sharp decline in the detection accuracy of the primary system and a steady increase in performance in the secondary system. It is surprising how closely the pattern of detection accuracy by visual field among male and female introverts matches: they are almost identical. What is difficult to interpret is that the visual fields of the primary and secondary systems for the males are reversed for the females.

Male introverts exhibited a high detection accuracy for left visual field signals during the initial 15 minutes period that continued to the second period, showed a significant decline during the third period, and a recovery during the fourth period. In contrast, these subjects exhibited a low accuracy for right visual field signals during the first period, improved during the second, and reach an asymptote during the third and fourth time periods. Female introverts exhibit an identical pattern but with an initial superiority in right visual field performance followed by decline and recovery. Females' left visual field performance was poor initially but showed a similar steady improvement to asymptote as is found in the right visual field performance of males.

Some speculations about these findings appeared warranted. In noting the general differences in the pattern of the lateralized performance between introverts and extraverts, it is likely that their

respective attentional styles resemble cognitive style differences noted previously (Witkin et al. 1962). Specifically, introverts have been found to be more field-independent and cognitively differentiated than extraverts. While extraverts do now show any clear differences in detection accuracy between visual fields, introverts exhibit clear differences in biases in which first one, then the other visual field is favored.

One of the possibilities that emerges to explain these results is that hemispheric interaction in the regulation of attention is a function of personality. Several general models of hemispheric general interaction noted previously (Allen 1983) are plausible depending upon the individual's personality. Extraverts do not exhibit lateral differences in vigilant performance and may therefore employ either a cooperative (i.e., Moscovitch et al. 1976) or parallel (Dimond & Beaumont 1971) mode of hemisphere function. In contrast, introverts exhibit a hierarchical arrangement of systems in which one system is initially accurate, yet fatigues quickly while a second system improves over time and gradually becomes dominant. This seems to provide support for the previously unsupported speculations of Dimond and Beaumont (1974) that attention is switched from a primary to a secondary system as fatigue sets in. Ironically, although Dimond and Beaumont (1973) proposed that the left hemisphere houses a primary vigilant system and the right hemisphere houses a secondary one, their own results failed to achieve significance. One of the results of the present study reveal primary and secondary vigilant systems which conform closely to the hypotheses of Dimond and Beaumont (1973), personality and sex codetermine their manifestation.

While male and female introverts should exhibit such clear, lateralized differences in vigilance performance is difficult to explain. Levy (1980), in her review of the literature on cerebral asymmetry, has noted that there is strong evidence that the left hemisphere matures earlier in females while among males, the right hemisphere seems to mature earlier. She suggests that the functions of the earlier developing hemisphere in both sexes condition the maturation of function in the other side of the brain. These, then, develop predominantly in the service of earlier developing functions. She proposes that the perceptual systems of the female right hemisphere may be activated and directed by the left hemisphere. Among males, it is proposed that the analytic functions of the left hemisphere are activated and directed by the right hemisphere. The key words here are "activating" and "directing" which recall an earlier theory of Levy (1974) and the recent discussion by Moskovitch (1979) on the functions of attention. If attention functions as a system for priming and directing cognitive processes then it is likely that the primary vigilance system would be in the hemisphere that directs and controls processing. In females, it is likely that this orientation bias would continue to be for the right sensory field since this would activate left hemisphere functions. Among males, the orientation bias would be more toward the left sensory field since that would activate right hemisphere control. It is likely that such clear differences are only evident in individuals who exhibit the greatest degree of functional separation of these two brain systems. Since introverts are more differentiated in cognitive functions, these

orientation biases emerge. Extraverts, who exhibit less cognitive differentiation do not exhibit such differences. Sex differences in the laterality of the primary activation system propose some worthy problems for the hypothesis that, in general, activation is primarily a function of the left hemisphere. In the present study, signals were detected more often in the right visual field and, although not achieving a conventional level of significance, it is more probable that a real difference exists than that it does not. Yet what does such a difference, if real, imply? It describes a general trend in brain laterality for a population in which sex, personality, cognitive style differences and other factors are pooled. This is analogous to a regression problem in which disparate subgroups are combined to achieve results which, while yielding a significant correlation coefficient, do not faithfully represent the true situation. The present results suggest that it is necessary to include sex and personality factors in lateralized vigilance paradigms in order to accurately represent the complexities of the true state of affairs.

The false-positive data also presented complex and unexpected problems. Previous research (Krupski et al. 1971; Gillespie & Eysenck 1980) has reported that extraverts make a higher number of commission errors than do introverts because they set less stringent response criteria. This has also been viewed as the aspect of reinforcement (Stellmack 1981). In this regard, introverts who are more susceptible to punishment, attach more importance than do extraverts on the cost of false alarms. Extraverts, however, who are more oriented to reward than introverts, attach greater importance to the potential gains

of correct responding. In the present study, however, the effects were related to both sex and personality. Males in general exhibited few false positives while females exhibited a significant number. Among the females, however, it was the introverts who exhibited the greater number. The issue here was not reinforcement since no feedback was given. Rather, the important factor may be the low intensity and frequency of signals. The vast majority of commission errors among all groups were made in the first time period. This suggests that a major difficulty was adjusting to the low levels of stimulation and, in essence, calibrating sensitivity to discriminate signals from errors in perception induced by the circumstances.

In reviewing the performance of individual subjects, it is likely that the high mean for female extraverts is due to sampling error since 21 of 35 errors were made by one subject. In contrast, a high rate of commission errors were made by 6 of the 9 female introverts. One possibility that suggests itself is that such errors are more likely if subjects are more attuned to one side of space than the other. Because of the research by Hillyard et al. (1973) which relates the amplitude of the N1 component to an attended channel, rank order correlations were computed between the number of false positives and the absolute asymmetry (in microvolts) between the left and right frontal and parietal sites for the N160 and P300 components. The only correlation to achieve significance was for the frontal channel asymmetry of the N160 component for the female introverts. Specifically, the number of commission errors correlated significantly ($r_s = .61$, $p < .05$) with the absolute asymmetry in the N160

component at the left and right frontal sites. It appears then that the high number of false positives was characteristic of only the female introverts and was related to the construction of attention to one channel.

The results of the ERP components are difficult to interpret. The anterior-posterior differences for both the N160 and P300 component were expected and have been reported previously (Cooper, Ossleton, & Shaw 1980). It was also expected that females would exhibit larger amplitude ERPs since this has also been a stable finding (Buchsbaum et al. 1974). However, it was not anticipated that sex and personality should interact as they did with anterior-posterior brain systems. In general, females exhibited much larger amplitude components over the frontal association areas. This occurred from both the early and late components. The amplitude of N160, however, was not related to the performance among the females although significant correlations were obtained for males over the parietal association areas. While it is tempting to consider possible laterality differences between introverts and extraverts because of correlation differences in Table 6, it is felt that these differences may be artifactual: the correlations of .46 to P5 for introverts and .40 at P6 for extraverts only narrowly miss significance. In fact, if the criteria for 1-tailed tests were applied, and the correlations between correct detections in N160 amplitudes at both parietal locations would have been significant for both groups. Considering the small sample sizes, any correlations should be replicated before they are regarded as stable.

The interpretation of the data on the P300 component presents considerable challenge because of the number of significant results and the complexity of their pattern. At this point, more questions than answers are presented. It is unclear why, for example, there should be a lateral asymmetry in P300 amplitudes with larger amplitudes occurring over the right hemisphere. Since the potentials are an average response to all signals which occurred equally to the right and left sensory fields, this asymmetry is not due to lateral biases in signal presentation. Rather, it appears that the right hemisphere is generally more responsive to low intensity infrequent signals. Why should this be so? One possibility is that the P300 amplitude over the right hemisphere is indexing the utilization of relatively greater cognitive resources which reflect the greater difficulty in detecting signals in the left sensory field. Although failing to achieve a suitable level of significance, correct detections were more frequent in the right visual field. P300 amplitude is sensitive to signal rarity, unexpectedness, and reflects perceptual evaluation within a limited capacity frame (Donchin et al. 1978; Pritchard 1981). Signals to the right hemisphere are processed less effectively and require a relatively greater allocation of resources to evaluate those signals.

There were also several important group differences in the topography of P300 amplitudes. In general, extraverts and females exhibited P300s over the frontal association areas that were comparable to the amplitudes over the parietal areas. Introverts, as a group, displayed very little response in the frontal areas but significantly

larger amplitudes over the parietal areas. A similar pattern was observed in males as a group. The implication here is that the different groups have unique ways of processing the visual signals. Males and introverts exhibit a greater degree of differentiation in the subsystems of the brain in response to visual signals. The relationships between P300 amplitude and detection accuracy followed along similar lines. For the male and introvert samples, the correlations were significantly high for parietal areas and negligible for frontal areas. This suggests that between 40 and 50% of the variance in detection accuracy could be accounted for by P300 amplitudes over the parietal areas. This indicates that, for these groups, greater allocation of perceptual resources in parietal areas results in improved detection of weak, infrequent visual signals. In contrast, both females and extraverts exhibited weaker correlations of significance. Females showed the least degree of differentiation since 3 or 4 correlations achieved significance. Extraverts also exhibit a relationship between a right hemisphere of P300 amplitudes and general detection accuracy. Unlike the more clearly differentiated male and introvert samples, however, these latter two groups exhibit fairly sizable correlations at all locations. It is therefore questionable whether these patterns of relationships observed among the female and extravert groups would be replicated.

The complex reaction time task was altogether disappointing. Unexpectedly, the obtained results failed to confirm the findings of Heilman and Van Den Abell (1979). The variance obtained was simply too large and overwhelmed any delicate differences between groups or

between laterality of warning signal and hand of response. In any event, the original hypothesis that a warning to the right cerebral hemisphere would result in faster reaction time was not substantiated by the present results.

In shifting through these findings, several nonsignificant relationships warrant a closer look. The 3-way interactions of hand-personality-sex and warning-personality-sex both show some effect although not to an accepted level of significance. What is surprising is that the variance, especially for the hand of response, is so large and obscures any pattern. In viewing these results it is interesting to note that there is a lateral asymmetry in response time improvement for extraverts that is in the same direction as the one previously observed in the vigilant study for introverts. Specifically, extraverted males showed greater mean improvement with the left hand regardless of laterality of the warning stimulus while extraverted females showed greater mean improvement of the right hand. The introverts did not exhibit such lateralized differences in mean improvement. Again, however, it must be recalled that these lateral asymmetries in the mean response time improvements are not significant in relation to the degree of variance observed.

Several significant results were achieved in the analysis of variance of the N160 component. Such a range of effects was not noted in the vigilance study. If N160 is seen as an electrophysiological expression of the early stage of attention, then the obtained results do provide some support for the notion that complex reaction time tasks may be an important way to assess this level of processing.

The personality differences are of interest since this suggests that introverts, as a group, allocate relatively more resources to early stages of stimulus processing. On closer examination of the mean scores, however, it is apparent that this result is due to the very low N160 amplitudes characteristic of male extroverts. While it is tempting to relate the low N160 amplitude to the high improvement scores among male extraverts, the correlations obtained do not support any substantial relationship. Yet this is not surprising since others have noted that ERP components usually are poorly correlated with actual response times (Donichin et al. 1978).

For both ERP components under examination, the females exhibit higher amplitudes over the frontal/cortical areas. Since the placement of electrodes probably indexes the activity of the frontal association areas, these results indicate a greater utilization of these areas in both the early and later stages of information processing among the females. It appears that males and females have fundamentally different ways of processing information at both the early and late stages. While females utilize both frontal and parietal association areas, males, and male extraverts especially, tend to exhibit much larger responses from the parietal areas alone.

The correlations between reaction time improvement and both N160 and P300 amplitudes were negligible. Only 2 of 40 correlations achieved significance, which is a result which could indicate the operation of chance factors alone. What is of interest is that the significant correlations occurred at the same location (right parietal) for the same group (males) for both components. The present

study examines only the ERPs for the left hand trial since it was reasoned a priori that this would reduce the volume of data and the redundancy of information. It has been noted previously that laterality effects in ERP components are not observed unless signals occur at a high frequency and the subject is directed to attend to a specific channel (Hillyard et al. 1973). Since the present study employed a very low frequency rate and there was no predirected attentional bias, laterality was not anticipated to be an issue. Yet some indications of lateral bias were present. There is the negative correlation between both ERP component amplitudes and reaction time improvements for males over the right parietal areas. This suggests attentional bias toward the left sensory field that may be related to hand of response. In addition, all groups except the male extroverts exhibited larger right frontal N160 amplitudes, although the differences failed to achieve significance. While the lack of significance is not surprising considering the infrequency of signals, the direction of the present results supports the notion that the N160 amplitudes reflect an attentional bias to the left visual field.

The present study incorporated many dichotomized variables in the study of the intensive aspects of attention. The issue was to examine how these various pairs of opposites might interact. In general, the present finding strongly indicates that oversimplified hypotheses advanced at the beginning of the study need to be replaced by new ones which reflect complex interactions of the variables: sex, personality, laterality, activation-arousal, early-late stages of processing, intensity-selectivity, and the components of

event related potentials. As always with exploratory studies, more questions and answers emerge. The present study was no exception: many results of significance were produced and the interpretations are given. Several points, however, seem especially important for a general discussion.

A major question that arises is whether it is most efficacious to study general laterality models or to employ more specific models which reflect differences in function among certain well defined groups. The present study has supplied results which could support either path. In the vigilance study the performance measure showed a lateral bias approaching significance when the subgroups were pooled. The P300 component to the signals in the vigilance study showed a significant laterality effect, one that was opposite to the direction of the performance measure. This invites speculation about both the lateral bias in vigilant attention and the meaning of P300 amplitude over the less efficient hemisphere.

Yet these general speculations are not applicable to the subgroups, each of which exhibits unique performance in electrophysiological characteristics. By focusing on the pooled results of extremely different groups the richness of group differences is lost, and most important, this results in an inaccurate picture of the true state of affairs. The clear lateralized vigilance performance of introverts must be contrasted with the lack of lateralized differences among extraverts. The fact that male and female introverts exhibit mirror image reflection in their lateralized vigilance performance is striking, yet would be lost if only the pooled results are examined.

In reviewing this, it is interesting to observe that the extraverts achieve the same lateralized pattern on the complex reaction time task although not to any acceptable level of significance. In contrast, the introverts exhibited little difference in lateralized performance on this task. These results suggest that several models of hemispheric interaction are likely, but these depend on the personality and sex of the subject pool. Further, it is possible that the same subjects can employ different types of hemispheric interaction depending upon the task demands. For example, introverts are more differentiated in vigilance performance but less so in reaction time performance while extraverts exhibit the opposite pattern. There is a suggestion that personality and sex are related to these differences in processing although the hows and whys will need to be fleshed out in future studies.

Conceptual issues as well as group differences merit discussion. Concepts such as arousal, activation and early-late stages of processing were initially thought to be interchangeable. Specifically, it was reasoned that arousal was synonymous with the early stage of processing since it represented registration and temporally preceded activation. In contrast, activation was thought to be involved with response preparation and so would be synonymous with the late stage of information processing. It is likely that this is not so. Arousal involves phasic alertness to input and may be more characteristic of stimulus evaluation for meaning. Activation may be more a factor in the early stage of processing since it would be manifested in a tonic alertness to one channel without regard to meaningfulness of

stimuli. Early and late stages of attention generally refer to differences in the process of selectivity while activation and arousal refer to different processes in the intensive aspects of attention.

It is questionable, though, whether these intensive processes are truly separable in experimental designs which involve complex acts such as vigilance or forewarned reaction times. Vigilance, for example, not only involves a tonic form of attention but also phasic responsiveness to signal stimuli. Typically, vigilance paradigms involve detection of signals under fairly monotonous background conditions. Does a failure in vigilance performance mean that the subject can no longer sustain his attention, fails to arouse to target stimuli, or fails in both systems? Similarly, reaction time tasks involve a temporal component and must deal with fatigue. This seems to indicate that failure on this task might be a result of decreased activation in keeping with the conceptualization of Heilman and Van Den Abell (1979). It is interesting to note that no subject fell asleep during the vigilance task but three had to be awakened during the complex reaction time task. The ERP data from two of these subjects had to be dropped from statistical analysis because the superposition of slow waves obscured the target components.

Additional error arises in the grouping of subjects according to self description as introvert and extravert. The two potential sources for this error are in the social desirability of extraversion and also in the nature of the construct. Extraversion is conceived as a personality type or dimension that is made up of several primary traits including impulsivity and sociability. Guilford (1975) has

criticized the construct as lacking cohesion since relationships between extraversion and any other entity may be due to predominance of either of the primary traits. The attentional style of impulsive and sociable extraverts may be very different. Since the present research focus is to examine laterality differences in attentional performance, it may be more fruitful to select extraverts on their degree of impulsivity rather than sociability. This may be done by combining the EPI with another scale such as Sensation Seeking Scale (Zuckerman et al. 1974). An alternative strategy would be to select extraverts on the basis of their performance on a measure such as Kagan's Matching Familiar Figures Test. This would provide a clear assessment of impulsivity in combination with the subjects' self descriptions.

The social desirability of extraversion is also a very real source of error. During the debriefing which followed the experiments, many of the introverts expressed disappointment that they had been so characterized. Several were very well socialized and felt that they more closely fit the picture of neurotic extroverts. Yet as they recalled various life experiences they all noted such "introverted" characteristics as inability to tolerate noise when concentrating, sensitivity to pain and punishment, and an inability to cram for tests. Most described adolescences characterized by some degree of isolation. What was remarkable was that each had consciously set about to correct this: to increase their social contacts and engage in more "extraverted" behavior. It is also likely, though, that some of the introverts "slipped through" and achieved EPI scores in the range

characteristics of extraverts. In any event it may be appropriate in the future, since this personality dimension appears to be important in attentional research, to use other cognitive and behavioral measures to more clearly define the subgroups according to specific characteristics.

Finally, several points concerning the use of ERPs deserve comment. Clearly experimental designs which employ both performance and electrophysiological measures are of great value. Correlations between both types of measures provide a sound approach to the study of brain-behavior relationships. As others have pointed out, however, it is difficult to know from ERP data alone what is going on in the brain (Pritchard 1981; Hillyard et al. 1978; Donchin 1978). The obtained results provide some support for the description of the N160 component as reflecting stimulus registration and P300 as reflecting stimulus evaluation. What is interesting is that the larger amplitudes seem to reflect the greater allocation of resources which were necessary to offset, at times poor performance. There were also topographical differences in the amplitudes of the ERP components among the four groups studied. In addition, the topographical patterns appeared to change depending on the nature of the task. The use of ERP data in this way suggests that several different models of brain system interactions are possible depending on sex, personality, and the nature of the task.

In the future it would be informative to view changes in the amplitude and latencies of ERPs over the temporal course of the experiment rather than obtaining one average ERP and correlating it

with some total performance measure. At least in the vigilance study, changes in performance over time were highly significant. It would be worthwhile to examine concurrent changes in brain potentials. Finally, measurement of ERPs in the present study presented a considerable source of error. The peak selection process involved considerable artistry in judgment and might be best replaced by a more objective method of analyzing the wave form. Principal components analysis of the data points of the whole wave form has been successfully used and is described in length elsewhere (Donichin & Heffley 1978).

SUMMARY

The present study examined how groups defined by sex and extreme introversion-extraversion score differ in attentional style. Style differences were conceptualized as biases towards either a phasic or tonic mode of attention in keeping with the theory of Pribram and McGuinness (1975). These styles were hypothesized to be a reflection of asymmetries in cognitive function which are determined by genetic, developmental and experiential factors. Attention was viewed functionally in accordance with Moscovitch's (1979) construction as priming and directing subsequent cognitive processing. Because of this, it was expected that the styles of attention were themselves lateralized to some degree. Activation, the tonic mode of attention, was seen as characteristic of left hemisphere cognition and the cognitive style of introverts. Arousal, the phasic mode of attention, was identified more closely with right hemisphere cognition and the cognitive style of extraverts. Sex differences, in accordance with previous research on cognitive styles (i.e., Witkin et al. 1962), were expected to result in greater lateral differentiation in attentional style for males and much less differentiation for females.

Four equal groups of nine subjects were selected on the basis of sex and extreme scores on the extraversion dimension of the Eysenck Personality Inventory. Neuroticism was controlled since it has been found to be a confounding factor in previous research. The selected

subjects took part in two lateralized attentional tasks. The first, a vigilance task modeled after a design by Dimond and Beaumont (1973) involved responding to infrequent visual signals of low intensity generated by lateralized sources. It was designed to tap the tonic attentive dimension. The second experiment was designed to tap the phasic, or Arousal dimension, and consisted of a complex reaction time task which employed lateralized warning stimuli. Both behavior and electrophysiological measures were recorded for both studies and analyzed by four-way mixed model analyses of variance.

What was found was not wholly unexpected although certainly richer than the initial hypotheses. Indeed, there was a general left hemisphere superiority in vigilance performance, which, if vigilance is accepted as a measure of Activation, supports the original hypothesis. Other results, however, were more intriguing since they revealed the important differences contributed by sex and personality. Male and female introverts exhibited clearly differentiated but mirror image patterns in lateralized performance. Extraverts did not exhibit any lateralized differences. These results also implied that the groups may employ different modes of hemisphere interaction. Introverts appear to use an attention-switching process in which one hemisphere acts as a primary and the other a secondary system. As the allocated resources in the primary system become exhausted, control is switched to the secondary system. The sex differences in the laterality of the primary and secondary systems are seen as consistent with Levy's (1980) observations on developmental sex differences in asymmetry.

The most disappointing result was the lack of significance on the complex reaction time study. In addition to failing to support the present hypotheses regarding arousal, extraversion and right hemisphere function, there was also no support for the previous findings of Heilman and Van Den Abell (1979) indicating a general right hemisphere superiority in alerting to warning stimuli.

Significant sex and personality differences were found in the topographical distribution of the event related potentials. Overall, it appears that females and extraverts utilize the frontal association areas on vigilance while the males and introverts place more demand on parietal areas. Neurophysiological differentiation on the anterior-posterior dimension is again clearest for the males and introverts. Correlations between vigilance performance and ERP amplitudes also underscored sex and personality differences. There was some limited support for the view that complex reaction time assesses early and vigilance, the later stage of information processing. As a result, the question arises whether the present paradigms tap Activation-Arousal or a model based on stages of processing.

Overall, it is concluded that sex and personality differences are important co-determiners of attentional style on the basis of both performance and electrophysiological measures. It is likely that many of the conflicting results reported in the experimental literature which have been used to support contrasting theories of information-processing are reconcilable by accounting for personality and sex differences in neuropsychological function.

APPENDICES

APPENDIX A
DIRECTIONS FOR THE VIGILANCE STUDY

DIRECTIONS FOR THE VIGILANCE STUDY

This task is designed to see how well you can sustain your attention. Directly in front of you notice the round, white light (Direct subject's attention to the Grass Instruments photostimulator.) This light will not be on during the experiment but you will be able to see it nonetheless even with the lights off. During the experiment, I want you to keep your gaze within the circumference of the light. As you are gazing at the light, you will see these two small red lights off to the sides. These lights will be on. Do not look at them directly since if you look right at one, you will not be able to see the other. Also, if you move your eyes while I am recording the EEG, the recording will be distorted by the eye-movement activity. That is why it will be very important to keep your gaze within the circumference of the light and to remain as still as possible.

This is what you are to do on this task. You will sit in the chair with your hands on the armrests, your gaze fixed within the circle of the light, seeing the two small red lights off to the side. Notice that there are two buttons, one on each armrest of the chair. Periodically, one or the other of these lights will brighten. They will not brighten slowly, but very fast, quicker than an eye blink. The brightening will be clear enough so that you won't have to guess. This is the signal to watch for. When the light on the right brightens, push the button in your right hand. When the light on the left brightens, push the button in your left hand. Now what are you to do? (Have subject repeat procedure, correcting errors.)

Now I want to cover several important points that may affect your performance. This first is that the experiment is monotonous. It is meant to be. Because of the monotony, though, you may experience two problems. The first is that you may find that you start to fall asleep. When you become aware that you are dozing, bring your attention back to the circle of the light. Do not shake your head, slap yourself or any other physical activity to wake yourself up. Do try to stay as alert and as focused as possible. The second problem is that you may find yourself daydreaming and that as you do so, your gaze drifts away from the white light. Please do not give in to the temptation to daydream but bring your attention back to the circle of light as soon as possible.

You may also find that you are uncomfortable and wish to change your position. Please wait until you get a signal and then immediately afterwards make any necessary physical adjustments. As soon as possible, however, resume a still posture and return your gaze to the circle of light. Any questions? (Answer any relevant questions.)

I will be watching you at all times and will alert you if you get off track.

We are ready to begin. First I want to get a ten second sample off your resting EEG. Please sit back, relax, breathe evenly, and close your eyes. (Close the door of the chamber and collect EEG.)

(Boot up the computer.) We are ready to start the experiment. Remember, keep your gaze within the circle of light and respond to the brightening of either of the two signal lights by pressing the button on the same side as the light. Stay alert and still. When we are all done I will answer any questions you have about the study. For now, do you have any questions about what you are to do? (Answer any questions regarding the running procedure above.) Good luck.

APPENDIX B

DIRECTIONS FOR THE COMPLEX REACTION TIME STUDY

DIRECTIONS FOR THE COMPLEX REACTION TIME STUDY

This task assesses how quickly you can react to a signal. Look directly in front of you. Notice that there is a small green light straight ahead and that there are two red lights to either side. The green light is a "go" light, the one that you will react to; the red lights are warning lights. Sometimes you will just get a green light and you have to react as fast as you can. Sometimes you will get one of the red lights first to let you know that in a second or two, the green light will come on. Now notice that there is a button on the front of each arm rest on your chair. These are the buttons that you will use to react to the green light. The first time through you will use one hand for all the trials. That will take about forty-five minutes using the other hand. When we actually start the experiment, the computer will tell us which hand to use first and which to use second. Any questions so far? (Answer any general questions about the procedure.)

The actual sequence of things goes like this: first you will hear a tone from these speakers. The tone means that a trial has started and that you should sit up and pay attention, focus on the green light, and press down the button you are using. As soon as the green light comes on, release the button. As I said before, sometimes one of the red lights will come on first. This is a warning light so don't release the button! It comes on to let you know that in a second or two, the green light will come on. Wait for the green light before you release the button. Okay, so what's the sequence of things and what do you do? (Have subject repeat the procedure and correct any mistakes.)

Now, when you release the button and the green light goes off, you will have a short rest period. During this time, I want you to daydream, look around, hum a tune, think great thoughts. In other words, relax and let your mind go. Don't keep your attention focused on the lights. Just relax. But as soon as you hear the next tone, sit up, press down the button and watch for the light.

I will be watching how you are doing at all times and will alert you if you get off track.

Let's try a few. (Begin sample trials and continue until subject completes three successive trials without error.)

We are ready to begin. First, I want to get a ten second sample of your EEG. So I want you to sit back, relax and close your eyes. Breathe deeply and evenly. (Collect EEG.)

We are now ready to begin. First you are going to use your (right-left) hand. The first set will last forty-five minutes. You can then take a break before starting the second set with your (left-right) hand. When we are all done I will tell you anything you want

to hear about the experiment. For now, do you have any questions about what you are to do? (Answer any questions about running procedures.) Good luck.

APPENDIX C
SCREENING INSTRUMENTS*

*Note: Accompanying the questionnaire was a green IBM sheet which served as an answer sheet for the questionnaire.

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INSTRUCTIONS FOR THE EXPERIMENT

1. Use a number 2 pencil when filling out both forms.
2. Please put your name, your sex, and your phone number on the green IBM sheet and the sheet entitled Self-Evaluation Questionnaire.
3. Do the Self-Evaluation Questionnaire first. Please read the directions carefully and follow them, darkening the appropriate circle to the right of each statement that best indicates how you generally feel. Be sure to darken only one circle per line, but be sure to respond to each and every statement.
4. Once you have completed the Self-Evaluation Questionnaire, start the other survey. Actually, this five-page booklet consists of three separate questionnaires so you need to be careful in filling it out.
 - a) Use the green IBM sheet for these questionnaires.
 - b) All of the questions or statements are of the yes-no, agree-disagree variety. For "yes" responses, darken in the "a" slots on your answer sheet. For "no" responses, darken in the "b" slots.
 - c) The second and third of these pages consist of a survey in which you must choose between two statements. Read each choice carefully and darken the appropriate slot on your answer sheet that corresponds to the statement with which you are in the most agreement.
 - d) Before you begin, notice that the numbering is crazy! This is for a reason. When you have finished the first page of the five page booklet you will have completed the first of three questionnaires. This will end at #57 on your IBM answer sheet. When you begin page 2, skip down to #65 on your answer sheet and start there. On the third page there is a numbering error: there are two #89's. Please just make the second one #90 and continue. When you finish page three, you will have finished the second of the three questionnaires and should be on #93. To start the third and last questionnaire, skip down to #101 and answer all items, finishing with #132.
5. When you have finished, please check everything over to make sure that you've answered all questions and have followed the numbering system correctly. Paperclip all other sheets back together and put them in the large manilla envelope marked "Completed Questionnaires" that will be in your department office.
6. Thank you very much for participating in this survey and I hope to get in touch with you about the actual experiment very soon.

	E	N	L
1. Do you often long for excitement?	Yes	No	
2. Do you often need understanding friends to cheer you up?	Yes	No	
3. Are you usually carefree?	Yes	No	
4. Do you find it very hard to take no for an answer? . . .	Yes	No	
5. Do you stop and think things over before doing anything?	Yes	No	
6. If you say you will do something do you always keep your promise, no matter how inconvenient it might be to do so?	Yes	No	
7. Does your mood often go up and down?	Yes	No	
8. Do you generally do and say things quickly without stopping to think?	Yes	No	
9. Do you ever feel "just miserable" for no good reason? . . .	Yes	No	
10. Would you do almost anything for a dare?	Yes	No	
11. Do you suddenly feel shy when you want to talk to an attractive stranger?	Yes	No	
12. Once in a while do you lose your temper and get angry?	Yes	No	
13. Do you often do things on the spur of the moment? . . .	Yes	No	
14. Do you often worry about things you should not have done or said?	Yes	No	
15. Generally do you prefer reading to meeting people? . . .	Yes	No	
16. Are your feelings rather easily hurt?	Yes	No	
17. Do you like going out a lot?	Yes	No	
18. Do you occasionally have thoughts and ideas that you would not like other people to know about?	Yes	No	
19. Are you sometimes bubbling over with energy and sometimes very sluggish?	Yes	No	
20. Do you prefer to have few but special friends?	Yes	No	
21. Do you daydream a lot?	Yes	No	
22. When people shout at you, do you shout back?	Yes	No	
23. Are you often troubled about feelings of guilt?	Yes	No	
24. Are all your habits good and desirable ones?	Yes	No	
25. Can you usually let yourself go and enjoy yourself a lot at a gay party?	Yes	No	
26. Would you call yourself tense or "highly-strung"? . . .	Yes	No	
27. Do other people think of you as being very lively? . . .	Yes	No	
28. After you have done something important, do you often come away feeling you could have done better?	Yes	No	
29. Are you mostly quiet when you are with other people? . . .	Yes	No	
30. Do you sometimes gossip?	Yes	No	
31. Do ideas run through your head so that you cannot sleep?	Yes	No	
32. If there is something you want to know about, would you rather look it up in a book than talk to someone about it?	Yes	No	
33. Do you get palpitations or thumping in your heart? . . .	Yes	No	
34. Do you like the kind of work that you need to pay close attention to?	Yes	No	
35. Do you get attacks of shaking or trembling?	Yes	No	
36. Would you always declare everything at the customs, even if you knew that you could never be found out? . .	Yes	No	
37. Do you hate being with a crowd who play jokes on one another?	Yes	No	
38. Are you an irritable person?	Yes	No	
39. Do you like doing things in which you have to act quickly?	Yes	No	
40. Do you worry about awful things that might happen? . .	Yes	No	
41. Are you slow and unhurried in the way you move? . . .	Yes	No	
42. Have you ever been late for an appointment or work? . .	Yes	No	
43. Do you have many nightmares?	Yes	No	
44. Do you like talking to people so much that you would never miss a chance of talking to a stranger?	Yes	No	
45. Are you troubled by aches and pains?	Yes	No	
46. Would you be very unhappy if you could not see lots of people most of the time?	Yes	No	
47. Would you call yourself a nervous person?	Yes	No	
48. Of all the people you know are there some whom you definitely do not like?	Yes	No	
49. Would you say you were fairly self-confident?	Yes	No	
50. Are you easily hurt when people find fault with you or your work?	Yes	No	
51. Do you find it hard to really enjoy yourself at a lively party?	Yes	No	
52. Are you troubled with feelings of inferiority?	Yes	No	
53. Can you easily get some life into a rather dull party? . .	Yes	No	
54. Do you sometimes talk about things you know nothing about?	Yes	No	
55. Do you worry about your health?	Yes	No	
56. Do you like playing pranks on others?	Yes	No	
57. Do you suffer from sleeplessness?	Yes	No	

PLEASE CHECK TO SEE THAT YOU HAVE ANSWERED ALL THE QUESTIONS

- 65. a. Children get into trouble because their parents punish them too much.
b. The trouble with most children nowadays is that their parents are too easy with them.
- 66. a. Many of the unhappy things in people's lives are partly due to bad luck.
b. People's misfortunes result from the mistakes they make.
- 67. a. One of the major reasons why we have wars is because people don't take enough interest in politics.
b. There will always be wars, no matter how hard people try to prevent them.
- 68. a. In the long run people get the respect they deserve in this world.
b. Unfortunately, an individual's worth often passes unrecognized no matter how hard he tries.
- 69. a. The idea that teachers are unfair to students is nonsense.
b. Most students don't realize the extent to which their grades are influenced by accidental happenings.
- 70. a. Without the right breaks one cannot be an effective leader.
b. Capable people who fail to become leaders have not taken advantage of their opportunities.
- 71. a. No matter how hard you try some people just don't like you.
b. People who can't get others to like them don't understand how to get along with others.
- 72. a. Heredity plays the major role in determining one's personality.
b. It is one's experiences in life which determine what they they're like.
- 73. a. I have often found that what is going to happen will happen.
b. Trusting to fate has never turned out as well for me as making a decision to take a definite course of action.
- 74. a. In the case of the well prepared student there is rarely if ever such a thing as an unfair test.
b. Many times exam questions tend to be so unrelated to course work that studying is really useless.
- 75. a. Becoming a success is a matter of hard work, luck has little to do with it.
b. Getting a good job depends mainly on being in the right place at the right time.
- 76. a. The average citizen can have an influence in government decisions.
b. This world is run by the few people in power, and there is not much the little guy can do about it.
- 77. a. When I make plans, I am almost certain that I can make them work.
b. It is not always wise to plan too far ahead because many things turn out to be a matter of good or bad fortune anyhow.

- 78. a. There are certain people who are just no good.
b. There is some good in everybody.
- 79. a. In my case getting what I want has little or nothing to do with luck.
b. Many times we might just as well decide what to do by flipping a coin.
- 80. a. Who gets to be the boss often depends on who was lucky enough to be in the right place first.
b. Getting people to do the right thing depends on ability, luck has little to do with it.
- 81. a. As far as world affairs are concerned, most of us are the victims of forces we can neither understand, nor control.
b. By taking an active part in political and social affairs the people can control world events.
- 82. a. Most people don't realize the extent to which their lives are controlled by accidental happenings.
b. There really is no such thing as "luck."
- 83. a. One should always be willing to admit mistakes.
b. It is usually best to cover up one's mistakes.
- 84. a. It is hard to know whether or not a person really likes you.
b. How many friends you have depends upon how nice a person you are.
- 85. a. In the long run the bad things that happen to us are balanced by the good ones.
b. Most misfortunes are the result of lack of ability, ignorance, laziness, or all three.
- 86. a. With enough effort we can wipe out political corruption.
b. It is difficult for people to have much control over the things politicians do in office.
- 87. a. Sometimes I can't understand how teachers arrive at the grades they give.
b. There is a direct connection between how hard I study and the grades I get.
- 88. a. A good leader expects people to decide for themselves what they should do.
b. A good leader makes it clear to everybody what their jobs are.
- 89. a. Many times I feel that I have little influence over the things that happen to me.
b. It is impossible for me to believe that chance or luck plays an important role in my life.
- 89. a. People are lonely because they don't try to be friendly.
b. There's not much use in trying too hard to please people, if they like you, they like you.
- 90. a. There is too much emphasis on athletics in high school.
b. Team sports are an excellent way to build character.

91. a. What happens to me is my own doing.
b. Sometimes I feel that I don't have enough control over the direction my life is taking.
92. a. Most of the time I can't understand why politicians behave the way they do.
b. In the long run the people are responsible for bad government on a national as well as on a local level.
101. I would like to hitchhike across the country.
102. I sometimes use "four-letter words" to express my feelings or to shock someone.
103. I like to dress in unusual styles.
104. I would like to travel to strange, out of the way places like the upper Amazon or Antarctica.
105. I have tried marijuana or would like to.
106. I would like to try some of the new drugs that produce hallucinations.
107. I would like to take off on a trip with no preplanned or definite routes or timetables.
108. I would like to make friends in some of the "far-out" groups like artists or "hippies."
109. I would like to see men wearing beards.
110. I would like to meet some persons who are homosexual (men or women).
111. I would prefer modern jazz or classical music to more popular or light classical music.
112. I like to listen to new and unusual kinds of music.
113. I prefer friends who are excitingly unpredictable.
114. I like to have new and exciting experiences and sensations even if they are a little frightening, unconventional, or illegal.
115. I often enjoy flouting irrational authority.
116. I often find beauty in the "clashing" colors and irregular forms of modern paintings.
117. I sometimes like to do "crazy" things just to see the effects on others.
118. People should dress in individual ways even if the effects are sometimes strange.
119. I like to gamble for money.
120. I like "wild" uninhibited parties.
121. I enjoy the company of real "swingers."

- 122. I often like to get high (drinking liquor or smoking marijuana).
- 123. It's normal to get bored after a time with the same sexual partner.
- 124. Most adultery happens because of sheer boredom.
- 125. I like to date members of the opposite sex who are physically exciting.
- 126. Keeping the drinks full is the key to a good party.
- 127. A person should have considerable sexual experience before marriage.
- 128. I could conceive of myself seeking pleasures around the world with the "jet set."
- 129. I like people who are sharp and witty even if they do sometimes insult others.
- 130. Almost everything enjoyable is illegal or immoral.
- 131. I enjoy watching many of the "sexy" scenes in movies.
- 132. I feel best after taking a couple of drinks.

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