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**LA THÈSE A ÉTÉ
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Individual Differences in Auditory
Brainstem Evoked Responses: the
Effect of Frequency and Extraversion

Charlotte Black

Thesis presented to the School of Graduate
Studies of the University of Ottawa in par-
tial fulfillment of the requirements for the
degree of Masters of Arts in Psychology

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CURRICULUM STUDORIUM

Charlotte Black was born May 1948, in Toronto, Ontario. She received a Bachelor of Arts degree from Ottawa University, Ottawa, Ontario in 1976.

ABSTRACT

Individual Differences in Auditory Brainstem Evoked Responses: the Effects of Frequency and Extraversion

Twenty-four subjects who differed in degree of extraversion, 12 introverts and 12 extraverts, received low, middle and high frequency tone pips at 80 dB intensity level. Their brainstem-evoked responses were recorded to investigate the reliability and extent of individual variability. An inverse relationship between latency and frequency effects was observed such that faster latencies at the high frequency were recorded. There were no differences between introverts and extraverts observed in amplitude measures. Introverts showed a decrement in responsiveness by greater amplitudes at high frequency, although this did not reach an acceptable level of confidence, ($P < 0.06$).

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INTRODUCTION

Historically, the notion of extraversion has existed as a description of personality types since ancient times, as evidenced by the works of Galen, Kant, and Wundt in their distinction of the four temperaments (Eysenck, 1967). Eysenck's personality theory has recognized the existence of two factors, which he labels Extraversion-Introversion and Neuroticism (Eysenck, 1967).

Behaviorally, extraverts and introverts exhibit traits such as sociability, impulsiveness, activity, liveliness and excitability in varying degrees. Extraverts are thought to be more sociable, active and lively, and behaviorally more excitable than introverts (Eysenck, 1970).

Eysenck's earlier work in psychometrics and factor analysis developed into what he thought to be an adequate system of classification which differentiated introverts from extraverts. Studies which attempted to detect differences in observable behaviors between the two personality groups were performed in the fields of learning and psychophysical research. Eysenck's theoretical framework was an adaptation of the Hullian notion of excitation-inhibition hypothesis. The differential build-up of reactive inhibition was thought to account for individual differences, whereby the introvert would condition more rapidly and display a slower habituation rate than the extravert (Eysenck, 1955).

Eysenck (1967) has proposed a neurophysiological model of the biological differences between introverts and extraverts. Differences along the extraversion dimension may be accounted for by individual variations in the corticoreticular loop which modulates cortical arousal and inhibition, with introverts characterized by relatively greater levels of arousal than extraverts (Eysenck, 1967).

The technique of recording auditory brainstem evoked responses (ESRs) may be usefully applied in considering the neurophysiological basis of individual differences in degree of extraversion. Specifically, the procedure may be helpful in determining the extent to which subcortical structures contribute to the enhanced auditory sensitivity of introverts that has been observed with psychophysical methods (Smith, 1968; Stelmack & Campbell, 1974) and the enhanced auditory responsiveness of introverts observed with the late (N1-P2) component of the auditory evoked response (Stelmack, Achorn & Michaud, 1977).

Jewett (1970) has suggested that the components of the auditory ESR which have a latency of less than 3 msec arise from the cochlear nerve and may serve as an index of peripheral responsiveness. Components with latencies between 3 and 8 msec are thought to arise from brainstem auditory nuclei (Jewett, Romano & Williston, 1970; Starr & Achorn, 1975; Stockard & Rossiter, 1977).

Since auditory BSRs are thought to be relatively insensitive to the effects of attention (Picton, Hillyard, Krauz & Galambos, 1974) and arousal, (Amadeo & Shagass, 1973) the demonstration of differences between introverts and extraverts in auditory BSR would place some constraint on the role of individual differences in the corticoreticular mechanisms as determinants of the degree of extraversion. Such an effect, particularly in regard to Wave 1 and Wave 11 in Jewett's (1970) nomenclature would give weight to the role of peripheral mechanisms and might be suggestive of an alternate explanation of individual differences in extraversion.

The low frequency stimulation used in psychophysical measures of absolute sensitivity (Smith, 1968; Stelmack & Campbell, 1974) has resulted in a greater responsiveness for introverts than extraverts. In addition, low frequency stimulation has enhanced N1-P2 amplitudes of the late components, which was not the case under high frequency stimulation (Stelmack, Achorn & Michaud, 1977). This was a justification to employ frequency manipulation in this thesis in order to facilitate optimal conditions which may differentiate introverts from extraverts.

The use of click stimulation to provide a reliable BSR is well documented in the literature. Click signals stimulate the high frequency section of the cochlea. Low frequency tones, which are characterized by slow rise times, are less effective in eliciting discernable BSRs (Davis & Hirsh, 1976).

Recently, however, some authors have shown that BSRs which are specific to low frequency can be elicited by fast rise time tone pips (Weber & Folsom, 1977; Suzuki, Hirai & Horiuchi, 1977) and by filtered click stimuli (Brama & Sohmer, 1977).

In this thesis, auditory BSRs to fast rise time tone pips were determined for groups of introverts and extraverts using frequencies of 0.5 kHz, 2 kHz and 4 kHz at 80 dB intensity.

CHAPTER 1

REVIEW OF THE LITERATURE

This chapter begins by presenting an historical overview of the notion of extraversion. It is followed by the development of Eysenck's theory of individual differences and leads to his present interpretation of the biological basis of extraversion. A review of the anatomy and physiology of the reticular formation, plus its application in the concepts of arousal and attention, will be presented. An overview of psychophysical and electrocortical research which contributes to the articulation of a biological basis of individual differences is then discussed. The chapter is concluded by a statement of the hypothesis:

An Historical Overview of the Notion of Extraversion

The notion of extraversion has had a long history. While the method of classifying personality types has changed from a categorical to a dimensional framework, the recurrent personality description has persisted.

In the second century B.C., Hippocrates attempted to differentiate varieties of temperament by the predominance of these four humours: blood, black bile, yellow bile and phlegm (Eysenck, 1964). The medieval view of Galen elaborated on the

theory by attributing a crude biochemical explanation to account for behavioral differences. According to Roback's (1928) historical account; Harvey's discovery of the circulation of the blood shifted the emphasis from the composition of the blood to its movement, as the determinant of the differences in temperament. Kant's (Roback, 1928) treatment of character reflected this shift. He examined two conditions of the blood: rate of flow and temperature. The sanguine, melancholic, choleric and phlegmatic constitutions varied by being light, heavy, warm and cold-blooded respectively. Kant then divided temperaments into those of feeling, (sanguine and melancholic) and those of action (choleric and phlegmatic). The sanguine was characterized by rapidity and force but not depth, while the melancholic's experiences took root with less speed and endured for a longer period of time. Similarly, the choleric temperament was that of a hasty person while the phlegmatic individual was simply not incited to action. Like his predecessors, Kant provided a descriptive categorical system to the extent that a person could be allocated to any of the four pure types and denies the possibility of composite temperaments.

Wundt's (Eysenck, 1964) description of personality differed from Kant's in that he proposed a dimensional classification system based on two continua, one he labelled "slow-quick"; the other "strong-weak". Thus he discarded descriptive terms

such as "light-blooded" and guided himself solely by the type of reaction that a given temperament called forth. The "slow-quick" dimension refers to the changeability of affect which is akin to extraversion, and the "strong-weak" continuum refers to emotionality similar to Eysenck's neuroticism factor. The choleric and melancholics would vary more in terms of emotionality than either the phlegmatics and sanguinics. Regarding the reactivity dimension; choleric and sanguinics would be characterized as more changeable than phlegmatics and melancholics.

Carl Jung (1923) popularized the notion of extraversion within a psychoanalytic framework. In his dimensional system, the extravert's libido was directed more toward his own inner mental state. Jung was credited as well with linking extraversion and introversion with Janet's two main neurotic disorders, hysteria and psychasthenia respectively.

One way in which Eysenck's system of personality classification differs from the ancients would be in terms of the quality of description. Eysenck adheres to a dimensional rather than a categorical view with regard to both extraversion and psychiatric disorders. Eysenck (1957) considers that a categorical view runs the risk of misclassification, in that allocation would be based on an intuitive choice of a predominant feature of personality. This would be a limiting feature in that the system only provides qualitative, environmentally-specific information whereby possession of the criteria would be sufficient for allocation to the category.

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The advantage of the dimensional framework would be that individual differences are more readily understood in degree, thus providing more detailed information than in a circumscribed category.

Another point of comparison which distinguished Eysenck is his explanatory framework. Galen attempted to explain personality types by a preponderance of humors. Jung's explanation was based on a psychoanalytic concept of psychic energy. Eysenck, on the other hand, accounts for individual differences in terms of models drawn from modern experimental psychology.

Development of Eysenck's Theory of Extraversion

Eysenck's theory of personality offers a comprehensive system which attempts to relate personality dimensions to the biological foundations of individual differences. The basic question that Eysenck poses is that in cases of neurotic breakdown, why is there a tendency for introverted individuals to develop dysthymic symptomatology, and extraverted individuals hysterical and psychopathic disorders? In the attempt to answer that question he has drawn from methods in psychometrics, statistics, learning theory, and currently, neurophysiology.

In 1947, Eysenck first described extraversion in the Dimensions of Personality. Two subfactors, sociability and impulsiveness, were revealed as first order factors of extraversion.

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In the Dynamics of Anxiety and Hysteria (1957), factor analytic studies repeatedly demonstrated two orthogonal higher-order factors, extraversion and neuroticism. Criterion analysis revealed that dysthymics tended to combine high neuroticism with a high degree of introversion. Conversely hysterics, although they scored above normal on neuroticism, were much more extraverted than dysthymics. Hence the extraversion-neuroticism classification system encompassed classical psychiatry.

The first order factors of neuroticism and extraversion have been challenged by other authors. Guilford (1977) claims that Eysenck has not obtained the simplest structure. Guilford purports that extraversion is a second order factor involving first order factors which he labels "R" (restraint versus rathymia) and "T" (thoughtfulness).

Eysenck's interpretation was that he had accomplished his first phase in personality description, namely a classification system on a descriptive level by statistical methods. His research then took the direction of following a hypothetico-deductive approach, and formulated an hypothesis as to the causality of these personality dimensions.

In the decade of the fifties, Eysenck attempted a theoretical unification of the experimental field with learning theory (Eysenck, 1969). Individual differences were hypothesized to be variances in an excitation-inhibition balance.

This approach was an adaptation of the Hullian concept of reactive inhibition and was more dynamic than Eysenck's previous work.

The thrust of this thesis was that an introvert would condition more readily than an extravert due to the differential build-up of reactive inhibition (Eysenck, 1957). The introvert's greater sensitivity to stimulation could be attributed to his tendency to quickly generate strong excitatory cerebral potentials and at the same time to slowly develop a weak reactive inhibition which would quickly dissipate. The extravert's response to stimulation would be different in that he would slowly generate weak excitatory potentials and yet develop strong reactive inhibition quickly which would dissipate slowly. The hypothetical construct of reactive inhibition suggests an impasse to the rate of conditionability, in that reactive inhibition would inhibit the evocation of the activity in question. The behavioral effect hypothesized was that the extravert appeared to seek stimulation while the introvert avoided overstimulation.

The attempted unification of the experimental field with learning theory provided Eysenck with a wealth of resources from Russian psychology. Eysenck suggested similarities between the Pavlovian concept of strength versus weakness of the central nervous system and the Eysenckian hypothesis of an excitation-inhibition balance.

Pavlov had demonstrated that cortical excitation facilitated conditioning, provided that the optimal degree of excitation had not yet been reached (Eysenck, 1967).

Recently Eysenck (1967) has proposed a neurophysiological model in the Biological Basis of Personality. He hypothesized that the extraversion factor would have been attributed to the level of tonic arousal determined constitutionally by differences in anatomical and physiological structures within the reticular formation.

The Biological Basis of Personality

Eysenck's publication in 1967 of the Biological Basis of Personality suggested a more specific neurophysiological hypothesis of individual differences than the excitation-inhibition model. The foundations of the excitation-inhibition balance rested in hypothetical constructs, which could not be specifically located in any physiological structures. These constructs could only be assessed by some observable variable. Hence it seemed impossible to isolate the particular influences of excitation and inhibition with any great efficiency.

Eysenck thought that a deficiency in performance was due to reactive inhibition, yet it was always open to the critic to suggest that such deficiencies were due rather to a lessening of excitation, thereby negating the reactive inhibition hypothesis. Hence a testable hypothesis was suggested through the use of physiological variables.

The degree of extraversion was hypothesized to be a direct function of the level of activity in the ascending reticular activating system. Eysenck then identified differences in behavior which were related to neuroticism with differential thresholds of activation in the visceral brain (Eysenck, 1967).

Eysenck made a distinction between arousal and emotionality. He refers to arousal when speaking of differences in cortical activity as mediated by the ascending reticular activating system. The concept of activation or emotionality refers to autonomic activity mediated by the limbic system and coordinated by the visceral brain. This distinction did not postulate complete independence of these structures due to connections that the reticular formation would have with the hypothalamus, but nonetheless there would have existed functional, fundamental differences. The main idea was that there could be cortical arousal without autonomic arousal but not the reverse.

To focus on the extraversion factor further, Eysenck (1965) states:

Introverts are characterized by a reticular formation, the activating part of which has a relatively low threshold of arousal while the recruiting (synchronization) part of it has a relatively high threshold of arousal; conversely, extraverts are characterized by their possession of a reticular formation whose activating part has a high threshold of arousal and whose recruiting part has a low threshold of arousal. Under identical conditions, therefore, cortical arousal will be more marked in introverts, cortical inhibition in extraverts.

More specifically, Eysenck (1967) delineated two subsystems of the reticular formation which determined either introversion or extraversion:

If we attribute the effects to cortically triggered activity of the thalamo-cortical inhibition system and the brainstem arousal system respectively, then we may also deduce that the lower thresholds of these two systems, postulated to characterize extraverts and introverts respectively, are responsible for the greater frequency of sensitization in introverts or of repression in extraverts. (p.252).

In this proposal the rationale for the introvert's greater arousal state and subsequent increased sensitivity as compared to those of the extravert would be due to a greater amount of neuronal messages conveyed to the cortex, facilitated by a lower threshold in the brainstem reticular system. The extravert was hypothesized to have a lower threshold of the thalamo-cortical inhibition system. A more inhibiting influence may characterize the extravert, with fewer neuronal messages reaching the cortex, as opposed to the introvert.

The Reticular Formation

The reticular formation is central to Eysenck's hypothesis. This section is devoted to a brief survey of the findings concerning the reticular formation as related to behavioral dimensions.

The reticular formation proper extends from the lower border of the medulla to the diencephalon. It is centrally located in the brainstem and surrounded on all sides by the pathways and

nuclei of the specific sensory projections and the pyramidal and extrapyramidal motor systems (Grossman, 1973).

Historically, the reticular formation has figured predominantly in the concepts of arousal and inhibition.

Bremer (1935) demonstrated the relation of the brainstem to the cortex in a "cerveau isole" (brainstem transected at the midbrain level) preparation in the cat. The electroencephalogram became characterized by sleep spindles and behavioral somnolence, which he interpreted as due primarily to the elimination of transmission in the classical sensory pathways. In 1949, Moruzzi and Magoun in an "encephale isole" preparation (transection at the point where the brain joins the spinal cord), demonstrated that stimulation of the reticular formation of the lower brainstem induced long lasting cortical arousal as well as autonomic and somatic responses commonly accompanying emotional reactions. However, lesions restricted to the midbrain reticular formation reproduced the "cerveaux isole" syndrome (behavioral coma and cortical slow wave activity), whereas transection of the classical sensory pathways to the cortex did not. In 1949, Lindsley, Bowden, and Magoun demonstrated a state of cortical arousal on the EEG of a prepared animal by leaving the reticular system intact while transecting the lemniscal pathway. Segundo, Arana, and French (1955) were able to show that a two-to-eight Volt electrical stimulus applied to appropriate areas in the brainstem of a sleeping monkey resulted in responses of behavioral arousal. When a slightly higher intensity of stimulation was applied, this type of behavioral arousal

appeared comparable to both spontaneous behavioral alerting and that produced when a novel, environmental stimulus was introduced.

The reticular formation not only plays an integral part in the waking state but also serves an integrative function between sensory input and information from other concurrently active sensory systems, as well as association and memory storage mechanisms in the central nervous system. The mechanism which achieves this function is accomplished by facilitatory or inhibitory controls, although suppression is thought to be more the case. As Grossman (1973) states, "The reticular formation maintains a tonic inhibitory influence on all sensory mechanisms. Facilitory effects are achieved by a decrease in this inhibition rather than active facilitation". (p.179).

Having briefly considered some historical highlights regarding the reticular formation in relation to arousal, let us now turn to a more precise examination of the functional significance of the reticular formation. The emphasis of this section is placed on the functional distinctions made between the brainstem reticular formation and the diffusely projecting thalamic system a distinction which Eysenck suggests differentiates introverts from extraverts.

According to Samuels (1959) the reticular formation may be divided into two functional systems, the brainstem reticular formation (ARAS), and the diffusely projecting thalamic

nuclei (DTFS). The brainstem formation includes structures at the level of the medulla, pons, midbrain, subthalamus, and hypothalamus. The midbrain reticular formation occupies a position of prime importance within the system. The diffuse or nonspecific thalamic projections represent the rostral continuation of the brainstem reticular formation. It consists of the intralaminar and midline nuclei of the thalamus, and the reticular nuclei of the subthalamic origin.

The ARAS courses upwards by extrathalamic projections, possibly by way of the subthalamus and internal capsule and also via the thalamus presumably terminating in the midline and intrathalamic nuclei, in the reticular nucleus or both (Lindsley, 1960). The extrathalamic influences are believed to be relatively rapid ones and concerned with general arousal. The thalamic influences are more likely concerned with graduations of alerting and attention, and may be related to scanning or modulating influences affecting projections from classical sensory pathways or the integration of the specific systems information by the DTFS. The ARAS influences the neocortex in a diffuse manner and in turn is influenced by the neocortex through widespread corticofugal connections.

The functions and relations of the DTFS are still less clear than those of the ARAS (Lindsley, 1960). The nuclei of this system appear to be capable of electrocortical activation or desynchronization. Another function appears to be the regulation

of temporal synchronization between the thalamus and the cortex, permitting the development of cortical recruiting waves, sleep spindles, perhaps including the alpha rhythm of normal resting EEG.)

Stimulation of the thalamic nuclei often produces sleep or behavioral arousal whereas brainstem stimulation almost always produces excitatory effects on cortical functions and behavioral arousal. Grossman (1973) and Samuel (1959) performed ablation studies and found that with the thalamic reticular system intact, lesions of the midbrain reticular formation produced a chronically, hypokinetic animal which could not be aroused behaviorally, even with intense stimulation. EEG responses did show an activation pattern, but it did not outlast the period of application of the stimulus. This was in contrast with animal preparations where the brainstem reticular system was intact, but whose specific sensory projection paths were transected. They gave evidence of both behavioral and electrophysiological arousal over sustained periods of time, even though specific sensory impulses failed to reach the cortex.

Two types of activation patterns have been distinguished (Sharpless & Jasper, 1959 ; Van. Olst & Orlebeke, 1967). A tonic reaction pattern was attributed to the brainstem reticular system and a phasic pattern was thought to be a function of the diffuse thalamic system. The brainstem reticular system would function in the maintenance of gross arousal while the

arousal of the thalamic nuclei, being of short duration, would continue to respond to repeated stimuli. The DTFS mediates a more differentiated attentional state to a stimulus after the first gross arousal induced by the brainstem reticular formation has adapted out. It is generally assumed that ascending brainstem reticular units are generally diffuse cortical activators, while the thalamic reticular units appear to be more specific, though this is still a matter of controversy (Jasper, 1949). Both the work of Gastaut (1954) and Chow's (1952) selective cortical ablation studies on regional degeneration within the thalamic reticular nucleus point to selectively localized activation of specific cortical areas by the thalamic nuclei. It is believed that this part of the reticular formation provides discriminative control and selective awareness.

Of interest are the findings where the arousal response initiated by the brainstem reticular formation could block the cortical recruiting response of the diffuse thalamic nuclei (Gellhorn, Koella, & Ballin, 1954): The proposition that optimal functioning of the brainstem overshadows the regulating effects mediated by the thalamic reticular system was suggested by Gellhorn, Koella and Ballin (1954). This overshadowing of the more differentiated functions of the thalamic nuclei by the diffuse arousal response of the brainstem could have its behavioral counterpart in the many failures of discrimination occurring under high emotion and excitement i.e., the inverted U phenomenon on performance

under conditions of high arousal or anxiety as reported by Malmö (1957).

The extent to which cortical areas exert an effect upon the reticular formation and participate in the control of sensory input is relevant to Eysenck's hypothesized corticoreticular feedback loop. The cortical connections to the reticular formation provide a means whereby the cortex could control the activating mechanism of the brainstem and thus influence its own level of arousal. French, Verzeano, and Magoun (1952) compared transmission latencies of the specific sensory pathways and those of the reticular formation. Impulse velocities were faster in the specific sensory pathways, which suggests that there is time for a stimulus to reach the cortex via the specific paths and then relay down to the reticular formation in time to affect its own arousal properties.

The inhibitory influence of the reticular formation is typically smallest whenever the sensory signal is more sudden or intense, or when a signal assumes a special significance as a cue for other stimuli. It is largest when the sensory input duplicates information classified as unimportant and already stored in the memory mechanisms of the brain (Inguar & Hunter, 1955; Livingston, French & Hernandez-Peon, 1953).

The efficacy of cortical processes in inducing wakefulness has been confirmed by Segundo, Arana, and French (1955).

Electrical stimulation of cortical areas with projections to the reticular formation aroused a sleeping animal just as effectively as an intense peripheral sensory stimulus. The reciprocal relationship between the cortex and the reticular formation would suggest a supporting framework for Eysenck's proposed feedback loop.

The possible link between reticular activation and perceptual sensitivity is of special interest to psychologists. A hypothesized relationship between levels of reticular activation and perceived brightness is suggested by evidence that stimulation of the midbrain formation leads to a great facilitation of the response of individual retinal units to a test flash of light (Granit, 1955). Fuster (1958) has shown that monkeys stimulated in the midbrain reticular formation made a higher percentage of correct responses and showed shorter reaction times in a discrimination problem than did the control group.

Of interest is a micro-electrode study cited by Lindsley (1960). Hubel, Henson, Rupert and Galambos (1956) studied single unit responses of the auditory cortex of unrestrained and unanaesthetized cats. These authors encountered units which are unresponsive to sounds, unless the cat is 'paying attention' to the sounds. Such units, presumably 'adapted' or 'habituated' by repetition, could regain functional status by an addition or slight change in the stimulating situation. Hernandez-Peon, Scherrev and Jouvét (1959) demonstrated how "attention", in

unanaesthetized cats with electrodes implanted in the cochlear nucleus, could influence the response of the cochlear nucleus to clicks. He achieved suppression of response in one modality by selective attention in another. Such an inhibitory mechanism imposed at various synaptic sites in the sensory pathways suggests that the selective exclusion of certain incoming signals may occur peripherally, as well as at the cortex or thalamic level. The origin of the effect may reside in the cortex or reticular formation of the brainstem. The important point would seem to be that "attention" or the selective process of the exclusion of certain sensory messages in favour of others may begin at various levels of sensory input, as well as at the thalamic and cortical levels (Lindsley 1960).

Alternatives to Eysenck's theory have been suggested by other authors. Gray (1970) has extended Eysenck's view somewhat by proposing that the physiological basis of extraversion consists not only in differences in activity of the ascending activating system, but also in the negative feedback loop. This loop involves the orbital frontal cortex, the medial septal area and the hypothalamus to which the ARAS is coupled.

This present research would attempt to explore individual differences at the brainstem level. If differences were observed between introverts and extraverts in response.

to stimulation at the peripheral or brainstem level, then a modification of Eysenck's hypothesis of a corticoreticular feedback loop as the sole determinant of individual differences could be tentatively proposed. Eysenck's theory may have to include the role of peripheral sensory factors that may influence individual differences in terms of discrepancies in the excitation-inhibition balance. The introvert may have greater efficiency of sensory stimuli processing structures which would contribute to their enhanced sensitivity because the BSR is relatively insensitive to reticular influences.

Psychophysical and Electrocortical Studies

The last section reviewed Eysenck's theoretical rationale which proposes that differences in the corticoreticular loop account for greater cortical arousal in introverts than extraverts. The present research attempts to investigate the possibility that individual differences may arise at the peripheral or subcortical level. Variances between introverts and extraverts in their BSRs may denote such differences. Previous studies in psychophysical and electrocortical research provided the rationale for this thesis. The first two sections will review these studies. The third section describes evoked potential findings and their utilization as a technique to observe the effects of arousal. The last section reviews personality and evoked potential research and is concluded by the hypothesis suggested for this study.

Extraversion and Sensory Sensitivity

It is generally accepted (though not clearly established), that activity in the corticoreticular system results in a lowering of sensory thresholds. From that assumption Eysenck (1967) predicts that:

Introverts have lower thresholds and show less adaptation of inhibition with continued stimulation; extraverts have higher thresholds and show more adaptation/inhibition to continued stimulation. It would follow that any given degree of stimulation would be experienced as effectively higher by introverts than by extraverts. (p.110)

There is some evidence which seems to support this assumption. Smith (1968) was the first to report lower absolute sensory thresholds for introverts than for extraverts. Using a 500 Hz pure tone as a stimulus and a test group consisting both of extreme introverts and extraverts, Smith detected a difference in absolute auditory thresholds. In this comparison, the confidence in his findings would have been enhanced if he had employed more than three subjects per group.

A recent study by Stelmack and Campbell (1974) showed that under low frequency auditory stimulation (500 Hz tone), introverts were more sensitive than extraverts. This study had the advantage of employing a signal detection method which purported to control response bias in individual response styles. This study found differences only under low-frequency conditions.

With high frequency stimulation (6,000 Hz tone) extraverts showed an increase in sensitivity, while the introverts showed a decrease. Stelmack and Campbell (1974) discussed their results in relation to Eysenck's (1963) hypothesis of the relationship between hedonic tone and strength of sensory stimulation. Introverts manifest lower intensity levels of optimal or preferred stimulation while extraverts are seen to prefer stronger more intense levels of stimulation. Stelmack and Campbell (1974) suggest that "introverts may have lower frequency levels of preferred stimulation as well as lower intensity levels."

Siddle, Morrish, White and Mangan (1969), utilizing a visual stimulus, presented evidence showing a relationship between introverts and lower absolute thresholds. This study, using classical psychophysical methods, did not account for response bias.

Shigehsia and Symons (1973) investigated the effect of simultaneous heteromodal stimulation on three levels of extraversion. Their hypothesis was that the effect could be inhibitory or facilitory in terms of sensitivity levels. The stimulus consisted of a simultaneous variation of light intensities while varying the intensity of an auditory pure tone (1000 Hz). Shigehsia and Symons demonstrated that auditory sensitivity increased under weak, and decreased under strong intensities of light in introverts, increased under all intensities for extraverts (greater increases at greater intensities) and increased under weak and medium intensities in ambiverts.

Shigehsia and Symons suggested that their findings provided support for the "stimulus-aversion/hunger hypothesis" (Eysenck, 1967). Higher intensity levels facilitate sensory performance for stimulus-hungry extraverts who are less cortically aroused whereas, the same conditions inhibit the more cortically-aroused introvert. Although this study cannot unequivocally assume that personality factors were fully responsible for the effects obtained (attentional factors were not controlled), it has assisted in clarifying to some extent a more precise definition of the conditions which differentiate various types of stimulus parameters in relation to personality.

Corcoran (1964) hypothesized that equal amounts of stimulation will produce greater response in introverts. Utilizing techniques where the amount of saliva produced by a lemon juice stimulus was related to Extraversion, his hypothesis was supported. The limited sample size and failure to take into account diurnal rhythms, (testing occurred under different conditions) his results have been questioned. These limitations, plus Corcoran's use of the Heron scale as a personality instrument, prompted Eysenck and Eysenck (1967) to replicate his study. They found a high degree of correlation between personality and the amount of secreted saliva.

In summary, the results obtained as reviewed above would seem to support a detectable variance between introverts and extraverts

when tested for sensory thresholds.

A Review of EEG and Extraversion Findings

The supposition that introverts are characterized by higher levels of cortical arousal than extraverts is central to Eysenck's biological basis of extraversion. It has been noted that a relaxed state produces synchronized, high amplitude, low frequency EEG patterns, while arousal produces desynchronized, low amplitude, and fast irregular frequency EEG patterns. For the most part, alpha rhythm, alpha abundance, alpha frequency, and alpha index are employed to describe an arousal state in EEG research.

The rationale for reviewing EEG studies which incorporate extraversion as a variable, was to ascertain whether specific EEG patterns were related to differences in personality. However, these studies have left rather a confused picture of both negative and positive findings in relation to individual differences.

Gottolber (1938) was the first to examine the relationship between resting EEG and extraversion. Gottolber showed that extraverts demonstrated a 'high percent time' during which alpha activity was present in the record, (which is indicative of a lower frequency) and supported Eysenck's hypothesis. Henry and Knott (1941) found contradictory results in the relationship of extraversion and alpha index. Introverts were found to display

a higher alpha index, or a lower frequency. Mundy-Castle (1955) reported findings along the same direction as Henry and Knott's results, where introverts displayed lower alpha frequency.

A critical review by Gale (1961) suggests a variety of methodological issues to account for discrepant findings in these three studies. Inventories employed to assess personality factors differed across studies; Gottolber utilized both clinical judges and the Nebraska Personality Inventory (NPI), Henry and Knott employed the NPI, and Mundy-Castle utilized the Biesheuvel Inventory. The sampling rate of EEG lacked consistency across studies, ranging from 30 seconds (Gottolber) to 20 minutes (Mundy-Castle). Gale (1961) criticized all three studies for features such as contaminated scoring techniques, prior experimenter knowledge of personality scores, confounding uncontrolled neuroticism factors, and uncontrolled sex differences.

The alpha amplitude or alpha abundance and extraversion was investigated by Savage (1964). He proposed that strong cortical inhibition as demonstrated by higher alpha amplitude was associated with reduced cortical arousal characterizing extraverted individuals. Savage utilized a well designed study to calculate the average amplitude of alpha frequency. From his results he suggested that extraverts had a higher alpha abundance than introverts, and that there was no relationship between neuroticism and extraversion. Unfortunately, the subjects lay with their eyes closed, and Savage's data may have been due to the onset of sleep

rather than a resting state.

Fenton and Scotton (1967) also assumed that extraverts would exhibit a more pronounced alpha wave and should habituate to stimulation faster than introverts. In their paradigm, resting EEG was measured by the alpha index which occurred in a prestimulus rest period. Habituation was operationally defined as the mean duration of alpha blocking (or rate of change of potential) to visual stimuli. In these results, there were no differences between introverted and extraverted subjects. In fact, no true resting state could be measured as a continuous masking tone was utilized. The method which Fenton and Scotton employed to assess habituation is open to question, as the criterion required to administer the visual stimulus depended upon the experimenters' visual inspection of the ongoing alpha activity.

Marton and Urban (1966) showed their results to be in line with the Eysenckian hypothesis. Extraverts had a higher index and a lower alpha frequency. As well, he found that extraverts' EEG response to repeated auditory stimulation ceased earlier and following habituation, they showed signs of sleep. However, the fact that out of the twenty introverts utilized, nine were noted to be without alpha rhythm, would suggest that this study's results are suspect. Broadhurst and Glass (1969) found a low but significant negative correlation between alpha blocking and extraversion. Recordings in this study were taken during periods of rest between presentations of mental arithmetic tasks. These

subjects were not tested under identical conditions however, and this may have possibly affected the level of arousal. Gale (1969) suggests that the main problem with any "resting" EEG study is that there will be systematic variances in EEG during the waking state.

Studies where subjects' tasks were manipulated again are inconclusive. Gales, Coles, and Blaydon (1969) gave subjects a simple task of opening and closing their eyes upon instruction. Utilizing alpha abundance scores and a new method of mean integration output and frequency, the authors confirmed Savage's findings. It was noted that the effects for alpha were strongest for all groups when eyes were open. Gale, Harpham and Lucas (1972) attempted to replicate Gale's, Cole's and Blaydon's (1969) study but they found no effect on alpha abundance when subjects' tasks varied. Similar findings of no differences between groups were obtained from the Winter, Broadhurst and Glass (1972) study when four experimental conditions of eyes opened, closed, solving for arithmetic problems and without arithmetic problems were employed. However, across groups it was found that the effect of heightened arousal was obtained with the eyes opened and solving arithmetic conditions.

In summary, EEG studies are at best inconclusive. Gales (1969) offered an hypothesis to account for these discrepant findings. He suggested that extraverted subjects may vary their state of arousal if they are too bored with the procedure or too interested with the task and hence becoming more aroused than their counter-

parts. He states that: "Extraverts by virtue of an inherently low level of arousal, are obliged to search for stimulation in order to sustain behavioral efficiency. This is the origin of the stimulus-hungry behavior of extraverts". Gale noted in his 1969 review that studies done by Strelau and Terlack (1974), Montgomery (1975), and Rosler (1975) which incorporated moderate arousal conditions have optimized personality difference and found results which favored Eysenck's hypothesis.

Evoked Potentials

Voltage changes apparent in raw EEG are determined from a multiplicity of neuronal generators, hence the extent to which a stimulus event influences cortical activity, is difficult to discern. Techniques such as time-locked stimuli and signal averaging are used to improve the signal-to-noise ratio of electroencephalographic activity when investigating the response to a physical stimulus employed in sensory information processing research.

An evoked potential (AER) is defined as a change in electrical activity of the nervous system elicited by some specific stimulus or psychological event given at a specific time (Picton & Hink, 1974). The technique of signal averaging is based on the assumption that an AER following a stimulus is a constant wave

form, time-locked to the stimulus, and therefore always at the same latency. When that stimulus is given many times, the spontaneous background activity averages out. In the resulting averaging of evoked potentials, the random background noise will algebraically sum towards zero and the subsequent time locked positive and negative waves precipitated by the recurring stimulus will emerge larger with each stimulus presentation, eventually emerging as summed evoked potentials.

The resultant positive peaks of evoked potentials elicited by an abrupt auditory stimulus consist of different components identified as early (0-8 msec after stimulus onset), middle (8-50 msec), and late (50-250 msec) components (Picton, Hillyard, Krausz & Galambos, 1974). The larger, longer-lasting potentials elicited by an auditory stimulus are the P_1 (50 msec), N_1 (100 msec), P_2 (170 msec), and N_2 (250 msec) late components of the vertex potential. Due to their large amplitude, they are believed to originate in the cortex rather than the thalamus or brainstem (Picton, Hillyard, Krausz & Galambos, 1974). The "P" and "N" stand for the positive and negative valence that the components take. This vertex potential is altered somewhat by attention, which increases the N_1 - P_2 amplitude and markedly decreases the N_2 component, for example during sleep (Picton & Hillyard, 1974).

In the period of time between 8 and 50 msec after the stimulus, there are a series of potentials recorded over a widespread area of the scalp, No, Po, Na, Pa, Nb. These are the middle components and may represent thalamic and early cortical potentials.

Brainstem evoked responses will be given a more detailed discussion as they are the focus of this thesis. The early components are thought to be generated in the brainstem auditory structures. Utilizing far-field averaging techniques, Jewett (1970) defined a series of seven deflections of submicrovolt amplitude, now colloquially referred to as "Jewett bumps", which occur during the initial 8 msec following a click stimulus.

Although the exact anatomical generator sites of the vertex positive peak remain a matter of controversy, they are related to sequential components of the auditory pathway. Evidence now the following wave origins: I auditory nerve, II cochlear nucleus, III superior olivary complex, IV midbrain possibly nucleus of the lateral lemniscus, V inferior colliculus, VI medial geniculate and VII possibly auditory radiation from the thalamus to the temporal cortex (Buchwald & Huang, 1975; Jewett, 1970; Jewett & Williston, 1971; Lev & Sohmer, 1972).

Studies have defined some of the stimulus and recording characteristics of the auditory brainstem responses. Waves I, III and V were consistently identifiable with click stimulus

(Stockard, Valerius & Rossiter, 1977). Jewett and Williston (1971) concluded that wave V is probably the best basis of comparison across subjects and laboratories because of its reliability and prominent amplitude compared to other peaks. The negative wave which follows wave V by approximately 1 to 1.5 msec is also very accurate for comparison purposes (Picton, Woods, Baribeau-Braun, & Healy, 1977).

The amplitude and latency of response components vary with stimulus intensity. Auditory brainstem responses (BSR) decrease in amplitude and increase in latency as signal intensity is reduced, (Starr & Achor, 1975). However, interpeak conduction times depend upon rate of stimulus presentation (Rowe, 1978). It was also found that binaural stimulus presentation increases the amplitude of these components (Davis & Hirsh, 1976). As the amplitude of wave V is insensitive to signal rise and fall times, it is solely an onset response (Hecox, Squires, & Galambos 1976).

Latency features of BSR are fairly consistent in some aspects. The latency of wave V is markedly delayed with increases in stimulus rise time, but unaffected by changes in fall time. Increases in stimulus duration and subsequent loudness were found to result in a systematic increase in latency (Rowe, 1978). Also, an inverse relationship between frequency and latency has been demonstrated by Suzuki, Hirai & Horiuchi (1977).

Amadeo and Shagass (1973) demonstrated that BSR show little

or no change in amplitude and latency characteristics of these potentials from waking to sleep stages. Therefore brainstem evoked potentials are thought to be independent of arousal, activation and attention. The significance of this finding in relation to Eysenck's hypothesis will be developed at the end of this chapter.

Brainstem evoked responses were originally evaluated by click stimulation (2,000 Hz and above). Controversy as to the applicability of the low frequency tones reliability seems current in the literature (Davis & Hirsh, 1976). More recently it has become possible to make highly reliable recordings of an evoked frequency following response (EFR) which is synchronous with low frequency tones (Moushegian, Rupert & Stillman, 1973). Yamane, and Koderia (1977), utilizing at 500 c/sec tone burst, found that by reversing the stimulus phase and the polarity of the recording, the BSR and EFR could be isolated from one another.

Weber and Folsom (1977) argued that the slow rise time of pure tones are the factors which render them ineffective in eliciting a reliable BSR. They suggested the tone pip as a compromise, with a rise time equalling about twice the period of the pure tone and a plateau of no more than one period. The resulting tone pip envelope would be diamond-shaped. This would be in concordance with Hecox, Squires and Galambos' (1976) findings, that stimulus onset rather than offset elicits a BSR. Because the tone pip is unlikely to be as effective in eliciting

a response as the abrupt click, Weber and Folsom (1977) suggested that a somewhat reduced BSR amplitude and prolonged latency occurs when tone pips are used. These authors reported stable BSR to tone pips at 2,000 Hz and 4,000 Hz across intensity levels from 10 to 70 dB.

In a similar study Suzuki, Hirai and Horiuchi (1977) utilized tone pips of 0.5 kHz, 1 kHz, 2 kHz and 4 kHz with a two cycle rise-decay time and a one cycle peak at low intensities. No significant differences were found in response detectability between the four test tones. These authors accounted for their findings of reliable BSR to low frequency tones by employing a filter band width of 0.5 to 3,000 Hz. This manipulation reduces the attenuation of the low frequency component of the BSRs. Davis and Hirsh (1976) did not employ such a filtering device. Authors, Brama and Söhmer, (1977) and Mitchell and Clemis (1977) have also demonstrated success eliciting brainstem responses under low frequency conditions.

There are many factors affecting brainstem responses of which one must be aware. The studies which support the utility of low frequency tones in eliciting BSR provide the opportunity to investigate individual differences under optimal conditions as demonstrated in sensory studies (Smith, 1968, Stelmack & Campbell, 1974). BSR also provide information which aides in differentiating whether the effects of individual differences are largely cortical or occur at subcortical levels.

EEG and Evoked Potential Correlates of Arousal

As noted in the preceding sections, the EEG correlates of arousal would be demonstrated in the EEG record by desynchronization, low amplitude, and high frequency patterns. Conflicting accounts appear in the literature as to the relationship between averaged evoked cortical potentials, diffuse arousal states and selective attention. (Jané, Smirnov, & Jasper, 1962; Garcia-Ausst, 1963; Haider, Spong & Lindsley, 1964; Davis, 1964; Donchin & Cohen, 1967; Spong, Haider & Lindsley, 1968; Wilkinson & Morlock, 1967; Haseeth, Shagass & Straumanis, 1969).

Evoked potential amplitude decreases when general arousal is lowered or attention is shifted away from the evoking stimulus. Conversely, the potentials are enhanced with increased arousal, or when attention is more intensely focused on the evoking stimulus. In contrast to the results obtained in these studies, Thompson and Shaw (1965) suggest that the amplitude of the evoked potentials of the cat is inversely related to arousal and the degree of focus of attention on the evoking stimulus.

Studies where attempts have been made to manipulate attention independently of arousal have found that similar effects on evoked potentials have been observed (Eason, Harter & White, 1969). Picton and Hillyard (1974) in fact suggest that it is probably impossible to change levels of arousal in the waking state

independently of any attentional change. The differential effects of general arousal and specific attention in the amplitude of the evoked response would probably produce the same effects in the EEG response pattern, demonstrated by desynchrony, low amplitude and fast frequency. It is thought that arousal produces fast waves (short latency) in EP late components similar to the fast waves (high frequency) observed in the EEG. Most studies however, note amplitude changes rather than latencies and thus late component evoked potential amplitudes are the most sensitive parameters that respond to changes in level of arousal.

The arousal-attention variable has provoked considerable controversy as to the exact mechanism responsible for the observed effect on EP amplitudes of N_1 , P_2 and P_3 . Näätänen (1967) concluded that amplitude changes are not related to changes in specific attention, but only to change in nonspecific arousal. Eason, Harter and White (1969) opted for a combination of attention and arousal variables, noting that the combined effects of these two variables would determine the net change in the evoked potential amplitude. Picton and Hillyard (1974) conclude that selective attention is the major generator of the N_1 - P_2 components. Indeed, selective attention can be further differentiated in terms of stimulus set (involving N_1 - P_2) and response set (P_3). Callway (1975) noted that increases in EP amplitude and latencies may occur with increases in the psychological strength of the stimulus (i.e. information value,

importance, etc.) which supports attentional factors as increasing enhancement of the components.

Agreement among authors seems to lie in the observation that brainstem evoked responses are independent from the effects of arousal and attention. Picton, Hillyard, Galambos and Schiff, (1971) and Picton, Hillyard, Krausz and Galambos, (1974) have shown that no significant change in auditory evoked potentials occur prior to the N_1 - P_2 component. A study by Amadeo and Shagass (1973) suggest that changes in latency, amplitude and shape of later (after 40 msec) AER components during sleep occur at levels above the brainstem, either at the thalamus or cortex. This evidence supports Baust, Berlucchi and Moruzzi's (1964) proposal that early auditory potentials would reflect peripheral changes, and that increased thresholds for arousal by acoustic stimuli are probably mediated centrally.

Changes in nonspecific cortical arousal may be reflected in evoked potential amplitudes for N_1 , P_2 and P_3 as suggested by certain authors (Näätänen, 1967; Karlin, 1970). In a broader context, EP amplitudes of late components are enhanced during conditions of heightened arousal or selective attention. Studies investigating the relationship between personality and evoked potential utilize these features and are reviewed in the next section.

Extraversion and Cortical Evoked Potentials

As noted, enhanced evoked potential amplitudes of the late component are thought to reflect increased levels of arousal by Näätänen, 1975. Evoked potential amplitude and intensity have been found to be related by power functions similar to those obtained by psychophysical measures for visual, auditory and somatic sensory modalities (Regan, 1972). Although power functions do not imply a direct relationship between sensitivity and the AER, it would seem reasonable that the AER provides a useful technique for investigating sensory information processing and arousal/attentional factors when exploring the psychophysical basis of differences in sensitivity (Smith, 1968; Stelmack & Campbell, 1974; Siddle, Morrish, White & Mangan, 1969) and vigilance (Krupski, Raskin & Bakan, 1971; Harkins & Green, (1975) between introverts and extraverts.

The first study to investigate the relationship between EP and individual differences was Shagass and Schwartz (1963). The key finding was that dysthymics (low E, high N) somatosensory EP amplitudes were lower than psychopaths and hysterics. The diffuse grouping detracted from the reliability of this study. Dysthymics were grouped with nonpatients and psychopaths, hysterics and behavior problems were grouped with psychotics.

Visual evoked responses, aging, and personality were studied by Straumanis, Shagass and Schwartz (1965). Their positive

findings supported their hypothesis that increased EP amplitudes reflect reduced inhibition thought to be typical of introverts. The finding was not supported however by Haseth, Shagass and Straumanis (1969) as no significant differences occurred between psychiatric and non-patient groups as reflected in somato sensory EP amplitudes. Nor was the hypothesis put forward by Shagass (1965) supported by Burgess (1973). In these cases, correcting for individual differences in sensitivity by applying different levels of stimulus intensity according to subjects' absolute threshold to somatic stimulation may have precluded the observation of individual differences in the evoked responses.

Significant negative correlations between extraversion and the amplitude of evoked responses to 1000 Hz, 60 dB tones were observed by Hendrickson.

A study by Stelmack, Achorn and Michaud (1977) found larger N_1-P_2 amplitudes displayed by introverts with low frequency (500 Hz) and high intensity (80 dB) and low intensity (40 dB) auditory tones. These findings were not apparent under high frequency, high intensity conditions. The authors argued that differences demonstrated between introverts and extraverts may have been facilitated by employing low frequency auditory stimulation. Greater intersubject variability has been observed for late evoked potential components with low frequency tones in studies performed by Davis and Zerlin (1966), and Rothman (1970).

A recent study by Joseph (1978) employed auditory stimulation of a 4,000 Hz signal over three intensity conditions, 50 dB, 70 dB and 90 dB (SPL) to detect individual differences in both ESR and the late components. Results showed that introverts displayed greater amplitudes for wave V at 50 dB and 70 dB intensity levels but not at 90 dB. There were no significant differences in amplitude intensity function for introverts as there were for extraverts. The extravert's amplitude measure for JV increased significantly with increases in intensity whereas the introvert was almost at a maximum amplitude measure for JV at both the lowest and highest intensities. Joseph suggested a saturation effect may be occurring for introverts at low intensities. Introverts again displayed greater amplitudes for N_1 , particularly at low intensity (50 dB) auditory signals, whereas extraverts displayed significantly greater amplitudes at 90 dB intensity. No significant extraversion effects were noted for P_2 and $N_1 - P_2$ amplitudes. There has not been a precedent for differences between introverts and extraverts at high frequencies from either psychophysical nor electrocortical research which may account for Joseph's negative findings for the late components.

In summary, previous work in psychophysical studies have demonstrated greater absolute sensitivity of introverts (Smith, 1968; Stelmack & Campbell, 1974) and electrocortical studies have shown enhanced amplitudes of the late (N_1 - P_2) auditory evoked potential component (Stelmack, Achorn & Michaud, 1977). A more complete study of sensory processing and individual differences would encompass an investigation of brainstem structures. To date, very little research has been done which employs the technique of auditory brainstem evoked responses in considering the neurophysiological basis of individual differences.

An effect of greater amplitudes and faster latencies displayed by introverts for peaks I and II in Jewett's (1970) nomenclature would indicate that individual differences were operating at a peripheral level. The SSR is relatively insensitive to reticular influences and the early evoked potentials are thought to be independent of both attention (Picton & Hillyard, 1974) and arousal manipulation (Amadeo & Shagass, 1973). Significant differences between introverts and extraverts in latency or amplitude measures displayed by brainstem components with latencies of 3-8 msec would reflect subcortical structures as possible determinants of individual differences.

Eysenck (1967) hypothesized that differences along the extraversion dimension may depend upon individual variations in the corticoreticular loop which modulates cortical

arousal and inhibition. If differences between introverts and extraverts were observed at a peripheral (wave I and II) or subcortical (auditory brainstem nuclei), then this tentative finding may point to the necessity of further research in an effort to modify Eysenck's hypothesis.

In addition, it has been demonstrated that individual variability of auditory evoked responses is greater at low frequencies than at higher frequencies for the late components (Davis & Zerlin, 1966; Rothman, 1970; Stelmack, Achorn & Michaud, 1977). Low frequency stimulation employed in psychophysical studies also demonstrated enhanced responsiveness of introverts in their absolute sensitivity level. In any case, further research which would observe the effect of frequency manipulation could possibly determine the efficacy of the conditions under which these positive results have been observed.

Statement of the Hypothesis

Eysenck (1967) has proposed that individuals differ in the dimension of extraversion, and that introverts (low extraversion group) are characterized by a highly aroused and less inhibited corticoreticular system compared to extraverts (high extraversion group), who are characterized by relatively low arousal and high inhibition.

If enhanced auditory evoked potentials of brainstem responses, (as measured by greater amplitudes and shorter latencies) were displayed by introverts as opposed to extraverts, then

these findings may contribute to the biological basis of extraversion, possibly at the brainstem level. In a broader context, if this were the case, one would be inclined to consider more closely the role of peripheral factors in accounting for individual differences, especially those that contribute to enhanced sensitivity.

CHAPTER 11

METHOD

This chapter presents the methodology of the experiment. It describes the subjects used in this study and the procedure employed for allocation of subjects into Introvert and Extravert groups. The other independent variable studied was the frequency condition, which was divided into three levels: 0.5 kHz, 2 kHz, and 4 kHz. An 80 dB intensity level was held constant in this experiment.

The instrumentation and procedure used for obtaining the dependent measure of brainstem evoked potentials are described. This chapter concludes with the methods of analysis of the dependent variable under study, and an explanation of the general experimental design and statistical procedures involved in the testing of the hypothesis outlined in chapter 1.

Subjects

Twenty-four female volunteers, ranging in age from 20 to 32 years, were selected from a sample of 70 students and professionals on the basis of extreme scores (± 1 S.D. from the mean) on the Extraversion dimension of Eysenck's Personality Questionnaire (Eysenck, 1975). Two groups of 12 subjects each were formed. The means and S.D.'s obtained by the introvert

group for the Extraversion (E) scale were 5.48 and 2.15, for Neuroticism (N), 11.75 and 4.43 and for Psychoticism (P) 2.67 and 3.0. The means and S.D.'s obtained for the extravert group were 19.17 and 1.34 for the (E) scale, 9.5 and 3.9 for (N) and 4.0 and 2.0 for (P). There were no significant differences between the introvert and extravert groups in either Neuroticism nor Psychoticism. The score distributions are presented in the appendix. Subjects were screened for normal auditory sensitivity at .5 kHz, 2 kHz and 4 kHz with a model 10 Lafayette audiometer.

Apparatus

A monopolar EEG signal was fed into a Nihon-Kohden RB-5 Biophysical amplifier in a Nihon-Kohden RM-85 polygraph. The amplification factor was 60 dB reference to input. The signal was filtered by a Krohn-Hite model 3550 filter with a bandpass of 100 Hz - 3,000 Hz. The filter output was sent to the interface of a PDP 8/e data processor programmed to perform on-line averaging of 512 samples per 14.6 msec sweep. A 10.0 msec sweep of prestimulus EEG was averaged to establish a baseline. The average EP was displayed on a model 204 Fairchild oscilloscope and plotted by a type 704-A Moseley XY plotter. The sensitivity of the system was 0.055 mv/cm.

A Hewlett Packard 3300 A function generator produced the three frequency conditions of 500 Hz, 2,000 Hz and 4,000 Hz

respectively. The frequency conditions were counterbalanced within groups.

Each stimulus was of 5 msec duration with a 95 msec inter-stimulus interval and a 1.5 msec rise and fall time set by a laboratory designed timer (Achorn 1977). A train of 4,096 stimuli were presented at a rate of 10 per second in polarity of alternating phase. The wave form of the 0.5 kHz tone pip is shown in Figure 1.

Intensity of the 80 dB (SPL) tone pip was regulated by a WA-44 C model 1421 audiogenerator. This intensity was maintained throughout the experiment, with the stimuli delivered binaurally through a set of Realistic stereo headphones model LV-10. The waveform for each stimulus was monitored on a type RM-564 storage oscilloscope in order to provide visual inspection for artifact free stimulation. A block diagram of equipment interconnections is shown for each frequency condition in Figure 2 (3 levels; 500 Hz, 2,000 Hz, 4,000Hz). The 4,096 stimuli were given in alternating phase by reversing the phase in a paired sequence. They were then averaged by summing an odd - even pattern. Alternating the phase of stimulus presentation was done to cancel the summation of stimulus artifact and to eliminate frequency following response (Yamada, Yamane & Kodera 1977).

Figure 1

Waveform of 0.5 kHz Tone Pip of 5
msec Duration with Rise and Fall
Time of 1.5 msec.



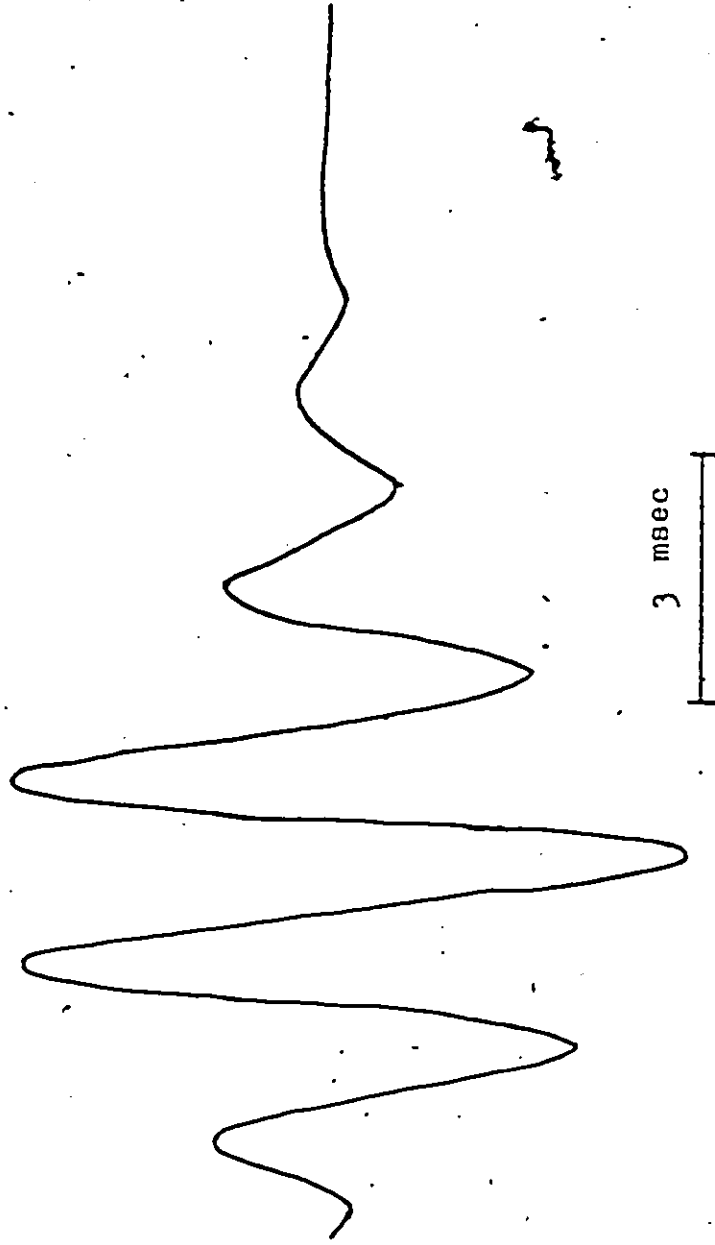


Figure 1. Waveform of 0.5 kHz. Tone Pip of 5 msec
Duration with a Rise and Fall of 1.5 msec.

Figure 2

Block Diagram of Equipment
Interconnections

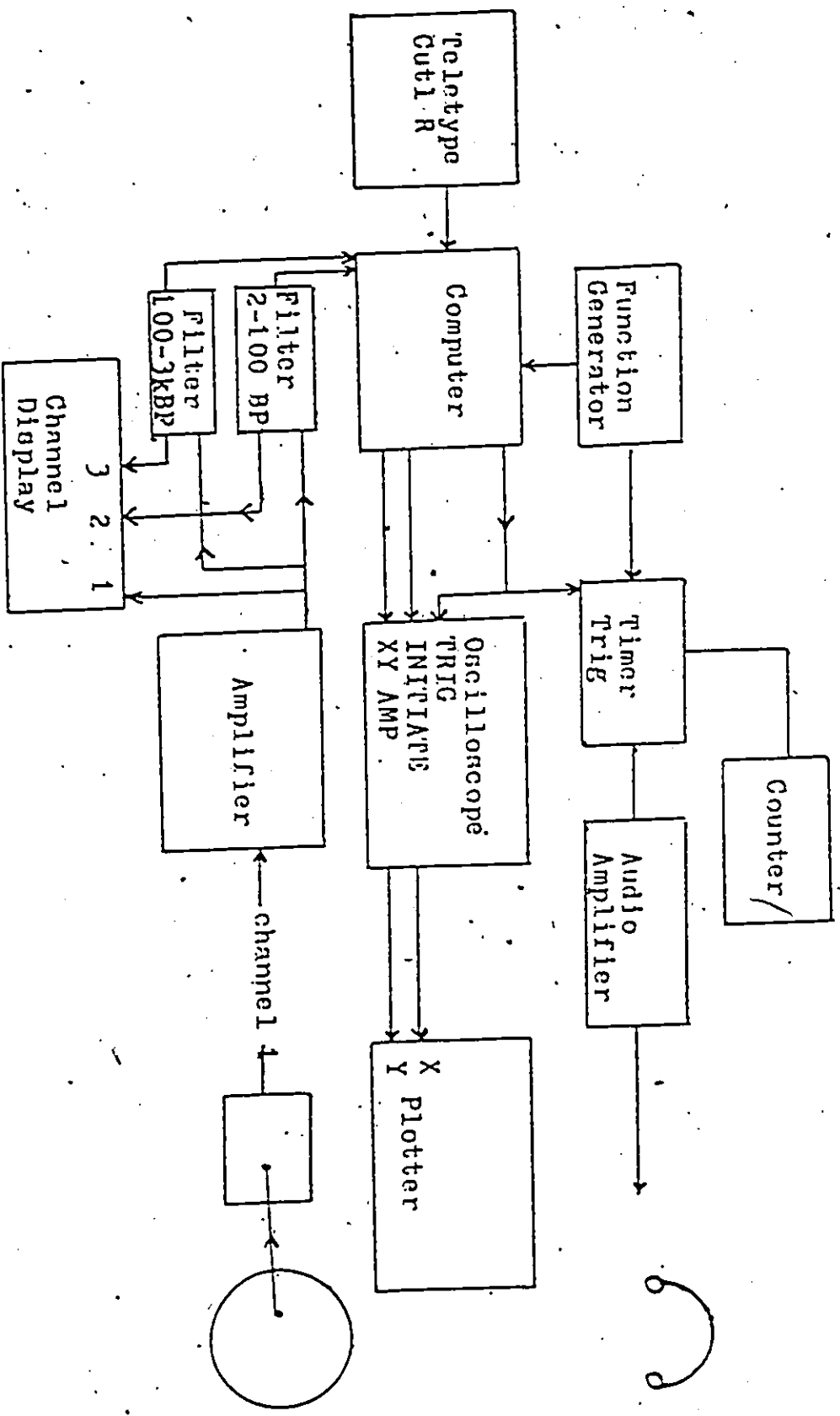


Figure 2. Block Diagram of Equipment

Connections

Equipment Calibration

The earphones were calibrated at 80 dB (SPL) intensity prior to the experiment for each frequency with a Bruel Kjaer type 2204 sound level meter, type 4152 artificial ear, and a type 1613 octave filter set with A weighting. This intensity was maintained throughout the experiment. The biophysical amplifiers, the averaging computer, and the plotters were calibrated with a 5uV DC input signal having the same temporal definition as the stimulus presentation procedure. Calibration amplitudes varied less than 4% and an average derived from all calibration values was used to calculate the BSR amplitudes ($\bar{x} = .014 \mu V$, S.D. = 0.00056)

Vertex-positive polarity was checked by introducing a positive upwards inflection in a noninverting system. The same procedure established negative as a downward deflection. The timebase of the scope was previously calibrated by a Fairchild Type 781 A Time Mark Generator. The PDP 8 computer timebases were calibrated using a DAWE type 901, Digital Frequency Meter.

Procedure

The purpose of the experiment was briefly explained to the subjects and they were asked to relax as much as possible. All subjects were given detailed instructions as to the nature and the duration of the sound stimuli they would receive. The

electrodes were then placed on the following locations: the EEG electrode was placed at Cz, which is the midpoint between nasion and inion, a midline location (Jasper, 1958), the reference being the left mastoid. The ground electrode position was the right wrist. Skin surface areas were prepared for electrode placement by cleansing the skin with cotton soaked in alcohol, and by then scratching the skin with a sterilized needle to prevent skin potential artifacts (Picton & Hillyard, 1972). The electrodes were then attached using Beckman Offner 0.5 NaCl conducting gel and adhesive collars. The impedance level was less than 2 kOhm.

The subject was then seated in a soundproof room adjacent to the equipment area. The ear phones were placed in position, and the subject was instructed to relax and to keep her eyes closed. A relaxation period of approximately fifteen minutes preceded the stimulus presentation which commenced when the EEG was free of muscle artefacts. The subject was also monitored by video for gross motor movement.

The command to initiate the presentation of the stimuli and the simultaneous analysis of the BSR was manually controlled by teletype. Once initiated, each subject received each of the three frequency conditions in counter-balanced order of presentation within groups. There was an interval of approximately five minutes between presentations when the plotters obtained a record for each

frequency condition. The subject's electrodes were then removed and they were shown their results when all three experimental conditions were completed satisfactorily.

Analysis of the Brainstem Responses

The reliability of obtaining the evoked potential wave form generated from a tone pip stimulus is not as consistent as that of click signal, especially with a low frequency tone, (Davis & Hirsh, 1976). Brainstem responses are obtained more frequently from click stimuli. Therefore, the literature provides a greater number of studies where high frequency normative data for latency intensity functions has been cited than for low frequency tone pip stimuli. The scoring was guided by latency measures as described by Yamada, Yamane and Kodera, (1977) Weber and Folsom, (1977) and Stillman, Moushégian and Ruper (1976). The anticipated latency for wave V, cited by Yamada, Yamane and Kodera, (1977) was approximately 6 msec following the onset of the stimulation at 70 dB with the higher frequencies inversely related to latency. Therefore, the criterion for scoring Jv was based upon visual inspection of the positive peak (Jv) followed by a negative peak, reliably discernable at the anticipated latencies for the specific intensity. Jv was clearly identifiable in all subjects,

while other waves were more variable. Therefore only Jv and the subsequent negative peak were scored within 0.075 msec for latencies and amplitude measurements. For the records of subjects where the two curves of BSR did not coincide, a midpoint of the two curves was estimated and latency of the maximum peak (Jv) and the following negative peak was scored. Therefore four characteristics of the BSR were measured: Jv and the subsequent negative peak latency, Jv amplitude from baseline, peak to trough amplitude of Jv and the subsequent negative peak. This visual inspection method of scoring was one of the two methods of analysing the BSR and will be discussed in the results section under Hand Scoring Technique.

In the attempt to identify the peaks preceding Jv, a group average waveform was computed by averaging all BSR for each frequency condition. For example, all 24 subjects' BSRs, consisting of two sets per individual record at 500 Hz were averaged to yield a group average waveform for this frequency condition. For this analysis, an Istronic Digitizer, which is a manually operated free cursor graphic-digital converter, was used. The Istronic digitizer sampled the records at the rate which provided 50 coordinates per msec. The digitized data was then processed on an IBM 360 computer and group waveforms were plotted graphically. Time windows defining where the peaks occurred across all subjects per frequency condition were obtained concurrently with the group

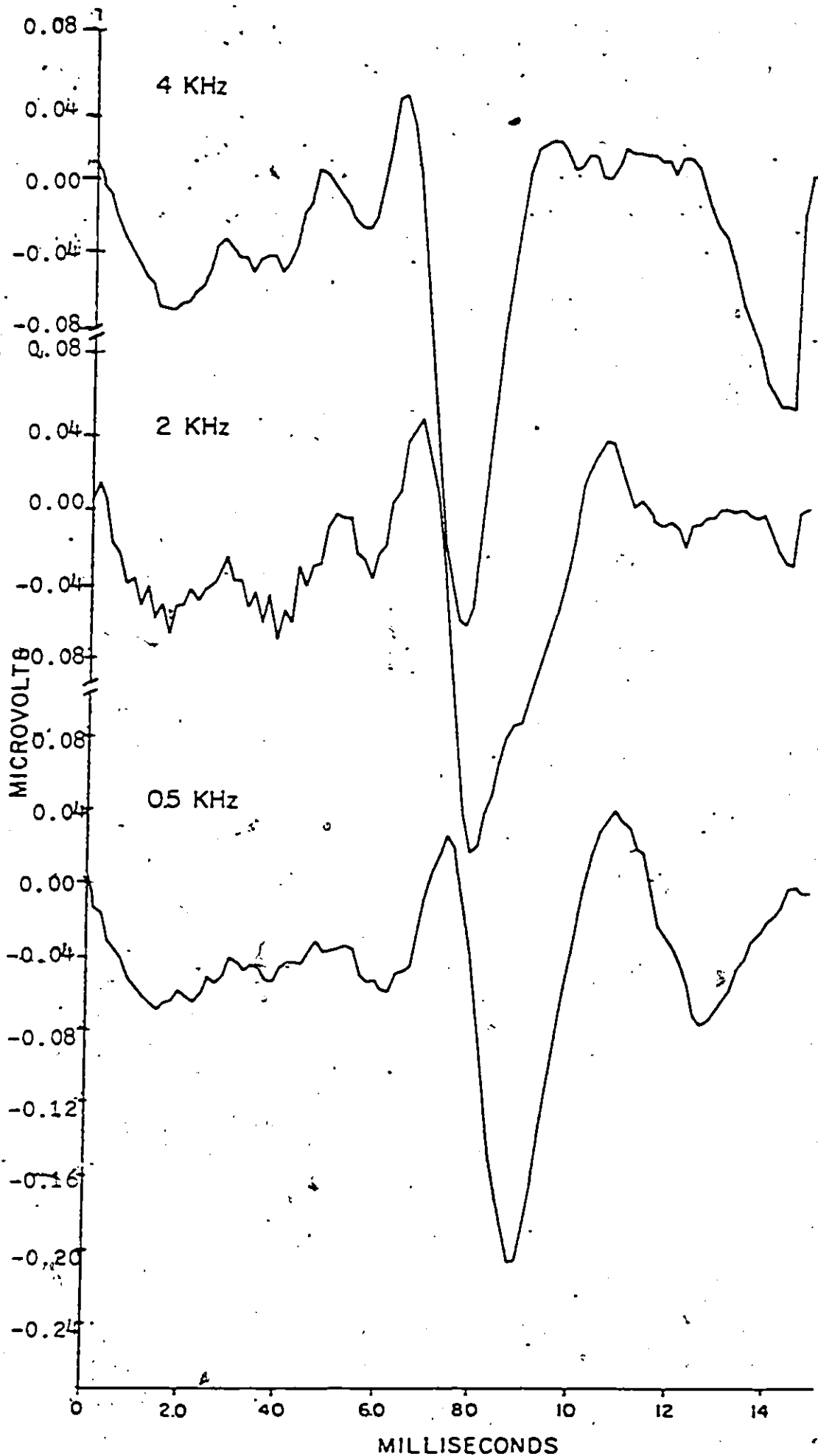
average waveform. This was accomplished by sampling BSR amplitudes at intervals of 0.15 msec (from stimulus onset to the end of analysis time) and then averaging these amplitudes across subjects per frequency condition. Figure 3 shows the three plots obtained at each frequency level.

Three peaks emerged, which defined time windows of 1.40-4.00 msec, 4.00-5.60 msec and 5.60-7.80 msec at 2kHz and 4kHz. At 0.5 kHz, the time windows were 1.40-3.90 msec, 3.90-6.4 msec and 6.40-8.80 msec. The third peak was identifiable as Jewett's (1970) wave V (Jv). The Pearson correlations obtained for these concurrently recorded BSRs were 0.95, 0.97 and 0.97 at 0.5 kHz, 2 kHz, and 4 kHz frequency levels respectively. These values were obtained by correlating each of the 100 points per graph (at 0.15 msec intervals) per individual subject's curve, with the mean obtained for all subjects at each of the 100 points. These grouped waveforms were used to estimate the reliability of the BSR recorded. The time windows provided guidelines when individual records were scored. The IBM 360 computer scored the maximum positive above baseline within the prescribed time windows. Therefore, six characteristics of the BSR were measured: latencies of peaks I, II, III and amplitudes taken from positive peak to baseline of peaks I, II, III. This method of analysis of the BSR is referred to as the Digitizer Method of scoring in chapter III.

Figure 3

Concurrent Auditory Brainstem
Evoked Responses to 0.5 kHz, 2kHz
and 4 kHz Tone Pips Averaged across
subjects, N=24

W
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Statistical Design

A two factor analysis of variance (Extraversion X Frequency) with repeated measures on the frequency condition was applied to the data. Two levels of extraversion (Introvert and Extravert Groups) and three levels of frequency (500 Hz, 2 kHz and 4 kHz) were considered. The .05 level of confidence was adopted for all statistical tests. The same statistical design was applied to both techniques of scoring, the digitizer and hand scoring methods.

CHAPTER 111

RESULTS

This chapter begins by reviewing the statistical procedures employed and the features of the ESR's analysed in this experimental design. Results are reported for both the hand scoring and the digitizer methods. The chapter concludes with a review of the results obtained from correlational studies utilized to ascertain the degree of relationship between the two scoring techniques.

Two-way analysis of variance (extraversion X frequency) with repeated measures on the frequency was applied to these specific components in the hand scoring technique: (i) latency measures of Jv and the subsequent negative peak, (ii) the amplitude of Jv as measured from baseline, and the amplitude of Jv as measured from the subsequent negative peak.

Applying the same statistical procedure to the Digitizer method latencies of the three predominant peaks as described by the time windows and taken from peak to baseline were analysed. Amplitude measures on these same three peaks as taken from baseline to positive peak were then analysed.

Hand Scoring Technique

Significant main effects for the latency of Jewett's wave V were observed. The mean latency at 4 kHz (6.64 msec) was faster than the latency at 2 kHz (7.01 msec) and at 500 Hz (7.67 msec); $F(2/44) = 181.5$, $MSe = .0361$. The interaction of the Extraversion X Frequency, although apparent $F(2/44) = 2.75$, $MSe = .037$, $p < .07$ failed to reach the acceptable levels of confidence. This interaction depended primarily on the extraverts' shorter latency at 500 Hz. The latency of the negative peak following Jv also indicated a significant main effect due to frequency $F(2/44) = 99.02$, $MSe = .01$ with the low frequency condition mean (8.99) msec longer than the mean (8.26 msec) at 2 kHz and the mean (7.71 msec) at 4 kHz. Amplitude of Jv from baseline showed no significant main effects or interactions. Amplitudes of Jv to the subsequent negative peak revealed significant main effects due to frequency $F(2/44) = 4.51$, $MSe = .005$ with the amplitude at 4 kHz significantly greater than at 2 kHz and 500 Hz. Table 1 and 2 shows the means, S.D.s of amplitude and latency measurements respectively, of wave V at 80 dB for introverts and extraverts for the hand scoring technique.

Table 1

Mean and SD Amplitude in microvolts (peak to baseline, peak to trough) of Wave V (Jv) under Three Levels of Frequency (500 Hz, 2 kHz, 4 kHz) at 80 dB (SPL) Intensity for Introverts and Extraverts, Handscoring Technique.

Measure	E Group	Frequency		
		0.5 kHz	2kHz	4kHz
Amplitude (uV) peak to baseline	Introvert (12)	0.076 (0.042)	0.084 (0.040)	0.071 (0.035)
	Extravert (12)	0.067 (0.047)	0.078 (0.031)	0.095 (0.053)
	Total (24)	0.071 (0.043)	0.081 (0.035)	0.083 (0.045)
Amplitude (uV) peak to trough	Introvert (12)	0.346 (0.096)	0.312 (0.067)	0.377 (0.065)
	Extravert (12)	0.313 (0.084)	0.336 (0.098)	0.381 (0.135)
	Total (24)	0.330 (0.090)	0.324 (0.083)	0.379 (0.103)

Note: SDs are given in parentheses.

Table 2

Mean and SD Latency in milliseconds of Jv (positive peak) and the Subsequent Negative Peak following Jv under Three Levels of Frequency (500 Hz, 2kHz, 4kHz) at 80 dB (SPL) Intensity for Introverts and Extraverts, Handscoring Technique.

Measure	E Group	Frequency		
		0.5kHz	2kHz	4kHz
Latency (msec) positive peak (Jv)	Introvert (12)	7.735 (0.179)	6.952 (0.171)	6.595 (0.205)
	Extravert (12)	7.610 (0.337)	7.064 (0.355)	6.678 (0.340)
	Total (24)	7.673 (0.271)	7.008 (0.278)	6.636 (0.278)
Latency (msec) negative peak following Jv	Introvert (12)	9.003 (0.311)	8.349 (0.511)	7.775 (0.295)
	Extravert (12)	8.982 (0.397)	8.181 (0.359)	7.652 ⁴ (0.273)
	Total (24)	8.993 (0.349)	8.265 (0.441)	7.715 (0.285)

Note: SDs are given in parentheses.

Digitizer Method of Scoring

The averaged group waveforms revealed three peaks within the time windows described at 1.40-4.00 msec, 4.00-5.60 msec and 5.60-7.8 msec at 2 kHz and 4 kHz. At 0.5 kHz the time windows were 1.40-3.90 msec, 3.90-6.40 msec, and 6.40-8.80 msec. The third peak was identified as Jewett's wave V.

Baseline to positive peak amplitude within each time window was determined. Analysis of the first peak revealed no significant differences between frequency conditions. For the second peak, the latency observed at 0.5 kHz was significantly longer than at 4 kHz and 2 kHz, $F_{2/44} = 6.60$, $MSe = 0.264$. For the third peak, Jv, the latencies were differentiated from each other at all three levels with 4 kHz less than 2 kHz, less than 0.5 kHz, $F_{2/44} = 5.76$, $MSe = 0.108$.

No significant effects were observed with the baseline to peak amplitude measures for any frequency condition.

Intersubject variability for the latency measures was generally smaller for the third peak and greater for the first peak. Differences in intersubject variability between frequency levels were slight with variability for low frequency greater than high frequencies, particularly for the first two peaks.

Intersubject variability concerning the amplitude measures was not significant. The means and standard deviations of the

latency and amplitude measures across 24 subjects are shown in Table 3 for the digitizer scoring technique. Table 4 and 5 shows the means and SDs of latency and amplitude measurements respectively, of wave V at 80 dB for introverts and extraverts for the digitizer scoring techniques.

The analysis showed no significant main effects due to extraversion for any of the three peaks considered. An Extraversion X Frequency interaction was observed in peak III (Jv) baseline to peak analysis. $F_{2/44} = 2.87$, $MSE = 0.001$, $P < 0.06$. In this interaction, the mean amplitude of the introvert group at the low frequency condition (0.072 uV) was greater than the mean amplitude of the extravert group (0.047 uV). At the high frequency condition, the extravert group was observed to have greater amplitudes (0.084 uV) than the introvert group (0.055 uV). For this interaction, the power of the effect is .09 and would require an increase in sample size to 80 to exceed the .05 level of confidence.

A correlational analysis between the two techniques of scoring showed the methods for obtaining peak III, (Jv) was highly correlated in the amplitude measures. The largest discrepancy was found in peak latency, with correlations ranging from .454 (4kHz), .516 (2kHz), to 0.702 (0.5 kHz). The analysis between the two methods for peak III (Jv) for the amplitude measures yielded Pearson correlations of the order of .918 (500 Hz), .959 (2 kHz) and .965 (4 kHz). Critical values of these correlations

Table 3

Mean and SD Latencies (msec) and Amplitudes (uV) for Peak I, Peak II, Peak III (Jv) at Low, Medium, and High Frequencies under 80 dB (SPL) Intensity, N=24, Digitizer Method of Scoring.

Peaks	Frequency		
	0.5kHz	2kHz	4 kHz
Peak I			
Latency (msec)	2.962 (0.824)	2.887 (0.727)	3.287 (0.595)
Amplitude (uV) baseline to peak	0.001 (0.031)	0.006 (0.023)	-0.006 (0.031)
Peak II			
Latency (msec)	5.537 (0.774)	5.112 (0.460)	5.037 (0.380)
Amplitude (uV) baseline to peak	0.019 (0.040)	0.022 (0.042)	0.028 (0.037)
Peak III (Jv)			
Latency (msec)	7.637 (0.375)	7.100 (0.249)	6.625 (0.358)
Amplitude (uV) baseline to peak	0.060 (0.042)	0.067 (0.040)	0.069 (0.046)

Note: SDs are given in parentheses.

Table 4

Mean and SD Amplitudes in microvolts (peak to baseline) for Peak I, Peak II, Peak III (Jv) under Low, Medium, and High Frequencies at 80 dB (SPL) Intensity for Introverts and Extraverts, Digitizer Method of Scoring.

Peaks	Group	Frequency		
		0.5kHz	2kHz	4kHz
Peak I Amplitude (uV) peak to baseline	Introvert (12)	-0.00908 (0.03055)	0.00600 (0.01928)	-0.00667 (0.02951)
	Extravert (12)	0.01025 (0.02877)	0.00650 (0.02737)	-0.00475 (0.03322)
	Total (24)	0.00058 (0.031)	0.00625 (0.023)	-0.00571 (0.031)
Peak II Amplitude (uV) peak to baseline	Introvert (12)	0.02233 (0.04067)	0.01358 (0.03996)	0.03050 (0.03588)
	Extravert (12)	0.01517 (0.03954)	0.03025 (0.04369)	0.02608 (0.03818)
	Total (24)	0.01875 (0.040)	0.02192 (0.042)	0.02829 (0.037)
Peak III (Jv) Amplitude (uV) peak to baseline	Introvert (12)	0.07208 (0.03892)	0.07042 (0.04087)	0.05517 (0.03712)
	Extravert (12)	0.04742 (0.04311)	0.06267 (0.04038)	0.08350 (0.05145)
	Total (24)	0.05975 (0.042)	0.06654 (0.040)	0.06933 (0.046)

Note: SDs are given in parentheses.

Table 5

Mean and SD Latencies in milliseconds for Peak I, Peak II, Peak III (Jv) under Low, Medium, and High Frequencies at 80 dB (SPL) Intensity for Introverts and Extraverts, Digitizer Method of Scoring.

Peaks	E Group	Frequency		
		0.5kHz	2kHz	4kHz
Peak I				
Latency (msec)	Introvert (12)	3.262 (0.743)	2.825 (0.652)	3.362 (0.548)
	Extravert (12)	2.663 (0.819)	2.950 (0.820)	3.213 (0.654)
	Total (24)	2.963 (0.824)	2.888 (0.727)	3.288 (0.595)
Peak II				
Latency (msec)	Introvert (12)	5.375 (0.743)	5.163 (0.652)	5.175 (0.548)
	Extravert (12)	5.700 (0.819)	5.063 (0.820)	4.900 (0.654)
	Total (24)	5.538 (0.774)	5.113 (0.460)	5.038 (0.380)
Peak III (Jv)				
Latency (msec)	Introvert (12)	7.700 (0.328)	7.050 (0.169)	6.525 (0.412)
	Extravert (12)	7.575 (0.423)	7.150 (0.309)	6.725 (0.278)
	Total (24)	7.638 (0.375)	7.100 (0.249)	6.625 (0.358)

Note : SDs are given in parentheses.

Table 6

Correlations Between Handscoring and Digitizer Scoring Techniques for Amplitude and Latency Measures of Jv under Low, Medium and High Frequencies, (0.5kHz, 2kHz, 4kHz) at 80 dB (SPL) Intensity, across Subjects (N=24)

Measures	Correlations (r) for Frequencies		
	0.5kHz	2kHz	4kHz
Amplitude	.91785	.95908	.96450
Latency	.51631	.70180	.45378

revealed that there were no significant differences between the two methods of scoring. Table 6 shows correlations for latency and amplitude measures for peak III (Jv) per frequency condition at 80 dB (SPL) across subjects. Discrepancies which occurred between the two methods of scoring will be discussed in chapter IV.

CHAPTER IV

DISCUSSION

This chapter begins with a discussion of the discrepancies which occurred between the scoring techniques. Implications are noted which emerged from the frequency effects. Extraversion results are then reviewed. The strengths and weaknesses of this study are discussed. Suggestions for future research conclude the chapter.

Discussion of Scoring Methods

The criteria employed by the hand scoring technique involved sighting the negative peak which preceded Jv, a peak which occurred approximately 6-9 msec after stimulus onset. Jv was identified as the maximum positive peak which was apparent on both curves and preceded a large negative peak. It was necessary to employ subjective judgement in situations where the two curves showed discrepancies in morphology (with midpoints being estimated) and when a train of several positive peaks of equal amplitude preceded the negative trough. The same criterion was employed to estimate the latency of the negative peak. Once a decision had been made as to the latency of the peak, the amplitude was measured from baseline to peak and from peak to trough.

The technique employed to score amplitude and latency measures by the manual digitizer (graphic-digital converter) involved the following steps. First, the amplitude at .15 msec intervals was determined for each evoked potential recording. These amplitudes were then averaged to form group curves at each frequency level and from these group curves time windows were established. Then the two curves for each frequency condition were averaged and the three peaks were determined to record the latency of each maximum peak for the individual graphs.

It should be noted that the correlations between the two methods were lower for latencies $r=.45$ at 4 kHz, $r=.70$ at 2kHz and $r=.51$ at .5 kHz than for amplitudes (mean $r=.91$). Inspection of the records confirmed that latency discrepancies resulting when the mean of the two curves was computed for the individual record would not occur in the hand scoring method owing to the fact that a visual inspection of the graph could focus only on the segment where Jv and the large negative wave following it occurred. The high correlations observed between the two methods for the amplitude measures could have occurred as a result of there being less displacement on the y axis of the two curves.

Overall, it would seem that more confidence could be placed in the computer scoring. This is evident in that the computer method utilized data provided on the entire graph by

establishing a mean curve. The hand scoring technique, which would require more rigorous steps to average the two curves, tends rather to focus on a small segment at the deflection site of Jv. Computer Scoring eliminates subjective judgement and hence consistency is maintained. Based on the assumption that the digitizer method provides a more objective scoring technique, the results obtained by this method, are discussed in this chapter.

Frequency Effects

Low frequency tonal stimulation, when employed in psychophysical and electrocortical studies, (Smith, 1968; Stelmack & Campbell, 1974; Stelmack, Achorn & Michaud, 1977) have demonstrated extraversion differences. When attempting to utilize the same physical stimulation, several technical issues must be observed when eliciting a brainstem response. Because the latency of the auditory BSR increase with increases in stimulus rise time, (Hecox, Squires and Galambos, (1976)) the BSRs elicited by pure tones, which are characterized by slow rise times, are confounded, low frequency tones in particular appear to be less effective in eliciting discernible BSRs (Davis & Hirsh, 1976).

Weber and Folsom, (1977) and Suzuki, Hirai and Horiuchi (1977) have described stable auditory BSRs with tone pips. The low frequency tones employed by Weber and Folsom consisted

of tone pips defined by rise times of twice the period of the pure tone and a plateau of one period. The rise time was sufficiently increased to elicit an onset BSR. Suzuki, Hirai and Horiuchi (1977) recording with a band width of 0.5 to 3,000 Hz reduced the attenuation of the low frequency components of the BSRs. Successive phase reversal was utilized to cancel frequency following response effects and prevent potential artifacts due to summation effect (Yamada, Yamane & Kodera, 1977).

In this study, clearly discernable frequency specific auditory BSRs were demonstrated using tone pip stimuli. The auditory BSRs elicited by low frequency, and high intensity tone pips were shown to have the same high degree of reliability as BSRs elicited by high frequency tone pips. This effect is complimentary to the auditory BSRs at 2 kHz and 4 kHz tone pips reported by Weber and Folsom (1977) and to the 0.5 kHz low intensity tone pips reported by Suzuki, Hirai, and Horiuchi (1977).

The waveform obtained by averaging the BSRs across subjects indicated that three peaks within 8 msec of stimulus onset may be consistently defined to enable comparisons between individuals and that this waveform is constant across frequency levels.

The first peak identified in this study cannot qualify as wave I (Jewett's nomenclature) in that the latency is longer

at 4 kHz than either 2kHz or 500 Hz. Without adequate identification of wave I and with wave II having a mean latency of 5 msec, the second peak identified should not be confused with Jewett's wave II. However, peak III was identified as Jewett's wave V because the latency obtained was in agreement with the literature (Weber & Folsom, 1977; Suzuki, Hirai & Horiuchi, 1977).

Significant frequency effects were described by an inverse relationship between latency and frequency with shorter latency at the high frequency levels for the second peak and most predominantly for Jv. This inverse dependence of latency on stimulus frequency suggests that low frequency tone pips are stimulating the basilar membrane tuned to lower frequencies. These findings are in line with the expectations based on the mechanical transmission time within the cochlea. Since the high frequencies offer a maximum stimulus for the basal part of the cochlea, it is assumed that high frequencies take less time to reach the cortex compared to the low frequencies which stimulate the relatively distant apex (Gacek, 1970; Weber & Folsom, 1977; Brama & Sohmer, 1977).

In summary, frequency effects demonstrated that utilization of low frequency stimuli were successful in eliciting ESRs. The frequency specification that was necessary to obtain optimal differences in the extraversion effect was met in this research.

Extraversion Effects

Eysenck hypothesized that introverts are more cortically aroused than extraverts, and that extraverts are more cortically inhibited than their counterparts. Neurophysiological studies of cortical excitability traditionally have utilized the amplitude of evoked potentials as an index of cortical excitability (Shagass & Schwartz, 1966). Cortical evoked potential research has shown some modest support for Eysenck's hypothesis.

Straumanis, Shagass and Schwartz' (1965) findings demonstrated extraversion effects were related to aging. Similarly Stelmack, Achorn and Michaud, (1976) and Hendrickson (1973) found greater AER amplitudes for introverts when low frequency tones were employed.

These electrocortical studies are related to the psychophysical studies in terms of the excitation-inhibition balance. Although, as yet not conclusively proven, authors of psychophysical studies (Stelmack & Campbell, 1974; Siddle, Morrish White & Mangat, 1966; Smith, 1968) suggest that introverts will manifest greater sensory sensitivity to equal intensities of stimulation than will extraverts. Stelmack and Campbell (1974) have suggested that introverts show greater absolute sensitivity to low frequency acoustic signals than extraverts. If introverts have lower thresholds of sensitivity, then equal intensities appli

to the introverts and the extraverts would be perceived as being higher by the introverts. This would be directly related to findings of several studies which have shown an increase in the amplitude of the evoked potential (Davis, Sowers & Hirsh, 1968; Rothman, 1969) as a result of an increase in the intensity of the stimulus. The greater N_1-P_2 amplitude displayed by introverts (Stelmack, Achorn & Michaud, 1977) could reflect the basic differences between introverts and extraverts in their reception of stimuli. This is understood in terms of lower thresholds of reticular arousal and greater efficiency of sensory processing structures of introverts. The late evoked potential and psychophysical studies are theoretically dependent upon arousal factors as mediated by the corticoreticular loop in the Eysenckian framework.

The question which may be raised is whether this same supposition can be applied to brainstem response investigations. It has been demonstrated by Brama and Sohmer (1977) that as stimulus intensity decreases, the BSR response latency increases and the amplitude decreases. Brainstem activity however, is thought to be relatively independent of corticoreticular activity which is involved in the mediation of attention and arousal (Lindsley, 1970; Jewett & Williston, 1971; Picton, Hillyard, Krauz & Galambos, 1974). Amadeo and Shagass (1973) have shown that auditory BSRs

do not differ between waking and sleeping states. Based on this literature, the hypothesis that no differences between introverts and extraverts as reflected in amplitude and latency measurements would be expected when defined by differences in arousal from an Eysenckian perspective. Indeed, from recognized statistical convention of .05 level of confidence the null hypothesis was observed in this study.

The trend towards an extraversion effect in this thesis and observed in Joseph's (1978) study merits some discussion. The question must be raised as to whether the findings obtained in Steimack, Achorn and Michaud's (1977) research were due to peripheral or brainstem activity; or were they due to central effects of arousal as Eysenck has suggested? Had greater amplitudes and shorter latencies been found in either waves I-II or (Jv) for introverts, then the hypothesis of individual differences at peripheral or brainstem levels, respectively, would have been supported.

Although an acceptable level of confidence was not obtained, there was a tendency for introverts to display greater baseline to peak Jv amplitude than extraverts for the low frequency condition. At the high frequency condition the extravert group was observed to have greater Jv amplitude than the introvert group. It is important to note that the results of the

present study are consistent with the findings of Stelmack, and Campbell, (1974) and Stelmack, Achorn and Michaud(1977). They both found introverts to be significantly more sensitive to low frequency auditory signals than extraverts. Response decrement at high frequencies for introverts relative to extraverts was not demonstrated in these studies.

In the case of Stelmack, Achorn and Michaud, (1977) the averages for the late components were based on the responses at 100 stimulations and this number may not be adequate for differences to emerge, given the relatively small signal to noise ratio of high frequency responses. Stelmack and Campbell (1974) endorse the hypothesis that the increase in sensitivity to high frequency tones for extraverts and the decrease for introverts suggests that introverts may have both low frequency and low intensity levels of preferred stimulation.

The results of Joseph's (1978) findings were that introverts displayed greater Jv amplitudes than extraverts for high frequency, low intensity conditions (50 dB, 70 dB) but not for high intensity (90 dB), and would seem to support this thesis's tentative findings. Joseph's results appear congruent with interactions between extraversion and intensity of auditory stimulation observed with electrodermal measures (Wigglesworth & Smith, 1976; Fowles, Roberts & Nagel, 1977). In these reports the decrement in responsiveness of the introvert at

higher levels of intensity relative to lower levels, is thought to indicate that introverts develop transmarginal or protective inhibition at lower levels of stress than extraverts. One could only speculate at this point that similar principles may apply to the interaction between extraversion and frequency (as demonstrated in this thesis) as with the interaction between extraversion and intensity.

Features of stimulus characteristics and recording techniques which might have been attributed to an inability to discern the positive peaks preceding wave V could have resulted from a slower rise time with tonal stimulation, (Weber & Folsom, 1977) or the possibility of a 5 msec tone duration which would increase the variability of peaks I to III (Hecox, Squires & Galambos, 1976). Also the effect of alternating the stimulus polarity may result in a latency shift of a half a cycle which would contribute to the smearing of the wave form prior to wave V (Davis & Hirsh, 1976; Brama & Sohmer, 1977). The recording technique of binaural stimulation could have been a feature which contributed to a less discernable ESR.

Had Jewett's waves I and II been identified and individual differences demonstrated, sensory reception per se at the receptor level would certainly justify an extension of Eysenck's hypothesis. That only three peaks emerged

within this period rather than the seven described by Jewett and Williston (1971) evidently stems from the complexity of the response to tone pips as compared to click stimuli. From this perspective, there would seem to be little a priori advantage favoring low frequency stimulation inquiries into the biological basis of individual differences using auditory BSR techniques. With further research into tonal stimulation and factors affecting alternating phase, reliable early peaks may emerge and provide impetus for continued studies in this direction.

A factor which could have attributed to the failure of finding significant extraversion effects might have been the limited sample size of twelve subjects in the two extreme groups. If more data had been collected with the inclusion of an ambivert group, delineation of effects may have been achieved. The aspect of diurnal rhythms was not rigidly controlled in this study. Corcoran, (1964) and Eysenck and Eysenck (1967) felt that individual differences were facilitated by controlling the time of day when testing. Attentional factors were not controlled in this study due to findings in previous research (Picton & Hillyard, 1974). However, in this research reliable BSRs were not obtained without the subject being free of muscle artifacts and in a semisombulent state. This leads one to question the possibility of cortical influences upon the BSR which may be controlled by implementing behavioral indices of attention, or at the very least, a subjective

report of their experiences while the experiment was in progress.

Future research might focus on measurement of both BSR and the late components in one experimental setting. This would better enable an investigation of, and a more complete understanding of, sensory processing along the extraversion dimension. Because of the decreased signal to noise factor observed for the earliest waves of the BSR, a repetition of this study utilizing click stimulation may provide information regarding peripheral sensitivity mechanisms operating between the two personality groups. Coles, Gale & Kline (1971) revealed that extraverts adapt more readily than their counterparts. Thornton and Coleman (1975) have found that by varying stimulus repetition rates the BSR latency decreases and amplitude increases. A study which combines individual differences and adaptation of the BSR may contribute to Eysenck's theory. Finally, this study introduced the digitizer method of scoring brainstem evoked responses. Comparison studies between hand scoring methods and the digitizer method utilizing click stimuli (a clear BSR would emerge) may clarify the effectiveness of this method.

In summary, the results of this study are inconclusive with regard to extraversion effects. The findings of greater N_1-P_2 amplitudes would appear to have provided encouraging evidence supporting the notion proposed by Eysenck that differences in the corticoreticular loop can account for the behavioral differences between introverts and extraverts (Stelmack, Achorn &

Michaud, 1977; Davis & Zerlin, 1966). Psychophysical studies have demonstrated that introverts display greater absolute sensitivity than extraverts. These studies have been interpreted as displaying individual differences in excitation-inhibition balance owing to the variance between introverts and extraverts in the corticoreticular loop. The effect of differences in neuronal substrates at the peripheral level (cochlear nerve transmission) or subcortical level (brainstem auditory nuclei) is a question that has not yet been answered. Although not significant, the interaction which was noted for wave V, with introverts tending to enhance amplitude at low frequency and extraverts tending to display greater amplitudes at high frequency, should not be dismissed out of hand. This interaction, is noteworthy because it resembles the psychophysical (Stelmack & Campbell, 1974) and psychophysiological effects previously cited (Stelmack, Achorn & Michaud, 1977). The question of the degree to which the brainstem contributes to individual differences merits the attention of further research.

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APPENDIX 1

Eysenck Personality Inventory (EPI)
 Form A; Scores of Extraversion (E)
 Neuroticism (N), Psychoticism (P)
 and Lie Scale (L) of Introverted
 and Extraverted Subjects

INTROVERTS	P	E	N	L
Subject # 1	1	7	13	2
2	11	3	9	12
3	2	8	9	6
4	1	6	18	8
5	3	1	13	8
6	4	2	15	6
7	1	4	9	8
8	1	3	11	4
9	0	7	1	9
10	5	5	16	10
11	1	4	14	10
12	2	5	13	5
EXTRAVERTS				
Subject #13	6	19	4	4
14	2	19	10	9
15	4	20	7	5
16	5	18	10	5
17	0	20	9	6
18	5	19	13	2
19	7	19	9	5
20	4	20	12	11
21	6	21	4	0
22	3	17	7	5
23	2	17	18	6
24	4	21	11	2

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IN APPENDIX 1, LEAVES 90 - 93,
NOT MICROFILMED

90 - 93 Eysenck Personality Questionnaire (Adult)

MAY BE OBTAINED FROM

Educational and Industrial Testing Service
Box 7234
San Diego, California 92107