INTROVERSION-EXTRAVERSION AND AUDITORY SENSITIVITY TO HIGH AND LOW FREQUENCY TONES

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CURRICULUM STUDIORUM

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INTRODUCTION

In recent years, H.J. Eysenck has expanded his descriptive definition of extraversion to incorporate the concepts of arousal, excitation, and inhibition. Paralleling this theoretical foundation, research in the Soviet Union begun by Pavlov and continued by his student Teplov, has developed similar concepts to account for individual differences found in the rate of conditioning.

Introverts in the Eysenckian dimension and "Weak Nervous System" individuals in the Soviet dimension tend to amplify stimulation and to be over-aroused, while extraverts or "Strong Nervous System" individuals tend to dampen stimulation and to be under-aroused. Such physiological differences have been reflected in individual differences in absolute thresholds, introverts responding at lower levels of intensity than extraverts. Within the area of auditory research, introverts have displayed lower thresholds than extraverts for low frequency stimuli.

The aim of this study is to investigate personality differences for high frequencies as well as low frequencies. Indirect and anatomical evidence suggest that while differences in sensitivity may be apparent for low frequencies, the same may not be true for high frequency.

In order to investigate the problem, subjects classified as Introverted, Middle, and Extraverted on the _Eysenck Personality Inventory_ and therefore assumed to have variable potential in terms of cortical excitability and thus perceptual sensitivity, will be employed. To examine the acoustic sensitivity of the three groups, a low frequency 500 Hz. tone and a high frequency 6000 Hz. tone will serve as stimuli to be detected against a background noise. To overcome methodological deficiencies inherent in traditional psychophysical threshold techniques, a method of analysis derived from the Theory of Signal Detection will be employed. It provides a measure of sensitivity independent of the criteria adopted by the observer in making his judgments as well as a measure of these criteria.

The first chapter contains a review of the literature and theoretical background instrumental in the development and formulation of the hypotheses.

Chapter two consists of a description of the procedures and methods used to test the hypotheses.

The results of the experiment are presented in Chapter three and interpreted in relation to the theoretical framework in Chapter four. The report concludes with a summary of the investigation and suggestions for further research.

CHAPTER I

REVIEW OF THE LITERATURE

This chapter presents a discussion of the various theoretical considerations and research findings that led to the formulation of the hypotheses to be tested in the present study. Section 1 examines the historical development of the Eysenckian dimension of extraversion-introversion and its physiological basis. Section 2 reviews perceptual sensitivity investigations which bear on the excitation-inhibition hypothesis. Section 3 proposes an extension of the existing auditory sensitivity data to incorporate high frequency stimuli, based on the interaction between personality, sensitivity, and tonal preference as well as anatomical distinctions. The Theory of Signal Detection is proposed as an alternate to traditional psychophysical methods in Section 4. The chapter ends with a brief summary of the theoretical background which led to the statement of the hypotheses.

1. Historical Development of Extraversion.

H.J. Eysenck began in the late 1940's and early 1950's the development of the organization of his definition of personality. His methodological approach from the earliest days has attempted to unite two schools of thought, a) the school of individual differences, genetic causes, and statistical investigation, represented by Galton, and b) the school of general laws, environmental modification, and experimental study, represented by Pavlov. Explained in other terms, Eysenck strives to unite experimental psychology with the study of personality. By taking such a united approach, two linked but separate aspects become inherent in his method. The first is a descriptive approach, which aims to theorize on the structure of personality, isolating and identifying the main dimensions. The second aspect, the hypothetico-deductive approach, follows upon the theory which should give birth to testable hypotheses. [1]

Eysenck's descriptive study of personality appears to be dependent on the writings of Kant and Wundt. Kant, himself influenced by a number of earlier writers, including Galen, described four temperaments, sanguine, phlegmatic, choleric, and melancholic, each occupying a unique and separate category. Wundt radically changed this position by postulating a continuum on two dimensions: (a) the strong versus weak emotions were represented by the melancholic-choleric versus phlegmatic-sanguine dimensions; (b) the choleric-sanguine versus melancholic-phlegmatic continuum was defined by the changeable-unchangeable dimension. Jung developed the changeable-unchangeable dimension one step further labelling it extroversion-introversion. He also described how these traits manifested themselves in

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1. H.J. Eysenck, The Structure of Human Personality, London, Methuen, 1953, p. i-xiv.

specific psychopathologies. [2]

Eysenck,by employing psychometric studies of individual differences and by factor analysis developed the two-dimensional basis of personality, one of which embodied emotionality, neuroticism or instability and the other, introversion-extraversion. Eysenck then formulated hypotheses as to the causality of these personality dimensions, employing concepts in vogue at that time in experimental psychology to test out these hypotheses. [3,4,5] From the Maudsley work with identical and fraternal twins, the genetic antecedents of extraversion were elaborated. In his latest revision [6] Eysenck has investigated the physiological aspects of personality to include such concepts as arousal, excitation, and inhibition. It will be these latter developments that will be concentrated on in this review.

While Eysenck and other Western personality theorists did not come to consider the physiological correlates of

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2. H.J. Eysenck and S.B.G. Eysenck, Personality Structure and Measurement, San Diego, R. Knapp, 1968, p.11-48.

3. H.J. Eysenck, The Dynamics of Anxiety and Hysteria, New York, Praeger, 1957.

4. ------------, Experiments in Personality, London, Routledge and K. Paul, 1960.

5. ------------, Experiments With Drugs, New York, Pergamon, 1963.

6. ------------, The Biological Basis of Personality, Springfield, Charles Thomas, 1967.

individual differences until recently, as early as 1922, Pavlov, in the Soviet Union, postulated the dimension of strength-weakness of the cortical cells. Paradoxically he linked sensitivity with weakness. Individuals characterized by a "weak nervous system" appear more sensitive, i.e., lack of strength or endurance of the nervous system, in that it is presumed to reflect the rapid destructability of the hypothetical excitatory substances in the cells. [7] Strength, on the other hand, is identified with the limit of functional capacity of the cells. The weak nervous system because of its ready excitability, soon becomes functionally exhausted; its working capacity is thus low. The weak nervous system then is a consequence of high reactivity or sensitivity. [8]

Teplov, a student of Pavlov, extended his theorizing and proposed the existence of a negative correlation between strength of the nervous system and sensitivity as measured by absolute thresholds. "Weak Nervous System" individuals begin to respond at low levels of intensities which are ineffective for "Strong Nervous System" individuals. Throughout the stimulus-intensity continuum, the responses of Weak Nervous System individuals are closer to the maximum level of

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7. J.A. Gray, Pavlov's Typology, New York, Pergamon, 1964, p. 248-260.

8. Ibid.

responding than the responses of the Strong Nervous System. [9] Nebylitsyn [10,11] in a series of experiments in both the auditory and visual modalities has verified with a high level of confidence a negative correlation between strength of the nervous system and absolute sensitivity (i.e., the lower the threshold, the weaker the nervous system).

Eysenck in the development of his model has similarly come to view the excitation-inhibition balance to underlie the personality dimension of introversion-extraversion. [12] Formally stated, Eysenck's proposal hypothesizes that extraverted individuals are marked by weak excitatory and strong inhibitory potentials. [13] To support his theory, Eysenck has pointed out specific physiological structures associated with arousal functions.

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9. B.M. Teplov, "Problems in the Study of General Types of Higher Nervous Activities in Man and Animals," translated by J.A. Gray, in J.A. Gray (ed.), op cit., p. 3-153.

10. V.D. Nebylitsyn, "The Relationship Between Sensitivity and Strength of the Nervous System," in J.A. Gray, op. cit., p. 157-287.

11. V.D. Nebylitsyn, "An Investigation of the Connection Between Sensitivity and Strength of the Nervous System," in J.A. Gray, op. cit., p. 402-445.

12. Eysenck, The Biological Basis of Personality, Springfield, Charles Thomas, 1967.

13. Eysenck, The Dynamics of Anxiety and Hysteria, New York, Praeger, 1957.

> Introverts are characterized by a reticular formation, the activating part of which has a relatively low threshold of arousal while the recruiting [synchronizing] 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. [13a]

Gray[13b] in his account of Teplov's work on Pavlov's properties of the nervous system suggests a rapprochement with Eysenck's introversion-extraversion dimension. The introverted, Weak Nervous System individual, being more sensitive, less stable, and more excitable than the extraverted, Strong Nervous System individual is thus more easily aroused cortically. Just as Eysenck has proposed that the excitation-inhibition balance is critically dependent on the activity of the reticular activating system, Nebylitsyn [13c] proposes that dynamism in excitation is dependent on activity in the same system.

13a. Eysenck, "Biological Factors in Neurosis and Crime," Scientia, 1965, p. 5.

13b. Gray, "Strength of the Nervous System, Introversion-Extraversion, Conditionability, and Arousal," Behavior Research and Therapy, Vol. 5, 1967, p. 151-169.

13c. Nebylitsyn, "The Relationship Between Sensitivity and Strength of the Nervous System," p. 207.

The reticular system, located caudally in the brainstem, extends from the caudal bulb to the diencephalon. Its rostral connection with the cortex is concerned in part at least with arousal and activation.

> Neural messages going along the classical ascending afferent pathways relay to the particular projection areas involved in the cortex; they also send collaterals into the reticular formation, which in turn sends 'arousal' messages to the cortex to keep it in a state of functional tonus. Depending on the nature of the information transmitted, the cortex in turn instructs the reticular formation to continue sending 'arousal' messages or else switch to 'inhibition.' This loop then is concerned with information processing, with cortical arousal and inhibition, and its application to personality differences with introversion and extraversion. 14

It would be expected then that the highly sensitive and aroused introvert's reticular formation would relay far more informatory sensations to the cortex than is the case for the cortically inhibited extravert. The reticular formation of the extravert would be expected to be less efficient, filtering out, through the inhibitory process, sensory stimulation. A direct consequence of the introvert's highly efficient reticular formation should be greater sensitivity to external stimulation reflected in lower absolute thresholds.

The introversion-extraversion dimension explained in terms of a cortical-reticular loop resembles to a large degree

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14. Eysenck, The Biological Basis of Personality, p. 231.

the Sokolovian model of the Orienting Reflex, [15] a biological reflex activity for attending to pertinent information in the environment. The particular feature of the Orienting Reflex (OR) is that after several applications of the same stimulus, the response disappears or becomes extinguished. However, the slightest possible change in any parameter, such as colour, magnitude, form, duration, or rhythm is sufficient to reawaken the process. The model provides for the cortex to analyze the sensory message relayed to it by the afferent pathways, which then sends a report back to the reticular formation. If the stimuli are new or significant, the cortex sends excitatory impulses to the reticular formation; repeated or familiar stimuli are inhibited.

Weak Nervous System individuals (introverts) habituate slowly, continually showing ORs because of their poor inhibitory mechanisms, whereas the Strong Nervous System individuals (extraverts), because of excessive inhibition, habituate with greater ease.

2. Personality and Perceptual Sensitivity.

The arousal level hypothesis as related to absolute

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15. E.N. Sokolov, "Neuronal Models and The Orienting Reflex," in M.A. Brazier (ed.), The Central Nervous System and Behavior, New York, J. Moon, 1960, p. 214-218.

thresholds has been investigated by Smith.[16] In his study, four groups representing both high and low extraversion and high and low neuroticism with three subjects in each group were tested audiometrically to determine absolute auditory thresholds for a 500 Hz. pure tone stimulus. Thresholds for the introverted group were considerably lower than those for the extraverted group. There was no significant difference for groups of high and low neuroticism. Smith furthermore controlled for some of the traditional methodological errors associated with the establishment of thresholds. Such "corrections for guessing" will be discussed in a later section.

Siddle, et al.[17] added additional support finding a rank correlation of +0.52 between absolute visual thresholds and extraversion. In a replication of this study, but with fewer subjects, a correlation of +0.57 was found.

Investigating the area of kinesthesis, Dunstone, et al.[18] arrived at the predicted conclusions. Using low

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16 . S. Smith, "Extraversion and Sensory Threshold," <u>Psychophysiology</u>, Vol.5, 1968, p. 293-299.

17 . D. Siddle, R.B. Morrish, K.D. White, and G.L. Mangan, "Relation of Visual Sensitivity to Extraversion," <u>Journal of Experimental Research in Personality</u>, Vol. 3, 1969, p. 264-267.

18 . J.J. Dunstone, G. Dzendolet, and O. Heuckeroth, "Effect of Some Personality Variables on Electrical Vestibular Stimulation," <u>Perceptual and Motor Skills</u>, Vol. 18, 1964, p. 689-695.

frequency sinusoidal electrical stimulation of the human vestibular apparatus, which produces lateral sway at and above threshold levels, they found that introverts responded at significantly lower levels than was the case for extraverts.

Finally Haslam [19] demonstrated that introverts had a lower mean pain threshold for radiant heat than extraverts. In this study subjects were asked to state subjectively when they felt a heat stimulus applied to the forehead to be painful.

It would thus seem that equal amounts of stimulation would be effectively experienced as amplified for introverts and dampened for extraverts, while at the extreme level (the threshold of transmarginal inhibition), introverts, because of their greater arousability, should show a decrement in performance at lower intensities or duration than extraverts.

Studies relating extraversion and the threshold of transmarginal inhibition have involved the application of painful stimulation. Lynn and Eysenck [20] using a thermo-stimulator

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19. D. Haslam, "Individual Differences in Pain Threshold and Level of Arousal," British Journal of Psychology, Vol. 58, 1967, p. 139-142.

20. R. Lynn and H.J. Eysenck, "Tolerance for Pain, Extraversion, and Neuroticism," Perceptual and Motor Skills, Vol. 12, 1961, p. 161-162.

to induce pain found that extraverts tolerated pain for significantly longer periods of time than introverts, the correlation being +0.69. In a related study, Petrie, Collins, and Solomon [21] found that those who were most tolerant of pain inflicted by various hospital operations tended to score high on the extraversion scale of the Maudsley Personality Inventory, while those who were the least tolerant of the pain tended to score low or in other words, were introverted.

The notable exception to these positive findings is the experimentation of Levine, Tursky, and Nichols, [22] who after using a large sample, failed to find a significant relationship between extraversion and tolerance of pain inflicted by electrical stimulation. An inferential study however by Clark and Bindra [23] found that those who tended to have high pain thresholds also tended to tolerate pain for longer intervals. They did not measure personality variables.

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21. A. Petrie, W. Collins, and P. Solomon, "The Tolerance for Pain and for Sensory Deprivation," American Journal of Psychology, Vol. 123, 1960, p. 80-90.

22. F.M. Levine, B. Tursky, and D.C. Nichols, "Tolerance for Pain, Extraversion, and Neuroticism: Failure to Replicate Results," Perceptual and Motor Skills, Vol. 23, 1966, p. 847-850.

23. J.W. Clark, and D. Bindra, "Individual Differences in Pain Thresholds," Canadian Journal of Psychology, Vol. 10, 1956, p. 69-76.

Finally, it would be predicted that equal amounts of stimulation will produce greater response in the introvert than in the extravert. Two studies looking at this aspect have both employed lemon juice as a stimulus. Corcoran [24] and Eysenck and Eysenck [25] found remarkably high correlations, ranging to approximately -0.70 between degree of extraversion and amount of saliva secreted to a few drops of lemon juice. When citric acid or a diluted commercial product were employed,no significant correlations were found.

3. Indirect Evidence for the Interaction of Pitch and Extraversion.

Studies in extraversion and auditory sensitivity [26,27] have tended to limit their range of stimuli to low, 500 Hz. or 1000 Hz. frequencies. Similarly in the related field of the Orienting Reflex, those investigations utilizing pure tones as stimuli again have limited the range of frequencies not taking into account possible individual differences to

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24. D.W.J. Corcoran, "The Relation Between Introversion and Salivation," American Journal of Psychology, Vol. 77, 1964, p. 298-300.

25. S.B.G. Eysenck and H.J. Eysenck, "Salivary Response to Lemon Juice as a Measure of Introversion," Perceptual and Motor Skills, Vol. 24, 1967, p. 1047-1053.

26. Nebylitsyn, "An Investigation of the Connection Between Sensitivity and Strength of the Nervous System," op. cit., p. 402-445.

27. Smith, op. cit., p. 293-299.

be noted with the incorporation of high frequencies.[28,29,30] The generalization is usually made that introverts, who have been found to be more reactive to a low frequency source, will also be more reactive to a high frequency stimulus. Indirect and anatomical evidence suggest that such a generalization may not be valid.

Guilford [31] upon expanding the analysis of the data earlier collected by Singer and Young [32] found that when subjects were asked to rate tones varying in intensity and frequency as to the degree of pleasantness or unpleasantness,

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28. G.L. Mangan and J.G. O'Gorman, "Initial Amplitude and Rate of Habituation OR in Relation to Extraversion and Neuroticism," Journal of Experimental Research in Personality, Vol. 3, 1969, p. 275-282.

29. N. Quirion, Extraversion, Neuroticism, and Habituation of the Orienting Reaction, Unpublished doctoral thesis presented to the Faculty of Psychology of the University of Ottawa, 1970, vii-79 p.

30. M.G.H. Coles, A. Gale, and P. Kline, "Personality and the Habituation of the Orienting Reaction: Tonic and Response Measures of Electrodermal Activity," Psychophysiology, Vol. 8, 1971, p. 54-63.

31 J. Guilford, "Systems in the Relationship of Affective Value to Frequency and Intensity of Auditory Stimuli," American Journal of Psychology, Vol. 67, 1954, p. 691-698.

32. W.B. Singer and P.T. Young, "Studies in Affective Reaction: II. Dependence of Affective Ratings Upon the Stimulus Situation," Journal of General Psychology, Vol. 24, 1941, p. 303-325.

those who found low intensity to be pleasant also preferred low frequency.

Davies and Hockey[33] looking at vigilance performance of introverts and extraverts found that the former's performance improved in general under quiet conditions while the latter's declined. Under the noise condition, extraverts tended to manifest an improved performance, while introverts were unaffected.

In sensory deprivation studies[34,35,36] extraverts in general have been less able to tolerate conditions of deprivation than introverts, suggesting that extraverts actively seek stimulation whereas introverts prefer quiet, nonarousing situations.

Combining both the vigilance and sensory deprivation studies with the Guilford-Singer and Young data, it would appear that introverts prefer quiet low intensity stimulation

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33. D.R. Davies, and G.R.J. Hockey, "The Effects of Noise and Doubling the Signal Frequency on Individual Differences in Visual Vigilance Performance," British Journal of Psychology, Vol. 57, 1966, p. 381-389.

34. Petrie, et al., op. cit., p. 80-90.

35. G.F. Reed and J.C. Keena, "Personality and Time Estimation in Sensory Deprivation," Perceptual and Motor Skills, Vol. 18, 1964, p. 182.

36. G.F. Reed and G. Sedman, "Personality and Depersonalization under Sensory Deprivation Conditions," Perceptual and Motor Skills, Vol. 18, 1964, p. 659-660.

whereas extraverts actively seek stimulation (noise conditions). Furthermore it has been shown that those who prefer low intensity (i.e. introverts) also prefer low frequencies. Moreover perceptually introverts have manifested greater sensitivity than extraverts for low frequency tones. Thus although the evidence is weak, it may be that those who prefer noise conditions (i.e. extraverts) will also prefer high frequency acoustic stimulation. It would then follow that extraverts should be more sensitive to a high frequency stimulus.

A second line of evidence questioning the generalizability of Eysenck's hypothesis, at least within the auditory system is the pattern of tonotopic localization evident at all levels of the auditory pathway, from the cochlear membrane to the cerebral cortex. A general review of research carried out until 1960 has been presented by Ades and up to 1970 by Gacek. [37,38]

Because high and low acoustic stimuli are processed by different anatomical systems, with possible different relays and collaterals and thus variant cortical arousal

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37. H.W. Ades, "Central Auditory Mechanisms," in J. Field (ed.), Handbook of Physiology, Section I, Vol. I, Washington, American Physiological Society, p. 585-261.

38. R.R. Gacek, "Neuroanatomy of the Auditory System," in J.V. Tobias (ed.), Foundations of Modern Auditory Theory, Vol. 2, New York, Academic Press, 1972, p. 239-261.

functioning, individual differences found in sensitivity for one of the systems (for example, the low frequency pathway) will not necessarily be reflected as well in the other system (for example, the high frequency pathway). As was seen in the earlier discussion of cortical arousal, introverts are characterized by a readily excited reticular formation, extraverts an inhibited reticular formation. Reticular activation has in fact served as an interpretation of the existing data linking low frequency acoustic sensitivity to introversion. The discussion to follow will attempt to demonstrate that the high frequency pathway in its route to the cortex is much more direct than that for low frequencies, sending fewer collaterals to the reticular formation and other relay centers. The auditory pathway will thus be examined in this light.

In the cochlea it has been shown that high frequency tones are received in the basal coils while the apical portion is sensitive to low frequencies. The auditory fibres from the cochlea synapse in the dorsal and ventral cochlear nuclei, low frequencies being located in the ventral nucleus, and in the ventral portion of the dorsal nucleus, while high frequencies occupy the dorsal portion of the dorsal nucleus. The ventral cochlear nucleus (low frequency) is much larger than the dorsal cochlear nucleus (low-high frequencies). The significance of this difference is seen in the relative size of the fibres arising from the nuclei. The tract arising from the dorsal nucleus is much smaller than that from the ventral nucleus. Because of its size limitation, the former will give rise to only a few branches, while the latter will have much more freedom in this regard. From the ventral nucleus, the fibres course medially along the ventral border of the pontine tegmentum. In their passage through the tegmentum, fibres terminate in the reticular formation, the superior olivary nuclei, and the nuclei of the trapezoid body. The superior olivary and trapezoid nuclei give rise to the tertiary fibres which ascend mainly on the contralateral lateral lemniscus, although some remain ipsilateral. For the study of extraversion, there appear to be two important phenomena occurring at this level. Firstly reticular activation by the low frequency tract is confirmed. Individual differences in efficiency of the activation would then seem to be plausible. Secondly, relays through as many as six stations (in its crossing the pathway encounters three stations ipsilateral and three contralateral) force low frequency encoding to be delayed in its arrival at the lateral lemniscus. The dorsal cochlear nuclei (low-high frequencies) on the other hand, project entirely to the contralateral lateral lemniscus, its relays to the reticular formation being less limited; relays to the trapezoid body and superior olivary nucleus being nonexistant. Again for the study of extraversion, the dorsal cochlear-lemniscal tract takes on significance. Branching to the reticular formation is limited. What branches there are appear to be largely relayed from the ventral portion of the tract, i.e. low frequencies. High frequencies therefore almost entirely ignore the reticular system at this level. As well information transport to the lateral lemniscus is direct; processing to higher centers will therefore be much more rapid. Because of the lack of reticular activation, and rapidity of relay, high frequency sensitivity differences for introverts and extraverts should be non-existant, unless higher centers counteract the tendency seen in these medullary regions.

Beyond the medulla, far less is known about the auditory pathway. The lateral lemniscus, forming the union of the dorsal and ventral cochlear fibres, projects to the inferior colliculus, sending branches into the reticular formation in its ascension. Tonotopic preference is not likely. From the inferior colliculus the pathway projects to the medial geniculate body and then to the auditory area of the cortex, the gyrus of Heschl. The auditory pathway is diagrammed as Figure 1.

The higher centers do not then affect individual, personality differences which were apparent at the level of the medulla. There are however descending feedback fibres. These follow essentially the same course as the ascending

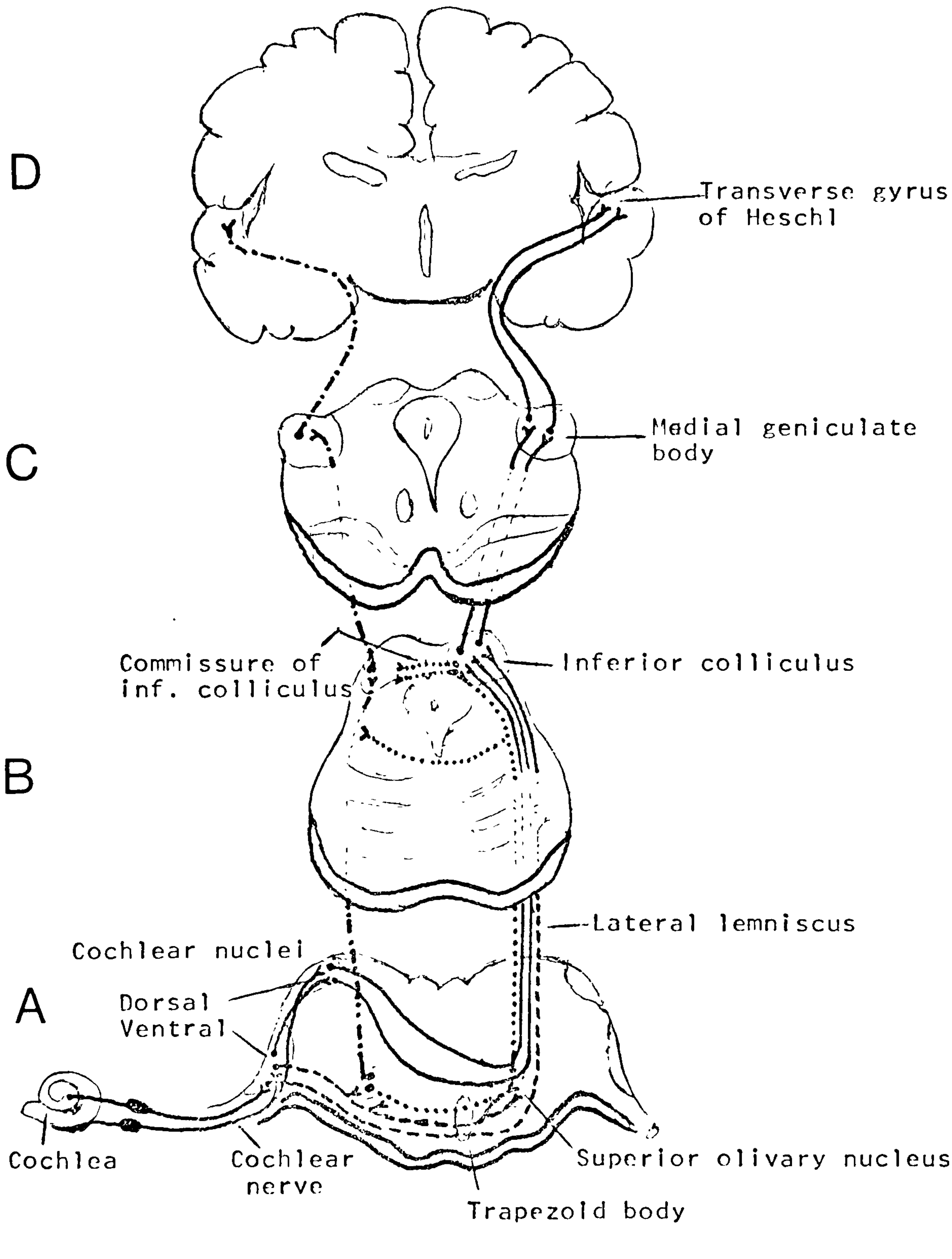

Figure 1. Schematic diagram of the auditory pathways. Fibres arising from the ventral cochlear nucleus are dashed; those from the dorsal cochlear nucleus are solid; Commissural fibres are dotted. A. Medulla; B. level of inferior colliculus; C. level of superior colliculus; D. transverse section through the cerebral hemisphere.

fibres and provide centrifugal, inhibitory control of the system. Such feedback inhibition appears to be minimal in the high frequency tract, once again because of the absence of relay centers in the medulla.

Because the low and high frequency pathways demonstrate differences in the degree of reticular activation, the latency period for information to reach the cortex, and the degree of feedback inhibitory control, it may not follow that individuals who have been found to be sensitive for one frequency condition will necessarily be as sensitive for another frequency condition. This is especially the case if levels of sensitivity are due to reticular activation and cortical feedback loops as claimed by Eysenck.

4. Sensitivity, Personality, and Signal Detection Theory.

The studies in the preceding sections represent a cross-section of classical psychophysical experiments. A basic assumption of these methods is the existence of a threshold, which has often been defined as the value at which a signal is perceived 50% of the time. An alternate approach to the measurement of sensitivity has been developed, based on statistical decision theory. This approach, called signal detection theory, questions the concept of the threshold and attempts to provide some degree of control over non-sensory factors which influence psychophysical judgments - a limitation inherent in traditional methods.

In the signal detection approach, the psychophysical experiment is considered as a discrimination or decision task in which the observer must decide if a signal is present or not. The problem is thus developed within the framework of statistical decision theory.[45,46] Figure 2 shows two overlapping normal distributions representing the discrimination task. The left distribution (A) represents the null hypothesis, H_0, that no signal was present, and the right distribution (B) represents an alternative hypothesis, H_1, that a signal was present. The construction of a statistical test divides the sensory effects (x-axis) into two regions: that is, setting a decision cutoff, or criterion (β - Beta) such that sensory values of x less than β lead to the acceptance of H_0 and sensory values of x greater than β lead to the acceptance of H_1.

The criterion (β) is affected by two factors: actual physiological sensitivity to the stimulus and confounding nonsensory, personal states such as motives, attitudes or sets which include such things as guessing. Both Boring[47]

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45. L.L. Thurstone, "A Law of Comparative Judgment," Psychological Rev, Vol. 34, 1927, p. 273-286.

46. H.R. Blackwell, "The Influence of Data Collection Procedures Upon Psychophysical Measurement of Two Sensory Functions," Journal of Experimental Psychology, Vol. 44, 1952, p. 306-315.

47. E.G. Boring, "The Control of Attitude in Psychophysical Experiments," Psychological Review, Vol. 27, 1920, p. 440-452.

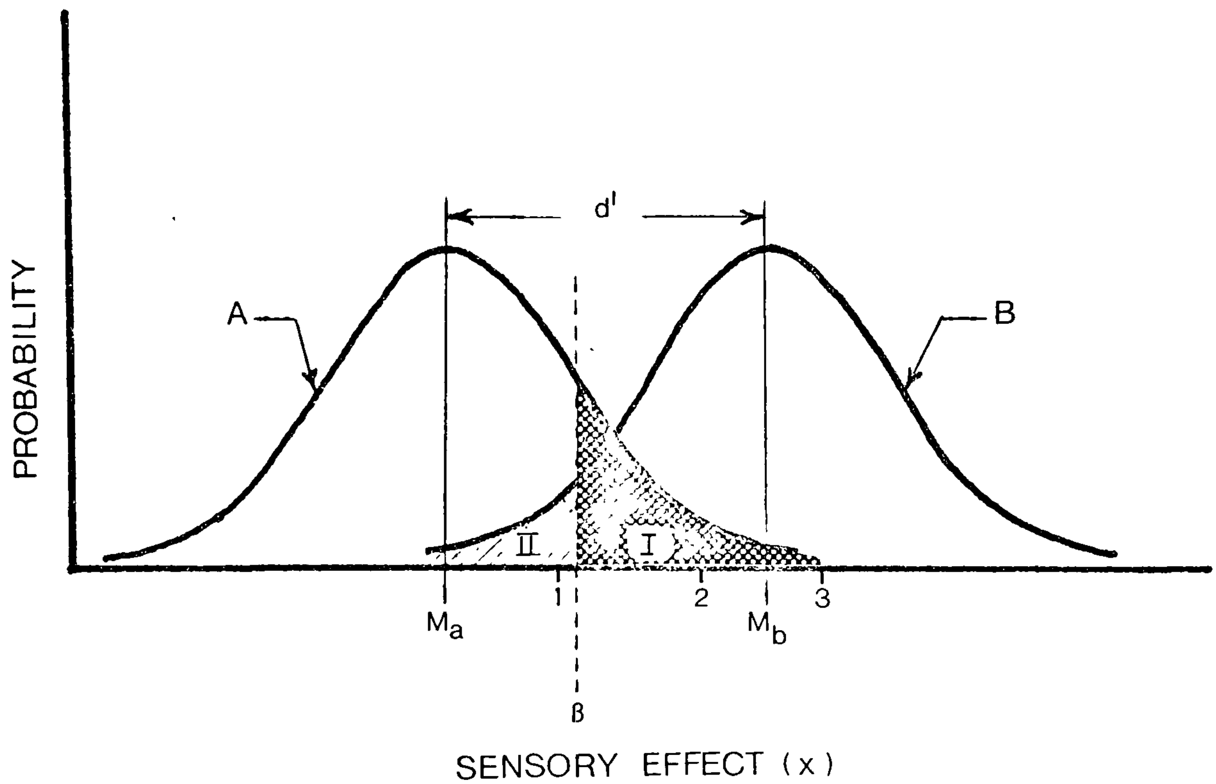

Figure 2 - Hypothetical distributions of sensory effect. Sensory effect is assumed to vary according to the left-hand distribution when the null stimulus, A, or noise alone is present and according to the right-hand distribution, B, when a given signal is added to the noise. The area under A to the right of the decision criterion, ß, represents the probability of a type I error (false alarm); the area under B to the left of ß represents the probability of a type II error (miss). The distance between the means, d', serves as the measure of sensitivity or discriminability.

and Guilford [48] have noted that estimates of sensory capacity (thresholds) obtained by traditional methods are confounded by the observer's nonsensory subjective standard or criterion for reporting the absence (H_0) or presence (H_1) of a signal. Hake and Rodwan [49] are more explicit. They point out that classical psychophysical procedures make no distinction between sensory and nonsensory aspects of the observer's performance. For example, observers unwilling to respond to a stimulus until the evidence for its presence is great, a nonsensory state termed the "error of habituation", appear to have low sensitivity when the threshold framework is applied. These individuals thus adopt a high certainty or strict criterion. Expressed statistically, type II error, that is accepting H_0 when H_1 is true, is large. On the other hand, observers readily willing to respond to the signal on the basis of minimal evidence, a nonsensory state termed the "error of anticipation," appear to have spuriously high sensitivity or lower thresholds. These individuals thus adopt a low certainty or lax criterion; statistically, type I errors, that is accepting H_1 when H_0 is true. Low thresholds may hence be produced through either actual

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48. J.P. Guilford, "Fluctuations of Attention With Weak Visual Stimuli," American Journal of Psychology, Vol. 38, 1927, p. 534-583.

49. H.W. Hake, and A.S. Rodwan, "Perception and Recognition," in J.B. Sidowski, (ed.) Experimental Methods and Instrumentation in Psychology, New York, McGraw-Hill, 1966, p. 332-381.

perceptual sensitivity or artificially by the adoption of a lax criterion. High thresholds may be produced by a lack of perceptual sensitivity or artificially by the adoption of a strict criterion. Concerning this issue, Eysenck has stated

> ... it would be difficult to test hypotheses about sensitivity by traditional methods of threshold measurement since a failure to find differences might pertain more to decision-making habits and risk-taking propensities of the subject groups than to their actual thresholds. In other words, extraverts might be predicted to guess more frequently and therefore appear to have thresholds as low as or lower than those of the careful, scrupulous introverts. [50]

The approach of signal detection theory has attempted to overcome some of the limitations of traditional psychophysics by providing a measure of sensitivity that is relatively independent of nonsensory factors.[51] In the context of the present study, it offers a means to separate the influence of sensory capacity or sensitivity from criterial factors on the detection of auditory stimuli for groups of introverted, middle, and extraverted subjects.

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50. Eysenck, The Biological Basis of Personality, p. 100-101.

51. J.A. Swets, W.P. Tanner, and T.G. Birdsall, "Decision Processes in Perception," Psychological Review, Vol. 68, 1961, p. 301-340.

While the Theory of Signal Detection has adopted the statistical model of the overlapping normal distributions, the concept of the null hypothesis changed from being nothing or a blank stimulus to being a stimulus in fact. What has come to be called "noise" produces sensorineural activity that could be confused with the sensory effect of the stimulus to be detected. Noise and signal effects can be plotted on the same x-axis because they are by definition qualitatively the same. [52] The basic task in a signal detection experiment involves the observation (detection) of signals that are weak relative to the background against which they are presented. In the simplest experiment, a series of trials are presented in which either noise alone or signal plus noise occurs; all trials are of the same duration. The observer attends to the events that occur during each trial and reaches a decision based on his observation; he reports whether the trial consisted of noise alone or signal plus noise. Noise whether internal (neural activity in the sensory channel) or external (induced by the experimenter or faults in the equipment) is always assumed to be present, [52] and the signal may or may not occur. The

52. D. Green and J.A. Swets, Signal Detection Theory and Psychophysics, New York, Wiley, 1966, p. 253-257.

signal is usually presented at different values of intensity according to a predetermined plan. It is assumed furthermore that every level of noise or signal plus noise can be detected. The ratio of noise to signal plus noise is fixed a priori, the observer being aware of this fixed ratio.

Upon close inspection of the observation interval, it is noted that four events may occur: the signal may or may not be present in the noise background, and for each of these alternatives the observer may respond whether the signal has or has not occurred, producing the following stimulus-response matrix. The observer may (a) respond "signal" when the signal occurs (hit), (b) respond "signal" when no signal occurred (false alarm), (c) respond "noise" when the signal occurred (miss), or (d) respond "noise" when no signal occurred (correct rejection). As Price [53] connotes, the psychophysical threshold by its definition is only a global indicator of the hit rate. Moreover no corrections for guessing in the threshold technique can account for all the information in this matrix. For example, the false alarm rate also conveys information about the observer's detection goals or strategies in the experiment.

The Theory of Signal Detection by accounting for both sensory and nonsensory effects in the above matrix provides

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53. R.H. Price, "Signal Detection Methods in Personality and Perception," Psychological Bulletin, Vol. 66, 1966, p. 55-62.

a measure of discrimination or sensitivity (d') that is independent of the criterion (β) that the observer adopts. The sensitivity index, d', is defined as the distance between the means of the noise and signal plus noise distributions (Figure 2). When data are available for several criterion locations, a graphic method may be employed to estimate d'. A plot of the hit rate versus the false alarm rate as the cut-off criterion is moved along the decision axis is compared to theoretical plots. The curve connecting these points is called the receiver operating characteristic (ROC). [54] Such curves, dependent on shifts in the criterion, and hence hit and false alarm proportions have experimentally been accomplished in a number of ways. In the first example, the observer was instructed by the experimenter to maintain a fixed criterion of judgment during a large series of trials. On a subsequent series, the observer was induced to adopt a more stringent criterion for judgment and on yet another series of trials to adopt a more lax criterion thereby influencing the hit and false alarm proportions. [55] In a second example, [56] the observer was asked to shift his criterion on each single trial by rating his degree of confidence that a signal was

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54. Green and Swets, op. cit., p. 34-35.

55. Ibid., p. 35

56. J.P. Egan, A.I. Schulman, and G.Z. Greenberg, "Operating Characteristics Determined by Binary Decisions and by Ratings," Journal of the Acoustical Society of America, Vol. 31, 1959, p. 768-773.

present, rather than adopting different criterion after a large series of trials. The ROC curve derived from the rating procedure was not found to significantly differ from that derived in the first example. The outstanding virtue of the rating procedure is its economy; it requires considerably fewer trials than other signal detection procedures. For this reason, the rating procedure was employed in this study.

5. Statement of the Hypotheses.

Individual differences in sensitivity between introverts and extraverts constitute a significant source of evidence in support of the excitation-inhibition hypothesis. Eysenck has proposed that the excitation-inhibition balance is critically dependent on the activity of the reticular formation. Introverts were hypothesized to be more cortically aroused and hence sensitive to auditory stimuli, regardless of the frequency. This proposal has anatomical and physiological support for low frequencies through the auditory pathway. Similar support for high frequency is not as evident. Little empirical study has been made on the aspect of personality differences and sensitivity to high frequencies. The sole study carried out with low frequencies employed a traditional psychophysical technique, which confounds sensory and nonsensory factors which influence the observer's judgment.

To reply to the final problem, the Theory of Signal Detection has been proposed as an alternate to the traditional psychophysical methods. A measure of sensitivity independent of the criteria adopted by the observer in making her judgments, and a measure of these criteria will serve as dependent variables in this study. The principal independent variables will be two auditory tones, one set at 500 Hz., and the other at 6000 Hz. Introverted, Middle, and Extraverted groups will serve as concomitant independent variables. With these variables in mind, the problems posed for the investigation, stated in the form of a null hypothesis are:

1. There is no significant difference between groups of introverted, middle, and extraverted subjects in their auditory detection of low and high frequency tones as indicated by a measure of sensory capacity independent of the criteria adopted by the observer in making her judgments.

2. There is no significant difference between low and high frequency stimuli in their influence on auditory detection as indicated by a measure of sensory capacity independent of the criteria adopted by the observer in making her judgments.

3. There is no significant interaction effect between Extraversion and Frequency variables on a measure of sensory capacity independent of the criteria adopted by the observer in making her judgments.

Three minor problems stated in the form of a null hypothesis will investigate criteria differences. They are:

4. There is no significant difference between groups of Introverted, Middle, and Extraverted subjects in a measure of the criteria adopted by the observer in making her judgments of low and high frequency auditory stimuli.

5. There is no significant difference between low and high frequency stimuli in their influence on a measure of the criteria adopted by the observer in making her auditory judgments.

6. There is no significant interaction effect between the Extraversion and Frequency variables in a measure of the criteria adopted by the observer in making her auditory judgments.

The methods employed to test the preceding hypotheses are presented in the following chapter.

CHAPTER II

EXPERIMENTAL DESIGN

This chapter presents the methodology of the experiment. It describes the subjects employed in the perceptual task as well as the procedure used in the classification of the subjects into groups of low, middle, and high extraversion. The psychological instrument and the apparatus used to present the stimuli as well as the procedure followed in the experiment are depicted. The chapter concludes with a note on the methods of analysis employed in the auditory judgment task and an explanation of the general experimental design and statistical procedures involved in the testing of the hypotheses outlined in Chapter I.

1. The Subjects

Thirty female university students, between the ages of eighteen and twenty-two were chosen for the experiment. They were selected from an initial sample of forty-eight volunteers on the basis of the scores obtained on the Eysenck Personality Inventory (EPI), Form A. [1] They represented

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1. H.J. Eysenck and S.B.G. Eysenck, Manual for the Eysenck Personality Inventory, San Diego, Educational Testing Service, 1968, p. 5-27.

those scoring below the sixteenth percentile, between the thirty-fourth and sixty-second percentile, and those above the eighty-fifth percentile. Within these three intervals, the ten subjects with the lowest Neuroticism scores were chosen and designated as the Introverted group, the Middle group, and the Extraverted group. The subjects were not paid for the testing sessions.

2. The Tools.

(a) Psychological Instrument: The Eysenck Personality Inventory was used as a measure of two independent factors identified as extraversion-introversion (E) and neuroticism-stability (N). A Lie scale was also included to detect attempts to falsify responses. The EPI, Form A, appears as Appendix 1.

(b) Apparatus: A Maico MA-24 research and clinical audiometer was used to present the auditory stimuli. The timing of the presentations was controlled by a Lafayette Four Bank Timer, Model No. 5430, and a specially constructed warning signal box.

The Maico MA-24 audiometer consisted of twin audiometer channels and an accessory control section. It was equipped with two conduction headsets, a monitoring headset, and a test headset, using the standard MX 41/AR cushions. Each channel was calibrated to its own earphone of the test headset.

Proper compensation was built into the circuitry to enable direct readings of Hearing Threshold Levels, taken from the "H.T.L." dial with references to standard reference thresholds. The H.T.L. control varied the intensity of the tone. With the addition of another control, the Vernier dial, 1 db. steps were available over the entire H.T.L. range, from -5 to 110 db., ISO.

Testing took place in an insulated soundproof and anechoic Industrial Acoustics laboratory. Subject and experimenter were separated by an insulated wall with a 2 x 3 foot plate window mounted approximately in the center of the wall.

To permit connections between the audiometric laboratory and the subject's testing laboratory, an input terminal was mounted on each side of the wall, into which electrical jacks were plugged.

A Lafayette Four Bank Timer was employed to switch tones on and off according to a phased timing sequence. It was connected to a specially constructed black signal box mounted on a microphone stand in the testing laboratory. Into the signal box, measuring 6" x 4" were mounted two lights, one red, and one white, approximately 3/4" in diameter, which served to warn subjects when a tone was about to occur and when it was actually occurring. Connections were also made from the light box to the audiometer via the input terminal and through the box to the left earphone of the headset.

3. The Experiment.

After the initial testing and selection of the sample using the EPI, the auditory testing segment of the experiment took place.

The procedure used in the auditory task was as follows: The subject was taken into the soundproof testing laboratory and seated facing the warning lights, at about a 45° angle from the viewing window. The headset was placed in position, care being taken to insure that hair did not fall between the headset and the ears.

The experimenter then left the testing laboratory and entered the adjoining laboratory where the following instructions were read to the subject by means of the "talkover" switch and microphone on the center panel of the audiometer.

> This is a task to determine your hearing ability. Directly in front of you is a black box containing a red and a white light. When the white light comes on, this serves to warn you that one second later the red light will come on. When the red light comes on, a very low intensity tone will occur in the left earphone, but only half of the time. On the other occassions, in other words, 50% of the time, when the red light comes on, there will be no tone. Your task is to tell me whether you hear the tone or not. Remember that on one-half of the trials no tone occurs. Some of the tones will be easy to hear and some will be more difficult. No one is able to hear them all, so just do your best. After you have said whether you have heard the tone or not, I want you to tell me how confident you are of your judgment. Tell me whether you were positive, fairly sure, or whether it was a guess. For example, if you are fairly sure that you heard a tone, you would say, yes, fairly sure. Try to use all three ratings: positive, fairly sure, and guess.

The instructions thus required the selection of one of the two permissible response alternatives as well as a confidence rating of positive, fairly sure, and guess. The rating scale therefore took the form: (1) yes, positive; (2) yes, fairly sure; (3) yes, guess; (4) no, guess; (5) no, fairly sure; (6) no, positive.

After the instructions were read, a series of thirty practice trials were administered to the subject employing a 2000 Hz. stimulus tone in a pre-determined order which was identical for all subjects.

In addition to verifying if the subject understood the task required of her, the practice trials served to eliminate the effects of the prior stimulation of the warning lights on perceptual sensitivity. Fuster[2] and Lansing, Schwartz, and Lindsley[3] have shown that stimulation of the reticular system either concurrent with or prior to a stimulus can improve behavioral performance. However in the present study, after thirty practice trials, the effects of the prior stimulation of the reticular formation by the white and red warning lights on auditory sensitivity can be expected to be minimal or in effect habituation to the warning lights after thirty trials would be expected to have occurred. [4]

Following the practice trials, the two frequency stimuli (500 Hz. and 6000 Hz.) were presented in blocks of 200 random experimental trials. The five intensity levels for each of the two frequency stimuli were presented

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2. J.M. Fuster, "Effects of Stimulation of Brain Stem on Tachistoscopic Perception," Science, Vol. 127, 1958, p. 150.

3. R.W. Lansing, E. Schwartz, and D.B. Lindsley, "Reaction Time and EEG Activation Under Alerted and Non-Alerted Conditions," Journal of Experimental Psychology, Vol. 58, 1959, p. 1-7.

4. E.N. Sokolov, "Neuronal Models and the Orientating Refelx," in M.A.B. Brazier (ed.) The Central Nervous System and Behaviour, New York, Moon, 1960, p. 191.

twenty times, and the noise trial (or trial in which the stimulus was OFF) one hundred times, both combined in random order. A written pre-determined random order of presentation was employed for each subject and for each of the two frequencies. Each subject thus made 400 judgments. [5]

The general procedure for the experiment followed the "fixed-interval observation experiment," described by Egan, et al. [6] In this design, the subject knows that a signal, if presented, will occur in a well-delimited interval of time, and in which a decision of some sort is required after each observation.

In the experiment, a trial began with the onset of a white light, which served as a warning signal and which remained on for 1.5 seconds. The last 0.5 seconds of the white light was the fixed interval for observation and was marked by the onset of the red light. The signal when presented also had a duration of 0.5 seconds with its onset and offset synchronous with the onset and offset of the red light. The interstimulus interval was 5 seconds during which time the subject responded with her decision. She was

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5. D.M. Green and J.H. Swets, Signal Detection Theory and Psychophysics, New York, Wiley, 1966, p. 393.

6. J.P. Egan, A.I. Shulman, and G.Z. Greenberg, "Operating Characteristics Determined by Binary Decisions and by Ratings," Journal of the Acoustical Society of America, Vol. 31, 1959, p. 769-778.

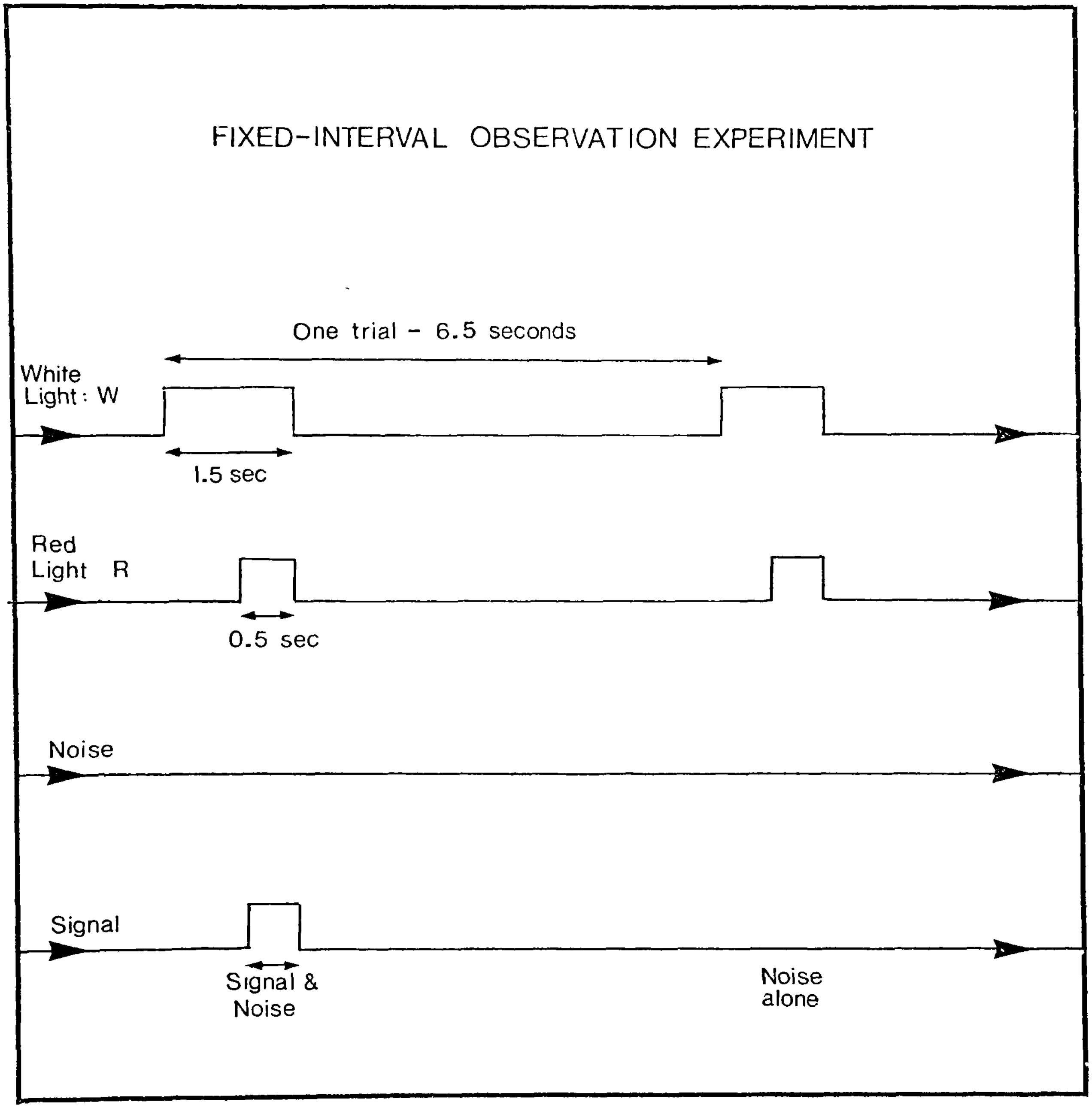

Figure 3 - Schema showing the sequence of events in each trial. The red light (R) marked the interval of observation, and the signal of 500 or 6000 Hz. was presented with a probability of 0.5. The observer responded after the termination of W and R.

not informed whether her decision was correct or incorrect. The sequence of events in the fixed-interval observation experiment is diagrammed in Figure 3.

4. Method of Analysis of Auditory Sensitivity Data.

Within the context of the theory of signal detection, two stimulus situations were defined corresponding to the noise and signal plus noise conditions. In the present study, the two stimulus situations were (1) presentation of the OFF stimulus or blank trial, defined as noise, and (2) presentation of the ON stimulus or the five variable intensity signals for the two frequencies, defined as signal plus noise. Even though white noise was not introduced, the theory of signal detection assumes that it is physically impossible to have a noise-free situation. Aside from irreducible noise in the equipment, an important source of noise is that associated with physiological processes such as breathing and blood circulation. Furthermore such non-sensory, personal factors as set, motivation, and attitude are considered to be noise.[8]

Following each presentation, the subject responded either "Yes" or "No." The two types of stimulus conditions,

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8. Green and Swets, op. cit., p. 253-257.

ON and OFF, and the two response categories, Yes, and No, resulted in four stimulus-response alternatives, which are illustrated in the stimulus response matrix in Figure 4.

The hit rate P(Jon/Son), i.e. judged On, stimulus ON, is the probability that the subject would judge the stimulus as being On when in fact it was ON. The false alarm rate P(Jon/Soff), ie. judged On, stimulus OFF, was the probability that the subject would judge the stimulus as being ON when in fact it was OFF. Only these two response values are needed. When the hit rate is known, in this binary situation the miss rate P(Joff/Son), i.e. judged Off, stimulus ON, is equal to 1.0 - Hit Rate. Similarly, the correct rejection rate P(Joff/Soff), i.e. judged Off, stimulus OFF, is equal to 1.0 - False Alarm Rate.

Following the rating procedure described by Egan, et al.,[9] each decision , i.e. Yes or No, was taken according to a response criterion (positive, fairly sure, guess) adopted by the subject. The three ratings given to the binary decision then in fact provided for six response categories, representing a continuum of various judgment criteria, attitude or motivation adopted by the subject during the psychophysical experiment.

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9. Egan, et al., op. cit., p. 768-773.

RESPONSE ALTERNATIVES		Stimulus Alternative: On	Stimulus Alternative: Off
	On	P(Jon/Son) Judged On/Stimulus ON Hit	P(Jon/Soff) Judged On/Stimulus OFF False Alarm
	Off	P(Joff/Son) Judged Off/Stimulus ON Miss	P(Joff/Soff) Judged Off/Stimulus OFF Correct Rejection

Figure 4 - Stimulus and Response Matrix for Signal Detection Analysis.

The frequency of response for the five variable stimuli for each of the six response categories was tabulated as well as the frequency of response for the OFF stimuli, again for the six response categories for one frequency condition. An example of this procedure is given in Appendix 5. These twelve values were punched on an IBM data card for subsequent analysis. The same procedure was followed for the other frequency condition. Computation of the signal detection data was carried out by an IBM Fortran IV computer program, for the rating procedure (EPCROC), developed by Ogilvie and Creelman.[10] The program was run on an IBM 360/120 computer.

The ratio of the proportion of hits to the proportion of false alarms provided an index of sensitivity. The greater the hit proportion, and the smaller the false alarm proportion, the greater the sensitivity to the auditory stimulation. The variation in the hit and false alarm proportions for the six response criteria adopted by the subject reflected the influence of different criterial or attitudinal factors on the observer's decision.

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10. J.C. Ogilvie and C.D. Creelman, "Maximum Likelihood Estimation of Receiver Operating Characteristic Curve Parameters," Journal of Mathematical Psychology, Vol. 5, 1968, p. 387.

By averaging the various criterion or "Beta" values that the program yielded, an estimate of the effect of nonsensory, criterial components such as set, attitude or motivation of the subject on her sensory accuracy was calculated. "Beta" is defined as the point at which the subject decides to make the cut-off point between Noise and Signal plus Noise responses in her criterion. In general, the greater the value of "Beta," the greater the degree of caution in the judgment task. On the other hand, the lower the value of Beta, the greater the degree of permissiveness in the judgment is indicated. [11]

5. Statistical Design

The statistical design followed the two-factor analysis of variance model with repeated measures on one factor. [12] The two factors considered were the introversion-extraversion dimension and frequency (low and high). Repeated measures were taken on the frequency factor consisting of high frequency (6000 Hz.) and low frequency (500 Hz.) tones. The extraversion-introversion factor

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11. J.F. Mackworth, "Vigilance, Arousal, and Habituation," Psychological Review, Vol. 75, 1968, p. 310.

12. B.J. Winer, Statistical Principles in Experimental Design, 2nd ed., New York, McGraw-Hill, 1971, p. 518.

consisted of three levels of extraversion, an Introverted group, a Middle group, and an Extraverted group. All subjects in a group were tested under two frequency treatments. This general design was employed in two phases, the dependent measures being (1) "D Star" or the sensory capacity of the subject independent of the criteria adopted by her in making her judgments; (2) "Beta" or the criteria adopted by the subject in making her judgments.

Where these procedures yielded over-all significant differences at the .05 level or above, the *post hoc* procedure employed was the Tukey test, [13] again set at the .05 level of significance. Where over-all significant interaction was found at the .05 level or above, simple main effects was carried out to locate exactly where significant differences were indicated. [14]

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13. V. Keith, *Design and Analysis in Experimentation*, Ottawa, University of Ottawa Press, 1972, p. 147-148.

14. Winer, *op. cit.*, p. 529-532.

CHAPTER III

PRESENTATION OF RESULTS

This chapter presents the results of the statistical analysis of the data. It begins with an examination of the selection data of the sample. In Section 2, the signal detection analysis for both D Star and Beta are investigated in lieu of the hypotheses stated in Chapter I.

1. Selection Data for Groups of Introverted, Middle, and Extraverted Subjects.

Three groups of ten Introverted, ten Middle, and ten Extraverted subjects were selected from an initial sample of forty-eight students, on the basis of their scores obtained on the Eysenck Personality Inventory, (EPI), Form A. The means of the Extraversion and Neuroticism dimensions for the total sample of thirty subjects was 11.23 and 12.56 respectively. From the norms provided by Eysenck and Eysenck in their EPI manual,[1] it may be seen that these values are in good agreement with those of the American student norm, the mean for Extraversion being 11.8 and the mean for

1. H.J. Eysenck and S.B.G. Eysenck, Manual for the Eysenck Personality Inventory, San Diego, Educational and Industrial Testing Service, 1968, p. 5-27.

Neuroticism, 9.2. The means for the Extraversion dimension for the ten Introverted, ten Middle, and ten Extraverted subjects were 4.80, 11.70, and 17.20 respectively. This corresponds to the American student norm's sixth percentile rank, the fiftieth percentile rank, and the ninety-third percentile rank, respectively. The means of the Neuroticism dimension for the ten Introverted, ten Middle, and ten Extraverted subjects were 13.80, 12.20, and 11.70 respectively. These scores are shown in Table I.

A one-way analysis of variance applied to the sample indicated that for the Extraversion dimension, significant differences among the three groups were found ($p < .001$). The analysis of main effects, using the Tukey test as a *post-hoc* procedure yielded a significant difference ($p < .01$) for between subjects, the difference being 6.90 between the Introverted and Middle groups, 12.40 between the Introverted and Extraverted groups, and 5.50 between the Middle and Extraverted groups. Hence on the Extraversion factor of the *Eysenck Personality Inventory*, (*EPI*), all three groups differed significantly from one another. On the other hand, no significant difference was found on the Neuroticism (N) dimension for the three groups, $F < 1.00$.

Table I

EPI (Form A) Score Distributions on Extraversion (E) and Neuroticism (N) for the Total Sample Group, Introverted, Middle, and Extraverted Groups

Group	No.	E		N	
		Mean	SD	Mean	SD
Total Sample Grp	30	11.23	5.33	12.56	3.67
Introverted Grp	10	4.80	1.87	13.80	2.48
Middle Grp	10	11.70	0.95	12.20	3.79
Extraverted Grp	10	17.20	1.23	11.70	4.50

Note: The raw Extraversion (E) and Neuroticism (N) scores for the Introverted, Middle, and Extraverted subjects are given in Appendix 2.

The mean age of the Introverted group was 20.3, for the Middle group, 19.6, and for the Extraverted group, 19.6. The analysis of variance failed to show significant difference between the three groups, $F = 2.32$ $(p > .05)$

Since all the subjects in the three groups were female, and all university students, the three groups were essentially equivalent in terms of the factors of sex, age, education, and neuroticism.

2. Signal Detection Analysis

(a) Perceptual Sensitivity, "D Star"

A measure of perceptual sensitivity to all absolute levels of intensity, independent of the criteria adopted by the subject was determined for both frequency conditions, for each subject. The larger the value of D Star, the sensitivity measure, the greater was the sensitivity to the auditory stimuli.

For the Introverted group, the mean D Star was highest for the low frequency condition (500 Hz.) and lowest for the high frequency condition (6000 Hz.). The trend was reversed for the Extraverted group, their mean D Star being highest for the high frequency condition and lowest for the low frequency condition. The Middle group tended to fall in between the Introverted and Extraverted groups for the low frequency condition, but showed a slightly decreased performance for the high frequency condition, their mean D Star being lower under this condition than was the case for either of the other groups.

The mean D Star measures under the low frequency condition for the Introverted, Middle, and Extraverted groups were 4.30, 2.36, and 1.79 respectively. Under the high frequency condition, the means were 3.09, 2.00, and 3.46 respectively. Overall, then the means were 3.70 for the Introverted group, 2.18 for the Middle group, and 2.63 for the Extraverted group. The grand mean was 2.83.

The results presented in Table II indicate a disordinal interaction between personality and frequency. The Introverted group displayed greater mean sensitivity to the low frequency stimulus but their performance decreased somewhat during the high frequency presentations. The Extraverted group on the other hand showed greater sensitivity to the high frequency stimulus than to the low frequency stimulus. The Middle group manifested a slight decline in their high frequency performance from their low frequency performance. The disordinal interaction is represented geometrically in Figure 5.

The analysis of variance failed to indicate significance

Table II

Mean "D Star" Scores for Low and High Frequencies for Introverted, Middle, and Extraverted Groups

Group	No.	Lo F	SD	Hi F	SD	Avg	SD
Introverted	10	4.30	1.24	3.09	2.69	3.70	2.13
Middle	10	2.36	1.46	2.00	2.32	2.18	1.89
Extraverted	10	1.79	1.76	3.46	2.83	2.63	2.45
Average	30/3	2.81	1.82	2.85	2.61	2.83	2.23

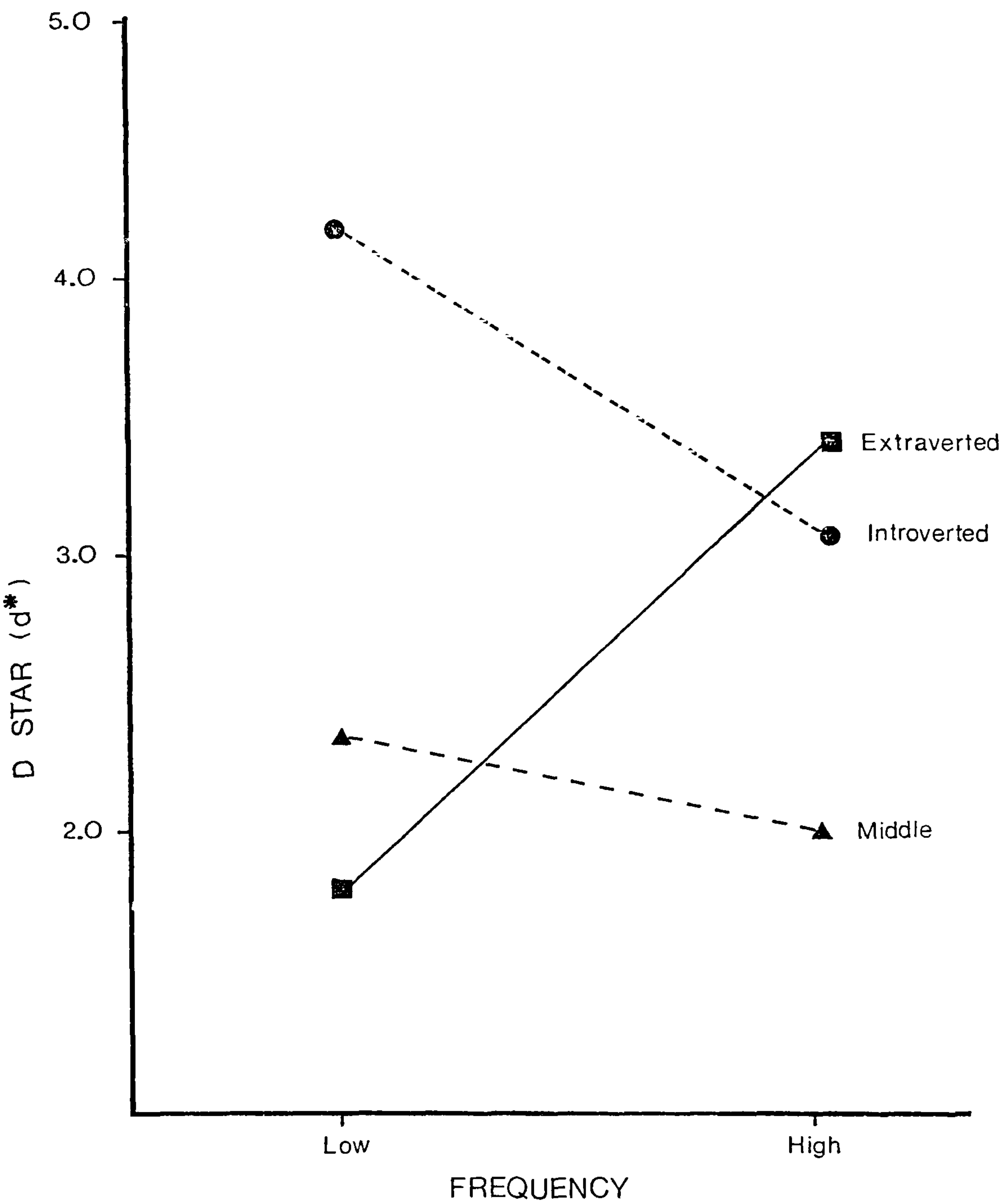

Figure 5 - Mean "D Star" Scores for Low and High Frequencies for Introverted, Middle, and Extraverted Groups.

for either the Extraversion or Frequency main effects. However an F ratio of 3.17 ($p < .07$) was found for the interaction of Frequency and Extraversion (Table III).

Because the F x E F ratio tended to approximate the appropriate P level (.05), a decision was made to discard the protection level and undertake simple main effects testing. Differences between the three groups were significant only under the low frequency condition, $F = 3.77$ ($p < .05$). No significant differences were found between the groups under the high frequency condition, $F = 1.01$ ($p > .05$). Hence differences between the mean D Star scores were significant for the Introverted and Extraverted groups at the low frequency condition, and not at the high frequency condition. No significant differences were found for either the Introverted or Middle groups in the frequency factor. A significant F ratio of 4.06 ($p < .06$) was found for the Extraverted group. Thus the difference between the mean D Stars at the low and high frequency conditions was significant only for the Extraverted group, who manifested a sharp rise in performance from the low frequency condition to the high frequency condition. It was however observed that the drop in mean D Star shown by the Introverted group at high frequency yielded an F ratio of 2.10 ($p < .20$). The assumption of homogenity of variance was not contradicted by the data, $F < 1.00$, employing the

Table III

Analysis of Variance of "D Star" Scores for Low and High Frequencies for Introverted, Middle, and Extraverted Groups

Source of Variation	SS	df	MS	F ratio
Between subjects	178.33	29		
E (Extraversion)	24.37	2	12.18	2.14
Subjects within groups	153.96	27	5.70	
Within subjects	114.76	30		
F (Frequency)	0.02	1	0.02	0.01
EF	21.82	2	10.91	3.17*
F x Subjects within groups	92.92	27	3.44	

$F_{.93}(2,27) = 3.02$

*p $<$ .07

Note: The "D Star" scores for low and high frequencies for the Introverted, Middle, and Extraverted subjects are given in Appendix 3.

Levene[2] technique.

A significant correlation of -.56 ($p < .05$) was found between extraversion and sensitivity scores for the low frequency condition. Neuroticism failed to significantly correlate with these same scores, $r = .06$. Similarly neither extraversion nor neuroticism was a significant predictor of sensitivity for the high frequency condition, $r = .12$ and $.22$ respectively ($p > .05$).

Variances in some instances, particularly in the case of high frequency scores, did tend to be quite large, an effect that is due to the presence of a few extremely high sensitivity indices. In Chapter I the sensitivity index was defined as the distance in standard deviation units between the means of the noise and signal plus noise distributions. Theoretically, due to the asymptotic nature of the normal distributions, as the hit rate approaches 1.00 and the false alarm rate approaches 0, the distance between the means of the distributions approaches infinity. For an individual obtaining near perfect discrimination in the present study, D Star was particularly great. In this extreme range, a small change in the hit or false alarm rates resulted in a large change in D Star. In order to account for this factor, maximum sensitivity was defined as a D Star of 6 (six) standard deviation units.

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2. H. Levene, "Robust Tests for Equality of Variances," in I. Olkin, ed., Contributions to Probability and Statistics, Stanford, Stanford University Press, 1960, p. 278-292.

The subsequent analysis of variance indicated a reduction of within group variance, resulting in increased F ratios for both Extraversion and Frequency main effects. A marked increase in the F ratio was noted for the interaction of Extraversion and Frequency effects, $F = 4.84$ ($p < .05$). The simple main effects analysis remained as before. Differences between the groups were significant only under the low frequency condition, $F = 5.78$ ($p < .05$). No significant differences were found between the groups under high frequency, $F = 1.52$ ($p > .05$). The Extraverted group displayed significantly greater sensitivity at high frequency than at low, $F = 3.97$ ($p < .07$), while the Introverted group manifested a significant decline in sensitivity under the high frequency condition, $F = 5.45$ ($p < .05$). The latter finding was the sole exception to the previous analysis. The assumption of homogenity of variance was not contradicted. The analysis of the revised data appears as Table IIIa.

(b) Response Criterion, Beta.

A measure of the response criterion adopted by the observer in the auditory task was determined for each variable

Table IIIa

Analysis of Variance of Maximized[1] D Star Scores for Low and High Frequencies for Introverted, Middle, and Extraverted Groups

Source of Variation	SS	df	MS	F Ratio
Between subjects				
E (Extraversion)	22.54	2	11.28	2.98
Subjects within groups	102.19	27	3.78	
Within subjects				
F (Frequency)	1.05	1	1.05	0.50
EF	20.44	2	10.22	4.84*
F x Subjects within groups	56.92	27	2.11	

1. Maximum D Star = 6.00

$F_{.95}(2,27) = 3.35$

*$p < .05$

stimulus and frequency, for each subject. In general, the larger the value of the criterion measure, "Beta," the more cautious or conservative was the subject in making his judgments.

For the Introverted group, the mean "Beta" was highest for the low frequency stimulus and lowest for the high frequency stimulus. As was the case with "D Star" measures, the trend was reversed for the Extraverted group but only to a marginal degree, their mean "Beta" being slightly higher at the high frequency stimulus than at the low frequency stimulus. The Middle group tended to mimic the Extraverted group with their mean "Beta" scores being highest at the high frequency stimulus and lowest at the low frequency stimulus.

The mean "Beta" scores at the low frequency stimulus condition for the Introverted, Middle, and Extraverted groups were 2.88, 1.90, and 1.90 respectively. For the high frequency stimulus condition, the means were 1.60 for the Introverted group, 2.49 for the Middle group, and 2.17 for the Extraverted group. The grand mean for the total sample for the low frequency condition was 2.23, and for the high frequency condition, 2.09. Overall, the grand mean was 2.15. Table IV presents these results.

Table IV

Mean "Beta" Scores for Low and High Frequencies for Introverted, Middle, and Extraverted Groups

Group	No	Lo F	SD	Hi F	SD	Avg	SD
Introverted	10	2.89	1.56	1.60	1.17	2.24	1.50
Middle	10	1.90	1.53	2.49	1.39	2.20	1.46
Extraverted	10	1.90	2.22	2.17	1.12	2.03	1.72
Average	30/3	2.23	1.80	2.09	1.25	2.15	1.54

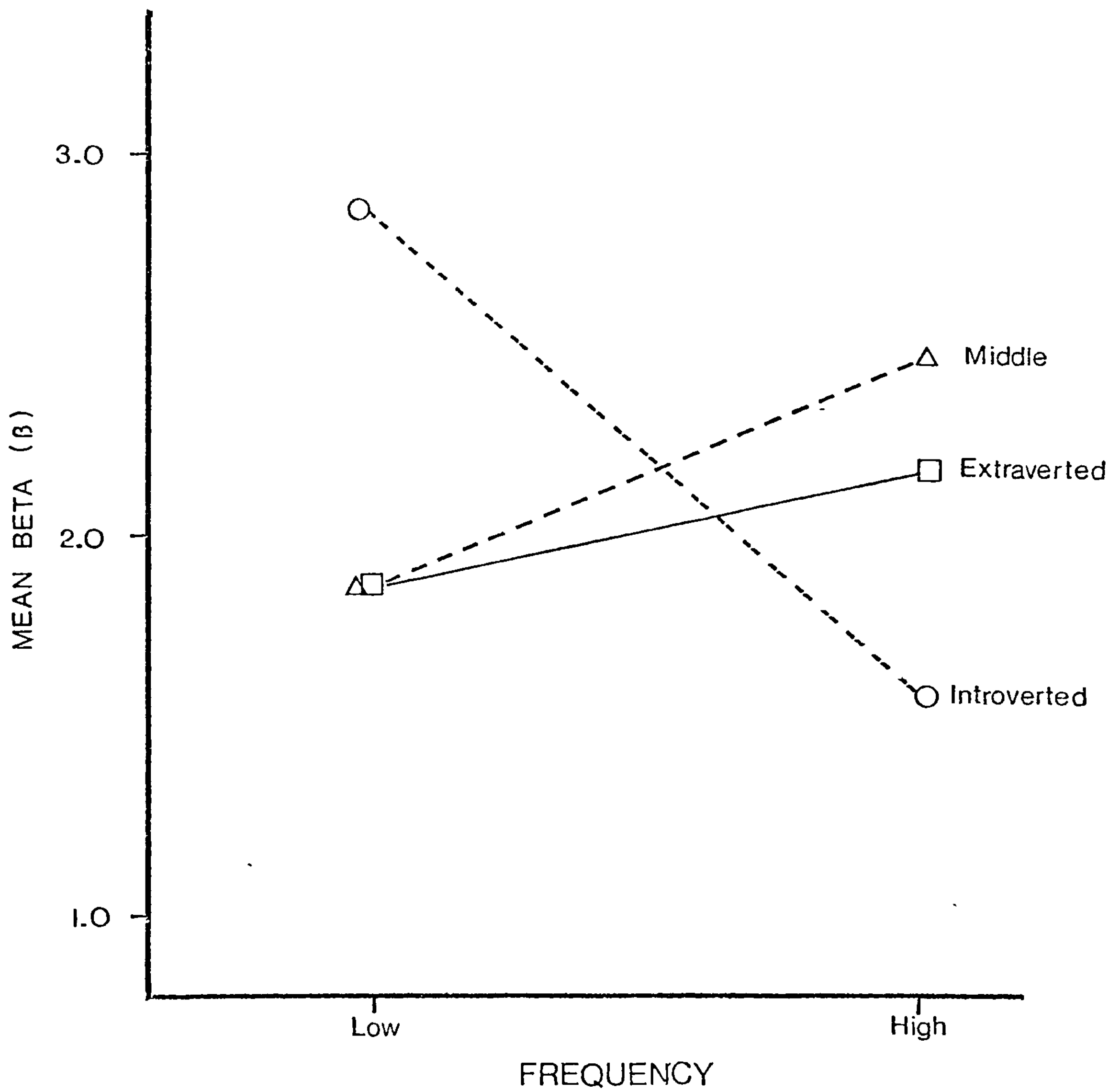

Figure 6 - Mean "Beta" Scores for Low and High Frequencies for Introverted, Middle, and Extraverted Groups.

The results indicate a similar pattern to the "D Star" scores, disordinal interaction between Frequency and Extraversion. The Introverted group displayed the greatest mean "Beta" at the low frequency condition but their mean score decreased at the high frequency condition. On the other hand, both the Middle and Extraverted groups displayed high criterion measures at the high frequency but adopted a lower criterion for the low frequency condition. The disordinal interaction is represented geometrically in Figure 6.

The analysis of variance failed to yield significant differences for either the Extraversion or Frequency main effects ($p > .05$). However the interaction between Frequency and Extraversion was found to be significant, $F = 3.36$ ($p < .05$). The analysis is presented as Table V.

To study the individual Extraversion levels for Frequency effect, simple main effects testing was carried out. No significant differences were noted for the Middle or Extraverted groups in the Frequency condition. However the analysis yielded a significant F ratio of 5.52 ($p < .05$) for the Introverted group. A significant decrease then in mean Beta scores between low and high frequency conditions was indicated for the Introverted group.

Table V

Analysis of Variance of "Beta" Scores for Low and High Frequencies for Introverted, Middle, and Extraverted Groups

Source of Variation	SS	df	MS	F Ratio
Between subjects	88.61	29		
E (Extraversion)	0.49	2	0.24	0.21
Subjects within groups	88.12	27	3.26	
Within subjects	50.88	30		
F (Frequency)	0.31	1	0.31	0.08
EF	10.07	2	5.04	3.36*
F x Subjects within groups	40.50	27	1.50	

$F_{.95}(2,27) = 3.35$

* $p < .05$

CHAPTER IV

DISCUSSION OF RESULTS

This chapter begins with a summary of the results of the auditory judgment task. Following this is an interpretation of the results in light of the literature on which the study was based. The generalizability of Eysenck's proposals is questioned as well as research supporting it. Finally, mention is made of the implications of this study on auditory perception and personality.

1. Summary of Results.

The results reported in the previous chapter may be summarized as first showing that the signal detection analysis, which provided measures of sensitivity independent of the criteria adopted by the observer and measures of the response criteria, or nonsensory, personal factors that affect the observer's sensory capacity in the judgment task, did not reveal significant differences for the Extraversion level. Similarly, neither the "D Star" measures or the "Beta" measures were significant for the Frequency level. A significant interaction, at the .07 level, for the "D Star" or sensitivity measure was noted for the interaction of Extraversion and Frequency. Simple main effects testing however showed that only the Extraverted group differed significantly between the two frequencies, their performance improving sharply under the high frequency condition. A reverse trend was noted for the Introverted group, whose mean sensitivity declined at high frequency, but the difference from low to high was not significant. In spite of the decline no significant differences were found between the Introverted and Extraverted groups for the high frequency condition. Only at low frequency was a significant difference between the groups indicated. Because a few extreme scores, particularly under the high frequency condition, tended to produce wide variances, a maximum sensitivity index was set at 6.00 and a subsequent analysis carried out. The results replicated the original analysis with one exception. The decline of the Introverted group's D Star scores at high frequency was significant in the re-analysis. Extraversion was significantly correlated with sensitivity indices only for the low frequency condition; neuroticism was a poor predictor under both conditions.

A significant interaction was also found between Extraversion and Frequency for the "Beta" or criterion measure. Simple main effects testing showed a significant difference between the frequencies for the Introverted group, who manifested a much higher mean Beta at low frequency than at high. The differences were not significant for the Middle or

Extraverted groups, although a tendency towards increased Beta was apparent for the Middle group for high frequency.

2. Interpretation of Results.

One of the primary questions of this study was whether or not subjects scoring low on the EPI, i.e., introverts, would have significantly higher sensitivity measures than those scoring high on the EPI, i.e. extraverts. The findings suggest that this can only be partially accepted. Introverts tended to be more sensitive than extraverts for a low frequency stimulus tone, confirming Eysenck's[1] expectations and replicating Smith's [2] and Nebylitsyn's [3] earlier findings. On the other hand, because no difference was found between the groups for high frequency, and because extraversion was unable to account for the variance found in those D Star scores, the generalizability of Eysenck's proposal is questioned. It would have been expected that introverts would have been more sensitive than extraverts regardless of the frequency of the stimulus source. Such was not the case.

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1. H.J. Eysenck, The Biological Basis of Personality, Springfield, Charles Thomas, 1967, p. 100.

2. S. Smith, "Extraversion and Sensory Threshold," Psychophysiology, Vol. 5, 1968, p. 293-299.

3. V.D. Nebylitsyn, "The Relationship Between Sensitivity and Strngth of the Nervous System," in J. Gray, (ed.), Pavlov's Typology, New York, Pergamon, 1964, p. 157-287.

A possible explanation for the interaction effect that Eysenck has offerred to make the findings compatible with his theory comes from the proposed inverted-U relationship between performance and arousal. [4,5,6,7]

According to this theory, the continuum extending from deep sleep at one end to a highly aroused state at the other end is very largely a function of cortical bombardment of the reticular formation. From low arousal up to a point that is optimal for a given function, level of performance rises monotonically with increasing arousal level, but beyond this optimal point the relation becomes nonmonotonic: further increases in arousal level beyond this point produces a fall in performance level, this fall being directly related to the amount of the increase in the level of arousal. [8]

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4. R.M. Yerkes and J.D. Dodson, "The Relation of Strngth of Stimulus to Rapidity of Habit Formation," Journal of Comparitive and Physiological Psychology, Vol. 18, 1908, p. 458-482.

5. H.S. Schlosberg, "Three Dimensions of Emotion," Psychological Review, Vol. 61, 1954, p. 81-85.

6. R.G. Stennett, "Performance Level and Level of Arousal," Journal of Experimental Psychology, Vol. 54, 1957, p. 54-61.

7. R.B. Malmo, "Activation: A Neuropsychological Dimension," Psychological Review, Vol. 66, 1959, p. 367-386.

8. Ibid., p. 369.

As was pointed out in Chapter I, equal amounts of stimulation are not experienced as equal by extraverts, ambiverts, and introverts. The optimal level of arousal for the introvert, using the ambivert as a reference point, is shifted negatively, while for the extravert, it is shifted positively.[9] If the curvilinear relationship between personality, arousal, and performance (sensitivity) is also taken into account, the relation appears as that in Figure 7. The mean performance of introverts, ambiverts, and extraverts under low and high frequency conditions reflected this relationship.

A stimulus then that is perceived as producing a moderately low level of arousal for the ambivert may be experienced as producing a moderate or optimal level of arousal for the introvert, while at the same time producing a low level of arousal for the extravert. In terms of performance or in the case of this study, sensitivity, the high level of sensitivity observed for the introvert under the low frequency condition may reflect an optimal level of arousal; for the ambivert the moderately low level of sensitivity correspondingly may be reflected in a moderately low level of arousal, while for the insensitive extravert, a low level of arousal is indicated.

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9. Eysenck, op.cit., p. 109.

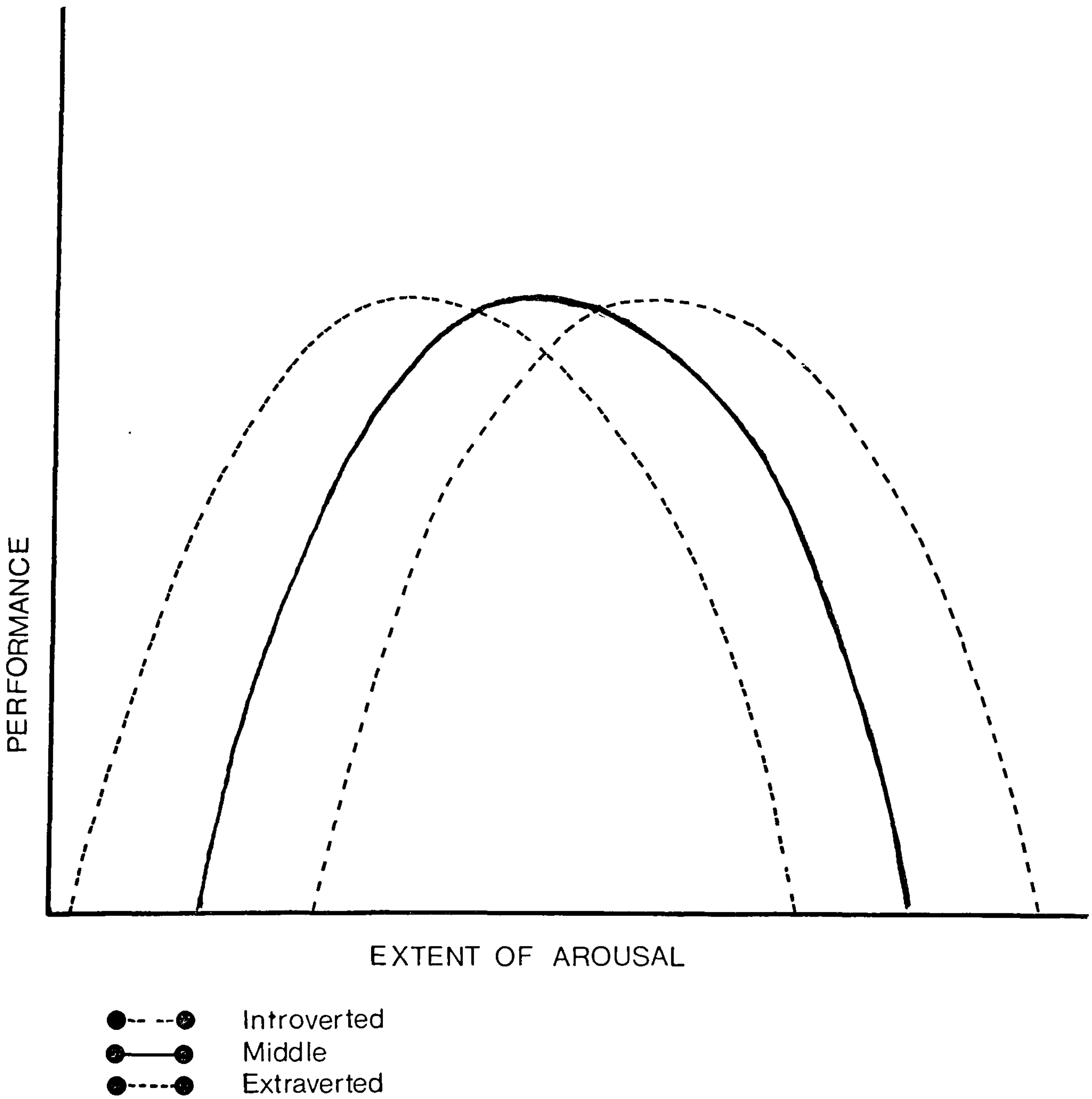

Figure 7 - Hypothesized Relationship Between Arousal, Personality, and Performance.

Assuming that high frequency auditory stimuli are more arousing than low frequency stimuli, it is plausible that the introvert would experience the former as being very arousing, with a resultant decrement in sensitivity, the ambivert experiencing it as moderately highly arousing, with a resultant moderate level of sensitivity, and the extravert experiencing it as moderately or optimally arousing, with a resultant improved level of sensitivity. The results largely pointed in this direction. However wide variation within groups brings into question individual differences within groups, which although partially accounted for by extreme scores, contests the applicability of the arousal hypothesis beyond grouped data. The arousal hypothesis suggests differences between groups. Differences among individuals within the respective groups pose additional query. For example, while the mean sensitivity scores of the Extraverted group under the high frequency condition significantly increased from the low frequency condition, four of the extraverts showed a decline. Nevertheless the fact remains that extraverts did manifest some increase in sensitivity as compared with introverts where only two displayed greater sensitivity at high frequency than at low.

The Singer-Guilford [10,11] data indicated that those who preferred low levels of intensity also preferred low frequency stimuli. Furthermore it was suggested that those who prefer noise conditions will also prefer high frequency sounds. Because both the findings of Smith and the present study indicate that introverts tend to be sensitive, and presumingly aroused for low frequency tones, a parallel may perhaps be made between arousal and pleasure. Those stimuli which tend to be judged as pleasureable will also be arousing; in the case of the introvert low frequency tones tended to be rated as pleasureable while high frequency may take on the same role for the extravert.

A second line of evidence is much more speculative, coming from the biological nature of audio frequency. Throughout the animal kingdom, high frequency sounds such as cries, screams, whistles, and other emotional calls, have come to serve as a type of warning or alerting system. [12] In the sphere of human development, infants have a much higher pitch level than older children or adults, as well as possessing

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10. W.B. Singer and P.T. Young, "Studies in Affective Reaction: II. Dependence of Affective Ratings Upon the Stimulus Situation," Journal of General Psychology, Vol. 24, 1941, p. 303-325.

11. J.P. Guilford, "Systems in the Relationship of Affective Value to Frequency and Intensity of Auditory Stimuli," American Journal of Psychology, Vol. 67, 1954, p. 691-698.

12. G. Fairbanks and W. Pronovost, "An Experimental Study of the Pitch Characteristics of the Voice During the Expression of Emotion," Speech Monographs, Vol. 6, 1939, p. 87-104.

the greatest range of pitches that can be utilized. [13] The dependence of the infant and the need for an alerting system may explain the high pitched voice. The guardian of the infant of course is the mother, again with a high pitched voice. The adult male having little to do with child care possesses a much deeper, low pitched voice. However as a child, the dependent male possesses an even higher pitched voice than the female. [14] It is not until adolescence, a period in which the male comes to break the dependency bonds of his parents that his voice deepens. [15] During old age, the male voice again takes on a higher pitch, and increases in pitch as he continues to age, again pointing to the need to rely on others. [16] The human voice then reflects a direct relationship between high pitch and dependency. Even the inventions of warning and emergency systems rely on high frequency, the best examples perhaps being the siren, and in sports, the whistle. If such an elaborate function is

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13. G. Fairbanks and W. Pronovost, "An Experimental Study of the Pitch Characteristics of the Voice During the Expression of Emotion," Speech Monographs, Vol. 6, 1939. p. 87-104.

14. G. Fairbanks, J.H. Wiley, and F.M. Lassman, "An Acoustical Study of Vocal Pitch in Seven and Eight Year Old Boys, Child Development, Vol. 20, 1949, p. 63-69.

15. E.T. Curry, "The Pitch Characteristics of the Adolescent Male Voice," Speech Monographs, Vol. 7, 1940, p. 48-62.

16. E.D. Mysak, "Vocal Attributes of Older Males," Journal of Speech Hearing Research, Vol. 2, 1959, p. 46-54.

indeed served by high frequency, it is likely that its end result would be cortical arousal.

Returning to the study of extraversion, the introvert whose baseline nervous reactivity is large, thus characterized by higher cortical levels of arousal may find the additional arousal produced by high frequency sources a burden on his system, thus commanding inhibition of stimulus input, inhibition being reflected in lower sensitivity. The extravert however requires such a warning-alerting stimulus to become aroused, this excitation being reflected in an increased level of sensitivity.

A biological alerting system assumes high frequency to be more arousing than low frequency. The performance of the Extraverted group lends support to this argument, but a barrier is posed by the performance of the Introverted group. If high frequency is highly arousing, it would have been expected, in keeping with the inverted-U relationship, that sensitivity indices for the Introverted group would have sharply fallen off. Although a drop from the low frequency condition was noted, it did not meet the predicted decline. Inhibition of input then, if it was existent at all, must have been limited. If high frequency acts as a biological activator of the cortex, it seems doubtful that afferent information would be inhibited regardless of individual differences in baseline arousal level. Anatomically it was noted that that the excitation-inhibition hypothesis may follow for low frequencies. The low frequency pathway sends a number of collaterals into the reticular formation as well as other medullary centers; the reticular formation serving the role of arousing the cortex as Eysenck maintains. On the other hand, the high frequency tract is much more direct at least at the level of the medulla. If inhibitory or excitatory influences play an effect on this tract, they must do so at higher colliculi or thalamic regions. A question arises as to how high frequency, without the assistance of reticular relay, can produce extensive cortical arousal. Hess [17] by direct high frequency electrical stimulation of intralaminar nuclei of the thalamus and posterior nuclei of the hypothalamus produced dramatic cortical arousal as measured by EEG. The cortical arousal was characterized behaviourally by general excitation, fear and escape reaction and also pronounced searching which succeeded the stimulation. The ultimate destination of the brain stem reticular formation is these centers as well as other diffuse thalamic regions. Thus cortical excitation may be accomplished in two ways: indirectly through the reticular formation or directly through

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17. W. Hess, "Bioelectric and Behavioral Arousal with Electrical Stimulation of Meso-Diencephalic Structures," <u>EEG and Clinical Neurophysiology</u>, Vol. 6, p. 528-529.

specific thalamic and hypothalamic structures. Low frequencies take the indirect route, and thus are subject to cortical feedback modification. High frequencies take a somewhat more direct route, thus are subject to less modification. If this be the case individual differences in personality should have minimal effect on arousal and sensitivity for high frequency stimuli, as was indicated by the grouped data. Upon closer examination of the data it was seen that wide variation among individual subjects contradicted this proposal. Individual variation was to be expected for low frequency but not for high. The variation was in fact greater for the high frequency condition than for the low. The opposite was expected. Additional evidence from Robinson [18] and Hempstock et al. [19] has pointed to similar findings. Neither offer explanations other than technical problems with acoustic equipment.

Individual variation within the Extraverted group for both frequency conditions remains as an issue. Unfortunately the studies reported in the first chapter usually do not report group variance. Corcoran, the sole exception, found greater variability in extraverts than in introverts.

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18 D. Robinson, "Variability in the Realization of the Audiometric Zero," Annals of Occupational Hygiene, 1960, p. 107.

19 T. Hempstock, M. Bryan, and J. Webster, "Free Field Threshold Variance," Journal of Sound and Vibration, Vol. 4, 1966, p. 33.

Beyond this study, information is lacking. It is difficult therefore to generalize to the extraverted population as a whole. Further evidence is required before it can be claimed that extraverted individuals are more fluctuant than their counterparts.

In summary, the results of the study at first appear to question the generalizability of Eysenck's proposal. Upon further inquiry with the inclusion of the arousal function of high frequency, a détente has been suggested. Low frequency takes on an arousing function for the already sensitive introvert but is only marginally arousing for the insensitive extravert. High frequency which was viewed as an arousing stimulus produced equal levels of stimulation for both introverts and extraverts due either to its direct transmission or to minimal inhibitory influences upon it.

The results of the criterion analysis do not substantiate Eysenck's belief that extraverts tend to be more risk taking than introverts, [17] as demonstrated by a non-significant main Extraversion effect. These findings

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17. Eysenck, op. cit., p. 100-101.

are however in agreement with the findings of Bourgeois.[18]

A significant Frequency x Extraversion interaction for the criterion analysis in correspondance with the significant Frequency x Extraversion interaction for the sensitivity analysis indicates that it is not so much extraversion that is the determinant of nonsensory behaviour such as risk-taking but rather the difficulty that the discrimination task presents.

In traditional signal detection thinking,[19,20] as the observer adopted a more relaxed criterion in making her judgments, reflected in an increased false alarm rate, the more the hit rate was expected to increase. On the other hand, the more the observer adopted a stringent criterion, reflected in a decreased false alarm rate, the more the hit rate was expected to decrease. Beta is also however dependent on perceptual sensitivity as well as nonsensory factors. Thus the more sensitive an individual is, the easier he finds the discrimination task, thus displaying a high hit and low false alarm proportion. In

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18. R-P Bourgeois, Introversion-Extraversion and the Role of the Orienting Reaction Habituation Rate to the Apparent Size of Hue, unpublished doctoral thesis, University of Ottawa, 1972, 128 p.

19. D. Green and J. Swets, Signal Detection Theory and Psychophysics, New York, Wiley, 1966, p. 35.

20. H.W. Hake and A.S. Rodwan, "Perception and Recognition," in J.B. Sidowski (ed.), Experimental Methods and Instrumentation in Psychology, New York, McGraw-Hill, 1966, p. 335-345.

general, this would appear to be the rational for the findings in the present study. Where the false alarm rate was high, the hit rate was low, suggesting that the more difficult the task (as reflected by the low hit rate), the more the observer was forced to rely on risk taking (reflected by high false alarm rate). The combination of a low hit rate and false alarm rate produced a resultant low D Star and low Beta score. On the other hand as the observer found the task easier (as reflected by a high hit rate) the less she found it necessary to rely on risk-taking because of the certainty of her decisions (manifested in a low false alarm rate). The combination of a high hit rate and low false alarm rate produced a resultant high D Star and high Beta. The criterion measure then in this instance may be looked upon as a general indicator of observation difficulty and to a lesser extent, degree of caution.

3. Implications of the Findings.

Implications for further research would appear to be vast. Because of the speculative nature of the interpretation of the results, a replication of this study may well be fruitful, with the addition of a wider range of frequencies. Where this study examined two such frequencies, a much more complete range should be considered to fully complement the arousal hypothesis. Using a fuller range of frequencies would however likely preclude the repeated measures statistical design. For optimal employment of the signal detection procedure, a very large number of trials per frequency is a necessity. Extending this time period over a number of frequencies would without doubt produce measureable amounts of fatigue in a subject. Another similar extension could investigate the role of high frequency stimulation in any sensory modality - proprioception being the most obvious.

The question of arousal and frequency cannot really be answered directly by a psychophysical experiment. Psychophysiological measures taken concomitant with the presentation of a range of frequencies would be expected to provide a more valid measure of arousal. In addition, intensities at both threshold and at very high levels could be employed as a means of looking at the effects of the interaction of frequency and intensity on reactivity. Considering the apparent directness, absence of feedback loops, and lack of collaterals into the reticular formation shown by the high frequency pathway in comparison to the low frequency pathway, the Orienting Reaction would appear to be a most obvious area of further inquiry. This is especially the case if indeed high frequency takes on the role of a biological alerter, affecting lower centers such as the limbic system. One would predict that high frequency habituation in comparison with low frequency would be limited. Furthermore, assuming that high frequency does take on emotional affect, then extreme groups on the Neuroticism (N) scale come to pose a problem for investigation.

Finally the study of the Orienting Reaction and habituation points to the area of classical conditioning. Differences in personality would likely affect the role of frequency as an unconditioned stimulus. This may have particular impetus in the developmental sphere as previously outlined.

SUMMARY AND CONCLUSIONS

The first major hypothesis stated that there is no significant difference between groups of low, middle, and high extraversion on a measure of sensitivity independent of the criteria adopted by the observer in making her judgments. Because the analysis of Extraversion main effects was not significant, the hypothesis was not rejected.

The second major hypothesis stated that there was no significant interaction effect between Extraversion and Frequency on a measure of sensitivity independent of the criteria adopted by the observer in making her decisions. A significant disordinal interaction resulted in the rejection of the hypothesis. Simple main effects testing showed a significant improvement for the Extraverted group under the high frequency condition. The Introverted group displayed a noticeable decline under the high frequency condition, the drop from the low frequency condition however being significant only after a maximum sensitivity index score was established. The Introverted and Extraverted groups differed significantly only under the low frequency condition.

This latter finding replicated an earlier finding by Smith. However because extraverts improved while at the same time introverts declined at high frequency, with a resultant failure to find significant difference between the two groups, the generalizability of Eysenck's proposal that introverts are more sensitive to any stimulus than extraverts, was questioned.

A minor hypothesis of significant difference between the three groups on a measure of the criteria adopted by the observer in making her judgments was not rejected. A significant disordinal interaction was however found on this measure. This interaction paralleling the significant Extraversion x Frequency interaction for the sensitivity measure suggests that it is not so much personality variables that are the determinants of the criteria that the observer adopts but rather the difficulty that the tasks presents.

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Guilford, J.P., "Systems in the Relationship of Affective Value to Frequency and Intensity of Auditory Stimuli," American Journal of Psychology, Vol. 67, 1954, p. 691-698.

This article reanalyzes the data earlier collected by Singer and Young, indicating the relationship between auditory intensity and frequency.

Hake, H.W., and R.S. Rodwan, "Perception and Recognition," in J.B. Sidowski (ed.), Experimental Methods and Instrumentation in Psychology, New York, McGraw-Hill, 1966, p. 332-381.

The authors argue convininingly against the classical concept of the threshold and other psychophysical procedures. They furthermore point out the inadequacies of "guessing corrections" applied to threshold data.

Malmo, R.B., "Activation: A Neuropsychological Dimension," Psychological Review, Vol. 66, 1959, p. 367-386.

Discusses the characterisitics of activation and arousal, and the effects of increased arousal on performance.

Nebylitsyn, V.D., "The Relationship Between Sensitivity and Strength of the Nervous System," translated by J.A. Gray, in J.A. Gray, (ed.), Pavlov's Typology, New York, Pergamon, 1964, p. 157-287.

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This article was one of the first to present perceptual evidence that introverts had lower auditory thresholds than extraverts. He however employed only a low, 500 Hz. pure tone as a stimulus and moreover implied that a "guessing correction" applied to his data adequately validated the threshold information that he found.

APPENDIX 1

THE EYSENCK PERSONALITY INVENTORY, (EPI), FORM A

EYSENCK PERSONALITY INVENTORY

FORM A

By H. J. Eysenck
and Sybil B. G. Eysenck

Name____________________ Age________ Sex________

Grade or Occupation ____________________ Date________

School or Firm____________________ Marital Status________

INSTRUCTIONS

Here are some questions regarding the way you behave, feel and act After each question is a space for answering "Yes," or "No"

Try and decide whether "Yes," or "No" represents your usual way of acting or feeling Then blacken in the space under the column headed "Yes" or "No"

Section of Answer Column Correctly Marked

Yes No

Yes No

Work quickly, and don't spend too much time over any question, we want your first reaction, not a long drawn-out thought process The whole questionnaire shouldn't take more than a few minutes Be sure not to omit any questions Now turn the page over and go ahead Work quickly, and remember to answer every question There are no right or wrong answers, and this isn't a test of intelligence or ability, but simply a measure of the way you behave

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E N L

1 Do you often long for excitement? Yes No

2 Do you often need understanding friends to cheer you up? Yes No

3 Are you usually carefree? Yes No

4 Do you find it very hard to take no for an answer? Yes No

5 Do you stop and think things over before doing anything? Yes No

6 If you say you will do something do you always keep your promise no matter how inconvenient it might be to do so? Yes No

7 Does your mood often go up and down? Yes No

Do you generally do and say things quickly without stopping to think? Yes No

9 Do you ever feel "just miserable" for no good reason? Yes No

10 Would you do almost anything for a dare? Yes No

11 Do you suddenly feel shy when you want to talk to an attractive stranger? Yes No

12 Once in a while do you lose your temper and get angry? Yes No

13 Do you often do things on the spur of the moment? Yes No

14 Do you often worry about things you should not have done or said? Yes No

15 Generally do you prefer reading to meeting people? Yes No

16 Are your feelings rather easily hurt? Yes No

17 Do you like going out a lot? Yes No

18 Do you occasionally have thoughts and ideas that you would not like other people to know about? Yes No

19 Are you sometimes bubbling over with energy and sometimes very sluggish? Yes No

20 Do you prefer to have few but special friends? Yes No

21 Do you daydream a lot? Yes No

22 When people shout at you, do you shout back? Yes No

23 Are you often troubled about feelings of guilt? Yes No

24 Are all your habits good and desirable ones? Yes No

25 Can you usually let yourself go and enjoy yourself a lot at a gay party? Yes No

26 Would you call yourself tense or "highly-strung"? Yes No

27 Do other people think of you as being very lively? Yes No

28 After you have done something important do you often come away feeling you could have done better? Yes No

29 Are you mostly quiet when you are with other people? Yes No

30 Do you sometimes gossip? Yes No

31 Do ideas run through your head so that you cannot sleep? Yes No

32 If there is something you want to know about would you rather look it up in a book than talk to someone about it? Yes No

33 Do you get palpitations or thumping in your heart? Yes No

34 Do you like the kind of work that you need to pay close attention to? Yes No

35 Do you get attacks of shaking or trembling? Yes No

36 Would you always declare everything at the customs even if you knew that you could never be found out? Yes No

37 Do you hate being with a crowd who play jokes on one another? Yes No

38 Are you an irritable person? Yes No

39 Do you like doing things in which you have to act quickly? Yes No

40 Do you worry about awful things that might happen? Yes No

41 Are you slow and unhurried in the way you move? Yes No

42 Have you ever been late for an appointment or work? Yes No

43 Do you have many nightmares? Yes No

44 Do you like talking to people so much that you would never miss a chance of talking to a stranger? Yes No

45 Are you troubled by aches and pains? Yes No

46 Would you be very unhappy if you could not see lots of people most of the time? Yes No

47 Would you call yourself a nervous person? Yes No

48 Of all the people you know are there some whom you definitely do not like? Yes No

49 Would you say you were fairly self-confident? Yes No

50 Are you easily hurt when people find fault with you or your work? Yes No

51 Do you find it hard to really enjoy yourself at a lively party? Yes No

52 Are you troubled with feelings of inferiority? Yes No

53 Can you easily get some life into a rather dull party? Yes No

54 Do you sometimes talk about things you know nothing about? Yes No

55 Do you worry about your health? Yes No

56 Do you like playing pranks on others? Yes No

57 Do you suffer from sleeplessness? Yes No

PLEASE CHECK TO SEE THAT YOU HAVE ANSWERED ALL THE QUESTIONS

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

PLEASE CHECK TO SEE THAT YOU HAVE ANSWERED ALL THE QUESTIONS.

EYSENCK PERSONALITY INVENTORY

FORM A

By H. J. Eysenck
and Sybil B. G. Eysenck

Name____________________ Age________ Sex________

Grade or Occupation ____________________ Date________

School or Firm____________________ Marital Status________

INSTRUCTIONS

Here are some questions regarding the way you behave, feel and act After each question is a space for answering "Yes," or "No."

Try and decide whether "Yes" or "No" represents your usual way of acting or feeling Then blacken in the space under the column headed "Yes" or "No"

Section of Answer Column Correctly Marked

Yes No
▮

Yes No
▮

Work quickly, and don't spend too much time over any question, we want your first reaction, not a long drawn-out thought process The whole questionnaire shouldn't take more than a few minutes Be sure not to omit any questions Now turn the page over and go ahead Work quickly, and remember to answer every question There are no right or wrong answers, and this isn't a test of intelligence or ability, but simply a measure of the way you behave

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APPENDIX 2

RAW *EPI* SCORES FOR GROUPS OF INTROVERTED, MIDDLE, AND EXTRAVERTED SUBJECTS

APPENDIX 2

Eysenck Personality Inventory (EPI), Form A, Scores for Extraversion (E) and Neuroticism (N) for Groups of Introverted, Middle, and Extraverted Subjects.

Subject	E	N
Introverted		
1	3	17
2	6	11
3	7	13
4	6	14
5	2	14
6	5	12
7	5	16
8	5	11
9	2	12
10	7	18
Middle		
11	10	15
12	11	13
13	13	13
14	12	9
15	11	16
16	12	7
17	11	18
18	13	7
19	12	10
20	12	14
Extraverted		
21	19	13
22	18	8
23	16	9
24	17	22
25	18	11
26	16	5
27	17	14
28	16	13
29	19	11
30	16	11

APPENDIX 3

RAW "D STAR" SCORES FOR TOTAL SAMPLE

APPENDIX 3

"D Star" of Frequencies for Groups of Introverted, Middle and Extraverted Subjects

Subject	Frequency	
	Low	High
Introverted		
1	3.821	1.123
2	2.592	0.970
3	3.936	3.185
4	6.295	6.393
5	5.607	1.322
6	3.395	2.174
7	4.003	0.544
8	3.126	2.975
9	4.271	3.215
10	5.920	9.046
Middle		
11	1.403	2.032
12	1.203	1.359
13	0.959	0.572
14	3.170	8.115
15	1.471	0.602
16	3.590	0.463
17	1.916	2.622
18	5.738	0.620
19	2.373	2.720
20	1.731	0.848
Extraverted		
21	0.671	1.900
22	0.556	1.818
23	1.536	0.745
24	0.718	5.187
25	3.113	2.319
26	1.163	1.152
27	6.195	6.786
28	1.359	4.411
29	0.363	9.190
30	2.254	1.134

APPENDIX 4

RAW "BETA" SCORES FOR TOTAL SAMPLE

APPENDIX 4

"Beta" of Frequencies for Groups of Introverted, Middle and Extraverted Subjects

Subject	Frequency	
	Low	High
Introverted		
1	2.126	0.930
2	1.456	1.175
3	3.123	2.293
4	1.843	1.843
5	2.800	1.832
6	2.792	2.154
7	4.722	-0.563
8	1.188	1.004
9	2.528	1.348
10	6.304	3.994
Middle		
11	0.498	0.812
12	-1.423	0.330
13	1.108	3.004
14	1.532	3.598
15	2.830	1.103
16	2.230	4.022
17	2.548	2.528
18	3.848	3.190
19	3.124	4.340
20	2.744	2.010
Extraverted		
21	-0.127	1.225
22	1.144	0.976
23	1.330	1.643
24	0.734	2.812
25	1.780	1.016
26	-0.838	1.284
27	3.530	3.095
28	6.653	2.260
29	3.953	3.035
30	0.843	4.331

APPENDIX 5

STIMULUS-RESPONSE FREQUENCY MATRIX

The calculations of the hit and false alarm proportions from the rating data, which were employed for the computer analysis, are illustrated in the stimulus-response matrix (Table A). The response categories are abbreviated as follows: yes positive, YP; yes fairly sure, YF; yes guess, YG; no guess, NG; no fairly sure, NF; no positive, NP. The intensity of the signal is the stimulus value, those being, -3, -1, +1, +3, +5 db., ISO. The total number of signal responses for each category (YP, YF, YG, NG, NF, NP) is the sum of the particular response category given for each stimulus value. For example, the response category, yes positive (YP), was given to the signal plus noise presentation 2+2+4+5+12 or 25 times by this subject. For the noise presentation, the response, YP, was given 3 times. The total number of responses per category for the signal plus noise and the noise presentation are underlined.

Table A

Stimulus-Response Frequency Matrix for One Subject on One Stimulus Condition

Response Category	Signal	Stimulus Value (in db., ISO) -3	-1	+1	+3	+5	Noise
YP	25	2	2	4	5	12	3
YF	20	2	6	5	4	3	6
YG	16	3	1	3	6	3	16
NG	5	1	1	3	0	0	9
NF	22	8	5	3	4	2	33
NP	12	4	5	2	1	0	33

APPENDIX 6

ABSTRACT OF

Introversion-Extraversion and Auditory Sensitivity to High and Low Frequency Tones [1]

H.J. Eysenck has proposed that introverts would be more sensitive to auditory stimuli than introverts, in line with other physiological differences between the groups. Smith, using threshold techniques and employing a 500 Hz. pure tone, arrived at the predicted result. However he failed to adequately account for nonsensory, personal factors that affect the subject's sensitivity, and moreover did not expand his range of stimuli to include high frequencies.

In this study, three groups of university students, representing those who scored low, in the middle, and high on the Eysenck Personality Inventory served as subjects. A signal detection approach was used to measure sensitivity to a low, 500 Hz. and high, 6000 Hz pure tone, independent of the criteria adopted by the observer in making her judgments.

The results failed to indicate significant main Extraversion effects, contrary to Eysenck's proposals. However a significant interaction between Extraversion and Frequency

1. Kenneth B. Campbell, master's thesis presented to the School Of Graduate Studies of the University of Ottawa, Ontario, August 1973, viii-85 p.

was found, the difference in sensitivity between introverts and extraverts being significant only at low frequency, replicating Smith's earlier findings. The difference at high frequency was not significant. The extraverts showed a significant improvement from low frequency to high. Introverts on the other hand declined from the low frequency condition, but the difference was significant only after a maximum sensitivity index was established.

The results raise the question of the generalizability of Eysenck's hypothesis. A rapprochement was attempted employing the curvilinear relationship between arousal, performance, and personality. High frequency may be more arousing than low frequency, with a resultant drop in sensitivity by the already highly aroused introvert, but an improvement by the lowly aroused extravert. Anatomically it was pointed out that the high frequency auditory pathway is subject to less inhibitory influences than the low.

On a measure of the criteria adopted by the observer in making her judgments, a significant Extraversion x Frequency interaction was again found. The suggestion was made that it was not so much personality differences that was the determinant of the criteria adopted but rather the difficulty of the task.

The study ended with a summary of the results and its implications for future research.