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Intelligence and Complexity of the Averaged Evoked Potential: An Attentional Theory

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Although the Hendricksons have proposed that the string length measure of human auditory evoked potential complexity is positively related to psychometric intelligence, this relationship is variable and may even in some circumstances be reversed. Previous studies relating string length to IQ are reviewed and it is proposed that inconsistencies between these reports reflect procedural differences in task—attention requirements or the absence thereof. In order to test this hypothesis, 21 subjects participated in two string length conditions: one in which attention was not required and one in which subjects were required to count oddball stimuli. String length was shown to be the product of an interaction between intelligence and attention such that high-IQ subjects recorded lower brain evoked potential string lengths in the attend condition, whereas low-IQ subjects showed maximal string lengths under attended conditions. This result is compatible with both the D.E. Hendrickson and Hendrickson (1980) and Bates and Eysenck (1993) findings of positive and negative IQ–string correlations, respectively, and supports the hypothesis that string length indexes efficiency and capacity under attended and unattended conditions, respectively. The string length correlation with IQ is thus suggested to result from opposite attention-induced changes in string length in high- and low-IQ subjects. This was supported by a correlational analysis of the difference in string length between high and low attention conditions revealing a wide spread high correlation maximal at frontal sites, where the difference measure accounted for over half the variance in intelligence test scores (uncorrected $R^2 = 0.53$). It is suggested that the string difference measure is a more reliable estimate of intelligence than raw string length in either attended or unattended conditions. The neural-efficiency model of intelligence is discussed in light of these experimental findings.

D.E. Hendrickson and Hendrickson (1980) developed a model of intelligence that relates individual differences in intelligence test performance to error rates in cortical information processing. Their model derived from the work of Fox and O'Brien (1965), whose animal work in the cat indicated that the cortical averaged

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evoked potential (AEP) corresponded closely to a histogram of single-cell spike activity. This similarity was interpreted by A.E. Hendrickson (1982) to suggest that, as pulse trains were transmitted from one neuron to the next, any errors in propagating the initial activity would result in the AEP waveform becoming less complex. In order to measure this information-processing accuracy, the Hendricksons derived a formula that measured the contour length of the EP as the sum of the voltage differences between adjacent AEP samples within a given interval, termed the string length, as it corresponds to the length of the AEP if stretched out straight like a piece of string. D.E. Hendrickson and Hendrickson (1980) postulated, then, that errors in the processing of stimuli will lead to variable brain responses to the invariant stimuli and, therefore, to less complicated AEPs as measured by the string length. They further suggested that intelligence may reflect neural accuracy and therefore, the string length should correlate positively with psychometric intelligence. To test this hypothesis, they reanalyzed data presented by Ertl and Schafer (1969). In a sample of 10 high and 10 low Wechsler Intelligence Scale for Children (WISC) IQ subjects, the Hendrickson's string length measure correlated +.77 with IQ, accounting for more than half of the IQ variance.

Eysenck (1982) suggested that error theory of the string length may also be able to account for the significant relationship supported between psychometric intelligence and measures of speed of information processing such as reaction time and inspection time (Jensen 1987; Nettlebeck, 1987). Higher mean speed on these tasks, Eysenck (1982) argued, is a consequence of cortical information-processing accuracy. Inaccurate processing will lead to slower information processing because the neuronal transmissions underlying stimulus processing will be variable and may need to be repeated to generate a correct behavioral outcome. For instance, a longer time will be required to adequately sample the stimulus in the inspection time (IT) paradigm and the amount of time required to react to a stimulus in the Jensen reaction time paradigm will be more variable.

The initial D.E. Hendrickson and Hendrickson reanalysis was soon confirmed by Blinkhorn and Hendrickson (1982) who found significant correlations between string length and scores on the Raven's Advanced Progressive Matrices (APM) in a student sample. AEPs from 100 tones presented at 1- to 8-s pseudorandom interstimulus interval (ISI), and 85 dB intensity were recorded, although only the first 90, 64, and 32 trials were used in later analyses. The correlations reported between the APM and string length were +.5, +.36, and +.45 with 90, 64, and 32 trial averages, respectively. Other verbal tests (NIIP GT90A, Verbal Concepts and Verbal Critical Reasoning, and various divergent thinking tests) were also administered but did not significantly correlate with the string length. Correcting the correlations for restriction in range of the APM scores increased the string length–IQ correlations to between +.7 and +.85, which is approximately the internal reliability of many IQ tests (Eysenck & Barrett, 1985). D.E. Hendrickson (1982) reported the most convincing support for the string length