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Intelligence and neural transmission time: a brain stem auditory evoked potential analysis

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Abstract

Brain stem auditory evoked potential (BAEP) measures were employed to assess the association of individual differences in mental ability and neural transmission time. The BAEP to brief click stimuli at 72, 80 and 88 dB intensity was recorded from 54 female participants. Overall, low positive correlations between full-scale intelligence (FIQ), as measured by the Multidimensional Aptitude Battery, and BAEP latency were observed, with salient effects at the 80 dB intensity level for wave III, wave V and interpeak latency I–V. The association of higher ability (HA) with longer BAEP latency contradicts the hypothesis of faster neural transmission for HA. Head size was also positively correlated with both mental ability and BAEP latency. An analysis using measures of head width and interpeak latency to calculate nerve conduction velocity (NCV) associated higher verbal intelligence with slower auditory NCV.

Keywords: Intelligence; Brain stem auditory evoked potentials; Neural transmission time; Nerve conduction velocity

1. Introduction

There is a long-standing hypothesis that higher mental ability (HA), as defined by psychometric tests of intelligence, may be determined, in part, by faster neural transmission time or neural efficiency (Ertl & Schafer, 1969). At the present time, this hypothesis still appeals to the well-established fact that HA individuals exhibit faster behavioral response times during the performance of simple sensory, motor, memory and decision tasks than do individuals with lower ability (Jensen, 1982; Vernon, 1990). However, the outcomes of research attempting to assess the neural transmission time hypothesis with event-related potential (ERP) and electromyographic procedures are decidedly mixed and inconclusive. The present project undertook a new approach

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to the question by employing brain stem auditory evoked potential (BAEP) measures to assess the association of neural transmission time and individual differences in mental ability.

During the past 35 years, a substantial literature accumulated that accounts the research employing ERP procedures to assess the hypothesis that higher mental ability is characterized by faster neural processing time or greater neural efficiency. In this work, the latency of early ERP waves, in the range of 100 ms, index the neural transmission time between the sensory receptor and sensory cortex. Specifically, the relation between mental ability and the latency of the ERP waves that were derived from the repetitive presentation of brief tones or light flashes was examined. From previous reviews of this work (Deary & Caryl, 1993; Stelmack & Houlihan, 1995), we concluded that there was no reliable relation between mental ability and the latency of early, exogenous ERP waves to simple repetitive sensory stimulation. Thus, there is no clear support for the neural transmission time hypothesis from those data. In more recent work, however, an analysis of the ERPs produced by averaging reversals of a checkerboard pattern did indicate shorter latency for HA participants. Specifically, a negative correlation ($r = -0.21$) between general intelligence and a positive wave at about 100 ms was reported (Reed & Jensen, 1992). Because there is minimal change in luminance in the pattern reversal, the effective stimulus is spatial frequency. In a recent study that used essentially the same procedures, a similar effect was also reported (Burns, Nettlebeck, & Cooper, 2000).

The relation of mental ability and neural transmission time was also investigated using electromyographic (EMG) recording from peripheral nerves in the arm or leg. Clearly, these peripheral nerves are not directly involved in mental activity that is associated with intelligence. In this work, however, it was supposed that peripheral neural transmission time and mental ability may be linked by properties of neural tissue that are common to both peripheral and cortical nerves (e.g. Jensen, 1998). In the typical EMG recording procedure, a brief electric pulse is applied to a finger and the time that is required to elicit an action potential at a site along the neural pathway, e.g. at the wrist, is recorded. A measure of nerve conduction velocity (NCV) is calculated by expressing the distance between the point of stimulation and the recording site as a ratio of the response latency. In a recent review of about 10 studies, it was concluded that "the evidence for an NCV-IQ correlation is weak and mixed" (Vernon, Wickett, Bazana, & Stelmack, 2000). These NCV-IQ correlations ranged from 0.62 to -0.61 with a mean correlation of 0.18.

BAEPs are derived from the electrical activity of the brain that develops during the first 10 ms following acoustic stimulation. Reliable waveforms, consisting of a series of positive and negative peaks, are obtained by averaging electroencephalographic activity that is elicited by the rapid presentation of brief (e.g. 0.1 ms) auditory click stimuli. Following intensive investigation, it was suggested that the neural generator sources of BAEP waves were as follows: wave I, auditory nerve; wave III, lower pons; wave V, lateral lemniscus or inferior colliculus (Chiappa, 1990). The peak latency of these waves provides one measure of neural transmission time.

BAEP waveforms are commonly used in clinical medicine to assess the integrity of the auditory pathway from the auditory nerve through the sequence of brain stem nuclei. Although the neural generators of BAEP waveforms are subcortical, and as peripheral nerves are not directly involved in mental activity, they do form the first stage of the auditory path that was employed in auditory ERP studies of individual differences in mental ability. BAEP abnormalities were also linked to a variety of forms of mental retardation, notably those that appear to involve auditory deficits (Sohmer & Student, 1978; Tanguay, Edwards, Buchwald, Schwafel, & Allen, 1982).