EFFECT OF WORKLOAD ON THE AUDITORY EVOKED BRAINSTEM RESPONSE

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ABSTRACT

The purpose of this study was to explore the effect of workload level of a grammatical reasoning task on the auditory brainstem evoked response. Ten male subjects were administered three difficulty levels of a grammatical reasoning task. Brainstem evoked responses were recorded before and after the randomly presented workload conditions, as well as during each workload condition. The results revealed a consistent increase in Wave VI latency during all workload conditions, but no apparent differentiation between workload conditions. Post-test brainstem measures revealed that latency of Wave VI did not recover to pre-test baseline levels.

INTRODUCTION

Recent investigations have demonstrated the utility of electroencephalographic event-related potentials as measures of human cognition and task performance. In coalescing these findings with more global human factors engineering concerns, O'Donnell (1979) has suggested that a number of EEG measures might provide considerable promise as metrics for workload assessment, among them the auditory evoked brainstem response(ABR).

The ABR provides an exceptionally stable measure of neural functioning in the auditory pathway. The ABR is derived by averaging the first 10msec of multiple (1000 or more) auditory pathway evoked potentials, elicited by short-latency click or tone stimuli. This average evoked potential results in seven, vertex-positive waves believed to reflect sequential neural activity at successively higher levels of the brainstem auditory pathway (Jewett, Romano, & Williston, 1970; Jewett & Williston, 1971). The putative generators of Wave I through Wave VII are the acoustic nerve, the cochlear nuclei, the superior olives, the lateral lemniscus, the inferior colliculus, the medial geniculate, and the thalamocortical radiations, respectively (Stockard & Rossiter, 1977). Thus, the ABR poses as a highly desirable psychophysiological measure because it is highly stable within individuals and because of the apparent close relationship between the waveform and specific neural structures.

Another characteristic of the ABR is that it is purportedly insensitive to cortical activity variations across wakeful states, as well as sleep or even sedation. However, several problems mitigate the findings of these investigations. For example, at least two of these studies failed to analyze a complete complement of waves prior to Wave V (Mendel & Goldstein, 1969; Picton, Hillyard, Galambos, & Schiff, 1971). Of the two studies that explored sleep versus wakeful states, one failed to provide any systematic analysis and both may have failed to consider that the wakeful condition used may not have provided an adequate range of arousal in relationship to the sleep condition (Amadeo & Shagass, 1973; Jewett & Williston, 1971). Of the four studies that examined resting versus task performance conditions, two studies failed to analyze a complete complement of waves (Mendel & Goldstein, 1969; Picton et al., 1971) and another confounded the treatment conditions by providing a vigilance-type task during the resting phase (Picton & Hillyard, 1974). Only two studies included an analysis of Wave VI. One was compromised by several of the factors mentioned above (Picton & Hillyard, 1974). The other study reported no Wave VI differences as subjects performed a dichotic listening task (Woods & Hillyard, 1978). Additional problems such as a lack of control for sex of subjects, low numbers of subjects, and inconsistency among comparison groups make many of these earlier findings appear tenuous.

There are also more recent studies which directly question the presumed stability of the ABR in relation to cortical state. Bullock (1982) reported lengthening of Wave I and Wave V latencies as a result of exposure to a visual selective attention task. Lucas (1981,1982) has also demonstrated reductions in ABR Wave I and Wave V amplitudes as a function of exposure to a visual attention task. Recent pilot data at the Workload and Ergonomics Branch, Wright-Patterson Air Force Base have revealed consistent Wave VI latency increases during attention states. This additional finding of Wave VI shifting is not surprising given that examination of Wave VI is rarely included in standard ABR analyses. (However, a reanalysis of the Bullock, 1982, data confirms the same pattern of Wave VI shifting under attention conditions.)

These latter investigations, as well as the previous reassessment of earlier ABR research on cortical

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state influences, suggest that ABR may very well be influenced by cortical state, and therefore be useful as a workload measure. The purpose of this investigation was to examine the influence of workload level of a grammatical reasoning task on the components of the ABR.

METHOD

Subjects

Ten male subjects (ages 20–36yrs) served as subjects. Each subject was screened for drug (caffeine, nicotine, alcohol) and medication use prior to the study. All subjects had normal hearing and 20/20 natural or corrected vision.

Procedure

Each subject was instrumented with Beckman, silver-silverchloride electrodes at vertex (Cz) and mastoids for ipsilateral ABR recording. The subject was then seated in a sound attenuated booth in a semi-reclined position with a push button response pad held in both hands.

Three workload levels of the U.S. Air Force Criterion Task Set, Grammatical Reasoning Task were presented to the subject in random order on a CRT monitor. This task is comprised of statements which define the ordinal relationship between two (or in some cases, more) symbols, followed by the actual symbols in some order. The subject simply responds true or false in relationship to the symbol ordering presented. Difficulty of the task is regulated by the number of symbol relationships presented and the tense (positive or negative) of the relationship. In this study, the Low Workload condition consisted of one-statement, positive tense cases; i.e., "# FOLLOWS * -- *# ." The Moderate Workload condition consisted of one-statement, negative tense cases; i.e., "# DOES NOT FOLLOW * -- *#." And, the High Workload condition consisted of two-statement, positive tense cases; i.e., " # FOLLOWS * * PRECEDES @ -- #*@." The relative difficulty of these conditions has been established through prior standardization studies of the Criterion Task Set (Shingledecker, personal communication, December 1983). Task performance sessions lasted approximately three minutes at each workload level with a two minute rest period between workload sessions.

Auditory brainstem evoked potentials were recorded during each workload session, as well as during a pre- and post-test baseline period. The ABR data were recorded on a Nicolet CA1000 Clinical Averager. The broadband click stimuli (center frequency 2 KHz) were presented at a rate of 11.1 c/sec, at 75 dB SL, with a duration of 100 usec. Low and high pass filters were 150 and 3000 Hz, respectively. A total of 2000 click trials were averaged for each ABR recording. These ABR data were collected as part of a larger study in which other EEG measures were recorded; however, only the ABR results will be reported here.

RESULTS

MANOVA analysis of latency and amplitude ABR data yielded only a significant difference for the latency data, $F(28,66) = 3.07$, $p < .001$ (Wilks' L.) ANOVA analyses of the latency data yielded significant differences for Wave I ($F(4,36) = 5.73$, $p < .01$), Wave III ($F(4,36) = 3.15$, $p < .05$), Wave V ($F(4,36) = 3.63$, $p < .05$), and Wave VI ($F(4,36) = 14.20$, $p < .0001$). Multiple comparison tests (Scheffé, 1953) failed to reveal any significant differences among conditions for Waves III and V. A significant difference at Wave I was found between the Moderate and Low Workload conditions only. At Wave VI, all workload conditions produced latencies which were significantly longer than the pre-test baseline latency. Also, the post-test baseline was significantly longer than the pre-test baseline latency. No significant differences were found in either the ANOVA or multiple comparison tests of the amplitude data for any waveform component.

A MANOVA analysis of interpeak latencies was also significant, $F(16,64) = 4.29$, $p < .001$ (Wilks' L). ANOVA analyses yielded significant differences for the I-III, I-V, and I-VI interpeak intervals. For the I-III interpeak interval, multiple comparisons yielded a significant difference between the Moderate Workload condition and all other conditions except Low Workload. The I-III interval was longer during Moderate Workload as compared to the other conditions. For the I-V interpeak interval, the only multiple comparison that was significant revealed a longer interval during Moderate Workload as compared to the pre-test baseline. The multiple comparison test results for the I-VI interpeak interval were similar to the Wave VI latency data, i.e., the I-VI interpeak latency was significantly shorter during pre-test baseline as compared to all other conditions.

Means and standard deviations for Wave VI latency and the Wave I-VI interpeak latency are presented in Table 1.

Table 1.

Means and standard deviations for Wave VI latency and Wave I-VI interpeak latency for baseline and workload conditions.

Condition	VI Latency	I-VI Latency
Pretest Baseline	7.32 (.24)	5.71 (.25)
Low Workload	7.49 (.28)	5.90 (.30)
Moderate Workload	7.46 (.29)	5.92 (.30)
High Workload	7.51 (.29)	5.88 (.28)
Post-test Baseline	7.45 (.30)	5.82 (.27)

DISCUSSION

The results of this study suggest that the auditory brainstem evoked response is affected by cognitive workload, as compared to prior resting conditions. This seemed especially true for Wave VI, the medial geniculate. The ABR differences observed did not differentiate in any systematic manner across the workload conditions represented in this study, however. Also, the failure of the post-test ABR (at 5 min following the last workload session) to return to pre-test baseline levels suggests a protracted recovery period for Wave VI shifting in relation to cognitive workload conditions.

While significant differences were found at earlier wave components of the ABR, only those found at Wave VI were consistently affected by all workload conditions. However, the effects found at other wave components seemed to involve longer latency at Moderate Workload as compared to other conditions or pre-test baseline. Of the three workload conditions, the Moderate condition was the only one which utilized the negative tense in the ordinal position statements (e.g., * DOES NOT FOLLOW #). Since the difficulty rating of these tasks was based primarily on reaction time and self-reported workload level, these ABR findings suggest that a different relationship may be revealed through ABR measurement than through performance or self-report measures.

These results present additional evidence that the ABR is sensitive to workload, i.e., cortical activity level. Unlike previous studies (Lucas, 1981, 1982), no consistent Wave I or Wave V alterations were found. Not unlike much of the previous research on ABR and cortical activity level, no evidence was found for peripheral gating. However, the evidence presented in this study does suggest that some form of processing or some allied processing mechanism seems to occur quite early (approximately 7.0 to 8.0 msec) after stimulus presentation. These data support the view that some ABR components do appear to be sensitive to workload demand or cortical activation state. Thus, ABR may hold potential as a measure of workload.

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