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ELECTROPHYSIOLOGICAL EFFECTS OF EXPERIENCE DURING AN AUDITORY TASK*

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SUMMARY

Past research has indicated that several electrophysiological components of the event-related potential (ERP) have been associated with the ability to process information. Some research indicates that developmental changes in the electrophysiological response of the human brain could be a reflection of structural maturity and organizational patterns that change as an individual interacts in the environment. If one assumes that individuals modify their processing strategy on a specific task as they gain experience and training, then this change may be reflected in their electrophysiological response. However, past research has primarily used naive college students as test subjects and little is known regarding the effect experience and/or training might have on electrophysiological data. The present research investigated the effect that experience and/or training had on the event-related potential data of sonar operators during an auditory task.

Twenty male subjects were divided into two groups based on their experience and training. Group I were naval recruits selected for sonar training. Subjects in Group II were sonar instructors with at least 4 years operational experience. The electrophysiological response was monitored using an EEG recorded from two midline sites, Fz and Pz, which was sampled and averaged as target and non-target tones were presented. The program included an artifact rejection routine which eliminated any trial in which extraneous muscle activity may have interfered with measuring the ERP. The stimulus was a high or low tone presented with a white noise background. The subject's task was to ignore the low tones while attending to the high ones by counting sub-vocally. This is similar to the auditory discrimination tasks sonar operators perform on a routine basis.

Results were consistent with previous findings which have shown an increase in the amplitude of specific ERP components when subjects focus attention. Differences between the two groups were found for two ERP components and both indicated electrode specific results. The inexperienced group indicated that component amplitude was greater at the parietal site (Pz), which parallels past research with naive subjects. The experienced group showed greater component amplitude at the frontal site (Fz). Differences between the two groups may reflect variations that occur in the brain between controlled and automatic attentional processes. It may be that individuals alter or develop processing strategies that are reflected in the redistribution of electrical activity in the brain. Therefore, experience and/or training appear to have a significant effect on certain components of the electrophysiological response.

Researchers have been investigating the utility of the event-related potential (ERP) measure as a technique to evaluate human performance, monitor human factors design, and assist in personnel selection. This procedure requires the placement of surface electrodes at selected sites, usually following the guidelines of the international ten-twenty electrode system (Jasper, 1958). The on-going EEG activity is time locked to the stimulus presentation, recorded, and averaged over a number of trials. Thus, a single waveform is produced for each electrode site which is a composite of many individual components. The components are normally denoted by a letter and a number (e.g., P300). The letter represents the polarity of the component, either positive (P) or negative (N). The number which follows indicates the elapsed time in milliseconds from stimulus onset until the component peaks. For example, the P300 is a positive component which peaks approximately 300 ms after the stimulus presentation.

Electrophysiological components are classified into two categories referred to as exogenous and endogenous. Components are exogenous if their amplitude and latency values are dependent upon the physical characteristics of the stimulus as well as the general state of the subject. However, if the components are dependent on internally generated cognitive or perceptual activity related to stimulus processing, they are referred to as endogenous. Their characteristics are only partially related to the physical parameters of the stimulus (Callaway, Tueting, and Koslow, 1978).

Several endogenous ERP components have been correlated with specific aspects of information processing (Donchin, Wickens, and Coles, 1983; Hillyard and Kutas, 1983; Pritchard, 1981; Ritter, Simson, Vaughan, and Macht, 1979; Sutton and Ruchkin, 1984). Additional studies have indicated that certain components appear to be related to attention, and these are generally of negative polarity (Naatanen, 1982). Early components, such as the N100 (N1), have been shown to be highly correlated to the early selection of stimulus set. Whereas an increase in the amplitude "difference" between the N1 and P200, commonly referred to as N1-P2, has been associated with the subject deciding if a specific stimulus belongs to the target set. Both components have been found to increase in amplitude during trials in which the subject focuses attention.

Components which occur later have been correlated with decision making processes regarding a specific stimulus and have generally been found to be of positive polarity. For example, the P300 has been shown to be highly correlated to a later selection of a target of interest (Hillyard, Picton, and Regan, 1978). Kutas, McCarthy, and Donchin (1977) have suggested that the P300 is correlated with the time required for stimulus evaluation.

Past research, therefore, has indicated that several electro physiological components have been associated with the ability to process information. In addition, Kurtzburg, Vaughan, Courchesne, Friedman, Harter, and Putnam (1984) have suggested that developmental changes in evoked responses of the human brain are related to structural maturity and organizational patterns that "reflect the individual's interaction with the environment". Therefore, it is reasonable to hypothesize that as individuals modify their processing strategy on a specific task based on experience and training, this change in strategy may be reflected in their electrophysiological response. Yet, most research has been conducted using naive college students as subjects and little is known regarding what effect experience and/or training may have upon electrophysiological data.

The present research investigated the effect that experience and/or training had upon the event-related potential data of sonar operators during an auditory task.

METHOD

Subjects

Twenty men from the Fleet Anti-Submarine Warfare School, San Diego, CA, were recruited as voluntary subjects. They were placed into one of two groups based on their sonar training and experience. Group I (inexperienced) were Naval recruits selected for sonar duty on the basis of their performance on the Armed Services Vocational Aptitude Battery (ASVAB). This group had no experience and/or training in sonar or related fields. The mean age for this group was 19.9 years (range=18 to 21; SD=1.37). Group II (experienced) consisted of sonar instructors with at least 4 years operational (at sea) experience in sonar. The mean age of this group was 29.1 years (range=26 to 35; SD=2.56).

Apparatus

EEGs were recorded from two midline sites (Fz and Pz) and referenced to linked mastoids. An electrode clipped to the left ear served as ground. All electrodes were Grass gold cup electrodes and were attached to the scalp with collodion. All electrode impedances were below 10 kohms. EEGs were amplified, recorded, averaged, and then stored on floppy disk using a Nicolet Compact Four Electrodiagnostic System (Model C4 Console). Internal amplification was set at a sensitivity of 100 microvolts. The recording epoch was sampled for 800 milliseconds and averaged over non-target (160) and target (40) trials. The program included an automatic artifact rejection which eliminated any trial in which extraneous muscle activity or eye movement interfered with the recording of the evoked response. An internal low frequency filter was set at 1 Hz while an internal high frequency filter was set at 30 Hz.

The stimulus was a high or low frequency tone presented for 22ms (2ms ramp). The lower tone was 750 Hz, the higher tone was 2000 Hz. Both stimuli were presented at a 70dB level. In addition, a white noise background of 50dB was presented binaurally. Stimuli were delivered through a Telephonics headset (TDH-39p). Each subject completed 200 artifact-free trials.

Procedure

Subjects were seated in a quiet room and listened through headphones to tones presented to both ears simultaneously. Two tones were presented using the standard oddball paradigm. The low frequency tone was presented for 80% of the trials. The high frequency tone was randomly intermixed and presented for 20% of the trials. The subject's task was to ignore the low tones while attending to the high tones by counting sub-vocally. All subjects reported the correct number of target tones (±2). The testing period lasted approximately 12 minutes.

RESULTS

Average waveforms for each electrode site were determined for non-target (ignored; n=160), as well as target tones (attended; n=40) for each subject.

Group grand mean waveforms for each electrode site and each condition are shown in Figure 1. The differences between the ignored and attended components are easily seen. Amplitude and latency values were determined for three major waveforms (N100, P200 and P300) and the N1-P2 difference component. Amplitude values were determined by finding the maximum deflection, negative or positive (depending upon the component of interest), within a predetermined time window. The time window for each component is shown in Table 1.

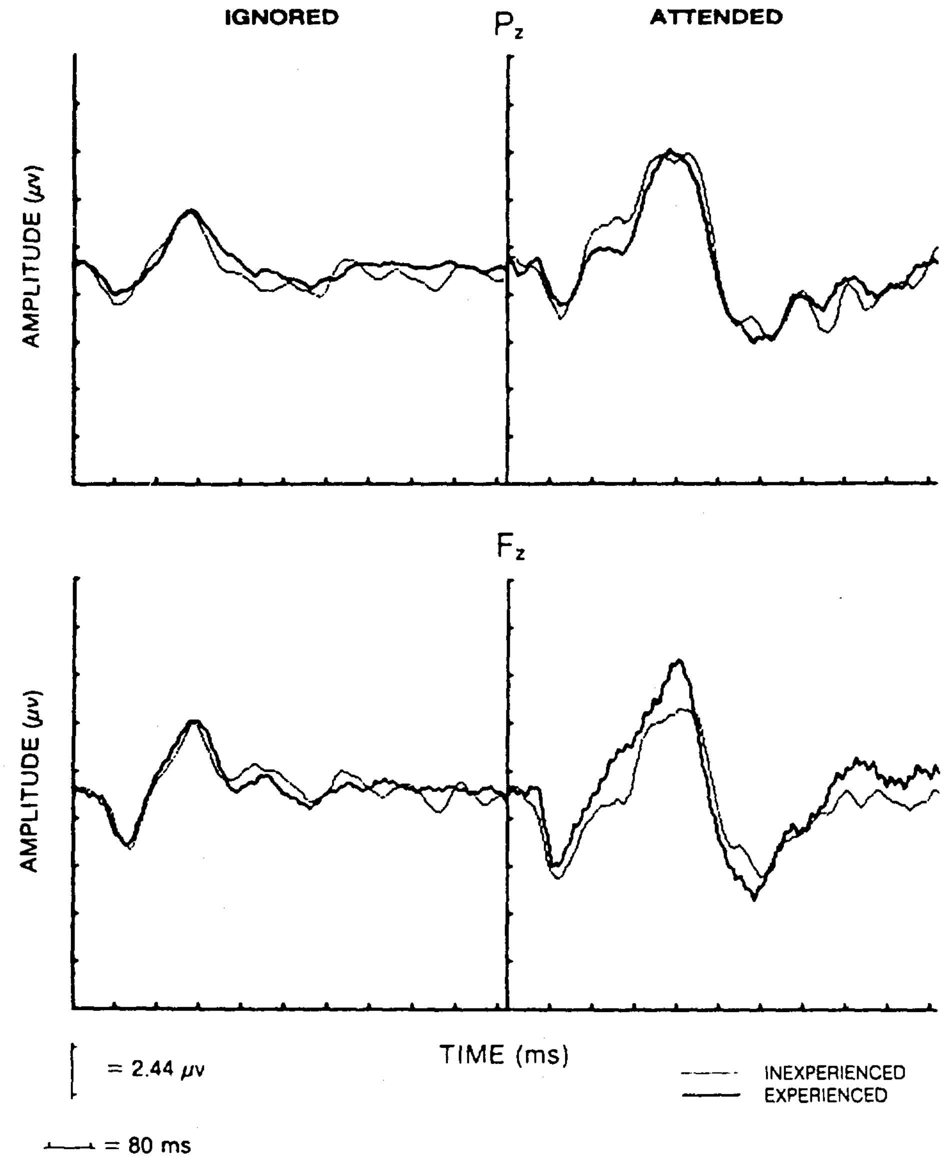


Figure 1. The grand average waveforms for Experienced and Inexperienced groups, for both conditions, Ignored and Attended, at both electrode sites, Fz and Pz.

TABLE 1

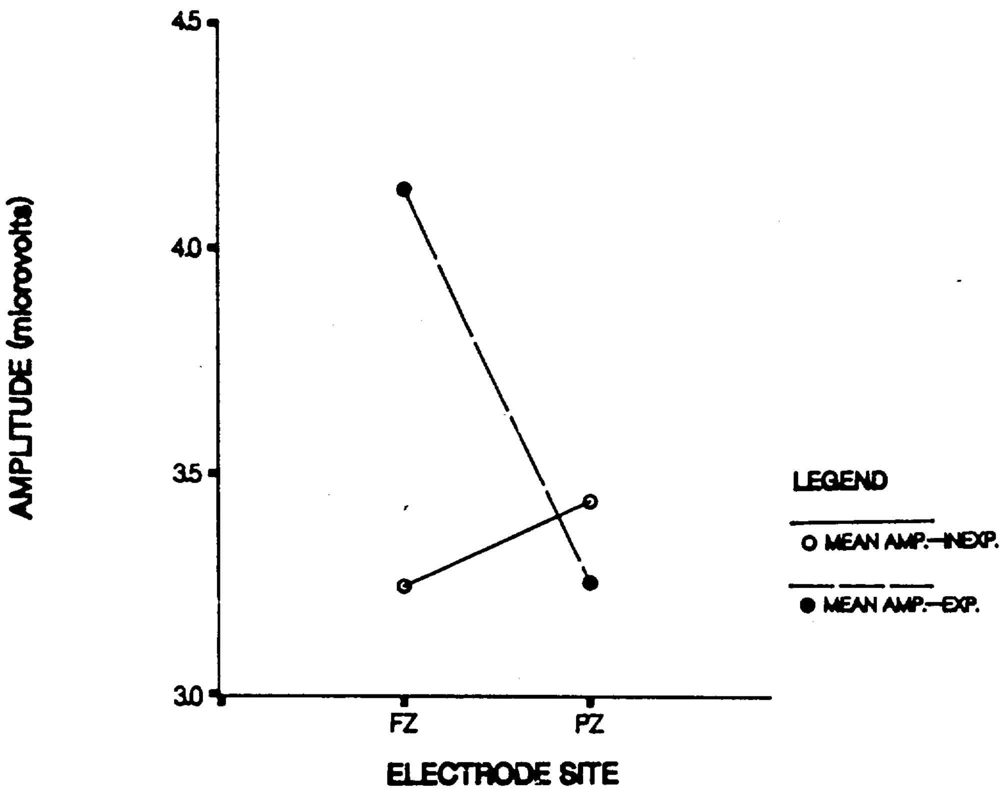
Latency Windows in Milliseconds for Identifiable Components

Component	Latency Window
N100	50 - 150
P200	150 - 250
P300	250 - 400

A three-way repeated-measure analysis of variance (ANOVA) was performed independently on the amplitude and latency values for each component listed in Table 1 including the N1-P2 difference component.

The analysis on the N100 amplitude data indicated an overall statistically significant effect for both groups between ignored and attended tones ($F(1,18)=29.41$, $p<.01$). Amplitude was significantly greater for trials in which the subjects were required to attend to the tone. There was also a highly significant difference in amplitude between electrode sites ($F(1,18)=37.08$, $p<.01$). This result indicated that, regardless of group, N100 amplitude was greatest at Fz and decreased in amplitude at the more posterior site (Fz > Pz). No significant latency differences were found for the N100 component.

Three-way ANOVA's were also determined for the P200 amplitude and latency values. The interaction between group and electrode was statistically significant ($F(1,18)=6.58$, $p<.05$). This finding is further displayed in Figure 2 by the experienced group showing greater amplitude at the Fz electrode site regardless of condition, whereas the inexperienced group displayed greater amplitude values at the Pz electrode site.



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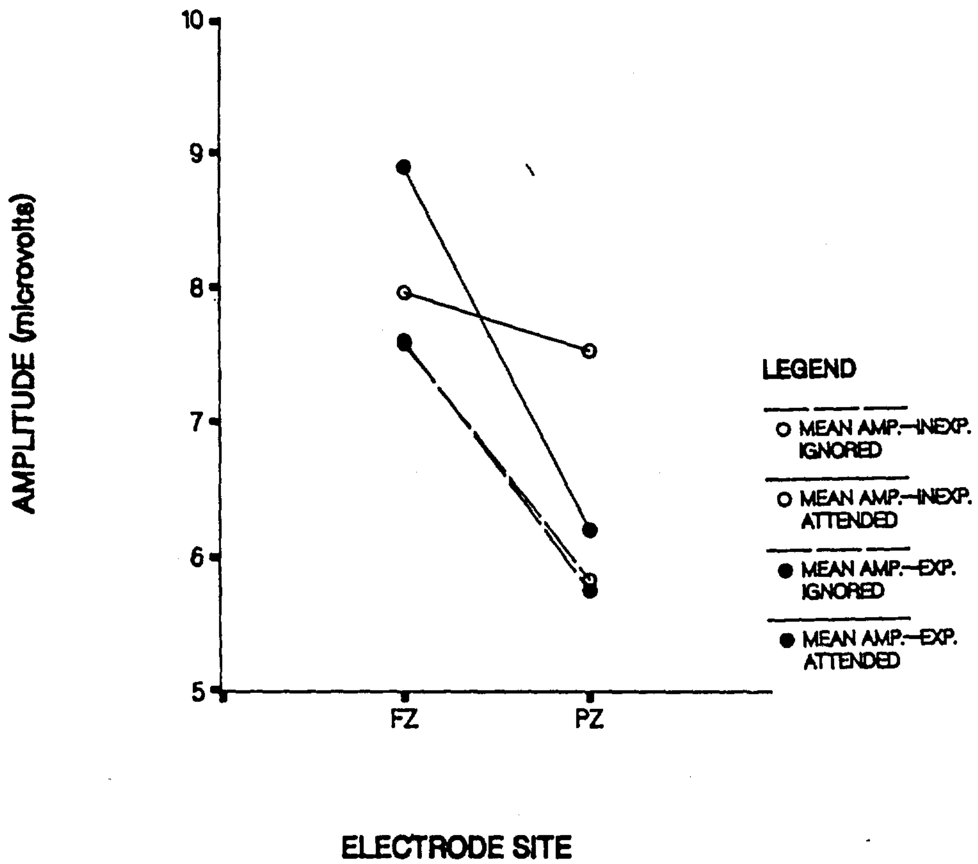
P200 latency decreased significantly between the ignored and attended conditions ($F(1,18)=4.39$, $p<.05$). In addition, the three-way interaction (Group x Electrode x Condition) was statistically significant for P200 latency ($F(1,18)=6.32$, $p<.05$). This result was primarily due to the latency differences between conditions indicating a larger decrease at the Fz electrode site for the inexperienced group whereas a larger decrease was shown at the Pz electrode site for the experienced group.

A three-way ANOVA on N1-P2 amplitude values indicated a statistically significant electrode effect ($F(1,18)=36.85$, $p<.01$). A two-way (Group X Electrode) interaction was also statistically significant ($F(1,18)=4.54$, $p<.05$). In fact, the scalp distribution relationship between the two groups was just the opposite (see Figure 3). The amplitude differences were largest for the inexperienced group at the Pz electrode site whereas the amplitude difference is greatest for the experienced group at the Fz electrode site.



The analysis of variance on the P300 amplitude and latency values did not indicate any statistically significant group differences. As with the N100, the P300 indicated a highly statistically significant difference between ignored versus attended tones ($F(1,18)=51.48$, $p<.01$).

The amplitude differences were larger for the attended trials regardless of group. However, it is interesting to note that the largest amplitude differences were found for the experienced group at the Fz electrode site. Also, electrode sites were significantly different for P300 latency ($\underline{F}(1,18)=5.91$, $\underline{p}<.05$), with Fz being greatest, Fz(325ms) > Pz(310ms).

DISCUSSION

The primary goal of this research was to determine what effect experience and training might have upon event-related potentials recorded during an auditory discrimination task. The task was similar to the auditory discriminations that sonar operators are required to make on a routine basis.

Overall, the results were consistent with previous research findings which demonstrated an increase in amplitude of specific ERP components during trials which required subjects to focus their attention (Hillyard, 1985). However, of primary interest were the subtle differences found between the two groups of subjects who differed in their level of experience. The major differences were for two of the components, the N1-P2 and the P200, both indicating electrode site specific results. The inexperienced group results indicated that component amplitude was greater at the parietal electrode site (Pz), which is in agreement with past research using naive subjects. The results of the experienced group, however, showed that component amplitude was greater at the frontal electrode site (Fz). Therefore, experience and/or training appear to have a significant effect upon the distribution of the N1-P2 and P200 components. It is interesting to note that the amplitude was greater for the experienced group at the location of the frontal lobes, which is known to be the area of the brain responsible for decision making. Although the recording site does not necessarily reflect the location in which the activity takes place, the results are in agreement with the distribution of brain activity found using highly experienced sonar operators in a signal detection task (Kobus, Santoro and Sturr, 1984). It may be that when individuals gain experience on a specific task, they alter or develop a processing strategy that is reflected in the redistribution of electrical activity in the brain. Considering the differences in experience level between the two groups, these results may be indicative of differences that occur in the brain between controlled and automatic attentional processes.

Another possible explanation for the results are that the differences between the two groups are related to age differences. Courchesne (1983) has indicated that age related changes in ERP components include a decrease in both latency and amplitude. However, the older group in this study demonstrated larger amplitude values for the components under investigation.

Although further research will be required to make a more definitive statement, the results are very suggestive. The three-way interaction (Group X Condition X Electrode site) for the N1-P2 was not statistically significant and this may be related to the complexity of the task. The task was fairly simple for the experienced group since it was similar to their normal working environment. It is hypothesized that a more difficult discrimination task would provide greater disparity between group results. Such a finding would provide additional support for ERP changes related to experience and provide more insight into our understanding of controlled versus automatic attentional processes.

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The primary goal of this research was to determine the effect experience and/or training might have on event-related potentials (ERPs) recorded during an auditory task. Twenty male subjects ranging in age from 19 to 35 years were divided into two groups based on their sonar experience and training. A standard oddball paradigm was utilized with two tones of differing frequency. The subject's task was to ignore the low tones (750Hz) and attend to the high tones (2000Hz) by sub-vocal counting. Average waveforms for each electrode site were determined for target (attended) and non-target (ignored) tones for each subject. Primary results indicate that N1-P2 difference values were consistent with past research, displaying an increase in component amplitude during attended trials. Amplitude values for the inexperienced group on attended trials were greatest at the Pz electrode site, which is consistent with previous research findings using naive subjects. However, the results of the experienced group indicated that attended amplitude was smallest at this site and largest at the Fz electrode site. Thus, experience and training appear to have a significant effect on the distribution of ERP components.

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