The Effect of Task Difficulty on the P300 Response in Children with Learning Disabilities

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Abstract

The study involved assessment of P 300, an auditory event related potential in children with learning disabilities (LD). Children with LD are known to have difficulty with challenging auditory listening tasks. Specifically, when they are tested using behavioral measures, they perform poorly if the stimulus is distorted. Therefore, the objective of this study was to determine if we can observe similar findings using auditory electrophysiological measures. P-300 recordings were obtained from Children with LD using stimuli that were difficult to discriminate and compared with the recordings from children without LD. The study revealed that P 300 latencies were significantly longer and P300 amplitudes were significantly smaller under difficult task compared to standard task for both children with LD and children without LD, however, there was no significant difference between the participant groups. When the inter-peak latencies between P3-P2 were compared between Children with LD and children without LD, a significant difference was noted in the difficult task condition. Specifically, Children with LD had significantly longer P3-P2 inter peak latency compared to children without LD for the difficult task condition. These results confirm that the strategy of stressing the auditory processing system by increasing the difficulty of the discrimination task was successful in differentiating children with LD from children without LD. However, one must use sophisticated measures such as inter-peak latency and not limit to evaluating absolute latency and amplitude of P 300 potential.

Key words: P300 potentials, Learning disability, inter-peak latency

Children who are classified as learning disabled are known to have multiple perceptual deficits. Some children with learning disability (LD) have been found to have disordered auditory perceptual processes (Public Law 94-142, 1975). This disorder is known as auditory processing disorder (APD).

APD is currently assessed through the use of behavioral tests and/or electrophysiologic measures. Although these behavioral measures have demonstrated performance deficits among children with LD (Gomez & Condon, 1999; Greenblatt, Bar, Zappulla, & Hughes, 1983; Jerger, Martin, & Jerger, 1987; Leavell, 1996; Musiek, Geurkink, & Keitel, 1982; Rigo, Arehole, & Hayes, 1998; Roush & Tait, 1984; Willeford & Bilger, 1978), their subjectivity sometimes limits their reliability. In light of the potential problems of the behavioral technique, it has been recommended that electrophysiologic measures be incorporated into the clinical assessment of APD in children with LD (Jirsa & Clontz, 1990).

The electrophysiologic technique involves the measurement of auditory evoked potentials (AEP). AEP investigations of children with LD have used both short-latency and middle-latency exogenous potentials and long-latency endogenous potentials (Arehole, Augustine, & Simhadri, 1995; Arehole, 1995; Arehole & Rigo, 1999; Jerger et al., 1987; Kraus, Smith, Reed, Stein, & Cartee 1985; Lubar, Mann, Gross, & Shively 1992; Satterfiled, Schell, Backs, & Hidaka, 1984). Studies have shown that long-latency endogenous potentials are better able to identify APD in participants with LD than are short-latency and middle-latency potentials (Jirsa & Clontz, 1990).

The P300 response (also referred to as the P3 response) is a long-latency endogenous potential that is generated by a listener making auditory discrimination decisions. It is a broad positive peak occurring at about 300 ms after the stimulus onset. Traditionally, the standard auditory stimuli that have been used to elicit the P300 response have included two tones (the “frequent” low-frequency tone and the “infrequent” high-frequency tone) which differ in frequency by 1000 Hz or more. For example, most P300 studies have used a frequent tone of 1000 Hz and an infrequent tone of 2000 Hz (Erez & Pratt, 1992; Frank,

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Sieden, & Napolitano, 1994; Frank, Sieden, & Napolitano, 1998; Holcomb, Ackerman, & Dykman, 1986; Mazzotta & Gallai, 1992). Other researchers have used either two tones with a frequency difference greater than 1000 Hz or have used non-tonal stimuli that are easy to differentiate (Ducan et al., 1994; Finley, Faux, Hutcheson, & Amstutz, 1985; Holcomb, Ackerman, & Dykman, 1985; Lubar, Gross, Shively, & Mann, 1990).

Behavioral tests of AP function have been successful in differentiating normal children from children with LD only when the tests have involved complex tasks that stress the auditory system (i.e., selective listening, binaural separation). Children with LD and children without LD, however, perform similarly on processing tasks that involve simple auditory stimuli. It could be hypothesized that this effect of task difficulty on the comparative performance of LD and non LD groups applies similarly to the P300 measure.

Task difficulty and its effect on P300 latency and amplitude has been studied extensively in normal subjects (Fitzgerald & Picton, 1983; Goodin, Squires, & Starr, 1983; Polich, 1987, & 1989). The effect was an increase in P300 latency and a reduction in P300 amplitude in their normal subjects. However, no investigations have evaluated the effect of increased P300 task difficulty on the comparative performance of children with LD vs children without LD.

All P300 studies that have reported on the comparative results of LD and non-LD participants have utilized the absolute latency and/or amplitude of the P300 waveform as their response measure(s). There are, however, other measures, such as inter-peak latency, that can be used to evaluate the P300 response (Jirsa and Clontz, 1990). It may be that the utilization of a more extensive array of P300 response measures may better differentiate the P300 responses of children with LD from those of children without LD.

The purpose of our study was two-fold. Our first objective was to determine whether differences in P300 latency and amplitude measures can be identified more effectively in children with LD vs children without LD when the discrimination task is made more difficult than what has been commonly employed in standard P300 protocols. Our second objective was to incorporate P3-P2 inter-peak latency difference as a response measure to determine its effectiveness in the assessment of children with LD.

Methods

Participants

Two groups of children (clinical and control) between 11.5 and 12.5 years of age participated in the study. All participants were Caucasian and from the middle socioeconomic class. No participant presented any significant otological or neurological history. All participants passed a hearing screening administered at 15 dB HL at octave frequencies 250 Hz to 8000 Hz. All participants were reimbursed $15.00 for their participation in the study. The reimbursement procedures followed those recommended by the American Psychological Association (APA, 1992). Informed consent was obtained from the parents of all participants after the experimental procedure was fully explained to both parents and participants.

The clinical group included 11 male participants identified as learning disabled by their respective school systems. The Louisiana state criterion for learning disability requires evidence of a severe discrepancy between achievement and ability as measured by performance comparisons in the student's strongest and weakest academic areas. All participants diagnosed as LD had specific problems with language and were grouped as dyslexics. The control group included 11 male participants who were reported by parents and school personnel as having no perceptual deficits or academic difficulties. These children were recruited from public school classrooms.

Equipment and Procedure

Stimulus Parameters

The P300 response was elicited and recorded using a Nicolet CA-2000 Compact Auditory Evoked Response System. The stimuli consisted of a frequent low-frequency tone presented a total of 240 times and an infrequent high-frequency tone presented a total of 60 times. The two tones were presented in a randomized sequence pre-determined by the Nicolet measurement system. The stimuli were presented binaurally through TDH 39 ear phones at an intensity of 70 dB nHL and at a rate of 0.7/s.

The P300 response was measured for each participant under two separate conditions: (1) a standard-task condition and (2) a difficult-task condition. In the standard-task condition, the frequent low-frequency stimulus was a 750 Hz tone and the infrequent high-frequency stimulus was a 2000 Hz tone (frequency difference of 1250 Hz). In the difficult-task condition, the frequent low-frequency stimulus was a 1000 Hz tone and the infrequent high-frequency stimulus was a 1500

Hz tone (frequency difference of 500 Hz). Under both conditions, all participants were instructed to keep a mental count of the number of high-frequency tones presented and report this number to the experimenter at the conclusion of each recording. All participants were capable of counting the high-frequency tones with at least a 95 % accuracy rate.

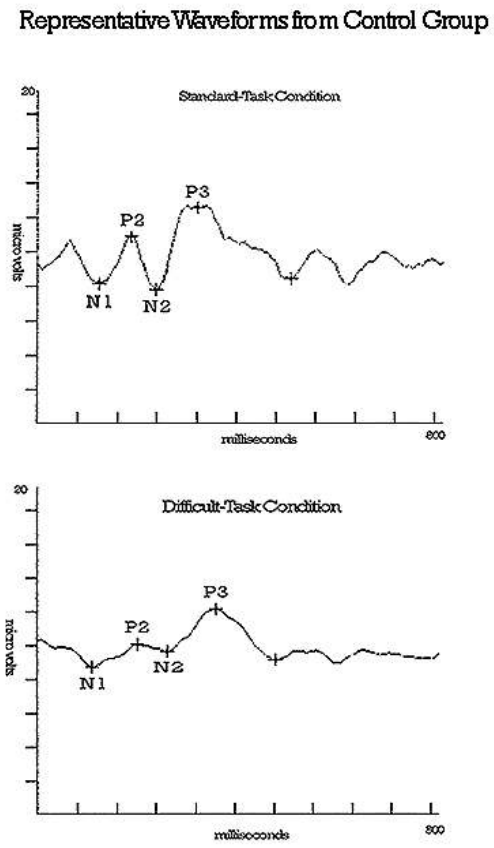

Figure1: Representative waveforms showing P2 and P3 in a child without learning disability, obtained in standard-task condition (top) and difficult-task condition (bottom).

Data Analysis

The P300 response measures utilized in this study included (1) absolute latency of P300 in milliseconds (2) P300 amplitude in microvolts (μV) and (3) P3-P2 inter-peak latency in milliseconds. Latencies of the P2 and P300 waves were measured at the peak of the waveform (Figure 1).

The absolute latency of P2 was identified as the largest positive wave peak occurring between 150 and 200 ms. The absolute latency of P300 was identified as the largest positive peak occurring after 250 ms. P3-P2 inter-peak latencies were calculated by subtracting P2 absolute latency from P300 absolute latency. The P300 amplitude was determined by calculating the difference in μV between the P300 wave peak and the baseline response.Acquisition parameters

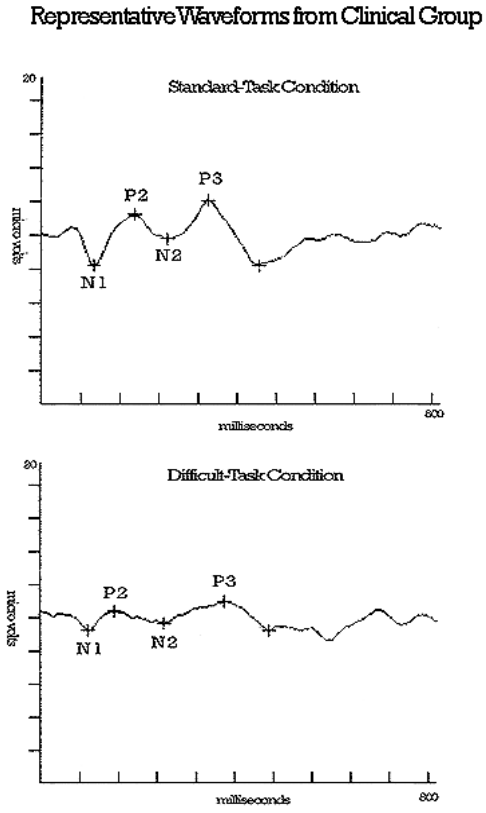

Figure 2: Representative waveforms showing P2 and P3 in children with learning disability, obtained in standard-task condition (top) and difficult-task condition (bottom).

The P300 response was recorded using standard silver-chloride disc electrodes. The electrodes were filled with electrode paste and secured to 4 scalp location: the vertex, the forehead, and behind each earlobe. This electrode array followed the international 10-20 system (Hall, 1992). Filters were set to band pass 1Hz to 100 Hz. Total of 300 artifact free trials were recorded. The artifact reject was set to automatically ignore any trials in which the ongoing EEG activity exceeded +/- 100 uV to eliminate muscle artifacts, eye blinks, and random eye movement. Time window of the recording was set at 800 milliseconds (ms).

All testing was performed in a quiet room with the subject seated comfortably in a reclining chair. A typical recording session lasted 45 minutes to 1 hour. Each waveform obtained was replicated to ensure response reliability. The data were stored on floppy disc during the test session and later retrieved for analysis.

Results

Figure 2 shows a sample of P300 waveforms recorded from a participant in clinical group obtained using both standard-task condition and difficult-task condition.

Group means and standard deviations for the three P300 response measures were calculated for both participant groups under the standard-task and difficult-task conditions.

Mixed two-factor ANOVAs were performed on group means for each of the three response measures: (1) P300 absolute latency in ms, (2) P300 amplitude in μV, and (3) P3-P2 inter-peak latency in ms. The main effects studied for each ANOVA were group (the performance of children with LD vs children from control group) and condition (performance on the standard listening task vs the difficult listening task).

P300 Absolute Latency

Group means and standard deviations for the P300 absolute latency response measure are shown in Table 1. The ANOVA revealed a significant main effect between the standard-task and difficult-task conditions ($F [1,39] = 17.597$, $p < .001$). There was no significant main effect between the two participant groups ($F [1,39] = 2.256$, $p > .05$) and no significant interaction ($F [1,39] = 1.50$, $p > .05$).

Simple comparisons revealed that P300 absolute latencies were longer under the difficult-task condition than those obtained under the standard-task condition for both children with out LD ($F [1,9] = 12.226$, $p < .01$) and children with LD ($F [1,9] = 8.663$, $p < .025$). The difference in P300 absolute latencies between the control and clinical groups were not significant under either the standard-task ($F [1,18] = 1.163$, $p > .05$) or difficult-task ($F [1,18] = 2.570$, $p > .05$) listening conditions.

Condition	Control group	Clinical group
Standard task		
Mean	323.84	337.28
S.D.	27.54	33.31
Difficult task		
Mean	364.00	389.12
S.D.	42.49	47.46

Table 1: Group means and standard deviations in ms for P300 absolute latency

P300 AmplitudeGroup means and standard deviations for the P300 amplitude response measure are shown in Table 2. Similar to the P300 absolute latency measure, the ANOVA of P300 amplitude demonstrated a significant main effect between the standard-task and difficult-task conditions ($F [1,39] = 25.596$, $p < .001$), no significant main effect between participant groups ($F [1,39] = 0.262$, $p > .05$), and no significant interaction ($F [1,39] = 0.289$, $p > .05$).

Simple comparisons were also similar to the performance trends found for the absolute latency measure. That is, P300 amplitudes were smaller under the difficult-task condition than under the standard-task condition for both the children with out LD($F [1,9] = 13.414$, $p < .01$) and children with LD ($F [1,9] = 12.580$, $p < .01$). However, like the P300 absolute latency measure, the difference in P300 amplitudes between the control and clinical groups were not significant under either the standard-task ($F [1, 18] = 0.114$, $p > .05$) or difficult-task ($F [1, 18] = 0.469$, $p > .05$) listening condition.

Condition	Control group	Clinical group
Standard task		
Mean	12.50	11.79
S.D.	3.37	6.16
Difficult task		
Mean	10.19	9.17
S.D.	2.62	5.53

Table 2: Group means and standard deviations in μV for P300 amplitude

P3-P2 Inter-peak latency

Group mean inter-peak latencies and standard deviations are presented in Table 3. The ANOVA of P3-P2 inter-peak latency main effects revealed a significant difference between standard-task and difficult-task listening conditions ($F [1,39] = 52.574$, $p < .001$) and no significant main effect between two test groups ($F [1,39] = 3.359$, $p > .05$). Unlike the two previous response measures, there was a significant interaction ($F [1, 39] = 6.385$, $p < .025$).

Simple comparisons revealed a trend similar to the P300 absolute latency and amplitude measures in that P3-P2 inter-peak latency was longer under the difficult-task condition than the standard-task for both control ($F [1,9] = 17.328$, $p < .01$) and clinical groups ($F [1,9] = 35.250$, $p < .001$). Simple comparisons of children with out LD vs children with LD under each of the two task conditions, however, demonstrateed a pattern unlike those found for absolute latency and amplitude. For the P3-P2 inter-peak latency measure, the difference between control and clinical groups under the standard-task condition was not significant ($F [1,18] = 0.733$, $p > .05$). In contrast, under the difficult-task condition, inter-peak latency was significantly longer for the children with LD when compared to control group ($F [1,18] = 8.223$, $p < .025$).

Condition	Control group	Clinical group
Standard task		
Mean	143.50	147.91
S.D.	39.27	33.36
Difficult task		
Mean	183.19	230.06
S.D.	38.13	34.89

Table 3: Group means and standard deviations in ms for P3-P2 inter-peak latency

In summary, our design allowed an analysis of the effect of task difficulty on P300 absolute latency, amplitude and P3-P2 inter-peak latency, as well as a comparison of control group vs clinical group responses under each task condition. First, in regard to task condition, the results revealed that the manipulation of task difficulty did have a significant effect on all responses studied. Specifically, the two P300 latency measures (absolute latency and P3-P2 inter-peak latency) were prolonged and P300 amplitude was reduced under the difficult-task condition when compared to responses obtained under the standard-task condition for both control and clinical groups. Second, in regard to the comparison of control group vs clinical group responses under each task condition, the patterns of responses were different for the P300 absolute latency and P300 amplitude measures vs the P3-P2 inter-peak latency measure. Specifically, there was no significant difference found between participant groups for P300 absolute latency or P300 amplitude under either test condition. On other hand, when P3-P2 inter-peak latency was measured, significant differences were apparent between the two groups. While P3-P2 inter-peak latency of the two participant groups could not be distinguished under the standard-task condition, the response was more prolonged for children with LD compared to children without LD under the difficult-task condition.

Discussion

This study was designed to determine whether differences in P300 latency and amplitude measures can be identified more effectively in children with LD vs children without LD when the discrimination task is made more difficult than that commonly employed in standard P300 protocols. A second objective was to determine whether a non-traditional measure, namely, inter-peak latency, would be effective in distinguishing children with LD from children without LD.

We found that increasing task difficulty from a 750 Hz/2000 Hz to a 1000 Hz/1500 Hz discrimination requirement had the effect of increasing both P300 absolute latency and P3-P2 inter-peak latency, and reducing P300 amplitude for both the children without LD and children with LD. These findings are consistent with past studies that have measured the effect of task difficulty on P300 absolute latency and amplitude in children without LD and have been attributed to P300 responsiveness to perceptual processing demands during stimulus discrimination (Fitzerald & Picton, 1983; Goodin, Squires, & Starr, 1983; Polich, 1987, 1989).

Although the increase in task difficulty had the effect of prolonging latency measures and reducing amplitude measures, these effects were similar for each participant group when utilizing measures associated with traditional P300 protocols. That is, responses of children from control group vs clinical group could not be differentiated under either the standard or difficult-task conditions when P300 absolute latency and P300 amplitude were utilized. This same trend was not observed when the P3-P2 inter-peak latency measure was analyzed. Like the P300 absolute latency and amplitude measures, P3-P2 inter-peak latency did not distinguish the two participant groups under the standard-task condition. However, the response was significantly more prolonged for children with LD than for children from control group under the difficult-task condition. These results indicate that the strategy of stressing the auditory processing system by increasing the difficulty of the discrimination task was successful in differentiating children with LD from control group only when performance was assessed by means of a P3-P2 response measure. The technique of taxing auditory capacity to draw out processing deficits in children with LD is supported by past studies that have utilized behavioral tests of auditory processing ability (Gomez & Condon, 1999; Musiek et al., 1985; Welsh, Welsh, Healey, & Cooper 1996).

The effectiveness of the P3-P2 inter-peak latency measure has been demonstrated in studies of children with APD. The differences found in P3-P2 inter-peak latency responses of children with APD vs children without APD has been attributed to a prolongation of neural conduction time in participants with APD (Jirsa & Clontz, 1990). Our results support the assertion that similar abnormalities may be present in children with LD and may contribute to their behavioral profiles (Gomez & Condon, 1999; Musiek et al., 1985; Welsh et al., 1996).

The findings of this study indicate that P3-P2 inter-peak latency can be quite sensitive to differentiating children with LD and without LD. It is obvious that the bases for this abnormality is higher-order in nature, however, the exact

neurophysiologic and perceptual correlates to this electrophysiologic measure have not been studied extensively nor has the measure been utilized across a range of populations. To date, the Jirsa and Clontz (1990) study of children with APD is the sole report in the literature of the use of the P3-P2 inter-peak latency response as a diagnostic measure. As such, future research should focus on the replicability of our findings, the stability of this measure across varying test protocols and participant groups, and the neurophysiologic bases of the P3-P2 inter-peak response.

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