The Effect of Auditory Stimulus Duration on the P300 Response

Effet de la durée du stimulus sonore sur la réponse P300

Patrick J. O'Brien and Andrew Stuart
Department of Communication Sciences and Disorders
East Carolina University
Greenville, North Carolina

Abstract

An examination of the effect of stimulus duration on the auditory P300 response was undertaken. Twelve young normal-hearing adults served as participants. P300 responses were obtained with an "oddball" stimulus paradigm. The frequency of stimuli were 1000 Hz tones of 75 ms duration with a 5 ms rise/fall time. The rare stimuli were either 50 ms or 25 ms 1,000 Hz tones with 5 ms rise/fall times. Stimuli were presented at 70 dB pSPL and 30 dB pSPL. All participants exhibited a response in the easiest discrimination condition (i.e., 75 ms frequent and 25 ms rare tonal stimuli presentation at 70 pSPL). When the stimuli intensity decreased and the duration of the rare tone increased, P300 responses were not observed with all participants. Shorter P300 latencies and greater response amplitudes were found at the higher stimulus intensities and when the duration difference between the frequent and rare tone was the greatest. The findings of this study suggest that auditory stimulus duration may serve as the sole discriminatory factor to evoke the P300 response.

Abrégé

Cette recherche effectuée auprès de douze jeunes adultes à l'ouïe normale a analysé l'effet de la durée du stimulus sur la réponse auditive P300. Les réponses ont été obtenues avec un paradigme de stimulus irrégulier. Les fréquences des stimuli étaient des tons de 1000 Hz d'une durée de 75 ms avec un temps de montée et de descente de 5 ms. Les stimuli rares représentaient des tons de 1000 Hz d'une durée de 50 ms ou de 25 ms avec un temps de montée et de descente de 5 ms. Les stimuli étaient présentés à 70 dB pSPL et à 30 dB pSPL. Tous les participants ont réagi à la condition de discrimination la plus simple (stimulus tonal fréquent de 75 ms et rare de 25 ms à un niveau de 70 pSPL). Lorsque l'intensité des stimuli diminuait et que la durée du ton rare augmentait, les participants n'ont pas tous eu de réponses P300. Des latences P300 plus courtes et des amplitudes de réponse plus grandes ont été observées dans les cas d'intensités de stimulus plus hautes et lorsque la différence de durée entre le ton fréquent et le ton rare était la plus élevée. Les conclusions de cette étude laissent entendre que la durée du stimulus sonore pourrait représenter le seul facteur de discrimination permettant de susciter une réponse P300.

Key words: P300, auditory stimulus duration, auditory system, hearing evaluation, electrophysiology

An acoustically evoked P300 typically requires listeners to consciously discriminate a rare target stimulus (i.e., an oddball with a low probability during pseudo-random presentation) embedded in a train of frequent stimuli (Hall, 1992; McPherson, 1996). The task generally involves two tones that vary in frequency or intensity but may also employ speech stimuli that differ along a temporal or spectral dimension. The P300 is an endogenous response believed to reflect cognitive processes invoked by psychological operations independent of the stimulus characteristics (Hillyard & Picton, 1979).

The issue of how "perceptually different" the rare stimuli has to be in order to evoke the P300 response has been the subject of numerous investigations. The effect of stimulus frequency (Cass & Polich, 1997; Sugg & Polich, 1995; Vesco, Bone, Ryan, & Polich, 1993) and intensity differences (Adler & Adler, 1991; Cass & Polich, 1997; Covington & Polich, 1996; Johnson & Donchin, 1978; Papanicolaou, Loring, Raz, & Eisenberg, 1985; Polich, Ellerson, Cohen, 1996; Roth, Doyle, Pfefferbaum, & Kopell, 1980; Sugg & Polich; Walton, Callaway, Halliday, & Naylor, 1987; Vesco et al., 1993) between rare and frequent tones have been explored. In general, more identifiable differences between rare and frequent stimuli yield shorter latencies and greater amplitudes with the P300 response.

How variations in auditory stimulus duration affect the P300 response, however, have not been explored in depth. To the best of our knowledge only two studies have explored changes in stimulus duration and the effect on the P300. Polich (1989) manipulated rare tone (2,000 Hz) and frequent tone (1,000 Hz) intensity (i.e., 30, 50, and 70 dB SPL) and duration (i.e., 20, 50, and 80 ms) in a factorial design. The rare and frequent tones were presented at the same intensity. Polich reported that P300 latency decreased significantly ($p < .05$) with increases in stimulus intensity and duration ($p < .001$). There was no effect of either stimulus intensity or duration on the amplitude of the P300 response ($p < .05$). In other words, the more identifiable differences between rare and frequent stimuli yield shorter latencies and greater amplitudes. Similarly, Obert and Cranford (1990) reported a significant change in P300 latency and amplitude with a discrimination task where stimulus frequency and duration varied. In their "easy" task, the stimulus duration was 20 ms while the frequency of the rare and frequent tones was 2000 and 750 Hz, respectively. Stimulus duration was five ms while the frequency of the rare and frequent tones was 1,000 and 750 Hz, respectively in their "hard" task. With their normal-hearing listeners, P300 latency was significantly decreased with a concomitant significant increase in amplitude in the easy discrimination task. Two of 10 participants with neocortical lesions failed to demonstrate a P300 response during the testing, while the remaining eight participants demonstrated absent or delayed P300 responses during 53% of test runs.

The effect of duration differences between the rare and frequent stimuli as the sole discriminatory factor with the P300 response is unavailable. Toward that end, the purpose of this study was to examine the effect of stimulus duration on P300 latency and amplitude among normal-hearing young adults. An examination of such could lead to the application of the P300 auditory evoked response to investigate electrophysiological correlates of perceptual processing of duration discrimination with normal-hearing listener's and listener's with auditory pathology.

Method

Participants

Twelve young adults served as participants (M = 25.8 years, SE = 0.9; six males and six females). All participants presented with normal middle ear function as assessed with immittance audiometry (American Speech-Language-Hearing Association, 1990) and normal hearing sensitivity defined as having pure-tone thresholds at octave frequencies from 250 to 8000 Hz and speech recognition thresholds of ≤ 20 dB HL (American National Standards Institute, 1996). All individuals had a negative history of neurological, otological, and psychiatric disorders.

Apparatus

A double wall sound-treated audiometric suite (Industrial Acoustics Corporation), meeting specifications for permissible ambient noise (American National Standards Institute, 1999), served as the test environment. Participants were tested with a Nicolet Spirit evoked potential system.

Tonal stimuli generated by the evoked potential system were applied to an insert earphone (Nicolet model TIP-300) at a rate of 1.1/s with alternating polarity. The frequent stimuli were 1,000 Hz tones of 75 ms duration with a five ms rise/fall time. The rare stimuli were either 50 ms or 25 ms 1,000 Hz tones with five ms rise/fall times. All stimuli were linearly gated. Stimuli were presented at 70 dB pSPL and 30 dB pSPL. These stimuli were chosen based on pilot data that suggested that the stimuli were easily discriminable for young adult normal-hearing listeners.

Procedures

P300 responses were obtained with an "oddball" stimulus paradigm (Squires & Hecox, 1983). Frequent and rare stimuli were presented with 80% and 20% probabilities, respectively. The four test conditions (i.e., 75 ms frequent and 50 ms rare tonal stimuli at 70 dB pSPL; 75 ms frequent and 25 ms rare tonal stimuli at 70 dB pSPL; 75 ms frequent and 50 ms rare tonal stimuli at 30 dB pSPL; and, 75 ms frequent and 25 ms rare tonal stimuli at 30 dB pSPL) were counterbalanced across participants. Stimuli were presented to the right ear of all participants.

Table 1. Numbers Of Participants Exhibiting a P300 Response as a Function of Stimulus Intensity Level (dB pSPL), Frequent and Rare Stimuli Duration, and Gender.

		Gender	
		Male	Female
	Intensity		
Stimuli Duration (Frequent/Rare)			
75/25 ms	70 dB p SPL	6	6
75/50 ms	70 dB p SPL	5	6
75/25 ms	30 dB p SPL	5	5
75/50 ms	30 dB p SPL	4	3

Silver-chloride cup electrodes consisting of one (noninverting) attached to the vertex (Cz), one (inverting) attached to the right mastoid (M2), and one (common) attached to the forehead (Fz) were employed. Interelectrode impedances were maintained below 5,000 Ω. The recorded electroencephalogram was amplified 50,000 times and analogue bandpass filtered (1 to 30 Hz, Butterworth filter with a roll-off slope of 12 dB/octave). Electroencephalogram samples exceeding ± 50 µV were rejected automatically. An analysis time of 750 ms post-stimulus onset was sampled at 667 Hz. A total of 300 (i.e., 240 frequent and 60 rare tones) samples were averaged simultaneously, but separately, and replicated for all trials.

Participants were tested while sitting comfortably. They were instructed to count the number of presentations of the rare stimuli during each trial. During the "easy" 75 ms frequent and 25 ms rare tonal stimuli presentation trials, participants displayed 96% (SD = 2.5) accuracy in total counts of the rare stimuli. Participants displayed an accuracy of 88% (SD = 4.6) in reporting total counts of the rare stimuli during the "difficult" 75 ms frequent and 50 ms rare tonal stimuli.

Presence of the P300 response required the agreement of three audiologists experienced in P300 testing. All observers, who were blind to test condition, inspected the waveforms jointly. The P300 response was defined as the largest positive going peak occurring between 250 and 500 ms. Replication was defined as two or more waveforms with identifiable P300 peaks within 25 ms. P300 latency was defined as the time point of maximum positive amplitude. P300 amplitude was measured from the P300 peak to the most negative following trough before positive deflection.

Table 2. Means and Standard Deviations Of The P300 Latencies And Amplitudes as a Function of Stimulus Intensity Level, Frequent and Rare Stimuli Duration, and Gender.

		Gender	
		Male	Female
Latency (µs)			
Stimuli Duration	**Intensity**		
75/25 ms	70 dB pSPL	328.8 (30.2)	342.0 (26.90)
75/50 ms	70 dB pSPL	438.2 (24.3)	429.3 (26.4)
75/25 ms	30 dB pSPL	363.3 (40.7)	368.4 (26.8)
75/50 ms	30 dB pSPL	419.5 (40.8)	423.0 (27.2)
Amplitude (µV)			
Stimuli Duration	**Intensity**		
75/25 ms	70 dB pSPL	14.3 (3.8)	13.2 (3.5)
75/50 ms	70 dB pSPL	8.8 (4.2)	8.6 (1.6)
75/25 ms	30 dB pSPL	8.7 (3.1)	12.6 (3.8)
75/50 ms	30 dB pSPL	6.4 (4.2)	6.6 (2.3)

Results

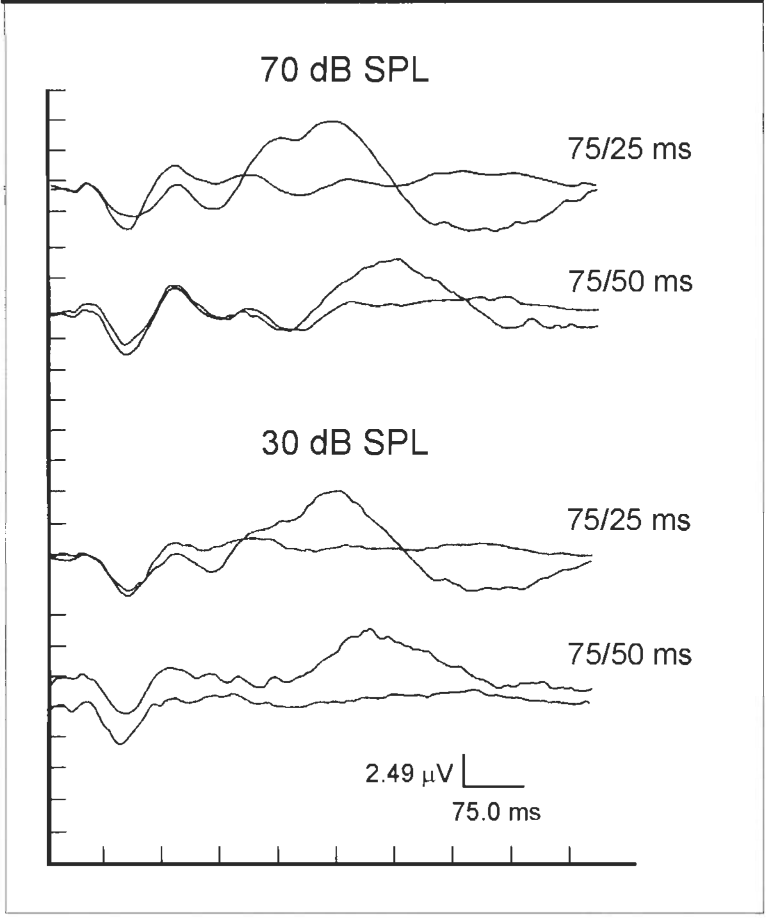
Numbers of participants exhibiting a P300 response as a function of stimulus intensity level, frequent and rare stimuli duration, and gender are presented in Table 1. As evident in the table, all participants exhibited a response in the easiest discrimination condition (i.e., 75 ms frequent and 25 ms rare tonal stimuli presentation at 70 pSPL). When the stimuli intensity decreased and the duration of the rare tone increased P300 responses were not observed with all participants. Means and standard deviations of the P300 latencies and amplitudes as a function of level of stimulus intensity, frequent and rare stimuli duration, and gender are presented in Table 2.

Inferential statistical analyses were not undertaken to investigate mean differences in P300 latencies and amplitudes as a function of stimulus intensity, duration, and gender due to missing data. It was believed that the missing data were not independent of the experimental treatment conditions (i.e., not random). Under such circumstances violations to analysis of variance are assumed (Keppel & Zedeck, 1989). What follows is a global assessment of the data set. In general, data for both genders were similar. Waveforms from the participants that evoked P300 responses were used to construct grand averages. These waveforms for the four test conditions are displayed in Figure 1. As evident in Table 2 and in Figure 1, shorter latencies and greater response amplitudes were found at the higher stimulus intensities and when the duration difference between the frequent and rare tone was the greatest (i.e., 75 ms vs. 25 ms).

Conclusions and Discussion

The findings of this study suggest that auditory stimulus duration may serve as the sole discriminatory factor to evoke the P300 response. It must be noted that when the discrimi-

Figure 1. Grand average P300 responses as a function of presentation level and duration of frequent/rare tones.



nation task became more difficult, P300 responses were not evident in all listeners. For those participants who displayed P300 responses, response latency increased and response amplitude decreased as the duration of the rare and frequent tones became more similar and stimulus intensity decreased. These findings are consistent with previous research that has demonstrated that the P300 response is more identifiable when frequent and rare tone differences are more salient (Cass & Polich, 1997; Obert & Cranford, 1990; Polich, 1989; Sugg & Polich, 1995; Vesco et al., 1993) and when evoking stimuli are presented at higher stimulus intensities (Adler & Adler, 1991; Cass & Polich; Covington & Polich, 1996; Johnson & Donchin, 1978; Papanicolaou et al., 1985; Polich et al., 1996; Roth et al., 1980; Sugg & Polich; Walton et al., 1987; Vesco et al.). It is likely that the changes in the P300 response "most likely stem from stimulus evaluation processes" (Polich, 1989, p. 285).

The implementation of this task as a clinical tool needs to be further explored. These findings suggest that a duration discrimination P300 paradigm should only be used if the difference between the rare and frequent tone is at least 50 ms. Evidence of all listeners demonstrating P300 response was not found when the duration difference between the rare and frequent tones was 25 ms. The application of the P300 auditory evoked response to investigate electrophysiological correlates of perceptual processing of duration discrimination among patients with temporal resolution difficulties may be profitable.

Author Notes

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Patrick O'Brien is currently affiliated with Otolaryngology and Cosmetic Surgery Institute of South Florida, Lauderdale Lakes, FL. Please address all correspondence to Andrew Stuart, PhD, Department of Communication Sciences and Disorders, East Carolina University, Greenville, North Carolina, 27858-4353; stuarta@mail.ecu.edu.

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