Comparisons of P300s from Standard Oddball and Omitted Paradigms: Implications to Exogenous/Endogenous Contributions

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Abstract

Purpose: To compare the amplitude, latency, morphology, and threshold of the auditory P300 using standard oddball and omitted paradigms.

Research Design: P300 waveforms were measured from the Cz electrode site. Frequent stimuli for both paradigms were 1000 Hz tone bursts. Target stimuli for the standard oddball paradigm were 2000 Hz tone bursts and an omitted stimulus, or silent gap, for the omitted paradigm.

Study Sample: Fifteen bilaterally normal-hearing young adults.

Results: There were significantly lower amplitudes, poorer morphology, and higher thresholds for the P300 using an omitted paradigm compared to the standard oddball paradigm.

Conclusion: These results suggest that the auditory P300 could have a larger exogenous component than traditionally thought.

Key Words: Endogenous, exogenous, intensity effects, omitted paradigm, P300

The auditory P300 is an auditory event-related potential represented by a large, positive peak occurring approximately 300 msec post–stimulus onset (Sutton et al, 1965; Debecker and Desmedt, 1966) and is thought to have multiple generator sites (Tarkka and Stokic, 1998). The auditory P300 is typically elicited using an oddball paradigm such that two different stimuli are used to generate the waveform. The standard oddball paradigm utilizes frequent and target (rare) acoustic stimuli that are perceptually different, such as 1000 and 2000 Hz tones. The patient is instructed to indicate in some way (i.e., counting) that the target tones are perceived, and the associated electrophysiologic functions related to that decision yield a P300.

The auditory P300 has long been considered an endogenous potential (Sutton et al, 1965; Sutton et al, 1967; Stapleton et al, 1987). An endogenous potential is considered to be the result of a cognitive (internal) event rather than an external event. The cognitive event for the auditory P300 is the decision that a target occurred. In contrast, an exogenous potential such as the auditory brainstem response is the result of an external acoustic event and is therefore influenced by physical stimulus characteristics (Donchin et al, 1978; Picton and Fitzgerald, 1983).

Evidence has emerged that argues for the P300 to possess not only endogenous but also exogenous origins. Researchers have shown external acoustic stimulus characteristics, such as intensity, to affect P300 amplitude and latency (Roth et al, 1982; Backs, 1987; Polich et al, 1996; Musiek et al, 2005). Increasing stimulus intensity will result in an increase in P300 amplitude and will decrease P300 latency (Backs, 1987; Polich et al, 1996). P300 waveforms have been shown to be larger in amplitude and shorter in latency at suprathreshold levels (75 dB SPL) compared to threshold levels (Musiek et al, 2005). Backs (1987) and

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Polich et al (1996) show that above 75 dB SPL, the amplitude of the P300 does not significantly increase, indicating that the exogenous component is maximized. It seems reasonable that if the P300 is truly an endogenous potential, the P300 amplitudes and latencies should be similar at suprathreshold and threshold levels because the decision-making task would be comparable at both intensity levels. Since intensity affects the latency and amplitude of the P300, an exogenous component must be considered, contrary to earlier beliefs (Sutton et al, 1967; Backs, 1987; Polich et al, 1996; Musiek et al, 2005).

In addition to stimulus intensity affecting P300 waveforms, the absence of a target stimulus can also affect the P300 waveforms. Many researchers have shown that it is possible to evoke a P300 using an omitted stimulus paradigm (Sutton et al, 1967; Ruchkin and Sutton, 1973, 1978; Squires et al, 1975; Ruchkin et al, 1981; Stapleton et al, 1987; Raij et al, 1997; Tarkka and Stokic, 1998; Jongasma et al, 2005). In 1967, Sutton and colleagues investigated late evoked potentials including the effect of an absent external stimulus. They found that the latency of the late positive peak was a result of the decision that the external stimulus was omitted. They concluded that the absence of an external stimulus, or the passing of time, was acting as an endogenous stimulus. Ruchkin and Sutton (1973) demonstrate that under similar stimulus conditions, the average amplitudes for the P300s generated by an absent external stimulus (“emitted” P300) were lower than the average amplitude for the P300s using an external stimulus (“evoked” P300). The average amplitude of the “emitted,” or omitted, P300 was determined to be smaller due to temporal uncertainty associated with the decision that the stimulus was absent (Ruchkin and Sutton, 1978). Other researchers have also found that P300 amplitude was smaller when evoked by an omitted stimulus compared to an external target stimulus (Squires et al, 1975; Stapleton et al, 1987; Tarkka and Stokic, 1998). Longer peak latencies were also noted for the omitted stimulus P300 compared to the P300 using an external target stimulus (Picton and Hillyard, 1974; Ruchkin et al, 1981; Stapleton et al, 1987). Researchers found the P300 waveform morphology to be less distinct and more widespread when elicited using an omitted paradigm compared to a standard oddball paradigm (Picton and Hillyard, 1974; Tarkka and Stokic, 1998). These researchers have shown that when relying entirely on endogenous components to generate a P300 (omitted stimulus paradigm), the waveform suffers, suggesting that external stimulus characteristics contribute to the P300. Since the P300 appears to have an exogenous component, a comparison between the P300s generated by the standard oddball paradigm (in which exogenous and endogenous components exist) and the omitted paradigm (in which only the endogenous component exists) could be used to determine the exogenous contributions to the P300 waveform.

Measurements of the P300 generated by an omitted paradigm, as well as the standard oddball paradigm, at threshold and suprathreshold levels are essential to determining the exogenous contributions because an external modification to the stimulus, such as intensity, is considered exogenous in nature (Polich et al, 1996). Theoretically, when using an omitted paradigm, the exogenous stimulus is eliminated, so the P300 should be essentially endogenous. When measuring the omitted P300 at suprathreshold levels one would expect the waveform to be larger in amplitude and shorter in latency based on the research of Polich et al (1996) and Musiek et al (2005) using the standard oddball paradigm. Based on intensity studies of evoked potentials (Backs, 1987; Polich et al, 1996), these findings could be indicative of an increase in neural activity contributing to the waveform (Parasuraman and Beatty, 1980; Pickles, 1982). Based on previous research (Squires et al, 1975; Ruchkin and Sutton, 1978; Stapleton et al, 1987), it would be expected that at threshold levels the omitted P300 would have smaller amplitudes and longer latencies compared to suprathreshold levels. The endogenous components of the P300 could potentially be considered at their “purest” form at or near threshold levels, reducing other potential influences such as intensity. Hence, stimulus intensity, or “external,” manipulations may be useful in endogenous/exogenous determinations.

In the current study the P300 was generated using the omitted paradigm as well as the standard oddball paradigm at suprathreshold and threshold levels in order to determine the exogenous contributions to the auditory P300. Audiometric intensity comparisons, such as comparing the omitted P300 to the standard oddball P300 at threshold levels, were used to determine the possible exogenous effects on the P300 waveform. If the P300 is purely an endogenous potential, it would be expected that as long as the individual accurately perceived the target, whether it be an omitted stimulus or an external stimulus, the cognitive decision-making task would not vary and for that reason, P300 waveforms would be similar. Given that stimulus characteristics do affect the P300, it is apparent that exogenous contributions to the P300 waveform exist. From an audiologic standpoint, the extents of these contributions, as yet, have not been determined. Clinically and experimentally, it is important to determine the feasibility of these two potentials because in situations where only one tone can be used, it would be important to know whether one could evaluate the two potentials (omitted and standard oddball) as if they were equal. The first goal of this
study was to investigate further which paradigm (omitted or standard oddball) yielded the most usable P300 waveform at suprathreshold levels as well as at or near threshold levels. The second goal of this study was to quantify the exogenous component of the P300 by audiologically comparing the amplitude of the waveforms using a standard oddball paradigm and an omitted paradigm at threshold levels.

**METHOD**

**Subjects**

Fifteen normal-hearing young adult subjects (mean = 23.7 years, SD = 4.2 years) participated in the study. Hearing sensitivity, established using the modified Hughson-Westlake procedure (Carhart and Jerger, 1959), was better than 20 dB HL for the octave frequencies from 250 to 8000 Hz bilaterally for each subject. Otologic examinations were normal bilaterally for all subjects. Distortion product otoacoustic emissions were within normal limits bilaterally according to the criteria established by Musiek and Baran in 1997 (1000 to 4000 Hz). All subjects performed within normal limits bilaterally (greater than or equal to 90%) on the dichotic digits test, which was used as a central auditory processing screening. All subjects had a negative history of audiologic, otologic, and neurologic involvement.

**Procedures**

Subjects were seated in a reclining chair in a double-walled Industrial Acoustics Company sound-treated booth. P300 waveforms were measured using the Nicolet Spirit 2000. Silver chloride cup electrodes were affixed at the Cz, C3, C4 (noninverting), and A1 or A2 (inverting) electrode sites. Cz, C3, and C4 electrode sites were used because in diagnostic audiology it is often important to obtain laterality measures. Electrode impedances were maintained at 8 kOhms or better and were balanced within 3 kOhms across electrode sites. An electrode was also placed at the outer canthus of the eye to monitor eye blinks. A ground electrode was placed at Fz. One ear was tested per subject, and selection of the test ear was randomized. For the standard oddball paradigm, tone bursts at the frequencies of 1000 Hz (85%) and 2000 Hz (15%) with a 10 msec rise and fall time and a 20 msec plateau were presented at a repetition rate of 0.9 per sec with 300 accepted trials. The omitted paradigm utilized only the 1000 Hz tone bursts with the target being the omission of a tone. For the omitted paradigm, the repetition rate and frequency of the frequent 1000 Hz tones and omitted targets were the same as those for the standard oddball paradigm (Figure 1). The modified Hughson-Westlake procedure was used in order to determine behavioral thresholds to the 1000 Hz and 2000 Hz stimuli generated by the Nicolet Spirit 2000. Paradigm (standard oddball and omitted) order was randomized for each subject. For each paradigm, the P300 was measured at suprathreshold (60 dB SL re: behavioral toneburst thresholds) and threshold levels. Threshold was considered the final intensity level at which the P300 was present and repeatable as judged by two independent researchers familiar with this evoked potential. P300 threshold was established by decreasing the intensity by 10 dB until the P300 waveform was not present or not repeatable. At this point, the intensity was increased 5 dB. If the P300 was not present or repeatable at this level, the intensity was increased in 5 dB steps until the waveform was replicated (Musiek et al, 2005). Since the level at which threshold for the P300 waveform tended to be at a higher sensation level for the omitted paradigm, the standard oddball paradigm P300 was also measured at the intensity at which threshold was established using the omitted paradigm to allow for additional comparisons.

Subjects were instructed to stay alert and keep their eyes fixated on a black-and-white picture affixed to the booth wall to minimize eye movements. Subjects were asked to silently count the number of target tones for the standard oddball paradigm and the number of stimulus omissions for the omitted paradigm in each trial. At the end of each trial the subject was asked how many targets he or she perceived. In order for the trial to be accepted, the perceived number of targets needed to be within 10 percent of the actual number of targets.

![Standard Oddball Paradigm](image1)

![Omitted Paradigm](image2)

Figure 1. Schematic diagram of the two paradigms. The standard oddball paradigm incorporates 1000 and 2000 Hz tones to generate the P300, whereas the omitted paradigm utilizes only a 1000 Hz tone and an omission of a tone to generate the P300.
Latency and Amplitude Measures

Measurements for all waveforms were made after the replicated waveforms were averaged from each of the electrode sites, so that for each subject three P300 tracings (Cz, C4, C3) were analyzed for each paradigm and condition. The P300 was considered the most positive peak between 245 and 450 msec post–stimulus onset. Occasionally, when the P300 peak was broad or bifid, the midpoint of the waveform was used as the latency measurement. The midpoint of the waveform was defined as the average latency of the two peak latencies of the waveform. For a broad P300 waveform the midpoint was defined as the average of the shortest peak latency and the longest peak latency. P300 amplitude was measured from the closest preceding negative trough (N2) and the closest negative trough following the P300. These two amplitude values were averaged to generate one amplitude value for the P300 (Goodin et al, 1986; Musiek et al, 1992). All questionable waveforms were independently observed by two researchers experienced with late evoked potentials to determine waveform absence or presence. Average amplitude and latency were taken if discrepancies existed between researchers as to the amplitude and latency measurements.

RESULTS

Although P300 was measured from three electrode sites in this study, only statistics from the Cz electrode site will be reported. Descriptive statistics for the P300 amplitudes and latencies in each condition for the Cz electrode site are presented in Table 1. Descriptive statistics indicate that the P300 waveforms measured from the Cz electrode site were largest compared to those measured from the C3 and C4 electrode sites. Amplitudes for the omitted paradigm P300s were on average 4.89 μV smaller than the standard oddball paradigm P300s at suprathreshold levels (60 dB SL re: toneburst threshold) and were on average 3.03 μV smaller for the omitted paradigm P300s compared to the standard oddball paradigm at threshold levels (Figure 2). On average, latencies were 30.05 msec and 13.23 msec longer for the omitted paradigm P300s compared to the standard oddball paradigm P300s at suprathreshold and threshold levels, respectively (Figure 3). Example waveforms from one subject are displayed to show amplitude, latency, and morphological differences between the standard oddball and the omitted paradigms at suprathreshold and threshold levels (Figures 4 and 5). Average threshold for the omitted paradigm P300s was 41.33 dB SL with a standard deviation of 5.16 dB compared to 8.67 dB SL with a standard deviation of 3.51 dB for the standard oddball paradigm P300s (Figure 6).

P300 Amplitude

A repeated-measures analysis of variance (ANOVA) was conducted for the experimental factor of amplitude with within-subjects factors of paradigm and intensity level as well as a between-subjects factor of ear. Huynh-Feldt corrected degrees of freedom were used for each within-subjects analysis (Max and Onghena, 1999). Amplitudes were significantly larger for the P300 waveform generated by the standard oddball paradigm compared to the omitted paradigm ($F[1, 13] = 26.87, p < .001$). No within-subjects effects of ear were found for amplitude ($F[1, 13] = 0.04, p = .84$). A significant effect of intensity ($F[1, 13]= 20.50, p = .001$) was revealed such that P300 amplitudes were significantly reduced as intensity decreased. A significant interaction was noted for paradigm and intensity levels, respectively.

<table>
<thead>
<tr>
<th>Paradigm and Threshold</th>
<th>Latency (msec)</th>
<th>Amplitude (μV)</th>
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<tr>
<td></td>
<td>N</td>
<td>Mean</td>
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<tr>
<td>Omitted Suprathreshold</td>
<td>15</td>
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<tr>
<td>Omitted Threshold</td>
<td>15</td>
<td>365.39</td>
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<tr>
<td>Standard Oddball Suprathreshold</td>
<td>15</td>
<td>307.15</td>
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<tr>
<td>Standard Oddball Threshold</td>
<td>15</td>
<td>352.17</td>
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Figure 2. Mean amplitudes and standard deviations for the omitted P300s compared to the standard P300s at suprathreshold and threshold levels.
(\(F(1, 13), p = .035\)); however, no other significant interactions were found.

A paired \(t\)-test was conducted to determine where significant differences occurred between paradigms at different intensity levels. Significant differences were found between the standard oddball paradigm at suprathreshold and threshold levels (\(t = 3.70, p = .002\)). Additionally, significant amplitude differences were not noted when comparing the omitted paradigm at suprathreshold and threshold levels (\(t = 1.750, p = .10\)). For both paradigms, the P300 waveforms were larger in amplitude when elicited at suprathreshold levels compared to threshold levels. Significantly reduced amplitudes were noted for the omitted paradigm compared to the standard oddball paradigm at suprathreshold (\(t = -5.17, p < .001\)) as well as threshold levels (\(t = -3.88, p = .002\)).

Paired \(t\)-tests were conducted to compare P300 amplitude at the level at which the omitted P300 threshold was established. Amplitudes were significantly smaller for the omitted P300 compared to the standard oddball P300 at omitted threshold level (\(t = -4.49, p = .001\)).

**P300 Latency**

A repeated-measures ANOVA was conducted for the experimental factor of latency with the within-subjects

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**Figure 3.** Mean latencies and standard deviations for the omitted P300s compared to the standard P300s at suprathreshold and threshold levels.

**Figure 4.** Averaged waveforms from one individual subject demonstrating amplitude, latency, and morphologic differences in the omitted paradigm at suprathreshold and threshold levels.

**Figure 5.** Averaged waveforms from one individual subject demonstrating amplitude, latency, and morphologic differences in the standard oddball paradigm at suprathreshold and threshold levels.

**Figure 6.** Mean and standard deviations for the P300 threshold level established for the omitted paradigm and the standard oddball paradigm.
factors of paradigm and intensity level and a between-subjects factor of ear. Huynh-Feldt corrected degrees of freedom were used for each within-subjects analysis (Max and Onghena, 1999). Latencies were not significantly different between the omitted and standard oddball paradigms ($F[1, 13] = 4.37, p = .057$). No within-subjects effects of ear were noted ($F[1, 13] = 0.240, p = .632$). Latencies were significantly affected by intensity ($F[1, 13] = 78.73, p < .001$) such that at lower intensities, the latencies of the P300 waveforms increased. No significant interactions were found.

A paired $t$-test was conducted to determine where significant differences occurred between paradigms at different intensity levels. A significant latency difference was found for the standard oddball paradigm at suprathreshold and threshold levels ($t = -9.17, p < .001$). The P300 waveforms occurred at shorter latencies when elicited at suprathreshold levels compared to threshold levels. Furthermore, P300 latencies were significantly longer for the waveforms generated with the omitted paradigm at threshold levels compared to suprathreshold levels ($t = -3.70, p = .002$).

Paired $t$-tests were conducted to compare the P300 latency at the level at which the omitted P300 threshold was established. Latencies were significantly longer at threshold levels for the omitted P300 compared to the standard oddball P300 ($t = 2.74, p = .016$).

**Test–Retest Reliability**

Test–retest reliability for amplitude and latency of the P300 waveforms were measured for three subjects on two different test dates at least three months apart. The following calculations were made by taking the difference of the mean of the test session and the mean of the retest session. The mean amplitude difference between the test and retest sessions did not exceed 1.7 $\mu$V for P300 for both the omitted and standard oddball paradigms. The mean latency difference between the test and retest sessions did not exceed 53.9 msec for P300 for either paradigm (omitted and standard oddball). P300 latency correlations were strong for the suprathreshold levels for the standard oddball paradigm ($r = 0.893, p = .297$) and moderate for the omitted paradigm ($r = -0.619, p = .575$). However, at threshold levels P300 latency correlations were poorer for the standard oddball paradigm ($r = 0.311, p = .799$) and omitted paradigm ($r = -0.009, p = .994$). Test and retest sessions indicated highly correlated P300 amplitude measurements at the Cz electrode site at suprathreshold levels for the standard oddball paradigm ($r = -0.994, p = .073$) and for the omitted paradigm ($r = -0.917, p = .262$), as well as at the threshold level for the standard oddball paradigm ($r = -0.960, p = .182$). A moderate correlation was noted at the threshold level for the omitted paradigm ($r = -0.640, p = .558$). Lack of significance among many of these correlations is likely due to the small sample sizes; however, moderate to strong correlations did exist for the test and retest sessions for amplitude at threshold and suprathreshold levels, as well as latency at suprathreshold levels.

**DISCUSSION**

The P300 waveforms elicited by standard oddball and omitted paradigms were analyzed to determine the effects that external stimulus presence or absence had on waveform amplitude, latency, and morphology. Intensity levels (suprathreshold and threshold) were also investigated to determine the effect, if any, on the waveform amplitudes, latencies, and morphology. The P300 waveform was significantly affected in terms of amplitude, latency, and morphology when comparing the omitted to the standard oddball paradigms at suprathreshold and threshold levels. These waveform differences will be discussed in the following sections.

**P300**

The results of this study indicate that the P300 waveforms are larger in amplitude and shorter in latency when generated with the standard oddball paradigm compared to the omitted paradigm. When visually analyzed, P300 waveforms elicited by the standard oddball paradigm were morphologically better defined than the omitted paradigm P300 waveforms. These findings hold true at suprathreshold as well as threshold or near threshold levels (see Figures 4 and 5). Two explanations will be entertained in explaining these findings. First, amplitude, latency, and morphology differences could be a consequence of the nonexistent exogenous component in the omitted paradigm. Effects of intensity on the P300 waveform in both conditions also indicate the influence of an exogenous component in P300 waveform amplitude, latency, and morphology (Backs, 1987; Polich et al, 1996; Musiek et al, 2005). Second, for the standard oddball paradigm the subject’s decision that a target occurred is more time-locked to the target stimulus (2000 Hz tone); while in the omitted paradigm that external target stimulus is absent, and the subject is left to use temporal estimations (which may vary from trial to trial) to make the decision that a tone was omitted (Ruchkin and Sutton, 1973, 1978). The averaging of these delayed and imprecise decisions can result in smaller amplitudes and poorer morphology.

**Exogenous Contributions to the P300**

The P300 waveform amplitude and latency are affected by altering the intensity level of the external...
stimulus, which is indicative of exogenous contributions to the P300. The results of the current study demonstrate that when stimulus intensity decreases, waveform amplitude decreases and latency increases. The mean P300 amplitude difference between the suprathreshold and threshold conditions with the standard oddball paradigm is 2.57 μV. The mean latency difference for the standard oddball paradigm P300s at suprathreshold and threshold conditions is 45.02 msec. This suprathreshold–threshold trend was true for not only the standard oddball but the omitted paradigm as well. Previous research has shown that changes in stimulus intensity lead to similar changes in P300 amplitude and latency, indicating a possible exogenous component (Backs, 1987; Polich et al, 1996; Musiek et al, 2005). Polich et al (1996) show that latency decreased and amplitude increased as stimulus intensity increased. Musiek et al (2005) found comparable trends at suprathreshold levels but also show that at threshold levels P300 amplitudes were significantly smaller and latencies were significantly longer than at suprathreshold levels. Amplitude changes from suprathreshold to threshold levels averaged 4.5 μV, and latency changes averaged 43.6 msec in the Musiek et al (2005) study. When comparing the current findings to Musiek et al’s (2005), the average amplitude and latency changes from suprathreshold to threshold levels using the standard oddball paradigm were similar. If this potential is exclusively endogenous in nature, external physical stimulus characteristics, such as intensity, should not have a significant effect on P300 waveform amplitude, latency, and morphology. Nevertheless, as seen in previous research and in the current study, it is undeniable that some exogenous component exists to the auditory P300, and therefore, the need to quantify the exogenous contribution to the P300 emerges.

The differences between the P300 waveform amplitude, latency, and morphology elicited by the standard oddball paradigm and omitted paradigm were also investigated and could be related to the endogenous and exogenous contributions to the waveforms. It seems reasonable to expect that the lack of an exogenous component in the omitted paradigm likely contributes to the decreased amplitude of P300 compared to the standard oddball paradigm P300. The omitted paradigm does not employ an external stimulus to generate the P300; instead it utilizes the omission of a tone to generate the waveform. The standard oddball paradigm utilizes the external stimulus (in this case a 2000 Hz tone) to generate the P300. The omitted P300 waveform was significantly longer in latency and smaller in amplitude than the P300 waveforms generated with the standard oddball paradigm. It could be argued that the exogenous component in the P300 waveform truly drives the waveform, and without it, the P300 waveform suffers in terms of amplitude, latency, and morphology.

Omitted P300 waveforms generated in the current study were less distinct and had a broader morphology than those generated with a standard oddball paradigm, which is consistent with previous research findings (Picton and Hillyard, 1974; Tarkka and Stokic, 1998). In addition, current findings indicate that the P300s generated at suprathreshold levels by the standard oddball paradigm were about 4.89 μV larger than the omitted P300s. Previous studies utilizing an omitted paradigm indicate similar trends that the “evoked,” or standard oddball, P300 was on average 3.78 μV larger than the “emitted,” or omitted, P300 when presented at 50 dB SL (Ruchkin and Sutton, 1978). Similarly, Squires et al (1975) found that P300s evoked from an omitted stimulus were approximately 3.12 μV smaller than those generated with an external target stimulus. More recently, Tarkka and Stokic (1998) showed that P300 amplitudes were approximately 5 μV smaller for the omitted stimulus paradigm compared to the standard oddball paradigm. Even at threshold levels, where other potential influences like intensity were minimized, the amplitude and morphology of the P300 waveforms were poorer when comparing the omitted paradigm to the standard oddball paradigm. Exogenous contributions continue to be present at threshold levels for the standard oddball paradigm and not present for the omitted paradigm. Musiek and colleagues (2005) theorize that to determine the exogenous contribution of the P300 waveform, the difference between the P300 amplitudes generated by the standard oddball paradigm could be subtracted from the P300 amplitudes generated by the omitted paradigm, since the exogenous component is only present in the standard oddball paradigm. Additionally, by minimizing other potential influences, such as intensity, via comparing P300 waveforms at or near threshold, a more accurate quantification of exogenous components could potentially be derived. The outcome of this subtraction procedure yields an average amplitude of 3.03 μV with a standard deviation of 3.02 μV attributable to the exogenous component. It is hypothesized that the smaller amplitudes of the omitted P300 could be the result of the absence of exogenous contributions to the P300 waveform.

**Target Uncertainty**

The amplitude differences found between the omitted and standard oddball paradigms at suprathreshold levels could reflect an uncertainty as to when the target stimulus was presented in the omitted paradigm compared to the standard oddball paradigm. Previous research has shown that under similar conditions the
“emitted,” or omitted, P300 was smaller in amplitude than the “evoked,” or standard oddball, P300 (Ruchkin and Sutton, 1973). In 1978, Ruchkin and Sutton explained that this finding was a result of temporal uncertainty. Thus, P300 amplitudes decrease in the omitted paradigm because the decision that a stimulus omission has occurred varies, and amplitudes suffer as a result. In the current study, a physical stimulus (2000 Hz tone) was presented as the target tone in the standard oddball paradigm, and the subject easily detected the presence of the tone and thus, the mental manipulation (counting) was made. In the omitted paradigm, the 2000 Hz tone was omitted and the subject was left to rely on a temporal cue, or timing, between the two frequent tones to alert him or her to make the mental manipulation (i.e., counting). When left to rely on a temporal cue to determine when the target stimulus occurred, the subjects’ awareness of the stimulus omission varied from presentation to presentation. In support of this idea, Holm et al (2005) show that reaction times to the targets were correlated with the P300. Additionally, research has shown significantly higher variability in reaction times to the target in the omitted paradigm compared to the reaction times to the target in the standard oddball paradigm at suprathreshold levels (Nagle et al, 2007). Thus, the averaging of these nonsynchronous voltages derived from uncertain decisions, which directly contribute to the P300, result in smaller amplitudes and longer latencies for the omitted paradigm compared to the standard oddball paradigm. Furthermore, the variability in the mental decision that a stimulus omission occurred could also affect the level at which P300 threshold was established for the omitted paradigm.

The level at which threshold was obtained was higher for the omitted paradigm compared to the standard oddball paradigm. Despite the fact that no significant latency differences were found, amplitudes were significantly different at threshold levels between the standard oddball and omitted paradigms. Based on a visual analysis of the waveforms at threshold levels, the P300 waveforms for the omitted paradigm suffered morphologically, more so than the P300 waveforms for the standard oddball paradigm. Squires et al (1975) concluded that when using an omitted stimulus paradigm a P300 will only be elicited when the absence of a stimulus is clearly recognizable. This could explain why the threshold level at which the omitted P300 was established was higher than the threshold level at which the standard oddball P300 was established. At decreased sensation levels the omitted P300 amplitude decreased and had poorer morphology than the standard oddball P300s at threshold levels, regardless of the fact that the threshold level was lower for the standard oddball paradigm. In the case of the omitted paradigm, at suprathreshold levels subjects reported that it was difficult to determine if a stimulus had been omitted, yet at threshold levels subjects reported that the task became even more challenging. This could explain why the omitted P300 thresholds (mean 41.33 dB SL) were higher than the standard oddball P300 thresholds (mean 8.67 dB SL). At the subjects’ behavioral threshold to the tone the task became more difficult to perceive an omitted stimulus, and therefore, no P300 was generated. Thus, higher thresholds were necessary in order to accurately perceive the omission of a tone in order to generate even a meager P300. This idea is supported by Squires et al (1975), who considered that the P300 may be absent in the omitted stimulus P300 when at or near threshold levels because the decision is made with less confidence and the absent target stimulus is less discernable than at suprathreshold levels. In the current study, the difference between the low-intensity frequent tone and the stimulus omissions was small compared to the difference when the frequent tone was at 60 dB SL. It could also be argued, as previously discussed, that the omitted paradigm lacks an exogenous component, unlike the standard oddball paradigm, to drive the P300 waveform, and therefore amplitude, latency, and morphology are poorer. The implications of such findings indicate that omitted paradigm P300s, when being used clinically or experimentally, should be obtained with frequent tones presented at moderately high sensation levels or the waveform might not be present or could be difficult to interpret.

CONCLUSIONS

The comparison of the P300 generated by an omitted paradigm and a standard oddball paradigm offers a glance at the endogenous and exogenous contributions to this waveform. Traditionally considered an entirely endogenous potential, the auditory P300 has been shown to be affected by external stimulus characteristics, alluding to exogenous contributions (Polich et al, 1996; Musiek et al, 2005). In both the omitted and standard oddball paradigms, amplitudes were significantly smaller and latencies were significantly longer for the P300 waveform at threshold levels compared to suprathreshold levels, demonstrating more synchronous neuronal activity at suprathreshold than threshold levels. Also, the intensity level at which P300 threshold was established was significantly higher for the omitted paradigm compared to the standard oddball paradigm, indicating that an external stimulus enhances the P300 waveform, which allows for lower thresholds. In clinical and experimental situations, the P300 is often elicited with the stimuli at the most comfortable listening level, which may not be sufficient to render an interpretable waveform if using an omitted stimulus paradigm. In
addition, this study has shown differences in amplitude, latency, and morphology between the omitted paradigm, where exogenous factors are essentially absent, and the standard oddball paradigm, where exogenous factors exist. Thus, theoretically, these differences are likely the result of the exogenous contributions to the P300 waveform. Audiologically, the P300 may have the capability of assessing higher-level central auditory processing, and thus acknowledging an exogenous contribution to this auditory evoked potential furthers our knowledge as to how the central auditory system functions. Additionally, the differences in amplitude, latency, and morphology between the omitted and standard oddball paradigms further our knowledge of the influence of paradigm and intensity on the P300 waveform. The decrements in amplitude, latency, and morphology in the auditory P300 with the omitted paradigm, as well as the influence of intensity, indicate the presence of exogenous contributions to this endogenous potential.

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