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# Effects of Discrimination Task Difficulty on N1 and P2 Components of Late Auditory Evoked Potential

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**Abstract**

The present study investigated the question of whether, in healthy young listeners, increases in discrimination task difficulty will alter the amplitude of either the N1 or P2 components of the late auditory evoked potential (LAEP). Using a stimulus oddball procedure, listeners discriminated changes in the frequency of ongoing tonal stimuli. On different test runs, task difficulty was manipulated by decreasing the size of the frequency differences and/or adding competing speech babble to the nontest ear. Both stimulus procedures produced significant decreases in P2 amplitude but had no effects on N1 amplitudes. This finding of selective effects on later rather than earlier occurring components of the LAEP provides objective evidence that some forms of auditory processing are mediated at more central levels of the system.

**Key Words:** Central auditory processing, discrimination task difficulty, electrophysiology, evoked responses, late auditory evoked potential, speech competition, tonal frequency

**Abbreviations:** EEG = electroencephalography; LAEP = late auditory evoked potential; N1, P2 = negative and positive voltage components of LAEP; PTA = pure-tone average (500, 1000, and 2000 Hz)

**Sumario**

El presente estudio investigó si en oyentes jóvenes y sanos, los incrementos en la dificultad de las tareas de discriminación alteraría la amplitud de los componentes N1 o P2 en los potenciales evocados auditivos tardíos (LAEP). Utilizando un procedimiento inusual de estimulación, los sujetos discriminaron cambios en la frecuencia de estímulos tonales continuos. En diferentes etapas de evaluación, la dificultad de la tarea fue manipulada disminuyendo el tamaño de las diferencias de frecuencia, y/o adicionando balbuceo competitivo en el oído no evaluado. Ambos procedimientos de estimulación produjeron disminuciones significativas en la amplitud de la P2, pero no tuvieron efecto en las amplitudes de las N1. Este hallazgo de los efectos selectivos sobre los componentes tardíos de los LAEP, más que sobre los componentes tempranos, aporta evidencia objetiva de que algunas formas de procesamiento auditivo están mediados a niveles más centrales del sistema.

**Palabras Clave:** Procesamiento auditivo central, dificultad en las tareas de discriminación, electrofisiología, respuestas evocadas, potenciales evocados auditivos tardíos, competencia de lenguaje, frecuencia tonal

**Abreviaturas:** EEG = electroencefalografía; LAEP = potencial evocados auditivo tardío; N1, P2 = componentes de voltaje negativo y positivo de los LAEP; PTA = promedio tonal puro (500, 1000 y 2000 Hz)

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While many investigators (e.g., Strouse et al, 1998; Fisher et al, 2000; Gordon-Salant and Fitzgibbons, 2001; DeChicchis et al, 2002) believe that temporal processing problems are much more complex than reflections of peripheral deficits, others (Humes and Roberts, 1990; Helfer and Wilber, 1990; van Rooij and Plomp, 1990, 1992; Humes and Christopherson, 1991; Helfer, 1992; Humes et al, 1994) believe that many of the complex listening problems of elderly persons can be explained by loss of sensitivity to high-frequency sounds at the level of the cochlea. These researchers believe that many of the physiologic changes in later occurring evoked potentials such as the N1, P2, and P300 components of the late auditory evoked potential (LAEP) may at least partially reflect this peripheral problem. Although much of the earlier research treated the N1 and P2 components as the "N1-P2 complex" (see Reneau and Hnatiow, 1975) with the implication of similar functional roles, a few earlier evoked potential and magnetoencephalography findings (Roth et al, 1976; Knight et al, 1980; Makela and Hari, 1990; Rif et al, 1991) did suggest that, while N1 and P2 may covary in many dimensions, the N1 response is independent of P2 and may reflect different underlying central processes. Tremblay and Kraus (2002) recently reported that, as listeners learned to discriminate synthetic speech sounds, increases in N1 amplitude were found only in the right hemisphere whereas P2 changes were observed bilaterally. This suggests that N1 and P2 may not only represent different functions but also neural generators located in different brain regions.

In earlier experiments (Martin and Cranford, 1991; Krumm and Cranford, 1994), we obtained evidence that the peak-to-peak amplitudes of the N1/P2 complex, but not the P300, were reduced when competing speech babble was present at the nontest ear. Two recent experiments (Hymel et al, 1998; Fisher et al, 2000) performed in the authors' laboratory provided unexpected new evidence that N1 and P2 may reflect different underlying central auditory functions. In both studies, we utilized topographic brain mapping procedures and investigated competition effects on the N1 and P2 components separately. These studies investigated whether multitalker speech competition at one ear might interfere with the ability of young and elderly listeners to attend to sounds at the opposite ear. In the first experiment (Hymel et al, 1998), participants counted the number of rare (20% probability of occurrence) 2 kHz tones randomly intermixed at one ear among frequent 1 kHz tones (80% probability). On different test runs, continual multitalker speech babble (Auditec) was either present or absent at the opposite ear. The second study (Fisher et al, 2000) was identical to the first except that /da/ and /ga/ syllabic events were used as the frequent and rare stimuli, respectively. The findings from the two studies suggest that either the nature of the target stimuli (i.e., tones vs. speech) or the level of discrimination difficulty of the target stimuli may determine which components of the LAEP are more affected by speech competition. Once again, no experimental changes were found with the P300. Regardless of the competition condition, both young and elderly listeners exhibited minimal difficulty discriminating the tones. With the Fisher et al study, however, while the young participants had no difficulty discriminating the /da/-/ga/ stimuli with the competition either present or absent, elderly listeners exhibited significantly reduced performances in the presence of contralateral competition. With the "easier" tonal task, while the amplitudes of both N1 and P2 were reduced in the presence of speech competition, an age-related difference was only found with N1. Elderly listeners exhibited significantly greater reductions in N1 amplitude than did young listeners. With the "harder" speech discrimination task, in contrast, while no competition-related changes in N1 amplitude were found with either group, elderly listeners exhibited significantly larger decreases in P2 amplitude than did the young group.

The present experiment was designed to investigate the hypothesis that task difficulty per se rather than the nature of the target stimuli might be a critical factor in determining which component of the LAEP is more effected by contralateral competition. This study tested a group of young listeners and found that increases in task difficulty affected the P2 rather than the N1 component of the LAEP.

## METHOD

A group of ten adult females (mean age: 25.5 years; range: 20–35 years) were tested in the present study. The participants were volunteers from the university student body. All were right handed and had a negative history of neurologic disorders, head trauma and/or surgery, otologic disease (including otitis media), vertigo or persistent tinnitus; ototoxic drug use, speech and language disorders, and significant occupational and recreational noise exposure.

### Apparatus and Procedures

***Audiometric Testing*** Tympanometry screening was performed to rule out significant middle ear pathology. Audiometric testing was performed in a sound-treated test booth (IAC) to ensure that the pure-tone average (PTA) of frequencies 500, 1000, and 2000 Hz were at or below 20 dBHL in both ears for all participants.

***Electrophysiologic Testing*** An oddball stimulus paradigm (Squires and Hecox, 1983) was used to evoke the LAEP. The frequent stimulus event in all conditions consisted of a 1000 Hz tone burst with an 80% probability of occurrence. The rare stimulus was either a 1100 Hz tone or a 2000 Hz tone, depending on test condition, with a 20% probability of occurrence. Each tone was 50 msec in duration, with a 10 msec rise-fall time. Three hundred presentations (240 frequent, 60 rare) were made during each test run with a 1.3 ± 0.1 sec interstimulus interval (ISI). Generation and randomization of the tones was performed using a PC-based computer stimulus package (NeuroScan STIM). Competition was provided using the Auditec Multitalker compact disc. Test and competing stimuli were presented at 55 dBSL with regard to the PTA of the ear receiving the respective target signal. All stimuli were presented via Etymotic ER-3A insert receivers. Calibration of stimuli and competing speech babble was performed using a Bruel & Kjaer Type 2231 Modular Precision Sound Level Meter coupled with a Type 4144 condenser microphone and a DB 1038 2-cc coupler.

Electrophysiologic recordings were conducted in a sound-treated and electrically shielded test booth with the participants seated in a reclining chair. Participants were asked to maintain visual fixation on a target placed at eye level on the wall in front of them and to blink normally in order to minimize contamination by ocular movement. Four recording runs were obtained per ear per participant. Two frequency discrimination tasks (1000 Hz versus 2000 Hz, and 1000 Hz versus 1100 Hz) were each run in quiet and again in the presence of contralateral speech competition. The presentation order of the initial test ear was counterbalanced across participants. Participants were instructed to ignore the speech competition when present and keep a mental count of the total rare tones heard during each test run. On all four types of test runs (easy versus hard tonal discrimination, presence or absence of competition), all participant counts fell within ±4 of the correct count of 60 deviant stimuli per run.

Neuroelectrical activity was recorded from 19 electrodes (FP1, FP2, F7, F3, Fz, F4, F8, T3, C3, Cz, C4, T5, P3, Pz, P4, T6, O1, and O2), fixed to the scalp with a commercial electrode cap (NeuroScan QuickCap) according to the International 10-20 system, referenced to linked mastoids. Ocular movement was monitored by electrodes placed vertically above and below the left eye. Electrode impedances were maintained below 3000 ohms. Individual sweeps of time-locked electroencephalographic (EEG) activity extended from -100 to +1000 msec relative to stimulus onset. EEG activity was amplified 1000 times, analog filtered (1–70 Hz, 24 dB/octave slope), and digitized at an analog-to-digital rate of 500/sec with a PC-based NeuroScan system and SynAmps 16-bit amplifiers.

The digitized epochs were then sent to a microcomputer for offline averaging and digital filtering (1–40 Hz, 24 dB/octave slope). The 100 msec pre-stimulus recording obtained at each electrode site was used to establish a baseline to correct for the DC (direct current) levels of spatio-temporal fluctuations in background EEG activity. Ocular movement artifacts were digitally removed from the epochs (Semlitsch et al, 1986). Epochs containing artifacts exceeding ± 50 microvolts were rejected from averaging. Epochs were sorted by type and averaged into frequent and rare stimuli. Grand-averaged waveforms were then constructed by ear/discrimination task/listening condition for analysis.

## RESULTS

The present study found that, in all test conditions, maximum amplitudes for both N1 and P2 components were centered in the vicinity of the Cz electrode site, with minimal

**Table 1. Mean Amplitudes (microvolts) and Standard Errors (in parentheses) of N1 and P2 Potentials Recorded at Each Ear in Each of Four Test Conditions**

| | Left Ear | | Right Ear | |
|---|---|---|---|---|
| | **Quiet** | **Comp.** | **Quiet** | **Comp.** |
| N1—1.0 kHz vs. 2.0 kHz Task | -3.85 | -4.21 | -4.91 | -3.96 |
| | (1.14) | (1.62) | (1.61) | (1.45) |
| N1—1.0 kHz vs. 1.1 kHz Task | -4.10 | -4.53 | -4.87 | -3.69 |
| | (1.82) | (1.53) | (1.78) | (1.57) |
| P2—1.0 kHz vs. 2.0 kHz Task | 5.29 | 5.43 | 6.37 | 5.05 |
| | (2.38) | (1.93) | (2.15) | (2.0) |
| P2—1.0 kHz vs. 1.1 kHz Task | 4.58 | 4.21 | 5.32 | 4.36 |
| | (1.91) | (1.52) | (1.68) | (1.74) |

differences in amplitudes across the scalp. Therefore, in the present study, all statistical analysis of amplitude data was restricted to Cz. The respective waveform peaks were independently selected by each of three experienced examiners with a required two-thirds consensus. N1 peak amplitude was defined as the lowest negative voltage value occurring between 75- and 150-msec post stimulus onset (Alexander et al, 1996). P2 peak amplitude was defined as the highest positive voltage value occurring between 150- and 250-msec poststimulus onset. Table 1 shows mean amplitudes (and standard errors) for the present N1 and P2 data.

Two separate three-way repeated measures analyses of variance (ANOVAs) were used to examine the N1 and P2 findings with respect to the variables of ear (right versus left), discrimination task (1000 Hz/2000 Hz versus 1000 Hz/1100 Hz), and listening condition (quiet versus contralateral competition). Omega squared values were also generated to examine the proportion of variance accounted for by the independent variable (Keren and Lewis, 1979; Keppel, 1991). Experiments producing omega squared values of .15 or greater are considered to have large effect sizes (Cohen, 1977).

Figure 1 shows the group-averaged waveforms recorded from Cz at each ear for

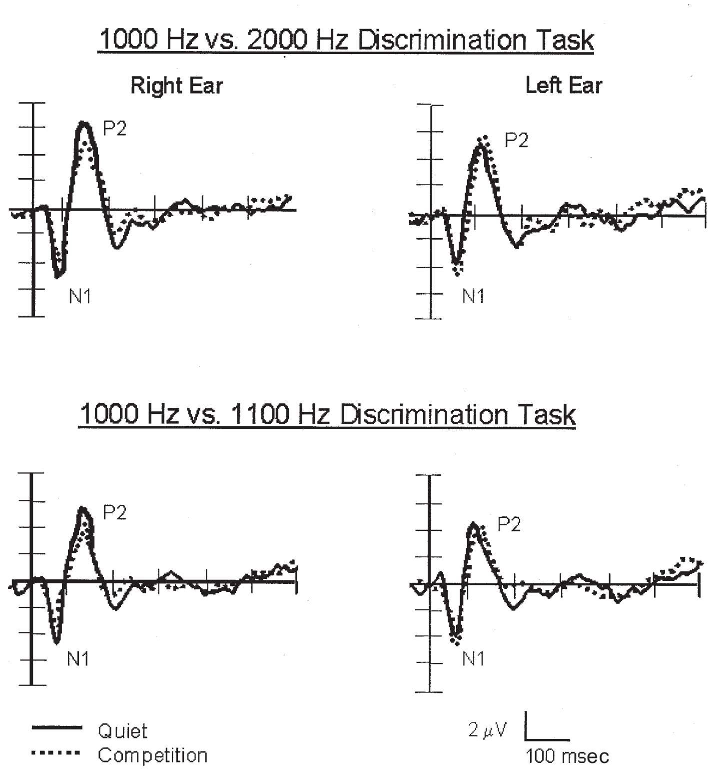


**Figure 1.** Grand-average N1 and P2 waveforms recorded to each of four discrimination task difficulty conditions from a vertex (Cz) electrode location.

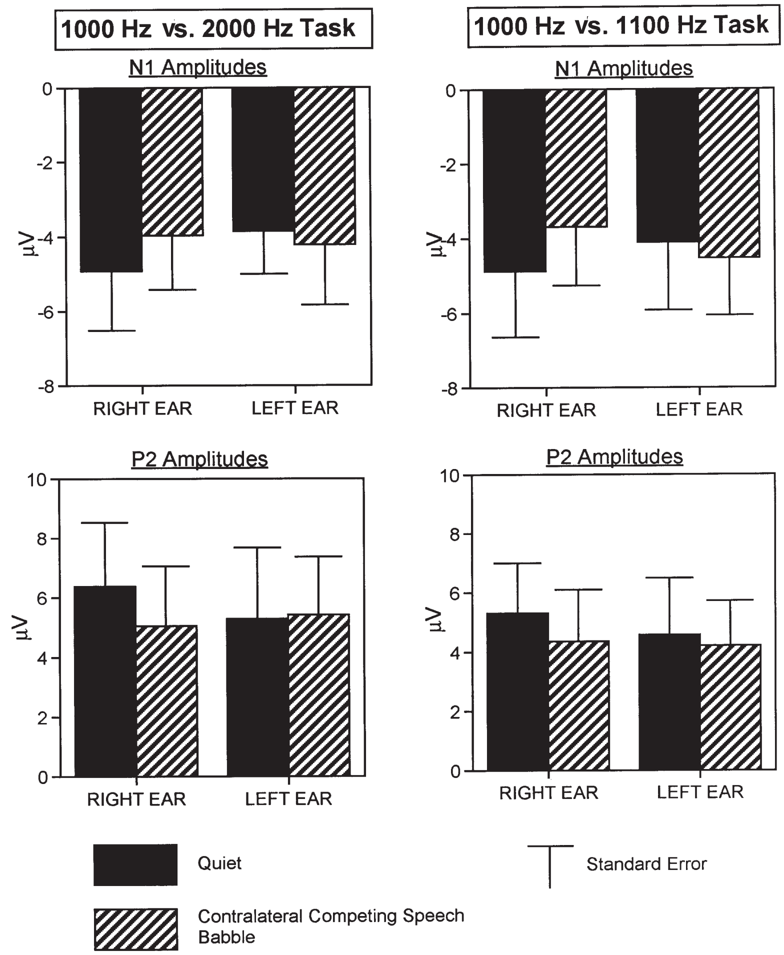


**Figure 2.** Mean amplitudes of N1 and P2 components recorded in response to each discrimination task difficulty condition.

the different test conditions. With respect to the N1 component, the present experiment found no significant changes in amplitude related to the discrimination task difficulty [F(1,9) = 0.127, p = 0.73, $\omega^2$ = .08] or competition [F(1,9) = 4.234, p = 0.32, $\omega^2$ = 0.04] variables. However, with P2, statistically significant main effects were found for both task difficulty [F(1,9) = 10.95, p = 0.009, $\omega^2$ = 0.475] and competition [F(1,9) = 5.538, p = 0.04, $\omega^2$ = 0.292]. The interaction between the task difficulty and competition variables, however, was nonsignificant [F(1,9) = 0.444, p = 0.522, $\omega^2$ = 0.05]. Figure 2 depicts the mean amplitude changes observed with N1 and P2. Although nonsignificant for both N1 [p ≥ .30] and P2 [p ≥ 0.24], this study found some evidence that, with both competition and increased task difficulty, greater decreases in amplitude occurred with target stimuli in the right ear.

## DISCUSSION

Thus, in young adults, it appears that increasing task difficulty as well as adding speech babble competition to the contralateral ear both produce significant decreases in P2 amplitude. The omega squared effect sizes for both experimental manipulations was large (Cohen, 1977). N1 amplitude, in contrast, was not affected by either stimulus manipulation. These findings appear to be in agreement with the earlier findings of Fisher et al (2000) that contralateral speech competition affects P2 but not N1. Hymel et al (1998), in contrast, found effects with N1 but not P2. The present data, therefore, supports the hypothesis that the differential effects found with P2 in these two earlier studies may have reflected differences in discrimination task difficulty rather than the nature of the target stimuli (tones vs. speech). It is worth noting, however, that the competition and task difficulty variables did not appear to have an additive effect. If each variable independently produces decreases in P2 amplitude, it might be expected that the magnitude of the effect would be increased by the simultaneous application of both variables. This suggests the existence of possible ceiling effects with respect to changes in P2 amplitude.

The findings of Fisher et al (2000) combined with the present results, which indicate that later (P2) rather than earlier (N1) components of the LAEP are affected by task difficulty and/or competition, provides objective physiologic evidence that such aspects of normal listening do reflect processing at higher stages of the central auditory nervous system rather than at the cochlear level. If central auditory processing problems were, in fact, a carryover of cochlear sensitivity problems, we would not expect such effects to "skip" the N1 level of the neural chain and specifically target the later occurring P2 component. Of course, while N1 and P2 appear to reflect different underlying neural functions, the question of whether they represent successive stages (i.e., a chain) of processing or parallel systems is a question that needs further investigation. The present experiment indicates that systematic manipulation of isolated stimulus or response variables of a task and looking for correlated changes in specific neural components is a viable technique for identifying structure-function relationships in the brain.

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