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Effects of Contralateral Speech Competition on the Late Auditory Evoked Potential in Children

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Abstract

Researchers recently reported evidence of a possible electrophysiologic correlate of impaired binaural processing or attention in elderly subjects. This experiment found that the presence of speech competition in the contralateral nontest ear produced significantly greater decreases in the peak-to-peak amplitude of the N_1–P_2 component of the late auditory evoked potential (LAEP) in an older group of subjects (50 to 80 years of age) than in a younger group (20 to 49 years). The present study used this same test paradigm with groups of children ranging in age from 7.5 to 14.9 years of age to investigate whether a comparable age-related effect might be found at the other end of the normal age spectrum in younger children. While the present children did exhibit statistically significant reductions in LAEP amplitude in the presence of speech competition, the magnitude of this effect did not differ among the different age groups.

Key Words: Binaural competition, children, late auditory evoked potentials (LAEPs)

Courchesne (1983) suggested that late auditory evoked potentials (LAEPs) can provide researchers with valuable clues about central auditory nervous system (CANS) development and concurrently emerging behavioral correlates. In addition to developmental studies, a number of investigators have used LAEPs in the study of pediatric CANS pathology at the level of the cortex (Zambelli et al, 1983; Martineau et al, 1987; Satterfield et al, 1988; Jirsa and Clontz, 1990). Most LAEP experiments conducted with children to diagnose CANS dysfunction, however, have utilized binaural (diotic) presentation of pure-tone stimuli. This is an important issue related to LAEP testing, since previous researchers have concluded that audiometric protocols that incorporate contralateral competing stimuli are more sensitive measures for identification of cortical dysfunction (Bocca et al, 1955; Jerger and Jerger, 1975; Musiek and Baran, 1987).

The possible value of using competing stimuli was shown in recent studies (Martin and Cranford, 1989; Cranford and Martin, 1991) that found evidence for an evoked-potential correlate of impaired binaural processing in elderly listeners. Groups of subjects, ranging in age from 20 to 80 years, were tested in an evoked-potential paradigm that measured the effects of competing speech babble at one ear on the LAEP elicited by tonal stimuli at the opposite ear. While the contralateral speech competition produced no significant amplitude or latency changes in the earlier auditory brainstem or middle latency responses, a statistically significant aging effect was observed with the later-occurring LAEP responses. With contralateral competition, the older groups exhibited significantly larger reductions in the N_1–P_2 peak-to-peak amplitude of the LAEP than did the younger groups. The present study was designed, therefore, to use the Cranford and Martin (1991) test protocol to investigate whether a similar age-related competition effect, perhaps related to maturational factors,

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might occur at the other end of the age spectrum in young children.

METHOD

Subjects

Fifty-four children were tested in the present study. Subjects were separated into three age groups: 7 years, 6 months to 9 years, 11 months (M = 8.7 years; SD = 0.63 years); 10 years, 0 months to 12 years, 5 months (M = 11.3; SD = 0.84); and 12 years, 6 months to 14 years, 11 months (M = 14.0; SD = 0.60). There were 19 subjects in the youngest group (9 male, 10 female), 19 subjects in the middle group (10 male, 9 female), and 16 subjects in the oldest group (8 male, 8 female). An additional 5 subjects were excluded from testing after they were found to have evidence of middle ear pathology or had received special education services. All test subjects fell within the 50th to 85th percentile on nationally standardized academic group tests (the Iowa Test of Basic Skills or the Stanford Achievement Tests). Based on parental reports, all children had negative histories of head injury or other forms of neurologic or psychological problems. All subjects had pure-tone thresholds (ANSI, 1989) that ranged between –5 dB HL and 15 dB HL from 250 Hz to 8000 Hz. Tympanometry screenings demonstrated normal admittance and middle ear pressure within the range of –100 mm/H_2O to +50 mm/H_2O. All audiometric and subsequent evoked-potential testing was performed in a sound-treated IAC booth.

Electrophysiologic Measures

For all tests, a Nicolet Compact Auditory Electrodiagnostic System was used for acquisition of evoked-response data and for generation of the different probe stimuli. Auditory stimuli were presented through Telephonics TDH-39 earphones mounted in MX 41/AR cushions. The commercially available Auditec Four-Talker Tape was used for presentation of competing speech to the nontest ear. This tape is a recording of four persons simultaneously reading aloud four different story passages. The tape was played on a standard cassette tape deck channeled through a Grason-Stadler 1701 clinical audiometer. The competing stimulus was presented to the nontest ear at an intensity level of 50 dB above the subject's pure-tone average threshold (at 0.5, 1, and 2 kHz) via a TDH-39 earphone.

An "oddball" stimulus presentation pattern was employed for evoking the LAEP (Squires and Hecox, 1983). This paradigm permits monitoring of subject attentiveness, since LAEP waveform definition is dependent on subject attention (Hillyard and Kutas, 1983). The oddball pattern consists of the random presentation of a stream of two different frequency tones, the two tones being referred to as either the rare or frequent tone. The probability of either tone being presented at each stimulus interval was predetermined with a 20 percent probability of the rare tone being presented and an 80 percent probability of presentation of the frequent tone. A 750-Hz tone was used for the frequent tone while a 2000-Hz tone served as the rare tone.

Table 1 shows the stimulus and acquisition parameters used in the LAEP tests. Electroencephalogram (EEG) activity was recorded from the vertex (Cz electrode site in the international 10–20 system) with a forehead ground, and referenced to the earlobe of the ear receiving the tone-burst stimuli. The tones were 20 msec in duration with a rise–fall time of 2 msec and were presented with an interstimulus interval of approximately 1.4 sec. The intensity of the two tones was set at 70 dB above each subject's pure-tone threshold at 750 and 2000 Hz, respectively. Electrode impedances were maintained below 5000 ohms and balanced within 2000 ohms of each other. A total of 150 artifact-free trials defined one complete run and were computer averaged to obtain the final tracing. Only waveforms recorded from the 750-Hz frequent tones (approximately 120 per trial) were analyzed in this study. Extraocular electrodes were not used to monitor eye movements and automatically reject contaminated trials. In order to minimize contamination from eye-

Table 1 Stimulus and Acquisition Parameters for LAEP Recordings

EEG Amplifier Gain	10,000
Sensitivity (microvolts)	100
Low-Frequency Filter (Hz)	1
High-Frequency Filter (Hz)	30
Time Window (msec)	800
Stimulus-Presentation Rate	0.7/sec
Artifact-Free Sweeps	150
Stimulus-Polarity	Condensation
Stimulus Rise/Fall (msec)	2
Stimulus-Plateau Time (msec)	20

movement artifacts, subjects were required to maintain fixation on a visual target prepared for this purpose during each test run. Thus, with the present 100-μV sensitivity setting, some eye-movement contamination may have occurred. Subjects were instructed to press a hand-held switch located within the sound booth (which advanced a counter located outside the booth) each time the 2000-Hz tone was heard during the trial run. Following the completion of the trial, the subjects were informed of the accuracy of the rare tone count. None of the subjects exhibited counts that varied by more than ±5 of the actual number presented. A total of four recording runs was obtained per ear per subject. Each subject was tested in two presentation modes: (1) tone stimuli in one ear with no stimulus in the opposite ear; and (2) tone stimuli in the test ear and speech competition in the opposite ear. For each ear condition, the competition and no-competition conditions were alternated across the four recording runs. The two repetitions of each condition allowed for determination of reliability of the response and counteracted any fatigue effects. The presentation order of the competition was counterbalanced to control for any possible order effects. The ear tested first was alternated between subjects so that half of the subjects were tested with the probe-right condition first and the other half were tested with the probe-left condition first.

LAEP data were analyzed using procedures similar to those reported in previous studies with children (Callaway, 1975; Courchesne, 1983; Satterfield et al, 1988). Specifically, the N_1 waveform was identified as the first prominent negative peak occurring at or after approximately 100 msec, and the P_2 waveform was identified as the first prominent positive peak following N_1. Clearly identifiable peaks, with similar latencies and amplitudes, had to be present in both the original and replication runs to be accepted for analysis. The N_1–P_2 peak-to-peak amplitudes (in microvolts) on the two runs were averaged. The second author analyzed the raw waveform tracings without knowledge as to the age or sex of the child or whether contralateral speech competition had been present or absent. Eighteen subjects (7 in the young, 7 in the middle, and 4 in the older group) failed to exhibit repeatable waves in one or more test runs and were excluded from final data analysis, leaving a total of 36 test subjects in the experiment. The 18 eliminated subjects fell within the range of the other subjects with respect to accuracy of rare tone counts plus performance on academic achievement tests.

RESULTS AND DISCUSSION

In agreement with Cranford and Martin (1991), the present study found that N_1 and P_2 latencies were not affected by the presence of contralateral speech competition. Three-way ANOVAs (age × test ear × competition condition, with repeated measures over the last two factors) revealed nonsignificant changes in both N_1 ($F[1, 33] = .045$, $p = .83$) and P_2 ($F[1, 33] = .324$, $p = .57$) latency. Table 2 shows these findings.

The means and standard deviations of the N_1–P_2 peak-to-peak amplitudes measured with and without contralateral speech competition are shown in Table 3, while examples of LAEP tracings obtained with subjects in each age group are shown in Figure 1. The present study confirmed the basic results of the Cranford and Martin study (1991) in finding the amplitude of the N_1–P_2 component of the LAEP to be significantly smaller at both ears (three-way repeated measures ANOVA; $F[1, 33] = 28.97$, $p < .0001$) when measured with speech competition at the opposite ear.

To make the present data analysis comparable to that used in the earlier studies (Martin and Cranford, 1989; Cranford and Martin (1991), percentage reduction scores (i.e., percentage decrease in N_1–P_2 peak-to-peak amplitude in the presence of contralateral competition) were computed for all subjects. These data are shown in Table 4, and a comparison with the Cranford and Martin (1991) data are shown in Figure 2. Whereas Cranford and Martin (1991) found evidence for the existence of possible reduced or "compromised" binaural processing in their older adult subjects, the present data revealed no evidence of an age effect with children. The magnitude of the amplitude-reduction scores did not differ among the three age groups at either ear (3 × 2 repeated measures ANOVA; $F[2, 33] = 1.049$, $p = .36$). This finding may reflect the considerably greater intersubject variability seen with the present children in contrast to the elderly subjects of the earlier investigation. Children, in comparison to adults, are known to exhibit considerably greater response variability with respect to these later-occurring cortical potentials (Goodin et al, 1978; Martin et al, 1988).

Because most previous LAEP studies with young children used different procedures and

Table 2 Means (and Standard Deviations) of N_1 and P_2 Latencies (Msec) Measured in Presence or Absence of Contralateral Speech Competition

	Young Group		*Middle Group*		*Older Group*	
	LE	*RE*	*LE*	*RE*	*LE*	*RE*
N_1 Latency						
Quiet	149.9 (45.7)	147.2 (47.4)	123.5 (48.5)	119.7 (41.4)	102.4 (12.6)	99.7 (12.5)
Speech	160.0 (59.2)	144.3 (58.2)	124.5 (55.7)	111.7 (49.1)	102.9 (19.0)	102.4 (10.8)
P_2 Latency						
Quiet	243.5 (78.1)	241.3 (83.7)	205.9 (62.2)	201.9 (72.5)	198.6 (37.3)	188.3 (30.5)
Speech	255.2 (88.5)	238.4 (86.6)	207.2 (69.4)	192.3 (66.6)	188.5 (35.8)	190.7 (35.9)

LE = left ear, RE = right ear.

conditions from those of the present investigation, the authors found it difficult to critically evaluate the validity of the present research findings. Previous studies involved numerous differences with respect to subject characteristics, EP recording methods, and stimulus-presentation/subject-response procedures (see Courchesne, 1983, for a recent review). For example, while several earlier studies used a stimulus "oddball" procedure (e.g., Martin et al, 1988; Jirsa and Clontz, 1990) and recorded responses from the midline (Cz) similar to the present study, all of the earlier studies, unlike the present study, used diotic tonal stimulation without any form of interaural competition. The present research findings do, therefore, conflict with those of some earlier studies. For example, while the present study found evidence of a decline in latency for both N_1 and P_2 over the age range of approximately 7.5 to 15 years, other studies (Dustman, Schenkenberg, and Beck, 1976; Goodin et al, 1978; Martin et al, 1988) reported no significant latency changes over this same age range. Two studies (Ohlrich and Barnet, 1972; Barnet et al, 1975) even reported evidence that children may exhibit LAEPs with close to "adult" morphology (latency, amplitude) before 1 year of age. However, while the present observed decline in N_1 latency was significant (three-way repeated measures ANOVA; F [2, 33] = 4.547, p = .02), that for P_2 latency was not significant (F [2, 33] = 2.347, p = .11).

Although the present children exhibited a nonsignificant age effect with respect to competition-related reductions in N_1–P_2 amplitude, the authors believe the potential importance of this topic area demands further investigation. The possibility of being able to identify electrophysiologic correlates of "compromised"

Table 3 Means (and Standard Deviations) of the N_1 – P_2 Peak-to-Peak Amplitudes (Microvolts) Measured in Presence or Absence of Contralateral Speech Competition

	Young Group		*Middle Group*		*Older Group*	
	LE	*RE*	*LE*	*RE*	*LE*	*RE*
Quiet	10.9 (5.2)	10.3 (4.0)	9.6 (4.5)	6.9 (3.1)	9.4 (2.8)	11.1 (3.5)
Speech	6.5 (2.8)	6.8 (1.9)	6.6 (2.6)	6.9 (2.6)	8.1 (2.3)	9.0 (3.6)

LE = left ear, RE = right ear.

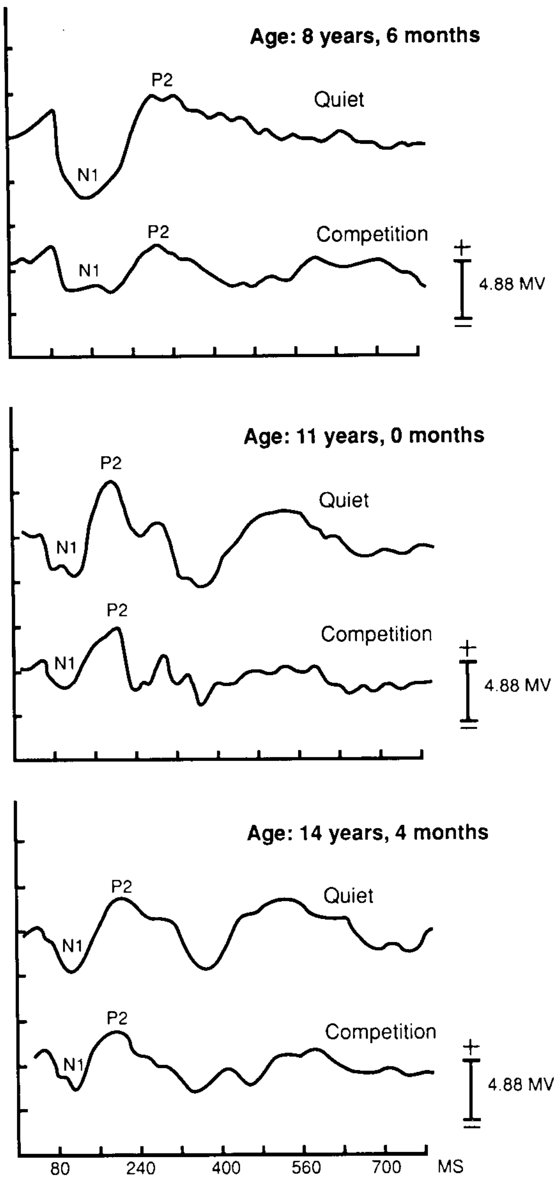

Figure 1 Examples of LAEP tracings obtained from children in the three age groups. Computer averages of the original and replication test runs are shown.

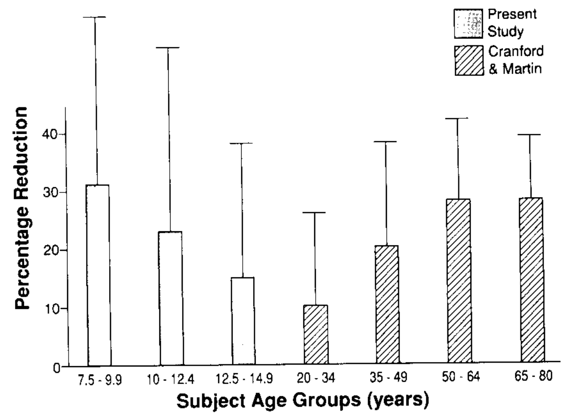

Figure 2 Compares results obtained in the present study with those of Cranford and Martin (1991). While the age effect found with adult subjects in the Cranford and Martin study was statistically significant, the age effect observed with the present children was nonsignificant.

Table 4 Means (and Standard Deviations) of the Percentage of N_1–P_2 Peak-to-Peak Amplitude Reduction Measured in the Presence of Contralateral Speech Competition

	Age Group		
	Young Group	*Middle Group*	*Older Group*
Right Ear	27.0% (29.9)	23.9% (34.9)	17.5% (20.3)
Left Ear	35.3% (32.3)	22.8% (34.2)	11.3% (31.2)
Average	31.1%	23.3%	14.4%

binaural processing in children and elderly adults could have considerable significance for aural rehabilitation purposes as well as facilitating early childhood education. Noise in the classroom environment may be a significant handicapping factor for even the normal young child. The present test might also provide important insights into the neurophysiologic substrates of certain forms of communication problems in children (Zambelli et al, 1983; Mason and Mellor, 1984; Satterfield et al, 1988; Jirsa and Clontz, 1990). For a test of this type to have clinical significance, however, future research must investigate and, if possible, develop a means of controlling the large degree of response variability seen in the present study. At issue is whether this variability is the result of particular behavioral test or LAEP recording protocols or is due to inherent intersubject differences (perhaps related to neural maturation) or intrasubject variability over time (reflecting possible changes in attention or central auditory processing functions). Future investigations should also broaden the age range to include children younger than 7 years.

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