Effects of Monaural versus Binaural Stimulation on $P_{300}$ Scalp Topography in Elderly Listeners

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Abstract
The $P_{300}$ event-related potential was recorded from groups of young and elderly listeners in response to monaural and binaural stimulation. An oddball stimulus paradigm was used to record responses from 19 scalp locations. When listening to binaural stimuli, the young group showed midline and central $P_{300}$ amplitude maxima, whereas the elderly group exhibited maximal responses in the midline and parietal regions. With monaural stimulation, the young group’s responses were similar to those obtained with binaural stimulation. The elderly group, however, showed evidence of a greater contralateral hemisphere response to monaural stimulation during the early part of the $P_{300}$ response. These findings support the possibility that the $P_{300}$ neural generators may change with age with respect to temporal onset characteristics or their orientation and strength.

Key Words: Auditory event-related potentials, auditory evoked potentials, brain map, elderly, $P_{300}$ scalp topography

Abbreviations: EEG = electroencephalographic, GFP = global field power

The late cortical evoked potentials can be categorized into those that depend on the physical nature of the eliciting stimulus (exogenous) and those that depend on the psychological or cognitive processing (endogenous) of stimulus information by the listener. Whereas exogenous potentials provide useful information regarding the physiologic integrity of peripheral and central sensory pathways, endogenous potentials provide important clues to the nature of higher mental functions. Beginning with the pioneering report by Sutton et al (1965), the $P_{300}$ has become the most widely investigated of the endogenous potentials. The $P_{300}$, a positive voltage event-related potential with a latency of 300 msec or longer, occurs in response to unexpected task-dependent stimuli presented randomly within the context of expected stimuli. The $P_{300}$ appears to be correlated with cognitive functions such as sequential information processing, stimulus discrimination, and short-term memory (Squires et al, 1976; Donchin, 1981). It has been found to be abnormal in a number of brain dysfunctions, including dementia and schizophrenia (Goodin et al, 1978; Brown et al, 1982; Syndulko et al, 1982; Neshige et al, 1988), Alzheimer’s disease (Ball et al, 1989; Polich et al, 1990; Holt et al, 1995), and central auditory processing disorders (Jirsa and Clontz, 1990).

There is evidence that the source of the $P_{300}$ recorded from the scalp may involve separate neural generators at multiple levels of the nervous system. Intracranial recording studies and tests in humans with brain lesions (Halgren et al, 1980; Knight, 1984; Yingling and Hosobuchi, 1984; Smith et al, 1990) have reported $P_{300}$-like waves in several different cortical and subcortical areas, including the frontal and temporoparietal cortex, the hippocampus and amygdala, and the pons and midbrain regions.
Several studies have compared the scalp topography of P300s in young and elderly listeners in an attempt to define possible age-related differences in underlying neural generators. Numerous studies (e.g., Goodin et al, 1978; Smith et al, 1980; Pfefferbaum et al, 1984; Picon et al, 1984; Ford and Pfefferbaum, 1991; Friedman et al, 1993, 1997; Kugler et al, 1993; Vesco et al, 1993; Polich et al, 1997) have reported that P300 amplitude maxima are centered in the parietal region in young listeners in contrast to a more frontally oriented scalp focus in the elderly. Although earlier P300 research used a large variety of test and recording methods, binaural stimulation has been the standard procedure used in this field. To the best of our knowledge, only one report used monaural stimulation to evoke the P300.

Hymel et al (1998) recently reported evidence that monaural stimulation may produce patterns of P300 scalp activity that differ markedly between young and elderly listeners. In their study, participants were required to attend to oddball tonal sequences in one ear in the presence of competing speech babble in the opposite ear. Whereas young subjects exhibited P300 maxima that remained centered at C, despite changes in stimulus ear or competition condition, the elderly group had P300 maxima that were centered in the parietal region of the hemisphere located contralateral to the test ear. This suggests that the P300 neural generators may change with age (i.e., the onset timing or the orientation and strengths of the equivalent current dipoles may be different). The present experiment was designed, therefore, to compare the P300 scalp topography of young and elderly listeners in response to monaural versus binaural stimulation.

**METHOD**

**Participants**

Ten young and 10 elderly listeners were tested. The younger group (5 male, 5 female; 20–26 years, mean = 23 years, 3 months) had pure-tone averages (500, 1000, and 2000 Hz) that were 20 dB HL or less, with interaural differences less than 10 dB HL at 1000 and 2000 Hz. The elderly participants (5 male, 5 female; 68–78 years, mean = 72 years, 1 month) were paid for their participation. All older listeners had pure-tone averages that were 30 dB HL or less, with interaural differences less than 10 dB HL at 1000 and 2000 Hz. All participants were right handed with negative histories of neurologic or otologic problems.

**Stimulus Test Procedures**

An oddball paradigm (Squires and Hecox, 1983), with infrequent (20% probability) 2000-Hz tones occurring randomly in a string of frequent (80% probability) 1000-Hz tones, was presented to either the right or left ear (monotic test condition) or to both ears (diotic test condition). Unlike the Hymel et al (1998) study, no contralateral speech competition was present during monotic test runs. The order of presentation of the three types of test runs was counterbalanced using Latin Square logic. Each tone was 50 msec in duration with a 10-msec rise–fall time. Three hundred presentations (240 frequent, 60 infrequent) were made during each test run with a 1.3 ± 0.1 sec interstimulus interval. Stimuli were presented using insert receivers (Etymotic ER-3A) at 72 dB pSPL.

**Apparatus and Recording Procedures**

Electrophysiologic recordings were conducted in a sound-treated and electrically isolated test booth with participants seated in a reclining chair. They 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. Participants were instructed to count the number of higher-pitched (infrequent) tones heard. All listeners in both groups exhibited counts that varied by no more than ± 5 of the actual number presented (60). Electroencephalographic (EEG) activity was recorded from 19 scalp locations (FP1, FP2, F3, F4, F5, F6, T3, T4, C3, C4, T5, T6, P3, P4, T, O1, and O2) using an ElectroCap referenced to linked earlobes. Vertical eye movements were recorded from electrodes placed above and below the left eye. Electrode impedance was maintained below 3000 ohms. Individual sweeps of time-locked EEG activity extended from −100 to +1000 msec relative to stimulus onset. EEG activity was amplified 500 times, analog filtered (1–70 Hz, 24 dB/octave slope), and digitized at an A/D rate of 500/sec with a PC-based NeuroScan system and SynAmps 16-bit amplifiers. The digitized epochs were averaged offline, filtered digitally (1–35 Hz, 24 dB/octave), and used to construct topographic brain maps. The 100-msec prestimulus recording obtained at each electrode site...
was used to establish a baseline to correct for the DC level of background EEG activity. Ocular movement artifacts were digitally removed from the epochs (Semlitsch et al., 1986). Epochs containing artifacts exceeding ± 50 µV were rejected from averaging. In the present investigation, the P300 was defined as the highest positive peak (relative to baseline) occurring after 250 msec. Two experienced examiners (RD and JC) independently selected P300 peaks from the averaged waveforms of individual participants. The two examiners had to be in agreement on selection of amplitude/latency values before entering the data into the spreadsheet. If not, a third experienced examiner (MH) was used to obtain a two-thirds consensus. Waveforms were examined without knowledge as to test condition (monotic or diotic).

To facilitate production of topographic maps, global field power (GFP) waveforms were constructed for each grand-averaged waveform (Skrandies, 1989, 1990). Based on these GFP waveforms, latencies of maximal P300 activity across all electrode locations were selected for the diotic and the two monotic test conditions. These latencies were then used as the temporal center for the respective maps. A four-point linear interpolation algorithm was used for constructing the maps. Voltage scales for the different group maps were set to maximize the number of color gradients present, allowing more detailed visualization of the topographic location of P300 activity.

RESULTS AND DISCUSSION

The present investigators used procedures similar to those reported by Hymel et al. (1998), including measurement and analysis of amplitudes from the same group of nine electrodes centered around the vertex (F3, F4, C3, C4, P3, P4, and P1). Figure 1 shows group-averaged topographic maps of P300 activity obtained with the present participants. Examination of these maps reveals two expected differences between the groups. First, in the elderly group, the overall amplitude is smaller than in the younger group, as evidenced by the different scales. Second, the mean latency of the response is approximately 120 msec later in the elderly group than in the younger group. Decreased P300 amplitude and increased latency in elderly listeners have been confirmed by numerous earlier studies (e.g., Goodin et al., 1978; Brown et al., 1983; Pfefferbaum et al., 1984; Picton et al., 1984; Kugler et al., 1993; Sangal and Sangal, 1996; Polich, 1997).

The present experiment replicated the Hymel et al. (1998) finding that, in both young and elderly listeners, maximum P300 amplitudes were centered more in the posterior cortical areas. Examination of the maps reveals that the elderly group exhibited P300 amplitude maxima that tended to be located more posteriorly than that of the young listeners. This latter finding is supported by the finding of a significant analysis of variance (mixed three-factor, p = .004) listening group by electrode location interaction. The discrepancy between our findings and those of earlier investigations, which reported more frontal scalp maxima in the elderly, is not easily explained in terms of differences in testing or EEG recording methods. Although different electronic test systems were involved, the studies used similar filtering and recording techniques, reference electrode placements (linked earlobes or mastoids), stimulus presentation, and patient task requirements. The present study also contraindicates a possible explanation for these topographic differences based on the use of monaural stimulation. With binaural stimulation, the present listeners showed similar maximal scalp topographies to those found with monaural stimulation. Figure 1 shows some evidence, however, that in the early portions of the P300 response of elderly listeners, higher amplitude activity tended to be located more in the posterior parietal area of the contralateral hemisphere.

Recently, there has been some discussion (e.g., Friedman et al., 1993, 1997; Anderer et al., 1996) regarding the extent to which age-related changes in P300 scalp topography may reflect structural changes (e.g., neural atrophy) as opposed to functional (e.g., changes in patterns of brain activation) or psychological (e.g., changes in the nature of the responses to differing task variables) factors. The Hymel et al. (1998) study, unlike the present study, required participants to actively ignore speech babble competition in the nontest ear. This may have produced a psychological set in the listeners involving more strongly focused attention to the test ear that, in turn, could have resulted in a greater degree of lateralized cortical activity. In this regard, it is interesting that, in a brain map investigation of middle latency evoked potentials in elderly listeners, Marvel et al. (1992) also observed a large contralateral response to monaural stimuli in combination with a midline response to binaural stimuli. The present experiment, therefore,
Figure 1  Topographic maps of the $P_{300}$ as recorded from young and elderly listeners in response to monaural and binaural stimulation. Shown are a series of images ("cartoons") depicting the development of the $P_{300}$ response over time. Each map depicts averaged activity in 10-msec windows centered at each of five poststimulus times. To contrast changes in amplitude, thick white lines were drawn to outline the areas of maximum positive voltage within each group (young, elderly) of maps, while thin white lines outline the next highest gradient.
suggests that the future contribution of brain mapping techniques may be more in revealing the temporospatial patterns of scalp activity involved in specific psychological processes rather than in identifying the physical locations of neural generators (Cranford and Hymel, 1998).

REFERENCES


