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Cortical Cognitive Potentials in Elderly Persons

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Abstract

The purpose of this study was to analyze the changes in the acoustically evoked cortical cognitive potentials N 200, P 300, and N 3 with age. There were 232 participants, who were 60 years or older, and each was examined using a battery of audiological tests including a questionnaire, otomicroscopy, pure-tone audiometry, and cortical cognitive potentials, measured at Fz using an auditory oddball paradigm. N 200 was elicited in 46.9%, P 300 in 45.1%, and N 3 in 52.2% of the elderly participants. The most significant predictors for presence of cortical responses were the participant's age and hearing level at target tone frequency. Monosyllabic speech recognition score was a less important predictor for presence of response. Response latency in the elderly sample increased steadily with age. Few changes in cortical response amplitude were found with age. We conclude that the speed of central auditory processing seems to be reduced with age.

Key Words: Aging, cortical cognitive potentials, elderly, event-related potential, presbyacusis

Abbreviations: ERP = event-related potential

Sumario

El propósito de este estudio fue analizar los cambios debidos a la edad en los potenciales cognitivos corticales N 200, P 300 y N 3 evocados acústicamente. Participaron 232 sujetos mayores de 60 años, quienes fueron examinados usando una batería de pruebas audiológicas incluyendo cuestionarios, oto-microscopía, audiometría tonal y potenciales cognitivos corticales, medidos en Fz con un paradigma auditivo inusual. La onda N 200 se generó en 46.9%, la P 300 en 45.1% y la N 3 en 52.2% de los participantes más viejos. Los elementos predictivos más significativos para la presencia de respuestas corticales fueron la edad y el nivel auditivo en el tono frecuencial meta. La latencia de la respuesta en la muestra de ancianos se incrementó establemente con la edad. Se encontraron pocos cambios relacionados con la edad en la amplitud de la respuesta cortical. Concluimos que la velocidad del procesamiento auditivo central parece reducirse con la edad.

Palabras Clave: Envejecimiento, potenciales cognitivos corticales, ancianos, potenciales relacionados con el evento, presbiacusia

Abreviaturas: ERP = potencial relacionado con el evento

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Preliminary results were presented at the 17th IERASG (International Evoked Response Audiometry Study Group) Symposium, July 22–27, 2001, in Vancouver, Canada, and at the 14th NAS (Nordic Audiological Society) Congress, May 26–29, 2002, in Helsinki, Finland.

Hearing is known to deteriorate with age (presbyacusis). There is some controversy surrounding the etiology of this hearing loss, specifically whether it is mainly due to environmental noise (socioacusis), a cochlear ageing process, or ageing of the central nervous system (Pearlman, 1982; Welsh et al, 1985; Hinchcliffe, 1990; Jennings and Jones, 2001).

In the elderly, there may be discrepancies between pure-tone audiometry and central auditory tests, which are attributed to age-related degeneration of the central nervous system. Event-related potentials (ERPs) may be used for testing central auditory function. They are voltage changes recorded from the scalp or brain itself following sensory stimulation or mental events. For this study, auditory long-latency components N 200, P 300, and N 3 in the poststimulus time window of 150–800 msec were studied. These cortical responses may be elicited in other sensory modalities, like visual or somatosensory stimuli (Gilmore, 1995). In the literature, these responses are considered to represent aspects of stimulus evaluation and interpretation in the central nervous system, at different levels of consciousness. While the N 200 may reflect an earlier phase of stimulus categorization, the N 3 is considered to reflect a later phase of stimulus interpretation. These late potentials have been described as the electrophysiological correlate of the "old-new" response, that is, the primary cognitive identification of environmental change. Hence, the N 200, P 300, and N 3 are referred to as cortical "cognitive" responses in this article. Further description of the actual cognitive events that occur when these potentials are evoked remains a matter of psychological debate and is beyond the scope of this article.

Attempts to localize the generators of the corresponding postsynaptic potentials in specific areas of the brain by electrophysiologic mapping or functional magnetic resonance studies have so far given divergent results (Kugler et al, 1993).

Long-latency potentials have been used to study central nervous dysfunction in encephalopathy, dementia (Ortiz et al, 1994), Parkinsons (Tachibana et al, 1999), and Alzheimer's diseases (Patterson et al, 1988), as well as physiologic changes in central nervous function with age (Kugler et al, 1993). There is an increasing interest in measurement of cortical responses as a possible instrument for early and objective diagnosis of cognitive dysfunction.

There is ample evidence in the literature that the N 200 (Coyle et al, 1991) and P 300 (Polich, 1996) latencies show a regular increase with age. Some authors find an age-related decrease in cortical response amplitudes (Picton et al, 1984), although others have not found decreasing amplitude with age (Amenedo and Diaz, 1998). Differences in sample sizes, paradigm, and electrode placement may explain some of the discrepancies (Kugler et al, 1993). In most studies, cortical cognitive potentials were elicited in nearly 100% of normal participants regardless of age.

Our purpose in this study was to use a simple auditory oddball paradigm to describe aspects of central auditory function in the presbyacusis age range. The study design included a control group of healthy, normal-hearing young adults. Furthermore, relationships between age, pure-tone audiometry, monosyllabic speech discrimination and cortical cognitive potentials were studied under the hypothesis that the central nervous processing of auditory stimuli deteriorates with age.

MATERIAL AND METHODS

Participants

The study was conducted in the municipality of Tromsø (population 60,000) between August 1998 and January 2002. A statistical bureau assisted in the random selection of 100 participants in each of the five-year age groups from 60 and upwards. For block randomization, a computer-based method developed by Statistics Norway (Statistisk sentralbyrå) was used. In the group above 90 years, all 162 live persons were selected. All selected participants received written invitations to participate. A total of 232 persons (30.5%) responded to our invitation and were examined at the audiology section of the ENT-Department, University Hospital of Tromsø. Twenty-two healthy volunteers from the staff at the ENT-Department and local medical students in the age range 19–26 years were recruited to the control group. This sample was not selected at random. Two of these controls were found to have previously unknown sensorineural hearing losses and were excluded from the study, leaving 20 participants (males = 10, females = 10) for our control group. None of the participants received payment, although travel expenses were covered for participants who were not affiliated with the hospital. Written informed consent was obtained from each participant.

Methods

The participants were interviewed by an experienced otologist using a modified standard questionnaire (International Organization for Standardization, 1996), and otomicroscopy and tuning fork tests were performed. For audiometry, we used a Madsen Orbiter 92 v. 2 with Sennheiser HDA 200 earphones. Pure-tone air-conduction thresholds were measured in the range 125–16,000 Hz according to a standardized protocol (International Organization for Standardization, 1989). For this study, only the hearing level of the best ear at the 2 kHz frequency was included in the analysis. Speech recognition score was recorded using a Norwegian monosyllabic test based on phonemically balanced words. Extended high-frequency and speech audiometry were not measured in the control group.

Cortical cognitive potentials were investigated using an auditory oddball paradigm with button-press response. The stimulus was a rarefaction tone burst with rise/fall times of 10 msec, plateau of 40 msec, and a linear ramp. Nontarget signals were set at 1 kHz and target signals at 2 kHz. For each participant there were two trials, with the total number of target signals of 25 in the first and 50 in the second trial. Target tone probability was 0.25. Stimuli were delivered binaurally using an Eartone 3A transducer with insert phones at an average rate of 0.7/sec and a level of 70–110 dB HL. Stimulus level was adjusted according to the subjects' best pure-tone hearing threshold at 2 kHz. Electrodes were placed at Fz and coupled to linked M1 and M2, with ground coupling at Fpz. This electrode placement was chosen to simplify the protocol and save time, as the amplitude differences between Pz (optimal placement for P 300 recording) and Fz were considered to be small. This is our standard electrode configuration for screening purposes. In this comparative analysis of age-related electrophysiologic changes, such an approach was considered adequate. The responses were recorded using one channel (Fz) with an 800 msec time window, a resolution of 512, and a gain of 50,000. Gain was occasionally reduced due to high electroencephalographic activity. The analog filter was set at 1–100 Hz with a 50 Hz notch filter included. Artifact detection was enabled. Measurements were performed in an audiometric booth by the second author, who was present throughout most of the recording. Participants were instructed to lie prone, fix their gaze at the roof, and relax. Recordings were done in the attend mode, requiring subjects to push a button at detection of the target stimulus. Reaction times were not measured in this study, and recordings of eye movements were not performed. However, recordings with an output exceeding 45 µV in either direction were retrospectively discarded due to possible contamination by eye movements. This corresponds to the previously reported approach used by Polich et al (1985).

Output was interpreted by the second author using a visual peak-picking procedure for identification of the cortical cognitive responses N 200, P 300, and N 3. N 200 was defined as the most negative peak within the poststimulus time window 150–350 msec, P 300 as the most positive peak within 250–450 msec poststimulus and N 3 as the most negative peak in the time window 350–800 msec poststimulus. Amplitudes were measured using interpeak subtraction, the N 200 wave being referenced to a preceding positive trough (P 180). This led to the exclusion of some amplitude measurements when preceding waves in the opposite direction were absent. The investigator monitored the behavioral accuracy of subjects' responses using a pass/fail algorithm. Hence, eight participants were excluded from the sample due to difficulties with active participation (button press), leaving 224 participants for the elderly sample. The cortical cognitive responses were recorded using the Bio-Logic Evoked Potential version 4.08 model 54 software on a personal computer.

The total measuring time for all procedures was approximately 1–1.5 hours. Results were entered into a computer and statistically analyzed using Statistical Package for the Social Sciences (SPSS) version 10.0, according to common standards for medical statistics (Altman, 1991). The protocol was approved by the regional ethics committee and the Norwegian social sciences data service (Datatilsynet).

RESULTS

Presence versus Absence of Cortical Responses

The occurrence of cortical cognitive responses across age groups is shown in Figure 1. The presence of responses decreases with increasing age. This trend was studied in the elderly sample by univariate logistic regression, yielding age as a significant predictor (N 200: $p = 0.01$, P 300: $p < 0.01$, N 3: $p < 0.01$) for all cortical cognitive responses when seen in isolation. However, when presence of responses was studied by backward multiple logistic regression on age (years), threshold at 2 kHz (dB), and speech discrimination (%), hearing level at 2 kHz appeared to be the only significant predictor for presence of N 200 ($p < 0.01$) and P 300 ($p = 0.04$). Using the same approach for N 3, age turned out to be the most significant predictor of occurrence ($p < 0.01$) with hearing level at 2 kHz as a significant confounder ($p = 0.03$). No interactions between covariates were found in the logistic regression models. Figure 2 shows the occurrence of cortical cognitive responses in the elderly sample with increasing hearing level. Audiometric thresholds are categorized by 10 dB intervals for simplicity. No cortical responses were recorded when the hearing level exceeded 70 dB HL. Using the chi-square test we found no significant gender differences in occurrence of cortical responses. There was an expected increase in mean hearing level at 2 kHz across age groups. Number of participants, median age, mean threshold at 2 kHz, and prevalence of cortical responses across age groups are given in Table 1. Table 2 shows the difference in mean hearing level at 2 kHz for groups with and without cortical responses present. The differences were significant at $p < 0.01$ for all responses, using the Wilcoxon signed ranks sum test. The participants with speech recognition score <100% were significantly less likely to have cortical responses present, when analyzed by the chi-square test (N 200: $p = 0.01$, P 300: $p = 0.02$, N 3: $p < 0.01$). Examples of recordings with and without cortical responses are displayed in Figures 3 and 4.

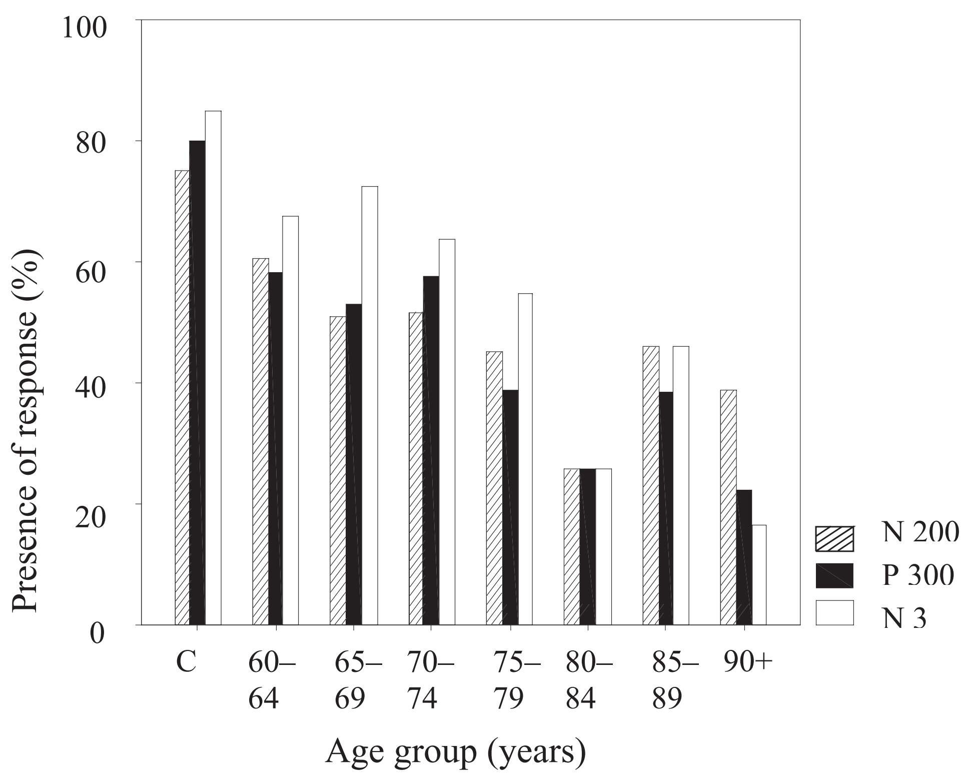

Figure 1. Presence of cortical cognitive potentials in the elderly group (n = 224). The decrease in prevalence of responses with age was significant at $p < 0.05$ for all response categories when analyzed by logistic regression. The control (C) group (n = 20) is displayed for comparison.

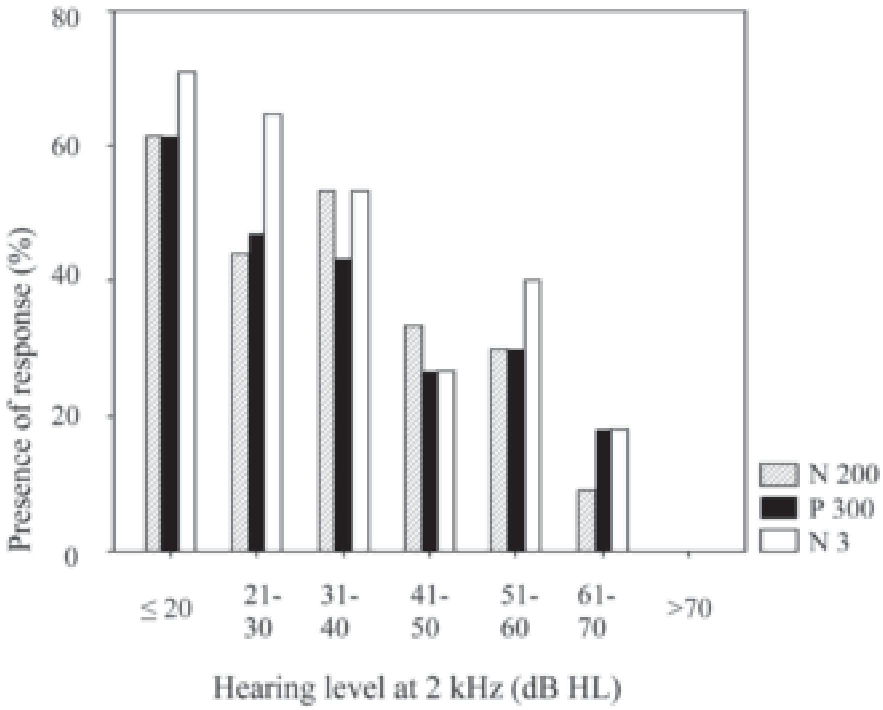

Figure 2. Presence of cortical cognitive potentials in the elderly sample (n = 224) with increasing hearing level at 2 kHz. For simplicity, hearing levels are categorized by 10 dB intervals. No cortical responses were recorded when hearing levels exceeded 70 dB HL. Threshold at 2 kHz was a significant predictor for presence of all response categories when analyzed by logistic regression ($p < 0.05$).

Latency and Amplitude of Cortical Responses

The distributions of age, threshold at 2 kHz, latencies, and amplitudes for all cortical responses were studied by Kolmogorov-Smirnov tests (K-S tests). The assumptions of normality were rejected for all these parameters ($p < 0.05$) except P 300 latency ($p = 0.23$), in the elderly subgroups with cortical responses present. In the control participants, all the corresponding parameters except threshold at 2 kHz were normally distributed when analyzed by the K-S test ($p > 0.05$). Consequently, nonparametric tests were chosen for comparisons with the control group.

Table 1. Number of Participants, Median Age, Percentage of Cortical Cognitive Responses, and Mean Hearing Level at 2 kHz across Age Groups

Age group	n	Age, median (years)	N 200 presence (%)	P 300 presence (%)	N 3 presence (%)	2 kHz threshold mean (dB)
60–64	43	63.0	60.5	58.1	67.4	15.6
65–69	51	67.0	51.0	52.9	72.5	23.4
70–74	33	73.0	51.5	57.6	63.6	27.0
75–79	31	76.0	45.2	38.7	54.8	31.8
80–84	35	82.0	25.7	25.7	25.7	43.4
85–89	13	87.0	46.2	38.5	46.2	33.8
90 +	18	92.5	38.9	22.2	16.7	53.1
Controls	20	23.5	75.0	80.0	85.0	-0.8
Overall, elderly	224	70.0	46.9	45.1	54.5	29.7

Note: Control group is included for comparison.

Table 2. Pure-Tone Threshold at 2 kHz vs. Presence of Cortical Cognitive Potentials

Response	dB at 2kHz Mean	SD	n	p
N 200 present	24.8	16.4	105	<0.01
N 200 absent	34.1	21.1	119	
P 300 present	24.4	16.7	101	<0.01
P 300 absent	34.1	20.7	123	
N 3 present	24.1	16.6	122	<0.01
N 3 absent	36.4	20.7	102	

Note: Hearing was significantly worse in participants with no cortical response present (Wilcoxon signed rank sum test).

N 200

N 200 was evoked in 105 elderly participants (46.9%). Latencies and amplitudes for these participants across age groups are displayed in Table 3. Mean latency shows an increase with age (Fig. 5). The trend is significant in the elderly sample at p = 0.02 using one-way analysis of variance (ANOVA) (df = 6, F = 2.7). Using linear regression, we found a significant (p < 0.01) yearly increase in N 200 latency of 0.92 msec for participants over 60 with a 95% confidence interval of 0.40–1.44 msec. When comparing latencies in the elderly sample versus the control group we did not find the latencies to be significantly longer in elderly participants using the Wilcoxon signed rank sum test (p = 0.49). By the same statistical approach we found the N 200 latencies to be significantly longer for females than males (p = 0.03). No association was found between N 200 latency and speech discrimination (Table 4). There was no significant association between threshold at 2 kHz and N 200 latency in the elderly when these parameters were compared by linear regression (p = 0.17).

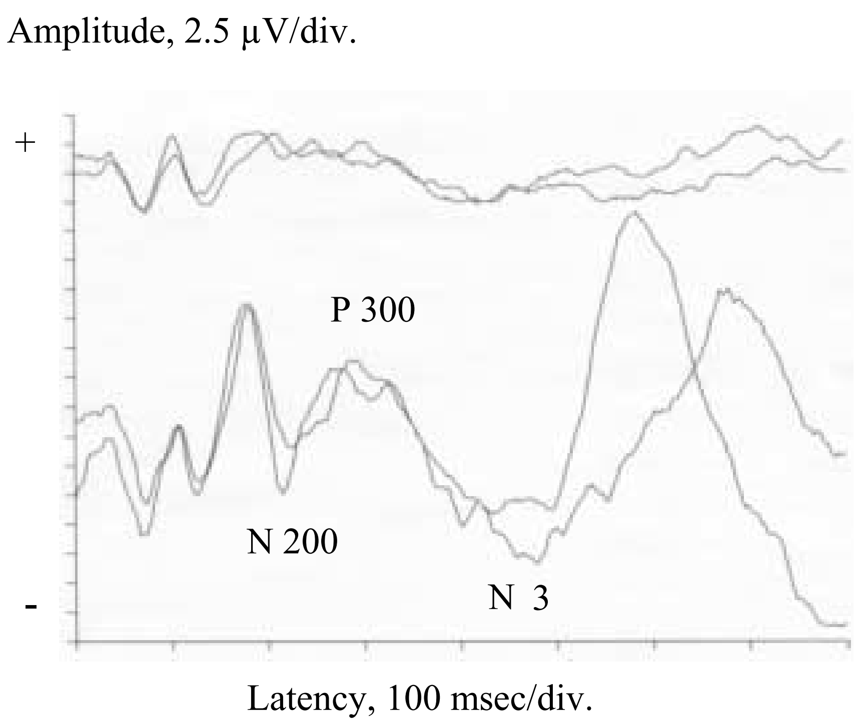

Figure 3. Cortical cognitive potentials: 73-year-old male with a pure-tone threshold at 2 kHz of 60 dB HL and speech discrimination 30%. The lower traces represent the target tone evoked potentials, the upper traces those of the nontarget tone. In this participant, all responses were present. Fz positive is up on the figure.

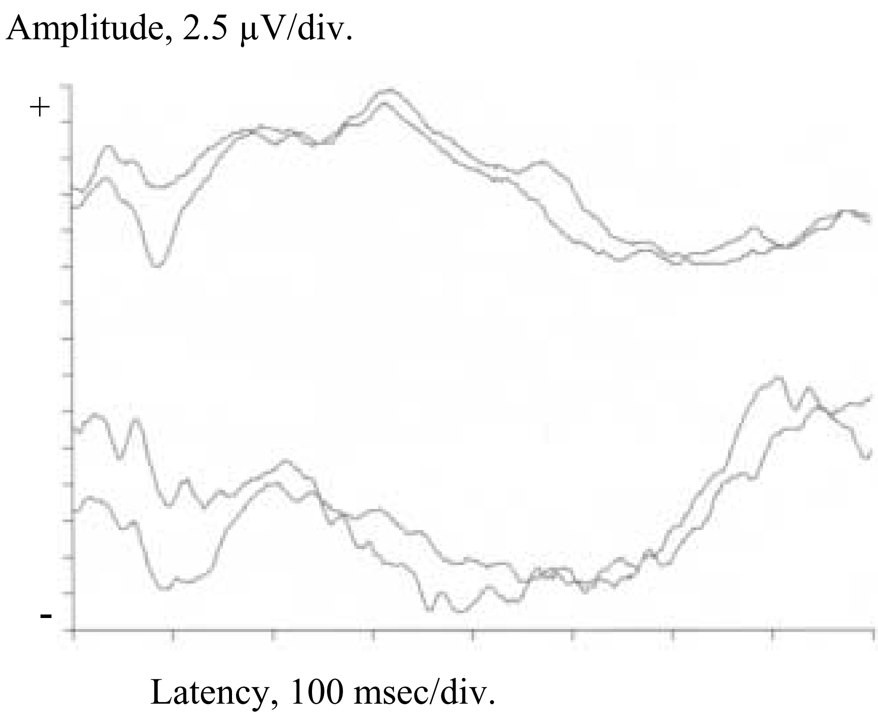

Figure 4. Cortical cognitive potentials: 93-year-old male with a pure-tone threshold at 2 kHz of 25 dB HL and speech discrimination 100%. The lower traces represent the target tone evoked potentials, the upper traces those of the nontarget tone. No responses were present in this subject. Fz positive is up on the figure.

Table 3. Distribution of N 200 Latencies and Amplitudes in the Subgroup with N 200 Present

Age group	Gender	n	Latency N 200, mean (msec)	Latency N 200, 95% confidence interval (msec)	Amplitude N 200, median (µV)
60–64	male	14	228	218–38	13.4
	female	13	234	220–47	8.6
65–69	male	14	238	216–60	5.9
	female	12	239	224–54	8.0
70–74	male	10	227	217–37	7.9
	female	7	236	221–51	7.9
75–79	male	10	237	225–49	6.2
	female	4	275	235–315	6.6
80–84	male	5	246	227–65	8.9
	female	3	247	232–61	9.9
85–89	male	1	230	—	—
	female	5	262	231–93	8.9
90 +	male	1	310	—	—
	female	6	255	226–83	7.5
Control group	male	10	230	215–44	8.2
	female	5	241	200–82	10.3
Elderly, overall		105	240	235–45	8.1
	male	55	235	228–42	8.0
	female	50	245	238–52	8.2

Note: Control group is included for comparison.

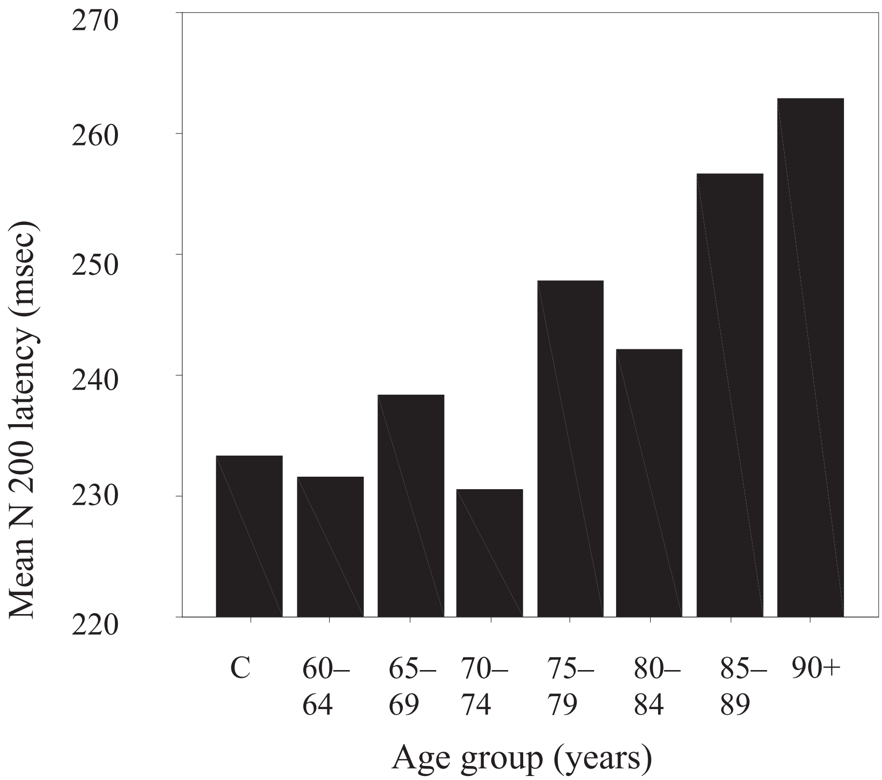

Figure 5. Mean N 200 latencies across age groups in the subgroup with N 200 present. The increase in latencies in the elderly sample (n = 105) was significant at p = 0.02 using one-way ANOVA. The control (C) group (n = 15) is displayed for comparison.

N 200 amplitudes were studied by the same statistical approaches. No significant changes were found with age either within the elderly group or when comparing elderly participants to controls. No significant association was found between hearing level at 2 kHz and N 200 amplitude. There were no significant associations between N 200 amplitude and gender or speech discrimination when studied by the Wilcoxon signed rank sum test.

P 300

P 300 was evoked in 101 elderly participants (45.1%). Latencies and amplitudes for these participants across age groups are displayed in Table 5. Mean latency shows an increase with age (Fig. 6). This trend was significant in the elderly sample at $p < 0.01$ using one-way ANOVA (df = 6, F = 5.1). Using linear regression we found a significant ($p < 0.01$) yearly increase in P

Table 4. Latency of Cortical Cognitive Responses in Separate Subgroups with Responses Present

Response	Discrimination %	Mean	SD	n	p
N 200	<100	241	23	22	>0.05
	100	239	26	83	
P 300	<100	328	30	21	>0.05
	100	323	32	80	
N 3	<100	491	45	26	>0.05
	100	477	39	96	

Note: No difference in mean latency was found across groups with or without speech discrimination at 100% (Wilcoxon signed rank sum test).

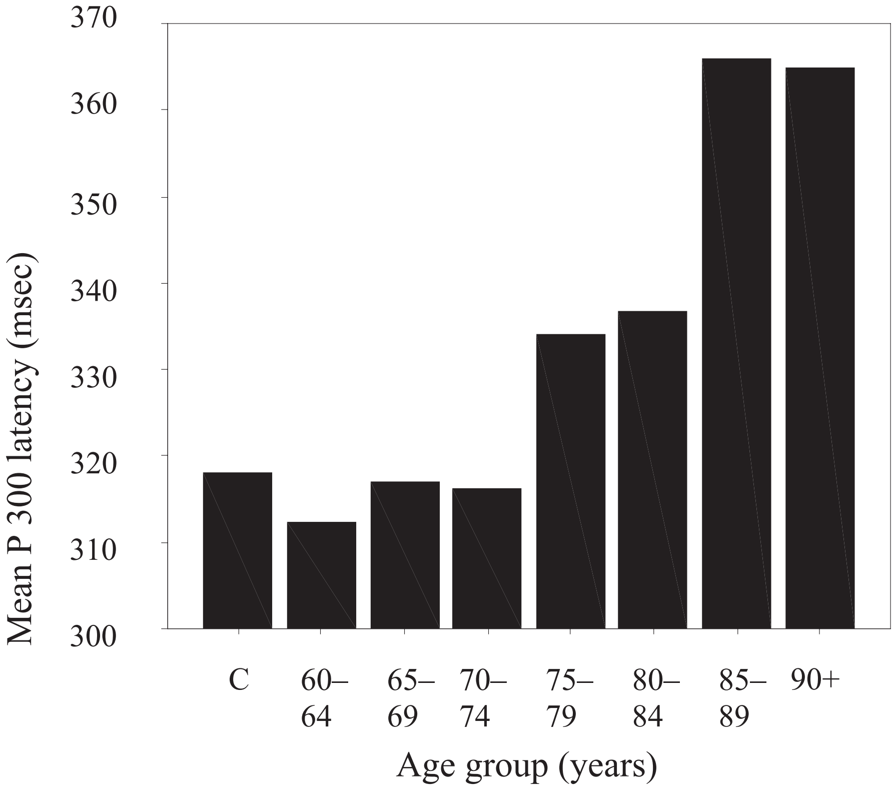

Figure 6. Mean P 300 latencies across age groups in the subgroup with P 300 present. The increase in latencies in the elderly sample (n = 101) was significant at $p < 0.01$ using one-way ANOVA. The control (C) group (n = 16) is displayed for comparison.

300 latency of 1.76 msec, for participants over 60 years, with a 95% confidence interval of 1.09–2.43 msec. When comparing latencies in the elderly versus the control group we did not find the latencies to be significantly prolonged in the elderly using Wilcoxon signed rank sum test ($p = 0.51$). Likewise, the P 300 latencies were not significantly different between females and males using this statistical approach ($p = 0.15$). No association was found between P 300 latency and speech discrimination (Table 4). There was no significant association between threshold at 2 kHz and P 300 latency in the elderly when

Table 5. Distribution of P 300 Latencies and Amplitudes in the Subgroup with P 300 Present

Age group	n	P 300 latency, mean (msec)	P 300 latency, 95% confidence interval (msec)	P 300 amplitude, median (µV)
60–64	25	312	301–24	9.9
65–69	27	317	306–28	7.0
70–74	19	316	301–22	6.9
75–79	12	334	320–48	4.7
80–84	9	337	313–81	5.2
85–89	5	366	335–97	11.2
90 +	4	365	298–432	6.4
Controls	16	318	305–35	8.1
Overall, elderly	101	324	317–30	7.2

Note: Control group is included for comparison.

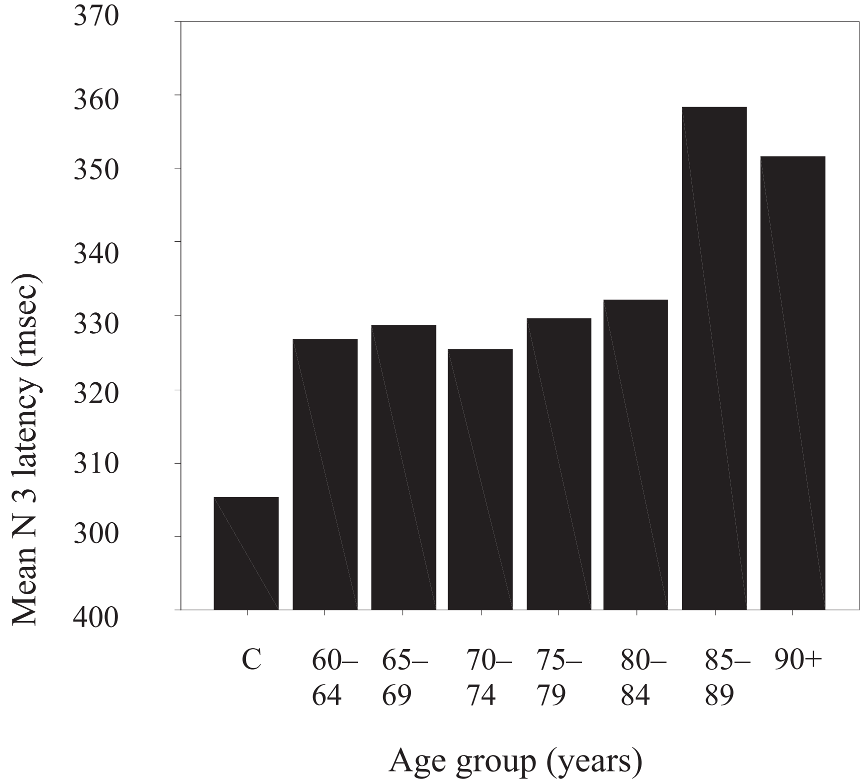

Figure 7. Mean N 3 latencies across age groups in the subgroup with N 3 present. The increase in latencies in the elderly sample (n = 117) was significant at $p < 0.01$ using one-way ANOVA. The control (C) group (n = 17) is shown for comparison.

these parameters were analyzed by linear regression ($p = 0.16$).

P 300 amplitudes were studied by the same statistical approaches, and no significant changes were found with age either within the elderly group or when comparing elderly participants to controls. No significant association was found between hearing level at 2 kHz and P 300 amplitude. There were no significant associations between P 300 amplitude and gender or speech discrimination when studied by the Wilcoxon signed rank sum test in the elderly sample.

Table 6. Distribution of N 3 Latencies and Amplitudes in the Subgroup with N 3 Present

Age group	n	N 3 latency, mean (msec)	N 3 latency, 95% confidence interval (msec)	N 3 amplitude, median (µV)
60–64	27	472	457–87	18.7
65–69	35	479	467–91	15.9
70–74	20	470	451–88	14.3
75–79	17	479	457–502	12.7
80–84	9	484	449–520	10.9
85–89	6	537	524–49	12.4
90 +	3	523	447–599	14.1
Controls	17	431	415–46	10.0
Overall, elderly	117	480	473–88	14.8

Note: Control group is included for comparison.

N 3

The N 3 was evoked in 117 elderly participants (52.2%). Latencies and amplitudes for these participants across age groups are displayed in Table 6. Mean latency shows an increase with age (Fig. 7). This trend was significant in the elderly sample at $p < 0.1$ using one-way ANOVA (df = 7, F = 6.7). Using linear regression we found a significant ($p < 0.01$) yearly increase in N 3 latency of 1.50 msec, for participants over 60 years, with a 95% confidence interval of 0.60–2.39 msec. When comparing latencies in the elderly vs. the control group there were significantly prolonged latencies in the elderly group at $p < 0.01$ using Wilcoxon signed rank sum test. The N 3 latencies were not significantly different in females and males using this statistical approach ($p = 0.87$). No significant association was found between N 3 latency and speech discrimination (Table 4). There was no significant association between threshold at 2 kHz and N 3 latency in the elderly when these parameters were analyzed by linear regression ($p = 0.08$).

The N 3 amplitudes were studied by the same statistical approaches. There was a significant ($p < 0.01$) decrease in N 3 amplitude with age of -0.39 µV per year in the elderly sample, with a 95% confidence interval of -0.68 to -0.10 µV. However, amplitudes were significantly larger in the elderly vs. the control group at $p < 0.01$ using the Wilcoxon signed rank sum test. No significant association was found between hearing level at 2 kHz and N 3 amplitude. There were no significant associations between N 3 amplitude and gender or speech discrimination when studied by the Wilcoxon signed rank sum test in the elderly sample.

Interpeak Latencies

The interpeak latencies were studied in 81 elderly participants with all cortical responses present (36.2%). By subtraction, we found the mean interpeak latency between N 200 and P 300 to be 85 msec with a confidence interval of 80–90 msec in the elderly group. There was no significant change in this parameter with age or hearing level at 2 kHz, when these associations were analyzed by linear regression. The N 200-P 300 interpeak latency differences between elderly and controls were studied by the Wilcoxon signed rank sum test and found to be not significant ($p = 0.74$). Likewise, there were no gender differences when this parameter was studied by the same statistical approach. Mean interpeak latency between P 300 and N 3 was 159 msec with a confidence interval of 151–167 msec. When studied by linear regression, this parameter did not change significantly with age or hearing level in the elderly sample, but when compared with the control group the interpeak latency P 300-N 3 was significantly prolonged in the elderly sample at $p < 0.01$, using the Wilcoxon signed rank sum test.

DISCUSSION

Occurrence of Cortical Cognitive Potentials

The systematic decrease in occurrence of cortical potentials with age in this sample seems to be partly explained by deteriorating pure-tone audiometric thresholds at the target tone frequency for all three categories of response. However, we found that hearing level was the single most significant predictor for presence of the N 200 and the P 300, while for the latest response, N 3, age was the most significant predictor for presence. Under the assumption that pure-tone thresholds predominantly reflect cochlear function, there is a possibility that the earlier cortical responses are more stimulus dependent than the later and, as such, more dependent on the cochlear amplifier. There is a known relationship between the acoustic properties of the stimulus and the properties of long-latency responses (Starr and Don, 1988). Auditory ERPs are dependent on stimulus repetition rate, rise time and duration, intensity and signal frequency. Furthermore, the adjustment of stimulus level in subjects with cochlear hearing loss may be problematic due to cochlear recruitment. In this study, no attempt was made to assess the degree of recruitment in individual participants. It was ascertained, however, that the target tone was well audible in all 224 elderly participants. Although these participants clearly heard the target stimulus and were able to press the button, cochlear factors in stimulus processing may have influenced the amplitude of cortical responses at Fz. Monosyllabic speech recognition score was in itself a predictor for presence of cortical cognitive responses, although the effect disappeared when we controlled for age and hearing level. This variable was not found to influence latency or amplitude in participants with cortical responses present. From our findings, we suggest that monosyllabic speech discrimination, measured in quiet by our standards, may be more dependent on cochlear status than on central auditory function. It is interesting that cortical cognitive responses were absent in 15 to 25% of normal-hearing young adults and in around 50% of the elderly. This may possibly be due to electrode placement at Fz, or to the increased hearing thresholds in the elderly. The relatively low prevalence of cortical cognitive responses would represent an obstacle to the application of this methodology in a clinical setting.

Cortical Response Latencies

As expected, latencies were found to increase steadily with age. The regression coefficients found for N 200 and P 300 in subjects over 60 seem to be comparable to earlier results (Polich et al, 1985; Coyle et al, 1991). However, the matter is somewhat unresolved as latencies were not found to be longer in the elderly as a group than in the young adult controls. This inconsistency cannot be explained by our data.

The N 3 was significantly prolonged in the elderly, both by intragroup analysis and comparison between elderly and controls. A similar age effect was found in an earlier study (Kutas and Iragui, 1998) of the N 400, although the paradigm and the regression coefficients in that study were not comparable to ours. The large confidence interval for the overall N 3 latency in the elderly sample is probably due to the considerable variability in observations. We are unable to explain the gender difference that was found for the N 200 latencies, although gender effects on cortical responses have been reported by other authors (Picton et al, 1984). In this study we have put the emphasis on simplicity of paradigm and recording conditions, although the test procedure may still be regarded as time-consuming. Any use of our data for diagnostic purposes will require strict adherence to the same paradigm and recording conditions. It is a fact that filter settings influence latency of peaks, and we emphasize that our data are related to a filter setting of 1–100 Hz.

Cortical Response Amplitudes

The amplitudes of N 200 and P 300 at Fz were found to be unaffected by age. This is in disagreement with some authors, although others (Amenedo and Diaz, 1998) have found that some cortical responses remain stable with age. The N 3 amplitude was found to decrease with age when studied within the elderly sample. However, N 3 amplitudes were larger in the elderly sample as a whole than in the control group. Mapping studies with multiple electrode derivations or functional magnetic resonance studies have suggested that a more frontal predominance of the N 200 and P 300 generators may occur with age (Picton et al, 1984; Anderer et al, 1998). This might have influenced our results, but as recordings were only made at the Fz, we cannot make inferences in this matter.

Our approach to the possible contamination by eye movements may be regarded as questionable by some researchers. However, we consider this approach to be adequate for screening purposes. We are unaware of any studies showing systematic changes in the eye movement related artifacts with age.

Interpeak Latencies

Although N 200, P 300, and N 3 probably reflect different cognitive events or levels of consciousness, we regard these responses to be related in the sense that they may all be evoked by the same auditory stimulus. More than one in three of our elderly participants showed electrophysiologic responses with all three categories of cortical potentials to the same kind of stimulus. We cannot, however, conclude from our data that the N 200, P 300, and N 3 are interrelated phenomena. The interpeak latencies from P 300 to N 3 were prolonged in the elderly sample when compared to the control group, but the issue remains unresolved as this parameter did not change with age within the elderly sample.

CONCLUSIONS

The occurrence of the auditory cortical cognitive potentials N 200, P 300, and N 3 is dependent on the age and the pure-tone hearing level of the subject. Their occurrence decreases with age and hearing level. Response latencies increase steadily with age in persons over 60 years. Response amplitudes do not show a clear-cut decrease with age when measured at the Fz by the simple auditory oddball paradigm. Our data suggest that the speed of central auditory processing decreases with age. This may be relevant to the evaluation of central auditory function in an auditory rehabilitation setting.

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