DOI: 10.2478/v10163-010-0014-5

ORIGINAL ARTICLE

Central Auditory Processing Disorders: Effects of Age and Hearing Loss to Electrophysiological and Behavioral Responses

Diana Raumane*, Ligija Kise*, Inara Logina,**
*Department of Otorhinolaryngology, Pauls Stradins Clinical University Hospital, Riga, Latvia
**Department of Neurology, Pauls Stradins Clinical University Hospital, Riga, Latvia

Summary
Introduction. Central auditory processing involve normal sound perception, speech recognition, ability of cognition and memory. Accordingly speech recognition difficulties may manifest due to changes at any segment of auditory processing. Cortical auditory evoked potentials (CAEPs) and behavioral measures provide insight into the neural mechanisms underlying speech recognition. These disorders are observed both in young and elderly population.
Aim of the study. To evaluate central auditory processing for subjects of different age and hearing level through the presentation of noise using CAEPs and behavioral measures of speech discrimination. However due to complicated connectivity in auditory pathway it is difficult to identify the central auditory processing damage. Behavioral tests in conjunction with electrophysiological examination will reveal more complicated information for differenciation between peripheral and central auditory processing disorders.
Materials and methods. Three groups of subjects participated: young normal hearing, young hearing-impaired and elderly hearing–impaired subjects. To minimaze subject variables, the CAEPs (wave peaks P1,N1,P2,N2,P3,N3 in miliseconds) was investigated using passive listening paradigme. The CAEPs were elicited by 1,1s change in frequency 1000 Hz and 2000 Hz in pure tones presented at 65, 70 and 75 dB SPL. Sentence recognition tests in quite and noise, Digit Pairs (DP) and Word Pairs (WP) were developed in Latvian language prior to investigation. They were presented to all subjects.
Results. The most prominent finding was the increased latency of P3, N3 in elderly and also in younger hearing impaired adults groups and highly differed within groups. More prolonged latencies were find of N1, P2 in elderly hearing impaired group than in younger hearing impaired group adults.
Conclusions. During this investigation the CAEPs are performed for the first time in our clinic therefore the main standarts are determined for our laboratory. The speech recognition tests (Sentence recognition test, DD, DW) are developed in Latvian. The present findings suggest patterns of CAEP are variable within individuals however shows that auditory perception and cognitive function is not only a result of aging and must be associated with a general slowing of neuronal processing or decreased neuronal synchrony within the central auditory nervous system. Determination of central auditory processing capacity level is of crucial significance to prognose and evaluate the hearing result after hearing prosthetics and to appraise indications for hearing prosthetics, cochlear and middle ear implantation including.
Key words: central auditory evoked potentials (CAEP); event related potentials (ERP); auditory processing; speech recognition threshold (SRT); peak latencies; P3.

INTRODUCTION

Difficulty in understanding speech especially in adverse listening conditions is a common complaint of elderly persons. However more and more young people complains of it. The auditory system must be able to select out signals of interest from surrounding information. In this selective attention process are involved peripheral, central auditory and cognitive factors, hence significant interactions among these factors have not been fully established. Aging is one of the reasons of impaired selective attention processes (Humes, 2005). Declined cognitive functioning in elderly population also negativly affects auditory processing, including selective attention (Mueller et al., 2008). Relationship between cognitive function and performance on central auditory tests have been reported (Golding et al., 2005). Dichotic listening correlated with measures of general cognitive function like auditory processing speed and working memory (Martin et al., 2008).

One of the remarkable characteristics of human hearing comprehension is its speed (Norris et al., 1995). Scalp-recorded evoked brain potentials including CAEPs derived from electroencephalogram (EEG) takes relevant place in investigations of central auditory processes. The CAEPs reflect changes of ongoing EEG activity evoked by the stimulus. The most important components of ERP studies are peaks such as N1, P1, N2, P2, N3 and P3 (Naatanen et al., 2007). It is observed that peaks N1 and P2 are earliar sensory-perceptual potencials and reflect response of early attention to stimulus (Anderer et al., 1996). The peak N2 is very sensitive to different deviant stimuli (Naatanen, Gaillard, 1983). The P1-N1-P2 complex reflects neural activity of structures in the thalamo-cortical part of the central auditory system

in response to acoustic changes (Martin et al., 2008). Later components N2 and P3 show endogenous or cognitive stages of the auditory processing (Naatanen, 2007). Auditory event related potential and behavioral investigations often have focused to examination of either age or age-related hearing loss.
The aim of the current study was to investigate the effects on CAEPs in young and elderly listeners suffering of speech recognition difficulties and to study the differences between this lesion in elderly and younger adults groups. Furthermore, it is important to determine how ERP waveforms are related to behavioral performance. Hence this study may reveal correlation between speech recognition scores and CAEPs speed.

MATERIALS AND METHODS

Subjects

Three groups of right-handed human subjects were included: 12 younger patients (YHI; aged 24-32 years, 6 males and 6 females) and 14 older (EHI; aged 52-65 years, 9 males and 10 females), and 12 control subjects (NH; aged 22-28 years, seven males and five females). All participants of the study were native-Latvian-speaking, with no history of otological or neurological disorder and nobody report having tinnitus at the time of testing.
All control subjects had air and bone conduction hearing thresholds of no more than 15 dB hearing loss in the range between 125 and 8000 Hz. Pure tone thresholds for both patient groups varied from mild to moderate bilateral sensoneural high-frequency hearing loss.
Pure tone thresholds and speech recognition tests were measured with a Madsen OB 922 clinical audiometer calibrated to appropriate ANSI standarts (ANSI S3.6.2004) and equipped with TDH-39 headphones. Thresholds were measured in 5-dB steps.
Prior to test sessions tympanometry was performed to exclude middle ear functionating disorders. The auditory brainstem evoked potential responses (ABR) were determined at three intensities (60, 65 and 75 dB) and the latencies of the fifth wave of the ABR (ABR V) were within norms (SD=0.1-0,2; ABR V latencies 5,4-5,57ms) for all participants in three groups (Fig.1).
The patients and the control subjects were fully informed about the experimental procedures in accordance with the decision of the Ethical Committee of Riga Stradins University.

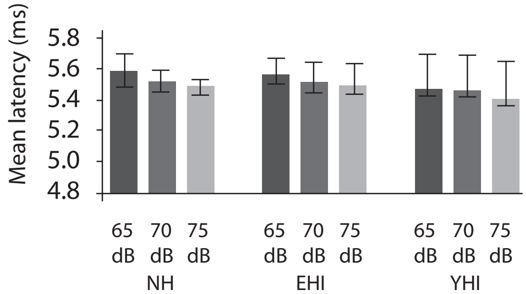


Fig. 1. Mean latencies (ms) of the fifth wave of auditory brainstem response for normal-hearing subjects (NH), elderly hearing-impaired subjects (EHI) and young hearing-impaired subjects (YHI) in stimulus intensities of 65,70 and 75 dB in noise

Speech recognition tests
Speech recognition tests (Sentence recognition test, word pairs (DW), digit pairs (DD)) were developed in Latvian prior to this study. Testing was conducted in a sound treated room. Testing lasted two hours including two breaks of 15 minutes.
Sentence recognition test (SRT) was developed in Latvian (Plomp and Mimpen,1979; Gelfand, 1998). The test material consists of ten short everyday sentences consisting of five or six words presented in quite and in background noise which increases the speech level for 20 dB. The listener is asked to repeat the last word of the sentence. The procedure is continuing increasing or decreasing the speech intensity level by 5 dB in accordance to whether the final word is recognized or not. The S/N ratio for 50 % of the identified final words was detected. Two lists of the SRT were presented monaurally to both ears. The results of the right ear were analized.
Word pair test (DW) in Latvian (Baran and Musiek, 1999; Jerger et al., 1993) consists of two-syllable words, the first of syllables of each word of the pair are similar. Five word pairs consisted of 10 words were presented. In addition simultaneously to rihgt and left ear one word of the pair was presented. The listener is asked to repeat each word. The number of identified words in percentage is fixed as a recognition score.
Digit pair test (DD) in Latvian (Musiek, 1983; Kimura, 1961a, 1961b) consists of two one-digit number. One pair of digits consists of similar syllable words (one, two or three) arranged in five pairs, ten words at all. Like in previous test simultaneously to every of ears one word of the word pair was presented. Partcipant must repeat each comprehended word and recognition score was determined in percentage.

Stimuli

For electrophysiological tests were used pure tones. The standart click stimuli were 1000Hz and 2000Hz pure tones with rise/fall times of 7 ms and duration of 700 ms in quite and in contralateral noise. The tone was presented at three intensity levels: 60, 65 and 75 dB SPL to the right ear and the noise 40 dB SPL to the left ear through TDH-39 earfones with S/N ratio 0 dB.
The tone was presented at three intensity levels: 60, 65 and 75 dB SPL to the right ear and the noise to the left ear that was 40 dB SPL lower then the current stimulus through TDH-39 earfones with S/N ratio 0 dB

Auditory evoked potential recordings

The auditory evoked potentials were obtained using two chanell recording configuration GNOtometrics EP Charter system connected with sound source with TDH-39 earphones. Surface EP electrodes were placed at the T3, T4, left mastoid (LM), right mastoid (RM) accordding to the International 10/20 system (Jasper, 1958). One electrode placed at the low forehead served as a ground electrode. Impedance was kept below 5 kΩ and was controlled during the recording session. Auditory evoked potential waves were digitally band-pass filtered at 0,1-30 Hz.

Procedure

Testing was conducted in a sound-treated room. During CAEP recordings subjects sat comfortably and read quietly. Testing lasted around two hours with 5 min brakes without auditory stimulation. Responses were averaged across a 500ms time window (100-ms prestimulus period and 400-ms post stimulus period). Epochs with artifact measuring in excess of 50 μV were excluded from average waveform. Acquisition was 1024 sweeps, every sweep time was 10 ms and rate 1,1/s.

Data analyses

For each subject and condition averages were created. P1,N1,P2, N2,P3,N3 peak latencies and amplitudes were determined. The group average waveforms (Fig.1) were used to appoint latency segments to detect the CAEP peaks (Picton et al., 1984). The P1-N1-P2 are lokalizated in time window within 200 ms, where P1 and P2 are positive peaks and N1 is the greatest negativity between them. Positive peak P3 originates around 300 ms after onset of stimuli. Negative peak N2 was identified after prominent peak P2 but N3 follows after P3. Peak amplitudes were calculated relative to baseline, and peak latencies to stimulus onset. ERP amplitudes, latencies and behavioral measures were analyzed by ANOVAs, the associations between ERP and behavioral measures were investigated using Pearson's product-moment correlations.

RESULTS

Speech recognition tests

The average S/N ratio of the SRT test in noise was 0,8 dB (SD ±2.6 dB) for NHI, 7 dB (SD ± 9,8 dB) for YHI and 9 dB(SD ±5,4) for EHI. The NH group had significantly smaller S/N ratio compare with YHI and EHI group ($p<0,05$). Variability of discrimination thresholds were larger in elder hearing impaired group however no reasonable differencies between YHI and EHI groups (Fig.2). Word and digit discrimination scores were significantly lower in young (YHI) and elderly hearing-impaired (EHI) groups in comparison with normal hearing (NH) subjects. The mean scores of digit discrimination (DD) was 95% (SD± 5,3) and word discrimination (DW) was 90% (SD± 6,7) for the NH; DD was 64,5% (SD± 10,1) and DW was 59,5% (SD± 14,6) for the EHI; DD was 70.0% (SD±13,5) and WD 65,5% (SD±14,2) for the YHI (Fig.3). Results of the behavioral measures reveal speech discrimination decreased level in both hearing impaired groups ($p<0.05$).

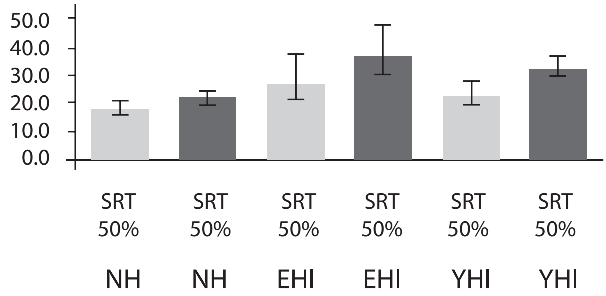


Fig. 2. Speech recognition threshold (dB) in quite (SRT50%) and in noise (SRT50%N) for normal-hearing subjects (NH), elderly hearing-impaired subjects (EHI) and young hearing-impaired subjects (YHI)

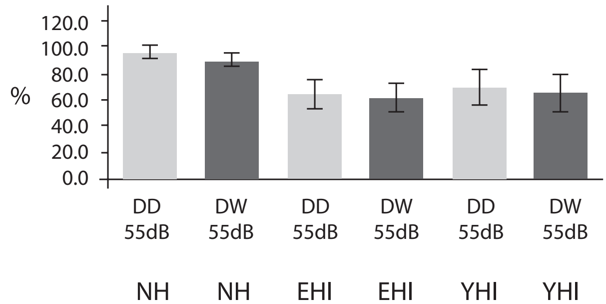
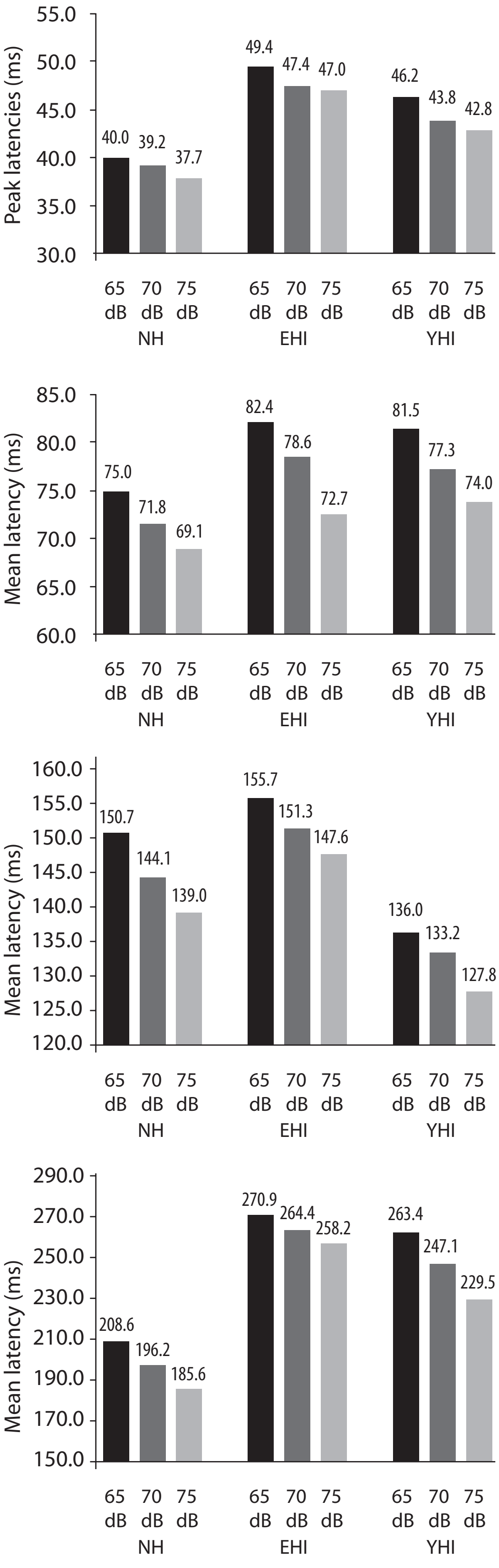


Fig. 3. Digit pair test (DD 55dB) and word pair (DW 55dB) recognition scores (%) for normal-hearing subjects (NH), elderly hearing-impaired subjects (EHI) and young hearing-impaired subjects (YHI)

Electrophysiological data: latency and amplitude characteristics

Similar response patterns were observed of other subjects for click stimuli at three intensities of 65, 70 and 75 dB SPL in presence of baskground noise 40 dB. The components P1, N1 and P2 represent earlier stages of auditory processing more sensitive to physical factors and can be evoked without attention. The average peak latencies in each subject group are shown in Fig.4. Waveforms clearly reflects a prominent negative peak N1 and positive peaks P1 and P2. According to analysis of ANOVA the latencies and amplitudes of peaks P1 and P2, were not significantly dependent to change of stimulus intensity or attendance. Results from these peaks were not of great diference between groups ($p<0,005$).



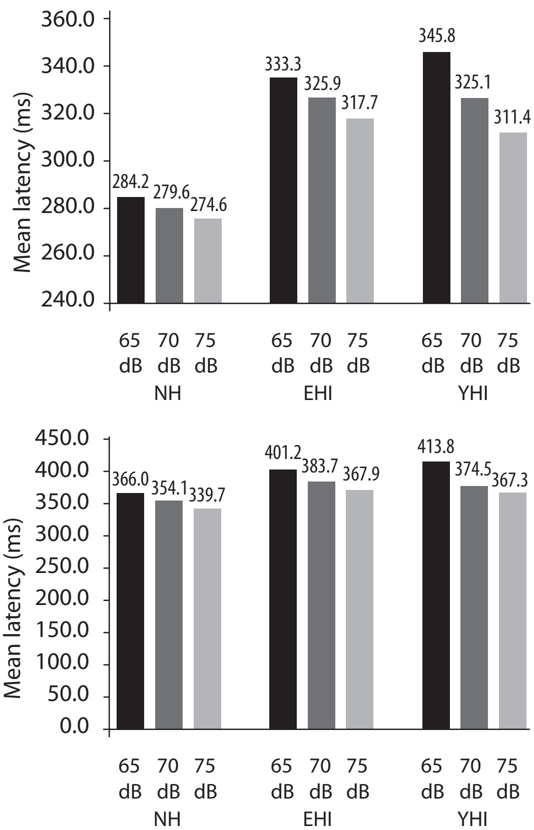


Fig. 4. Mean latencies (ms) of peaks P1, N1,P2, N2, P3 and N3 for normal-hearing subjects (NH), elderly hearing-impaired subjects (EHI) and young hearing-impaired subjects (YHI) in stimulus intensities of 65,70, and 75 dB in noise

More sensitive to attention level and signal intensity and noise was component N1. Latencies increased and amplitudes decresed in noise and without attention in YHI and EHI groups ($p<0,005$). P3 and N2 peaks are significantly smaller between NH and both hearing-impaired groups, in same cases very difficult to identify. Attention increases the amplitude of the N2 ($p<0,05$). The main effect in subject groups was observed on latencies of P3. Responses in YHI and EHI group were significantly longer in comparison with NH group ($p<0.005$) and these latences did not differ in YHI and EHI groups. Waveform for one of subjects of YNH group at signal intensity 70 dB SPL is shown in Fig.5.

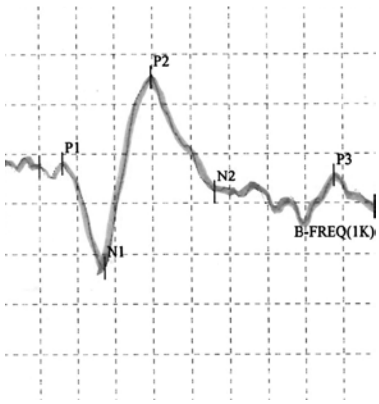


Fig. 5. Waveform for YHI subject at signal intensity level 70 dB SPL

Correlation between ERP and behavioral measures

The relationship between CAEP measures (P3 latences) and behavioral measures (SRT, S/N ratio, DW, DD) of speech discrimination performance was studied using Pearson's product-moment correlations. The correlation coefficients are shown in Fig.6. The most considerable correlations were between P3 latencies and speech recognition threshold and word pair (DW) scores in young and elderly hearing impaired groups (R2=0,244; p<0,05).

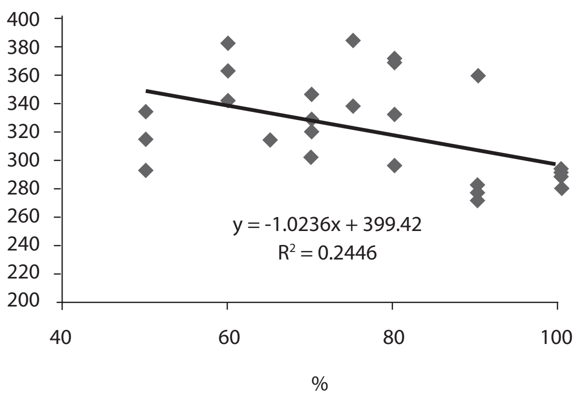


Fig. 6. Pearson's product-moment correlations coefficient between P3 latencies and speech recognition threshold (SRT), word pair (DW) and digit pair (DD) scores in young (YHI) and elderly hearing impaired (EHI) groups (R2=0,244; p<0,05)

DISCUSSION

Cortical auditory evoked potentials were recorded in response to periodic click stimulation at three intensities, in quite and presence of noise, and speech recognition scores were determined. The aim of this study was to investigate the age and hearing impairment influence to the different evoked potential components and speech recognition abilities. For this goal was determined intensity – latency characteristics, correlation between auditory evoked potential latencies and speech recognition scores in three participant groups. The main findings from this study is that the responses of definite CAEP components to noise and deviant stimulus intensity are different for normal hearing subjects in comparison with both hearing impaired subjects. Earlier peak P1, N1 and P2 latencies and amplitudes were not changed greatly between groups and within groups at different sitimulus intensity. The most considerable changes were observed for peaks N2 and P3. These peaks are very small or even absent unattended in, both hearing-impaired groups. They increase considerably if the listener is more attentive in all of tested groups (Naatanen,2004). Speech recognition abilities were significantly affected in hearing-impaired groups in comparison with normal hearing subjects. Recognition scores decreased significantly for DD and DW tests in less for SRT level in YHI and EHI groups in quite and more considerably in noise. These findings were rather similar in both hearing-impaired groups). P3 and N3 were significantly prolonged in elderly and younger hearing impaired adults. These later components P3 and N2 are connected with brain working memory (Stadler,2006) and ability of cognition. Accordingly speech recognition difficulties may manifest in these populations. These findings suggest that auditory signal recognition and discrimination is not only age-related hearing disorder. There is an evidence that CAEP may help to reveal processing disorders before they have manifest.

CONCLUSIONS

1. During this investigation the CAEPs are used for the first time in our clinic therefore the mean standarts were determined for our laboratory. The speech recognition tests (Sentence recognition test, DD,WP) are developed in Latvian.
2. Based on the results from behavioral and electrophysiological measures hearing difficulties were observed in both, elderly and young hearing-impaired subject groups. All of CAEP components are affected by tone level and the presence of noise by apearing prolonged later CAEP components that confirm about slower speed of auditory information. The present findings suggest that patterns of CAEP are variable within individuals however shows that auditory perception and cognitive function is not only a result of aging and must be associated with a general slowing of neuronal processing or decreased neuronal synchrony within the central auditory nervous system.

3. Determination of central auditory processing capacity level is of crucial significance to prognose and evaluate the hearing result after hearing prosthetics and to appraise indications for hearing prosthetics, cochlear and middle ear implantation including.

ACKNOWLEDGMENTS
The authors wish to thank Professor Uldis Teibe for his great assistance in field of methodology of statistics.

Conflict of interest: None

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Address:
Diana Raumane
Department of Otorhinolaryngology
Pauls Stradins Clinical University Hospital
13 Pilsonu Street,
Riga, Latvia, LV-1002
E-mail: diana.raumane@apollo.lv