AUDITORY BEHAVIOURAL AND ELECTROPHYSIOLOGICAL RESPONSES IN ADULTS: EVALUATING CENTRAL AUDITORY PROCESSING

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Abstract

Background: In addition to well known declines in the peripheral auditory system successful perception of speech is dependent on behavioural factors, as well as sound processing at subcortical and cortical levels. We hypothesized that cause and hence localization of impairment in the brain may be diverse in young and elderly people with hearing impairment, accordingly not always related with aging. The aim of the study is to determine the hallmarks of auditory behaviour and auditory cortical evoked responses that could be used in audiology clinics to help explain deficits in speech recognition in young and elderly listeners and recognize the most indicative effects of cortical auditory evoked potentials associated with difficulties of speech intelligibility.

Material and methods: Three groups of adults participated: young normal hearing, young and elderly subjects with difficulty to understand speech especially in complex listening environments despite normal pure tone thresholds. We supposed that differences could be found between young and elderly subjects. Procedure involved behavioural hearing tests, dichotic word tests and sentence recognition test in quiet and noise, and electrophysiological measures as cortical auditory evoked potential components P1, N1, P2, P3 in quiet and noise.

Results: Significant correlation was found between hearing behavioural tests and auditory cortical evoked potentials. This dichotic study demonstrated differences in cortical processing in people with good hearing, young and elderly listeners with speech recognition difficulties. Results provide information about central tests showing significant decrease of perception in young and elderly participants with hearing impairment and it is most strongly associated with event related potential response P3. Sensitivity to signal intensity level significantly changes in the group of young and elderly subjects with hearing impairment for responses P1, N1, P2($p<0.5$).

Conclusions: Despite of resembling results from behaviour tests outcomes of auditory evoked potentials mark less influence of signal intensity level latencies in young then in older subject group. They could be useful in audiology practice for clinical diagnostics and evaluation of hearing rehabilitation.

Keywords: hearing impairment • auditory evoked potentials • speech recognition tests

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RESPUESTAS AUDITIVAS CONDUCTUALES Y ELECTROFISIOLÓGICAS EN ADULTOS: VALORACIÓN DEL PROCESAMIENTO AUDITIVO CENTRAL

Resumen

Introducción: La correcta comprensión del habla depende del buen procesamiento de los sonidos a nivel subcortical y cortical y de una serie de factores conductuales. Los trastornos del sistema auditivo periférico pueden influir en estos procesos. Hemos planteado la hipótesis de que la causa de la discapacidad puede ser diferente en jóvenes y mayores, sobre todo la localización en el cerebro, y que este factor no siempre tiene que estar relacionado con la edad. El objetivo del estudio fue establecer los rasgos característicos del comportamiento auditivo y de los potenciales evocados auditivos corticales, que se podrían utilizar en las clínicas audiológicas para explicar los problemas de comprensión del habla en pacientes tanto jóvenes como de edad avanzada. Ciertas alteraciones de los potenciales evocados auditivos corticales pueden estar relacionadas con los problemas para hablar con claridad.

Material y método: En el estudio participaron tres grupos de paciente adultos: personas jóvenes con audición normal, personas jóvenes con dificultades de comprensión del habla (sobre todo en un ambiente auditivo complejo, a pesar de los resultados normales de la audiometría tonal), y personas de edad avanzada con problemas similares. El procedimiento aplicado comprendía exámenes conductuales del oído, pruebas verbales de escucha dicótica, pruebas de reconocimiento de frases en silencio y con ruido y mediciones electrofisiológicas constitutivas P1, N1, P2 y P3 de los potenciales evocados auditivos corticales en silencio y con ruido.

Resultados: Se encontraron correlaciones importantes entre los estudios conductuales del oído y los potenciales evocados auditivos corticales. Las pruebas de escucha dicótica mostraron diferencias en el procesamiento cortical entre personas con buen oído y oyentes jóvenes y mayores con problemas de reconocimiento del habla. Los estudios centrales mostraron una disminución significativa de la percepción en pacientes jóvenes y mayores con defectos auditivos y estaban fuertemente relacionados con el potencial evocado P3 en pacientes mayores. También se observó cierto debilitamiento de la sensibilidad a los cambios de intensidad en el grupo de pacientes jóvenes con defectos auditivos ($p<0.5$).

Conclusión: A pesar del parecido general a las pruebas conductuales, los potenciales evocados auditivos mostraron un efecto menor de la latencia de la señal en los pacientes jóvenes que en los mayores. Este descubrimiento podría ser útil en la práctica audiológica para el diagnóstico clínico y la valoración de la rehabilitación auditiva.

Palabras clave: hipoacusia • potenciales evocados auditivos • pruebas del habla

СЛУХОВЫЕ БИХЕВИОРАЛЬНЫЕ И ЭЛЕКТРОФИЗИОЛОГИЧЕСКИЕ ОТВЕТЫ У ВЗРОСЛЫХ: ОЦЕНКА ЦЕНТРАЛЬНОЙ ЗВУКОВОЙ ОБРАБОТКИ

Изложение

Введение. Правильное понимание речи зависит от хорошей обработки звуков на подкорковом и корковом уровне, а также от ряда бихевиоральных факторов. Нарушения периферической слуховой системы могут влиять на эти процессы. Мы выдвинули гипотезу, что причины нарушения могут быть разными у молодых и старших людей, особенно размещение в мозгу, и что этот фактор может не всегда быть связан с возрастом. Целью исследования являлось определение характеристических признаков слухового поведения и слуховых корковых вызванных потенциалов, которые могли бы быть использованы в аудиологических клиниках для решения проблем с пониманием речи как молодых, так и старших пациентов. Некоторые изменения слуховых корковых вызванных потенциалов могут быть связаны с проблемами с разборчивой речью.

Материал и метод. В исследовании участвовали три группы взрослых пациентов: молодые люди с нормальным слухом, молодые люди с проблемами с пониманием речи (особенно в сложной слуховой среде, несмотря на нормальные результаты тональной аудиометрии) и люди старшего возраста с подобными проблемами. Использованная процедура охватывала бихевиоральные исследования слуха, словесные тесты дихотического слушания, тесты понимания предложений в тишине и при шуме, а также электрофизиологические измерения – составные части P1, N1, P2 i P3 слуховых корковых вызванных потенциалов в тишине и при шуме.

Результаты. Открыты существенные взаимосвязи между бихевиоральными исследованиями слуха и слуховыми корковыми вызванными потенциалами. Тесты дихотического слушания показали разницу в корковой обработке между людьми с хорошим слухом и молодыми, старшими слушателями с проблемами с пониманием речи. Центральные исследования показали значительное снижение перцепции у молодых и старших пациентов с дефектом слуха, а у старшизх пациентов они были сильно связанные с вызванным потенциалом P3. Замечено также некоторое снижение чувствительности к изменениям напряжения в группе молодых пациентов с дефектом слуха ($p<0.5$).

Заключение. Несмотря на общее сходство с бихевиоральными тестами, слуховые вызванные потенциалы показали меньший эффект латенции сигнала у молодых чем у старших пациентов. Это открытие могло бы быть полезно в аудиологической практике для клинической диагностики и оценки реабилитации слуха.

Ключевые слова: тугоухость • вызванные потенциалы • тесты речи

SŁUCHOWE ODPOWIEDZI BEHAWIORALNE I ELEKTROFIZJOLOGICZNE U DOROSŁYCH: OCENA OŚRODKOWEGO PRZETWARZANIA SŁUCHOWEGO

Streszczenie

Wprowadzenie: Poprawne rozumienie mowy zależy od dobrego przetwarzania dźwięków na poziomie podkorowym i korowym, oraz od szeregu czynników behawioralnych. Zaburzenia obwodowego układu słuchowego mogą wpływać na te procesy. Postawiliśmy hipotezę, że przyczyna upośledzenia może być różna u młodych i starszych osób, szczególnie lokalizacja w mózgu, i że ten czynnik może nie zawsze być związany z wiekiem. Celem badania było ustalenie cech charakterystycznych zachowania słuchowego i korowych słuchowych potencjałów wywołanych, które mogłyby być wykorzystane w klinikach audiologicznych do wyjaśnienia problemów z rozumieniem mowy pacjentów zarówno młodych, jak i w podeszłym wieku. Pewne zmiany korowych słuchowych potencjałów wywołanych mogą być powiązane z problemami z wyraźnym mówieniem.

Materiał i metoda: W badaniu uczestniczyły trzy grupy pacjentów dorosłych: osoby młode z normalnym słuchem, osoby młode z trudnościami z rozumieniem mowy (szczególnie w złożonym otoczeniu słuchowym pomimo normalnych wyników audiometrii tonalnej), oraz osoby w podeszłym wieku z podobnymi problemami. Zastosowana procedura obejmowała behawioralne badania słuchu, testy słowne słyszenia rozdzielnousznego, testy rozpoznawania zdań w ciszy i w szumie, oraz pomiary elektrofizjologiczne – składowe P1, N1, P2 i P3 korowych słuchowych potencjałów wywołanych w ciszy i w szumie.

Wyniki: Znaleziono istotne korelacje pomiędzy behawioralnymi badaniami słuchu a korowymi słuchowymi potencjałami wywołanymi. Testy słyszenia rozdzielnousznego pokazały różnice w przetwarzaniu korowym pomiędzy osobami z dobrym słuchem a młodymi i starszymi słuchaczami z problemami z rozpoznawaniem mowy. Badania ośrodkowe pokazały znaczne obniżenie percepcji u młodych i starszych pacjentów z wadą słuchu i były silnie powiązane z potencjałem wywołanym P3 u starszych pacjentów. Zaobserwowano także pewne osłabienie wrażliwości na zmiany natężenia w grupie młodych pacjentów z wada słuchu ($p<0.5$).

Wniosek: Pomimo ogólnego podobieństwa do testów behawioralnych, słuchowe potencjały wywołane pokazały mniejszy efekt latencji sygnału u młodych niż u starszych pacjentów. Odkrycie to mogłoby być użyteczne w praktyce audiologicznej dla diagnostyki klinicznej i oceny rehabilitacji słuchu.

Keywords: niedosłuch • słuchowe potencjały wywołane • testy mowy

Background

Everyday communication requires auditory system to focus on relevant information among competing sounds. The percentage of people complaining about difficulty to understand speech, especially in challenging listening environments, is increasing [1]. The reason may be not only caused by aging of the society, though this decline commonly affects elderly adults [2], nevertheless this disorder is observed among younger adults. Loss of peripheral hearing sensitivity explains many hearing problems of elderly persons [3]. In addition to well known declines in the peripheral auditory system, successful perception of speech depends on behavioural factors, as well as sound processing at subcortical and cortical levels [4,5]. Speech processing requires rapid temporal resolution of hearing sensitivity [6]. The investigation is focused on the neurophysiological changes of the central auditory processing and possible underlying impairment of this condition [7]. It may be partly associated with aging [8]. We hypothesized that cause and localization of impairment in the brain may be diverse in younger and older people with hearing impairment, accordingly not always related with aging.

The cortical evoked potentials may be indicators of cognitive dysfunction showing speed of auditory information perception. The way to measure the features how neurons represent sensory stimuli is detected by timing "peaks" [9]. Evoked potential P3 is considered to reflect attention resources and memory and is less dependent on stimulus modality [10]. Background noise prolongs subcortical response latencies, but it is not so clear for cortical potentials [5,7].

For decades the main methods for detecting information about central segment of auditory abilities were behavioural measures performed by various complex tones and speech recognition tests [13,19]. Dichotic tests are recommended as apart of test battery in diagnosis of central auditory disorders [14]. Dichotic digit test acknowledges as a most reliable for detecting central auditory disorder because least affected by peripheral hearing impairment no [15,16]. These methods have disadvantages, as they are influenced by numerous factors contributing to understanding speech such as patient's native language, lack of collaboration with patient, high degree of hearing loss, emotional disorder, neurological disease, and cognitive factors [17]. Age-related changes in cognitive functioning as well as presbycusis negatively affect performance on auditory processing [1]. A speech perception in masking noise (sentence recognition test) was administered to obtain information about speech understanding in a realistic everyday listening situation [13]. During electrophysiological procedure responses are investigated excluding cognition and cortical evoked responses are very suitable tools for detection of central auditory disorder. Besides behavioural measures continue to be evaluated and are useful to find out correlations with electrophysiological outcomes, thereby they are helpful to identify the characteristic features at different levels of subcortical and cortical auditory processing [18,19] There is a whale of reports showing age-related changes in the central auditory system that affects conduction of sound, less is known about the sound processing speed in neural structures and behavioural tests of speech perception.

The aim of the current study was to evaluate whether there is difference of ERP component results between young and older hearing impaired subjects, how does auditory ERP vary with condition and stimulus intensity level within groups, and to compare these responses between groups [20–22]. To review how changes in auditory behaviour are associated with response time of cortical evoked potentials, correlation between behavioural and cortical auditory responses were evaluated. Other purpose is to develop electrophysiological paradigms for assessing changes in central auditory processing that could be useful in clinical practice as a diagnostic tool and sensitive measurements of hearing rehabilitation outcome. New protocols and better frameworks can be evaluated, tested, and implemented for testing central auditory processing [24,25].

Material and Methods

Participants. Three groups of listeners participated in the study: two groups of subjects with difficulty to understand speech especially in complex listening environments despite normal pure tone thresholds: 35 young adults (YHI) (age range 25–42; 19 females), and 35 elderly adults (OHI) (age range 62–72; 18 females), 30 adults with normal hearing (NH) (age range 24–27; 13 females) to find out characteristic features for central auditory processing disorder and to indicate features of aging hearing loss. Inclusion in testing required that participants were within limits of normal pure-tone hearing thresholds in both ears: 500–1000 Hz ≤10 dB; at 2000–8000 Hz: for young participants ≤20 dB, for older participants ≤25 dB. Thresholds were measured in 5-dB steps. Normal tympanometry and latencies of V wave of auditory brainstem response (ABR), no history of neurological and otologic pathology. Subjects gave consent after they understood the nature of the study.

The procedure involved behavioural and electrophysiological measurements. The procedure of behavioural component was performed by presentation of three speech tests in Latvian: dichotic digit test and dichotic word test, each of them contains 5 pairs of 2-syllable words simultaneously presented to each ear at 55 dB, and sentence recognition test consisting of 12-sentence sets spoken by male, recorded in quiet and noisy conditions, sound intensity level was increased or decreased depending on individual performance. Free recall was used as response condition. The speech was presented binaurally through clinical audiometer Madsen OB 922 (ANSI S.3 62004) headphones TDH-39 via stimulus presentation recorder. The cortical auditory evoked potentials were collected using GN Otometrics Evoked Potential system with software for stimulus generation and presentation. The sounds were delivered via headphones to the subject's left ear and masking noise to the right ear, after that similar procedure was done delivering sounds to the right ear and masking noise to the left ear. Auditory evoked cortical potentials were elicited using repeated measures design, participants were tested under different conditions: three tone levels (65, 70, 75 dB) diotic and monotic with masking noise (–20 dB) in the opposite ear for evoked responses P1, N1, P2 under passive paradigm and event related response P3 under attended paradigm.

Continual white noise was added as a masking noise: for the 65 dB tone noise level was 45 dB, for the 70 dB tone noise level was 50 dB, for the 75 dB tone noise level was 55 dB. The stimuli were frequent standard tones with frequency of 1000 Hz at a rate of 1.1/s, and rare deviant tones with frequency of 2000 Hz. The duration of standard tone was 70 ms, 10 ms rise and fall time. Deviant tone duration was 25 ms, 12.5 ms rise and fall time. The stimuli were presented so that a large majority of the sounds were standards, standard and deviant tones with probabilities of 0.90 and 0.10, respectively. The sequence of tones was randomly intermixed with the constraint that no two-target tones were presented in succession.

During ERP recordings, the subjects sat in sound-isolated room and read quietly and were instructed not to pay attention to auditory stimuli. While collecting event related response P3, subjects were instructed to count deviant stimuli and report the total number at the end of the session. Each condition lasted for 8–10 minutes with a 5 minute listening breaks between recording series, 15 minute listening brake after sixth serie. Testing occurred over two days consisting of about two hours every day, and the third day for two hours of behavioural testing.

The selection of electrode points was based on the grand-average ERPs waveforms and topographic maps observed, the differences were prominent over the frontocentral scalp regions [23]. Thus the silver silver-chloride surface electrodes were placed at the vertex (Cz) and on each mastoid. The active electrode was the Cz (vertex) and reference electrode was the ipsilateral (stimulated) ear. The ground electrode was in forehead position Fz. Impedance was kept below 5 kΩ. The continuous file was epoched –100 ms of prestimulus activity and 500 ms of poststimulus activity, 650 artifact free sweeps were collected twice to check double recordings. High-pass and low-pass filtered stimuli at 1–100 Hz were used to minimize the artifacts, 100.0 K gain in both channels.

Data analyses were conducted using analysis of variance (ANOVA), Pearson's r correlations, Student *t*-test, p value, LSD *post-hoc* analysis, 20th version of IBM SPSS. Only statistically significant analyses are reported. Investigations were approved by Research Ethics Committee of Riga Stradins University.

Results

The main outcome of behaviour measurements demonstrates dichotic speech and sentence recognition thresholds. Dichotic tests show significant decrease of perception in groups of young and elderly subjects with hearing impairment in comparison with group of subjects with normal hearing ($p<0.001$) (Figure 1). The percentage of digit recognition thresholds are higher than recognition of dichotic words within group ($p<0.001$). Sentence recognition

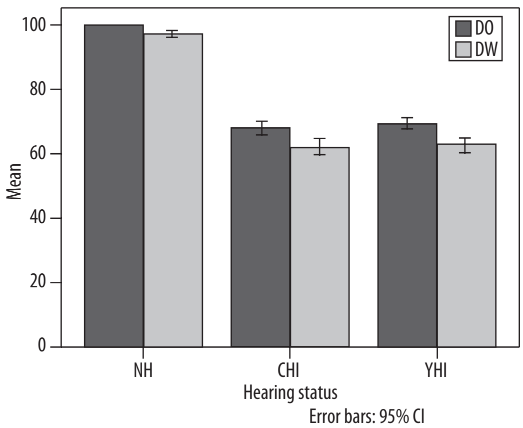

Figure 1. Recognition of dichotic words (DW) and dichotic digits (DD) shows significant decrease (p<0.001) in young (YHI) and elderly hearing impaired (EHI) groups in comparison with normal hearing group (NH).

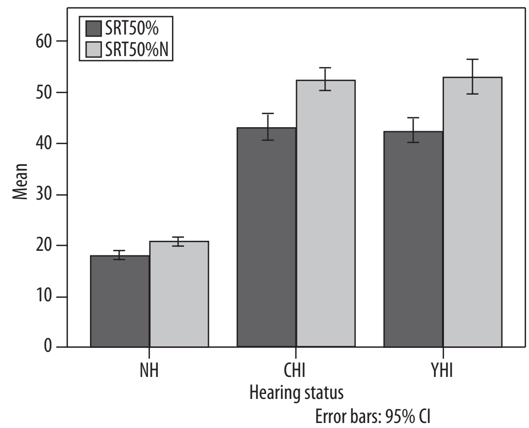

Figure 2. Sentence recognition thresholds highly increased for young (YHI) and elderly hearing impaired (OHI) participant groups in noise (SRT 50% N) and quite (SRT 50%), and showed more manifested difference between recognition thresholds in both conditions than in normal hearing (NH) participant group (F(2.96)=161.49; p<0.001).

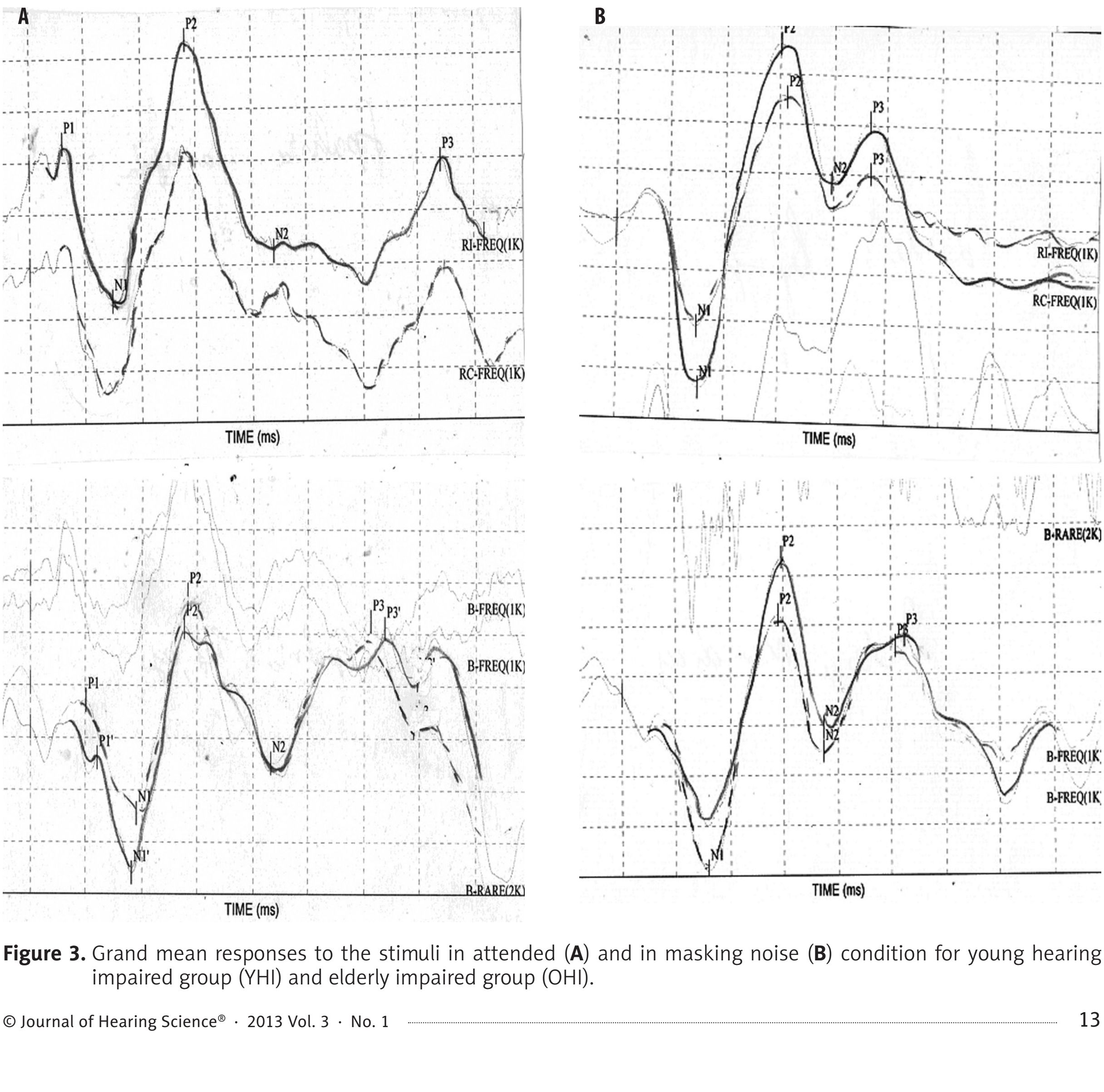

Figure 3. Grand mean responses to the stimuli in attended (**A**) and in masking noise (**B**) condition for young hearing impaired group (YHI) and elderly impaired group (OHI).

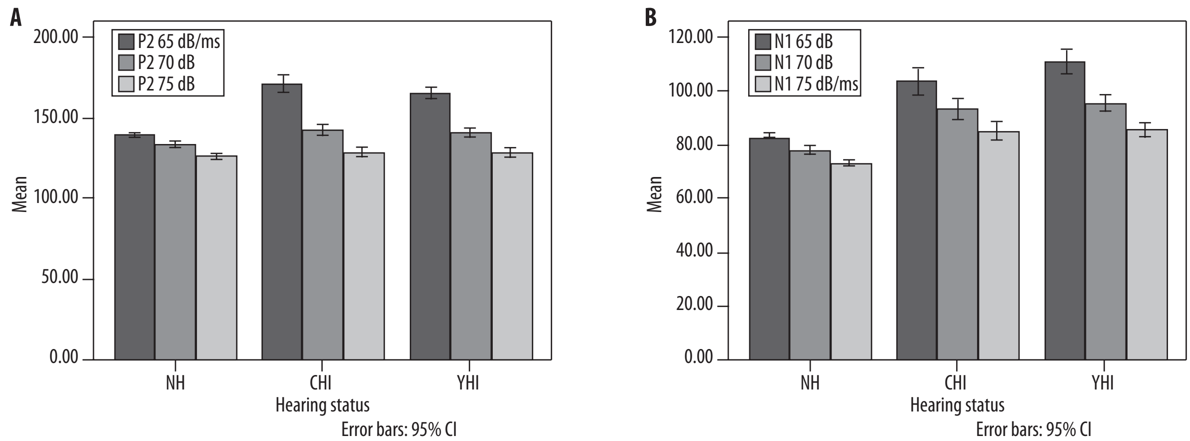

Figure 4. Relationship between cortical responses and signal intensity. Cortical responses demonstrated a significant decrease of latencies for N1 (**A**) and P2 (**B**) in response to increase of sound intensity in all groups (p<0.005).

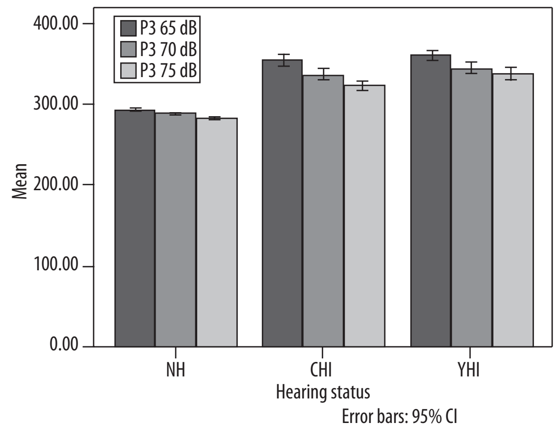

Figure 5. Cortical response P3 latencies significantly decreased with increased signal intensity in hearing impaired groups in quiet (p<0.05). P3 latencies significantly differ between normal hearing and both hearing impaired groups (p<0.05), hence YHI subjects had decreased sensitivity to small changes of stimulus intensity level.

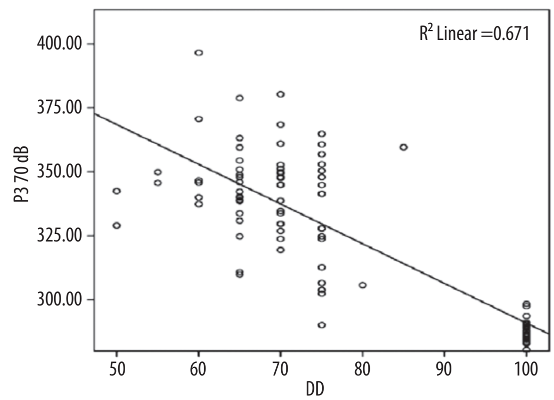

Figure 6. Relationship between behavioural and electrophysiological measurements. A strong negative correlation in Pearson's *r* values between dichotic digit recognition (DD) and cortical response P3 (P3 70 dB) (r=–0.81; p<0.001; linear regression determination ratio 0.61).

test in noise condition shows significant increase of speech recognition thresholds for groups of young and elderly subjects with hearing impairment (F(2.96)=161.49; p<0.005). No significant difference in speech recognition for individuals with normal hearing in noisy and quiet conditions. Based on *t*-test analysis mean values of speech recognition threshold for younger hearing impaired (42.36±7.07) and for older hearing impaired subjects (43.18±7.26) did not differ significantly (p=0.63) (Figure 2). Analysing responses of cortical potentials the data from the right ear were evaluated (Figure 3). Latencies of cortical responses were in normal values in groups of young and elderly subjects in comparison with normal hearing participants in quiet (Figure 4) but only N1 and P2 latencies increased significantly in all groups in noise. Amplitudes for response P1 were low, similar with research reports from other authors and commonly observed in adults. N1 amplitude becomes larger in noisy conditions in all groups. N1 latencies without ‘masking (F(2.96)=34.97; p<0.001) and in masking condition (F(2.95)=10.63; p<0.001) differ significantly in all groups. LSD *post-hoc* analysis shows that N1 latencies differs between NH group and both hearing impaired groups (YHI and OHI) significantly (p<0.001), but difference between both hearing impaired groups was not significant (p=0.30). P2 latencies without `masking (F(2.96)=10.41; p<0.001) and in masking condition (F(2.95)=12.26; p<0.001) differ significantly in all groups. LSD *post-hoc* analysis shows that P2 latencies differs between NH group and both hearing impaired groups (YHI and OHI) significantly (p<0.001), but difference between both hearing impaired groups was not significant (p=0.47).

The most essential effects were detected of P3 responses: P3 latencies significantly decreased with increased signal intensity in group of elderly subjects with hearing impairment in masking noise and also but less without masking. Sensitivity to signal intensity change in the group of young subjects with hearing impairment and the group with normal hearing was less than in the group of elderly subjects with hearing impairment in masking noise and without masking ($p<0.5$). In all tested signal intensity levels P3 latencies significantly differ between the groups: without masking ($F(2.96)=113.35$; $p<0.001$) and in condition with masking ($F(2.95)=137.18$; $p<0.001$) (Figure 5). LSD *post-hoc* analysis shows that P3 latencies (without masking) differ significantly between normal hearing group and both hearing impaired groups in both listening conditions (with and without masking) ($p<0.001$). For P3 significant difference between both hearing impaired groups were without masking ($p=0.04$) and not in masking condition ($p=0.08$).

To assess the relationship between scores of auditory behavioural tests and latencies of auditory evoked potentials, Pearson product correlations were analyzed. Significant relationship was found between dichotic digit perception and P3 in noisy conditions: negative correlation in elderly patient group ($r=-0.81$; $p=0.001$; linear regression determination ratio 0.61) (Figure 6). No significant correlations among other evoked potentials and dichotic speech recognition in any group.

Discussion

The study reviews how changes in auditory behaviour are associated with reaction time of cortical evoked responses, relationships between behavioural and cortical auditory processing investigation outcomes. Auditory processing was identified by electrophysiological measurements indicated auditory evoked response components which are the most sensitive for changes in the perception of auditory stimulus [26]. Auditory evoked responses elicited by nonspeech signals permit the validation of auditory processing disorder independent of language status and other pansensory [27] functions that are not auditory specific.

During our study the auditory processing was indicated by behavioural measures. We found some correlations among electrophysiological and hearing behaviour. Modality of auditory stimuli significantly influenced auditory responses [14]. Signal type, noise type and evoking paradigm of evoked potentials must be considered to understand perception distinctions [20,28]. Significant changes in the neurophysiologic measurements were detected and they consort with the results with our previous study.

Aging may affect the ability of communication between two hemispheres of the brain and decrease performance of the *corpus callosum* leading to decreased speech signal speed which shows cortical responses, resulting in decreased speech understanding [29]. The dichotic speech is considered to be the most sensitive test for this condition [14]. Our study demonstrates decreased dichotic recognition scores in both groups of subjects with hearing impairment. Mean percent correct scores for pair digits from subjects with normal hearing and subjects with hearing impairment in the present study agree with data from Wilson [30] and Musiek [15]. The different results of both dichotic tests, i.e., higher percentage of recognised words were from dichotic digits in comparison with dichotic words tests [31] indicates the relevance of semantics, accordingly influenced by cognitive factors [32,33].

Evoked potentials are considered as sensitive measurements of electrocortical activity during auditory processing [22,34]. Significant relationship between changes of stimulus intensity and latencies of the evoked responses P1, N1, P2 and N2 were found that agree with findings of published results of other authors [28,35] But not always relationship between changes of stimulus intensity and latencies of the evoked response P3 has been found [36]. Human cortical evoked potential data related to investigations of signals in noise are limited. P3 responses of elderly subjects were more related to stimulus level change and masking noise than younger hearing impaired subjects. Younger subjects had significantly decreased sensitivity to small changes of stimulus intensity reflected by invariable P3 latency in quiet and masking noise conditions [17]. This finding may show the distinct cause from auditory perception depending on age. Late component P3 is the one that is the hardest to influence by stimulus changes in all groups. The majority of studies suggest that masking noise and changes of stimulus intensity delays brain responses to speech sounds strongly only at subcortical level [21]. Phillips [37,38], Phillips and Kelly [39] found that it was the relation between the tone and masker level rather than the tone level. This factor may be relevant for neural responses in the central auditory system.

Correlation between signal intensity and speech recognition thresholds and evoked response timings in elderly subjects, as contrasted with young adults, demonstrated the implication of changes in subcortical and cortical levels of speech processing [4], which may be caused by aging, whereas in young adults it could be explained by different neurobiological reason than in elder people [9]. The correlation of speech recognition with aging does not receive unequivocal support in reported investigations. Snell and Frisina [40], Humes [8] found significantly larger mean speech recognition thresholds in older subjects in comparison with younger subjects. Prolonged cortical evoked responses were detected in groups of participants with hearing impairment in quiet and noisy conditions [41,42]. In cases of relationship between specific aspects of neural coding of sound at cortical level are found in noisy condition in older subjects [43]. He et al. [44] reported that N1 latencies were prolonged in older subjects in response to complex and speech stimuli, but not to a pure-tone stimulus. Based on these studies many authors, Schroeder et al. [45] and Harris et al. [21], are of the opinion that prolonged N1 and P2 latencies are associated with general slowing of neuronal processing, decreased neuronal synchrony within central auditory nervous system with aging [40,46]. Various correlations between dichotic speech perception and attention related auditory responses show differences and alterations of auditory processing during lifetime, more in groups of younger than in groups of elderly individuals [48]. This is indicated by variant topological distributions of cortical potentials in younger and elderly individuals. Martin and Jerger [5], Parbery-Clark et al. [49] reported studies of subjects who suffered from difficulty hearing, but had normal pure-tone audiometry. These studies clearly show electrophysiological evidence of abnormal auditory processing similar to segregated our data. In cortical segment hearing decline traditional amplification devices are not satisfactory to improve hearing loss. Hence investigations are performed in this field [28,35], however, solution about rehabilitation remains controversial and complicated. Studies of He et al. [44] also review that temporal auditory processing conforms to speech recognition threshold, but not with pure-tone audiometry and not directly with age. Accordingly, reduced temporal auditory processing does not seem to be an unavoidable component of aging. The main goal remains the improvement of signal temporal processing. Cortical auditory evoked potentials reflect neural activity of the thalamic-cortical segment of the central auditory system [6]. Based on the results from animal studies that show age-related changes in temporal processing [50,51] and declines of inhibitory neurotransmitters (such as GABA) in the central auditory system [47,52,53], contribution of the brain plasticity could be of great importance in the improvement of this function. Dissociation between young and older groups indicates that all brain processes do not slow down at the same rate according to response. Despite similar speech discrimination performance on behavioural measures, marked effects of age were observed in the cortical responses, such that younger adults were less sensitive signal intensity level than to frequency change and older adults had delayed latencies and reduced amplitudes of P3.

Conclusions

The results suggest dissimilarities between normal hearing and individuals with hearing difficulty, as well as between younger and elderly individuals. Correlations between dichotic speech recognition and auditory evoked responses show differences and alterations of auditory processing during lifetime, more in groups of younger than in groups of elderly individuals. The most constitutive changes developed around responses N1, P1 and P3 and dichotic speech recognition scores. Despite of resembling results from behaviour tests, outcomes of auditory evoked potentials mark less influence of signal intensity level latencies in young then in older subject group. The essential finding of this study was the relevant permanence of latency of event related auditory cortical potential P3 in response to increase of sound intensity in young participant group. This feature could be indicative for identification of changes more in central auditory processing than other segments of hearing system. This finding could be considered as sensitive tool for identification of central auditory disorders and must be completed in order to understand underlying origins of central auditory processing in further investigations.

Statement of conflict of interest

The authors state no conflict of interest.

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