Effect of Noise Spectrum on Cortical Evoked Auditory Potentials In Younger and Older Adults With Normal Hearing Sensitivity

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Abstract

Cortical auditory evoked responses (CAEPs) can be employed to study the neural encoding of speech. This on the other hand helps us in understanding the speech processing that happens at higher level. CAEPs can be used on different populations to see how their perception is affected by noise. Older individuals often complain about trouble in understanding speech in noisy situations. These individuals with or without hearing loss usually exhibit difficulty in perception of speech compared to young listeners especially in the presence of background noise. The present study was designed to identify the effect of different type of noise spectrums on the cortical auditory evoked potentials (CAEPs) in younger and older population and its correlation with behavioral measure (speech in noise test results). 15 younger adults and 15 older adults with normal hearing sensitivity participated in the study. Stimulus /ba/ and /da/ stop consonants in four different test environment such as in quiet, high pass noise (>4000 Hz), low pass noise (<200 Hz) and speech noise was used in the study. Latency and amplitude of N1 and P2 were considered for the study. Significant shift in latency and reduction in amplitude was seen in N1 of the older adults. Stimulus condition quiet showed significantly better latency and amplitude compare to other three noise conditions in both the groups. Significant negative correlation was seen between SPIN scores and N1 and P2 latencies. These results indicate, age-related refractory differences in younger and older auditory systems could have reflected in CAEPs. Refractory issues might in turn affect synchronized neural activity and hence result in poorer latency and amplitude. Different noise spectrum affects CAEPs differentially and N1 is most affected by low pass noise and P2 is most affected by high pass noise. The data indicates that use of CAEPs in measuring effect of noise at cortical level and its correlation with speech perception has excellent potential for future research among older adults.

Key words: *Cortical potentials, noise spectrum, older adults, younger adults*

Introduction

Speech is heard and understood through a series of events which occur in the auditory system. The ear converts sound waves into mechanical signal and then to electrical signals. These electrical signals then generate nerve impulses and sent to the brain where they are interpreted and perceived as meaningful sound. Different sounds having different frequency composition stimulate different parts of the inner ear and sent to the auditory cortex thus helping the brain to distinguish among various sounds.

One way to evaluate what is happening in the cortex as it performs cognitive acts is to record the electrical fields that it generates. Late latency responses (LLR) are believed to index the sound arrival information to the cortex and initiation of cortical sound processing. Presence of LLR complex indicates that the stimulus has been detected. Cortical auditory evoked potentials (CAEPs) evoked by speech sounds have recently been investigated to determine the effect of phonologic and acoustic features on the cortical waveform (Crottaz-Herbette & Ragot, 2000) and to identify the cortical areas activated by these features. Late latency responses (LLR) are believed to index the sound arrival information to the cortex and initiation of cortical sound processing. Presence of LLR complex indicates that the stimulus has been detected at the cortical level.

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The obligatory components of cortical potentials (P1, N1, P2 and N2) have a systematic developmental time-course (Sharma et al., 1997; Ponton et al., 2000; Sussman et al., 2008; Cunningham et al., 2001). In adulthood the cortical response is dominated by the N1-P2 complex, but in childhood the P1 and N2 components dominate the response (Ceponiene et al., 2002). The P1 component serves as a central auditory developmental marker, with shorter latencies and smaller amplitudes as children mature from infancy to young adulthood (Sharma et al., 2002). Likewise, the N2 amplitude decreases, whereas the N1 component becomes more prominent with development (Sussman et al., 2008). Furthermore, the P1 and N2 components may reflect different aspects of sound processing, with P1 encoding the acoustic features of sound, such as frequency and timing, and N2 synthesizes these features into a sensory representation (Shtyrov et al., 1998; Ceponiene et al., 2005).

Human auditory system also has the ability to extract important information in the presence of noise and helps us to understand what has been said. Extracting a speaker's voice from background of competing voices is essential for communication. This process is often challenging, even for younger adults with normal hearing individuals (Assmann & Summerfield, 2004; Neff & Green, 1987). Older adults tend to have more difficulty in speech perception than younger adults in the presence of noise and they experience still more difficulty when the noise is temporally modulated

(Dubno et al., 2002). Anderson et al (2010) concluded that relationship between higher-level perception and obligatory cortical activity and, specifically, demonstrate that a greater N2 response magnitude in noise is associated with poorer speech in noise (SIN) perception. These differences in cortical processing emerge only in challenging listening conditions.

As the age increases from 50 years to 89 years the prevalence of auditory processing disorders increases from 20% to 95% (Stach, Spetnjak & Jerger, 1990). Among individuals aged 55years or older the prevalence of auditory processing disorder found to be 76.4% (Golding et al, 2004). This probably happens due to consequence of structural changes that happens in the auditory system. It is well documented that older individuals have difficulty in understanding speech. The most common problem that they report is inability to comprehend speech in the presence of a background noise irrespective of their hearing threshold.

Yilmaz, Sennaroglu, Sennaroglu and Kose (2007) reported that that with advancing age the ability to identify speech in the presence of background noise decreases. Many researches demonstrated that the speech understanding ability and temporal processing gets affected in older adults. Helfer and Vargo (2009) concluded that the temporal processing may be an underlying cause for difficulty in understanding speech in competing speech.

Kim et.al (2012) reported that N1 latency to tones with lower intensity and noise were delayed in older adults compared with those in younger adults. These stimulus intensity and noise issues can affect synchronized neural activity underlying the auditory processing and may provide a partial explanation for the difficulties shown by older adults in understanding speech. Douglas S Goodin et.al (1978) observed that in adults there was a systematic increase in the latency and decrease in amplitude of each component (P1, N1 & P2) with age. Also the rate of the age-related increase in latency was proportional to the latency of the component seeing these results they concluded that an aging process is reflected in the auditory evoked potential which is not the simple inverse of maturational processes. K L.Tremblay(2004) found out that N1 and P2 latencies are prolonged for older listeners in response to the speech stimulus but not the tone stimulus. While age-related delays were present for both stimuli at the faster rate, these age effects are absent when presented at slower stimulus presentation rates.

Research ?ndings from studies done by Kim JR et.al (2012), K L.Tremblay (2004), Yilmaz, Sennaroglu, Sennaroglu and Kose (2007) and clinical experience suggests that older adults require a diagnostic and management protocol unique to their needs. The protocol proposed by the 'American Academy of Audiology Guideline for the Audiological Management of Adult Hearing Impairment (2005), stress on gaining an objective measure for hearing status and speech understanding under a variety of conditions and at differing Signal to Noise Ratios (SNRs). It also insists to design objective tests to uncover the listening difficulties and to determine listening strategies used in degraded/noisy listening conditions. This warrants the need for an objective test which measures the effect of noise on speech stimulation to compare with the behavioral measures. One approach to study speech in presence of noise encoded in the human central auditory system is to use cortical auditory evoked potentials (CAEPs). This can provide valuable information about the temporal encoding of large populations of cortical neurons recorded at the scalp (Billings et al. 2011).

Although studies show effect of age on cortical potentials some studies have shown no effect. Maria José et al (2004) stated that, Latencies of auditory potentials of N1 and P2 long latency did not present any alterations on elderly patients who complained of speech understanding difficulty and who presented normal tonal audiometry on frequencies lower than 4000 Hz, which suggested that the latency of such potentials is not affected by age of the individuals. The fact that this population (complaining of speech understanding) did not present alterations on latency of such potentials suggests that hearing disorder would not be in the sites from those studied in this work electrophysiologically. Further by correlating the results of electrophysiological test with a behavioral test, will aid in relating the neural encoding to the behavior of the individual in terms of speech identi?cation difficulties. This in turn helps in determining the selection of appropriate management option and counseling.

The aim of the study was to find the effect of different types of noise spectrum on various peaks of ALLR in younger and older adults with normal hearing sensitivity and to investigate which component of ALLR best correlates with the speech perception ability.

Method

Participants:

Two groups, of normal hearing individuals were taken for the study.

Group I: Normal hearing young healthy adults aged from 15 to 40 years.

Group II: Normal hearing elderly healthy adults aged above 50 years.

Participants were selected based on the following criteria for both the groups:

Group I (control group): 15 participants in the age range of 15 to 40 years diagnosed as having normal hearing sensitivity based on a test battery approach including, pure tone audiometry, speech audiometry, immittance and reflex audiometry were considered for the study.

Group II (Clinical Group): 15 participants who are above 50 years old and diagnosed as having normal hearing sensitivity based on a test battery approach including, pure tone audiometry, speech audiometry, immittance and reflex audiometry were considered for the study.

Instrumentation:

A calibrated two channel diagnostic audiometer, GSI-61 (Grason-Stadler Incorporation, USA) with TelephonicsTDH 39 supra aural headphones and Radio ear B-71 bone vibrator calibrated as per ANSI (2004) was used for threshold estimation and speech audiometry.

A calibrated GSI-tympstar(Grason-Stadler Incorporation, USA) clinical immittance meter, calibrated as per ANSI 1987will be used for tympanometry and reflexometry. ILO 292 DPEcho port system (Otodynamics Inc., UK) was used to assess transient evoked otoacoustic emissions.

Intelligent Hearing Systems (IHS smart EP windows USB version 3.91) with AgCl electrodes and ER-3A insert earphones was used to record brainstem auditory responses. Stimuli were generated by using Intelligent Hearing Systems.

Stimulus: Two naturally recorded speech syllables /da/ and /ba / from an adult native male speaker. This was recorded on to a PC at 64 bits and 44100/sec sampling frequency using Adobe Audition 3 software. Stimulus / ba/ and /da/ were considered since they occur frequently, and differ in terms of F2, which is an important cue for speech perception. The stimulus consisted of 400 ms of noise onto which, a 100 ms stop consonant was mixed at 300 ms.

Three types of noise were considered: Low pass noise (<200Hz), High pass noise (>4000Hz) and Speech noise. Two stop consonants /ba/ and /da/ of 100 ms were mixed at 0 dB SNR with the final 100 ms of noise. The initial and final 10 ms was ramped with a cosine window to ensure smooth onset and offset as shown in the figure below.

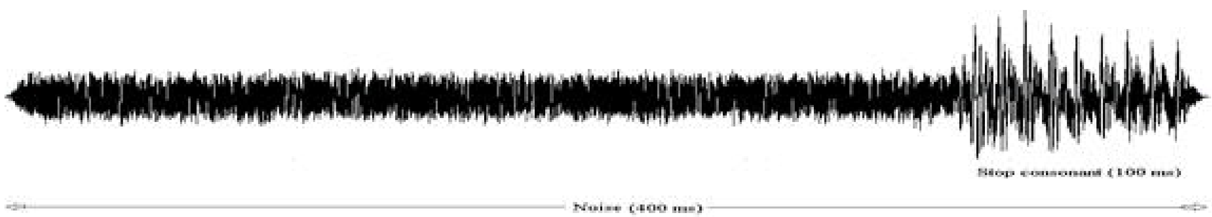

Figure 1: stimulus of 400 ms including target stimulus of 100ms (/da/)

Procedure:

A detailed case history was taken before the commencement of routine audiological assessment. Pure-tone thresholds were obtained using modified version of Hughson and Westlake procedure (Carhart&Jerger, 1959). Speech audiometry including Speech reception threshold (spondee word list given by Vandana, 1998) and Speech Identification Scores (Yathiraj &Vijayalakshmi, 2005), and uncomfortable level for running speech were obtained.

Immittance audiometry was carried out with a probe tone frequency of 226 Hz. Ipsilateral and contralateral acoustic reflexes thresholds were measured for 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz. Otoacoustic emissions were obtained for 260 nonlinear click stimuli. SNR of more than 6 dB in at least 3 consecutive octave frequencies in both ears, with reproducibility greater than 50% was considered as presence of OAEs.

Testing environment: All the tests were carried out in an air conditioned, double room situation with ambient noise levels within permissible limits (ANSI S-3, 1991).

Testing phase: The testing phase was carried out similarly in both the groups.

Phase I: Speech in Noise (SPIN) scores were obtained at 0 dB SNR monaurally. The SPIN was done for sentences (Geeta & Manjula, 2015).

Phase II. Recording and Analysis of evoked potentials

The patients were seated in an electrically and acoustically shielded room. A skin abrasive was used to clean the electrode sites in accordance with the 10-20 International system (Jasper HH, 1958). The disc electrodes dipped in a conduction paste were placed on their respective sites using a surgical tape. They were asked to relax and will be made to watch a film with the soundtrack turned off. They were asked not to pay attention to the stimulus and to avoid excessive blinking.

A baseline LLR was taken without noise in the stimulus i.e. in quiet and in noise that has been mentioned above. Thus LLRs were recorded in 4 different conditions both in normal and clinical group. The speech stimulus was given in 5 sets of 30 sweeps, in all 4 conditions, where the recordings with less noise were considered for the process of averaging.

Acquisition parameters	Transducer	Insert earphones ER-3A
	Analysis Time	-100ms to 900ms
	Band pass filter	1Hz-30Hz
	Electrode placement	Cz,:Non inverting Tip of the nose: Inverting electrode Fpz: Ground
	Sweeps	300
	Electrode Impedance	≤5 kΩ
	Inter Electrode Impedance	≤2kΩ
	Number of trials	2
	Line filter	Off
	Artifact rejection	±100 micro Volt
	Gain	50000

Averaged waveforms obtained from same stimulus blocks were used to check for replication between waveforms and to aid in peak marking. The peaks were marked by three experienced Audiologists.

Analysis: The latency and amplitude of the P1, N1, P2 and the positivities and negativities of the LLR were measured with respect to the baseline and subjected to analysis. Mean and standard deviation of amplitude and latency were calculated. Grand-average waveform analysis as well as individual subject analysis were done keeping in mind the individual variability among subjects. The following analysis was carried out using appropriate statistical methods.

There was presence of two LLRs, one for the onset of noise and other for the onset of speech in noise. The LLR obtained for the speech in noise was considered for the analysis. Comparison between the latency and amplitude of the baseline LLR in quiet and LLR obtained in various noise maskers and see the differential effect of noise on different components of LLR.

Correlations between behavioral speech identification and LLR components in the older adult group were done. Comparison between LLR's of individuals with normal hearing in high pass masking, low pass masking, speech noise masking to the LLR of older adults was carried out.

Results

Latency

Descriptive statistics across groups and conditions: Descriptive statistics were carried out to obtain the mean, median and standard deviation for the latencies of N1 and P2 in different test conditions in both the groups for /ba/ and /da/ stimulus. The mean, median and standard deviations for N1 and P2 obtained at different test conditions by both the stimulus /ba/ and /da/in both the groups are tabulated and shown in the Table 1 and 2.

Table 1: Mean, median and standard deviation (SD) of latency of N1 elicited by speech syllable /ba/ and /da/ in different test conditions for younger and older adults

Stimulus	Younger adults Mean (ms)	Median (ms)	SD	Older adults Mean (ms)	Median (ms)	SD
/ba/ in quiet	114.86	110	20.38	110.33	108	22.41
/ba/ in highpass noise	122.26	122	25.25	110.86	104	14.37
/ba/ in lowpass noise	129.73	136	33.15	117.20	120	19.58
/ba/ in speech noise	126.70	125	20.86	104.26	100	28.30
/da/ in quiet	98.80	100	7.24	102.20	102	9.57
/da/ in highpass noise	113.46	112	12.29	110.86	110	7.18
/da/ in lowpass noise	101.33	110	23.09	114.20	116	5.85
/da/ in speech noise	104.73	102	23.61	116.66	118	14.81

The above table shows that, latencies of N1 elicited by speech stimulus /ba/ in younger adults are longer than older adults in all stimulus conditions. Also latency of N1 obtained in quiet condition is shorter than other conditions except in the presence of speech noise in older adult group. In younger adults N1 latencies are longer for noise condition than quiet. Latencies of N1 elicited by speech syllable /da/ in younger adults are earlier than older adults in all stimulus conditions except for high pass noise condition. And it can be observed that N1 latency in quiet condition are earlier than other three conditions in both groups.

Table 2: Mean, median and standard deviation (SD) of P2 latency elicited by speech syllable /ba/ and /da/ in different test conditions for younger and older adults

Stimulus	Younger adults			Older adults		
	Mean (ms)	Median (ms)	Median	Mean (ms)	Median (ms)	SD
/ba/ in quiet	173.33	170	22.24	196.33	182	40.48
/ba/ in highpass noise	202.66	218	39.85	209.66	234	50.20
/ba/ in lowpass noise	191.40	198	40.97	194.06	174	42.60
/ba/ in speech noise	178.06	165	46.64	176.60	199	41.45
/da/ in quiet	162.00	154	13.24	165.86	160	17.07
/da/ in highpass noise	187.06	190	22.19	188.93	180	34.06
/da/ in lowpass noise	172.00	174	18.09	182.80	178	17.05
/da/ in speech noise	186.60	187	43.59	199.86	186	20.44

The above table shows that for speech stimulus /ba/, latencies of P2 in younger adults are earlier than older adults except in the presence of speech noise. And also latency of P2 in quiet condition is earlier than other three conditions for younger adults. Whereas in older adults it can be observed that P2 latency is least for /ba/ in the presence of speech noise followed by /ba/ in the presence of lowpass, quiet condition and in the presence of highpass noise.

P2 latencies elicited by speech syllable /da/ in younger adults are earlier than older adults in all three conditions. And it can also be observed that for speech syllable / da/ in quiet condition P2 latency is earlier than other three stimulus conditions in both the groups.

Comparison of effect of noise on N1 and P2 latency across group (younger vs older adults) and conditions for /ba/ and /da/ stimulus.: Descriptive statistics showed there are variations in latencies of N1 and P2 elicited by /ba/ stimulus across conditions and groups. To see whether the group has any effect on N1 and P2 latencies in different stimulus condition Mann-Whitney U test was administered.

Mann Whitney U test result showed a significant difference for N1 latency between the groups in two conditions i.e. /ba/ in lowpass noise and /da/ in low pass noise. This suggest that low pass noise has significant effect on N1 latency.

Within group comparison of effect of different type of noise on N1 and P2 latency elicited by speech syllable /ba/: To see the effect of noise on latencies of ALLR components (N1 and P2), Friedman's test was administered. This was done separately for each group. It was observed that none of the conditions exhibited significance difference for speech syllable /ba/ in all four conditions. Hence, Wilcoxon's signed rank test was not conducted to see pairwise comparision for different test conditions in.

Within group comparison of effect of different type of noise on N1 and P2 latency obtained by speech syllable /da/ in younger adults: To see the effect of noise on latencies of ALLR components (N1 and P2) repeated measure ANOVA was used as it was normally distributed data. It was observed that P2 latency showed significant effect of noise for younger adults. Hence, pairwise comparison was carried out by using Bonferroni test only for P2 latency in younger adult group to see the differences between different noise conditions within the group.

It was seen that, there was a significant difference in P2 latency obtained in the quiet condition and in highpass noise for speech stimulus /da/. This significant difference was seen only for P2 latency in younger adults. The results showed that the highpass noise had more effect on cortical potentials than other noises used in the study.

Within group comparison of effect of different type of noise on N1 and P2 latency obtained by speech syllable /da/ in older adult group: To see the effect of noise on latency of ALLR components (N1 and P2), Friedman's test was administered. This was done separately for each group. It was observed that both N1 and P2 latencies elicited by speech syllable /da/ for older adults showed significance main effect within group across test conditions. Hence, pairwise comparison was carried out by using Wilcoxon's signed rank test or both N1 and P2 latency in older adult group. It was observed that there was significant difference in N1 and P2 latency obtained in quiet condition from rest of the stimulus condition (highpass noise, lowpass noise, speech noise). This significant difference was seen for both N1 and P2 latencies in older adults. The result showed that all type of noise had some effect on the N1 and P2 latencies.

Amplitude

Descriptive statistics across groups and conditions: Descriptive statistics were carried out to obtain the mean, median and standard deviation for the amplitudes of N1 and P2 in different test conditions in both the groups for /ba/ and /da/ stimulus. The mean, median and standard deviations for N1 and P2 obtained by different test conditions in both the groups are tabulated in the Table 3 and 4.

Table 3: Mean, median and standard deviation (SD) of amplitudes of N1 elicited by speech syllable /ba/ and /da/ in different test conditions for younger and older adults

Stimulus	Younger adults Mean (µv)	Younger adults Median (µv)	Younger adults SD	Older adults Mean (µv)	Older adults Median (µv)	Older adults SD
/ba/ in quiet	-3.39	-3.29	1.36	-3.08	-3.29	1.01
/ba/ in highpass noise	-1.93	-1.79	1.40	-1.52	-1.63	1.91
/ba/ in lowpass noise	-2.23	-1.81	1.37	-2.02	-1.48	2.02
/ba/ in speech noise	-0.38	-.23	1.29	-0.89	-.34	1.44
/da/ in quiet	-3.94	-3.90	1.49	-3.50	-3.19	1.49
/da/ in highpass noise	-2.87	1.97	1.68	-2.59	-2.68	0.99
/da/ in lowpass noise	-2.74	-2.17	1.47	-2.33	-2.11	1.32
/da/ in speech noise	-0.31	0.02	1.08	-2.05	2.63	1.46

The above table shows that, amplitude of N1 elicited by speech stimulus /ba/ in younger adults are greater than older adults except in the presence of speech noise. Also N1 amplitude obtained in quiet condition is greater than other three test conditions (lowpass noise, highpass noise, speech noise) in both the groups. Amplitude of N1 elicited by speech stimulus /da/ in younger adults are greater than older adults except in the presence of speech noise. Also N1 amplitude obtained in quiet condition is greater than other three test conditions (lowpass noise, highpass noise, speech noise) in both the groups.

Table 4: Mean, median and standard deviation (SD) of P2 amplitude elicited by speech syllable /ba/ and /da/ in different test conditions for younger and older adults

Stimulus	Younger adults Mean (µv)	Younger adults Median (µv)	Younger adults SD	Older adults Mean (µv)	Older adults Median (µv)	Older adults SD
/ba/ in quiet	4.39	4.54	2.24	2.33	2.49	2.43
/ba/ in highpass noise	3.27	3.34	1.85	1.94	1.70	1.89
/ba/ in lowpass noise	3.01	3.28	2.30	2.58	1.95	2.29
/ba/ in speech noise	2.57	1.73	1.37	1.77	1.10	1.26
/da/ in quiet	4.05	3.88	1.97	3.64	3.33	1.45
/da/ in highpass noise	3.85	3.41	1.65	3.29	2.72	2.45
/da/ in lowpass noise	3.65	3.59	1.68	3.10	2.96	1.81
/da/ in speech noise	2.63	2.92	1.23	3.15	3.51	1.66

The above table shows that for speech syllable /ba/, P2 amplitude in younger adults are greater than older adults in all four conditions. In younger adults, quiet condition has greater amplitude than other three conditions. In older adults, /ba/ in lowpass noise had greater amplitude than other three conditions.

For speech syllable /da/, P2 amplitude elicited in younger adults had greater amplitude than that of older adults except in speech noise condition. P2 amplitudes were greater for quiet condition than other three conditions for both the groups.

Comparison of effect of noise on N1 and P2 amplitude across group (younger vs older adults) and conditions for /ba/ stimulus: Descriptive statistics showed there are variations in amplitudes of N1 and P2 elicited by /ba/ and /da/ stimulus across conditions and groups. To see whether the group has any significant effect on N1 and P2 amplitudes in different stimulus condition Mann-Whitney U test was administered

Mann Whitney test showed a significant difference in N1 amplitude between two groups i.e. /da/ in lowpass noise and /da/ in speech noise). Within group comparison of effect of different types of noise on N1 and P2 amplitude elicited by speech syllable /ba/: To see the effect of noise on amplitudes of ALLR components (N1 and P2), Friedman's test was administered. This was done separately for each group. It was observed that conditions have significant effect on N1 and P2 amplitude for both younger and older adults. Hence, pairwise comparison was carried out by using Wilcoxon's signed rank test for N1 and P1 in younger adults. It was observed that for speech syllable /ba/ there is a significant difference in N1 and P1 amplitudes between quiet condition and other three conditions.

Similarly, pairwise comparison was carried out by using Wilcoxon's signed rank test for amplitudes of N1 and P1 in older adults. It was observed that, for speech syllable /ba/ there is a significant difference in N1 amplitudes obtained between quiet and other three noise conditions. Whereas for P2 amplitude significant differences were seen between speech noise and quiet, lowpass noise and highpass noise, and speech noise and highpass noise.

Within group comparison of effect of different types of noise on N1 and P2 amplitude elicited by speech

syllable /da/: To see the effect of noise on amplitudes of ALLR components (N1 and P2), Friedman's test was administered. This was done separately for each group. It was seen that there in a significant effect of noise on N1 amplitude for both younger and older adults. However, there was no significant effect of noise on P2 amplitude. Hence, pairwise comparison was carried out by using Wilcoxon's signed rank test was used for N1 amplitude in younger and older adult group. It was observed that, in younger adults there is a significant difference in N1 amplitude between quiet and other three conditions and between speech noise and highpass noise and also between speech noise and lowpass noise condition. Whereas in older adults, significant difference was seen between quiet and other three conditions.

Correlation between components of ALLR with SPIN test scores: One of the objective was to find the correlation between N1 and P2 latency of ALLR and SPIN for speech syllables /ba/ and /da/. To do so Pearson correlation was used for normally distributed data (N1, P2 latencies for /da/ in younger adults) and Spearman correlation was used for the data which was not normally distributed (N1 and P2 latencies for /ba/ in both groups and for /da/ in older adults).

It was observe that there is strong negative significant correlation between SPIN scores and N1 latency of speech syllable /ba/ in quiet condition. Moderate negative significant correlation between SPIN scores and P2 latency for speech syllable /ba/ in the presence of lowpass noise in younger adults. Moderate significant correlation between SPIN scores and N1 latency for speech syllable /da/ in quiet condition for older adults. No other N1 and P2 latency obtained at other stimulus condition showed significant correlation with SPIN scores for younger and older adults.

Similarly, correlation between N1 and P2 amplitude of ALLR and SPIN was done for speech syllables /ba/ and /da/. Spearman correlation was used as the data was not normally distributed. Results suggested that there is moderate negative correlation between SPIN scores and N1 amplitude elicited by speech syllable /ba/ in the presence of lowpass noise observed in younger adults. None of the other N1 and P2 amplitude obtained at different stimulus condition showed significant correlation with SPIN scores in younger and older adults.

Discussion

Latency:

Effect of spectrum of masker on latency in younger and older adults: In the present study significance latency shift was seen for N1 in older adults only in lowpass noise suggesting lowpass noise affected older adults more than younger adults. This agrees with the previous investigators, Kim et al., (2012) found that N1 latencies to tones in quiet for older adults were delayed than younger adults when stimulus was presented at 60 dB SPL.

Older adults had prolonged N1 latency in the presence of lowpass noise for speech stimulus /da/ and /ba/. However this significance was not observed in highpass noise and lowpass noise. This suggests that lowpass noise has significant effect on N1 latency. The result of the present study agrees with the previous investigators (Martin, Krutzburg & Staples 1999). They concluded that as the lowpass cutoff frequency increases N1 showed a smaller increase in latency and a smaller decrease in amplitude.

In contrast to above mentioned results, Martin and Stapells (2005) found that N1 latencies did not show latency shift until lowpass noise cutoff was raised to 1000 Hz. Significant delay was present only when low-pass noise masker was raised above 1000 Hz. Speech sounds usually have more energy at low frequencies. Thus probably masking effect is observed more for lowpass noise. This could be the possible reason for prolonged latencies in N1.

Effect of spectrum of masker on ALLR latency: For speech stimulus /ba/, there was no significant effect of different types of noise on N1 and P2 latencies in both groups. This result is in consensus with the results obtained by Martin and Stapells (2005). They found that N1 amplitudes showed significant changes when the low-pass noise masker cutoff was raised to 1000 Hz. Also Martin, Sigal, Kurtzberg and Stapells (1997) found that significant latency shifts was seen in N1 latency when highpass cutoff of reduced to 1000 Hz. In the present study we have used lowpass cutoff as 200 Hz and highpass cutoff as 4000 Hz. This may be the reason for not getting significant difference.

In younger adults: For speech stimulus /da/, it was found that P2 latency was significantly prolonged for highpass noise condition in younger adults. Latency prolongation was also present in other noise conditions, but did not reach statistical significance.

We can see similar results in other studies, Martin et al., (1997) found that presence of highpass noise decreases the audibility of the stimulus which may affect the latency of the response. Effect of highpass noise on /da/ is more pronounced may be because both /da/ and highpass nose has similar frequency range so highpass noise could have probably affected perception of /da/ which lead to prolonged P2 latency. Also since P2 comes at relatively longer latency it is possible that increased P2 latency suggests a distortion in central auditory processing.

In this study we have found significant latency shift for /da/ but not for /ba/. One reason for latency delay in /da/ but not in /ba/ may be due to their differing spectra.

Another reason could be due to differences in rise time. /da/ had shorter rise time (19 ms) than /ba/ (43ms) and hence must have result in a differential neural activation (Davis & Zerlin, 1966).

In older adults: For speech stimulus /da/, prolongation of latencies was found in all noise conditions with respect to quiet condition. Prolongation of latency could be due to reduction in audibility due to noise (Martin & Stapells, 2005) as well as due to reduced speed of sensory information processing (Leppanen & Lyytinen, 1997).

Though there was a trend for increased latencies with noise, statistical significance was not found in some noise conditions due to larger variability. N1 latency had a trend to be more prolonged for /da/ in high pass noise than /da/ for low pass noise probably due to its high frequency spectral energy.

Statistically significant shifts in latency were found for N1 in highpass noise and lowpass noise conditions and for P2 in lowpass noise and speech noise condition. These results are in consensus with the results obtained by Martin, Sigal, Kurtzberg and Stapells (1997). They found that N1 showed gradual changes as the lowpass masker cutoff frequency was lowered. N2, P3, and behavioral measures showed marked changes below a masker cutoff of 2000Hz.

In contrast to above mentioned results, Martin and Stapells (2005) found that N1 latencies showed significant delay when the low-pass noise masker was raised to 1000 Hz, whereas other latencies i.e. N2 and P3 latencies did not change significantly until the low-pass noise masker was raised to 2000 Hz. Showing lowpass maskers affects N1 in a differential manner compared with N2 and P3. N1 indexes the presence of audible stimulus energy, being present when speech sounds are audible, whether or not they are discriminable.

Amplitude:

Effect of spectrum of masker on amplitude in younger and older adults: There was a trend towards reduction in amplitude in the older group compared to the younger group for both N1 and P2 amplitudes. Statistical significance however was achieved only for /da/ in low pass noise condition. This agrees with the previous investigators, Tremblay, Billings and Rohila (2004) found that N1 amplitude reduced for older adults. These age effects were absent when stimuli were presented at a slower rate (1510 msec Inter stimulus interval). Tremblay, Piskosz and Souz (2003) also found that N1 amplitude was reduced for older group. Dum, (1983) studied cortical potentials in guinea pigs and found that threshold was 44 dB higher in the cortical potentials in old animals than young animals. One potential explanation for this age effect might be the age-related refractory differences in younger and older auditory systems. Refractory issues might in turn affect synchronized neural activity and hence result in reduced amplitudes. (Tremblay, Billings and Rohila (2004).

It was also observed that N1 amplitude in the older group was significantly more than that of the younger group for /da/ in speech noise. This Increase in amplitude in older adults may be due decrease in inhibition at the cortical level (Bromfield, Cavazos & Sirven, 2006). Similar results have been reported in those with learning disability (Anderson, Chandrashekar, Yi & Kraus, 2010) and hearing loss (Oats, Kurtzberg & Staplles, 2002).

Effect of spectrum of masker on amplitude in different conditions:

In younger adults: There was a trend towards reduction in amplitudes of both N1 and P2 in all noise conditions when compared to quiet condition. Significant differences were found between quiet and all noise conditions for both N1 and P2 amplitudes in /ba/ and only for N1 amplitude in /da/. This was true for both younger and older adults. Speech noise caused a greater reduction in amplitude than low and high pass noise conditions for /da/ in both the groups, but was significant only in the younger adults. These results are in consensus with the results obtained by Martin and Staplles (2005). They found that N1 amplitude significantly reduced in the presence of different spectral noises. Martin et al., 1995 found that N1 amplitude decreased by 0.63 mV when the highpass cutoff was increased to 2000 Hz.

Decreased audibility results in decreased ERP amplitudes (Martin & Stapells, 2005). The lowpass noise and speech noise probably affects the audibility, hence affected N1 amplitude. Whereas high frequency noise and speech noise probably has masked perception of /ba/, which leads to decreased P2 amplitude.

Correlation between ALLR and Speech in noise test results: In latencies, Strong negative significant correlation was found between SPIN scores and N1 latency of /ba/ in quiet condition in older adults. Moderate negative significant correlation was found in P2 latency of /ba/ in lowpass noise in younger adults. Negative correlation seen between SPIN scores and N1 and P2 latencies hints us about the relation between behavioral and electrophysiological aspects of speech perception. This negative correlation indicates that as the SPIN scores increased N1 and P2 latencies decreased. Suggesting latencies were better for individuals who had better SPIN scores. This agrees with the previous investigators, Narne and Vanaja (2005) found that there were better latencies and amplitudes for higher SPIN score group in individuals with auditory neuropathy.

It was also observed that there was moderate significant negative correlation between SPIN and N1 amplitude for /ba/ in lowpass noise. These correlations in this study are contradictory. Possible potential reason for this contraindication may be the inhibition at the cortical level (Bromfield, Cavazos & Sirven, 2006). Oats, Kurtzberg and Stapells (2002) found better latencies and amplitudes in individuals with hearing loss who had poor speech scores than that of normal hearing individuals. Anderson et al., (2010) also found similar results in learning disability children.

Conclusions

From the above results, it can be concluded that cortical electrophysiological measures are sensitive to subtle changes in the auditory processing in older individuals. By assessing cortical potentials in noise, one can partly understand the effects of noise on audibility and perception of sounds. In this study, we found that, Low pass noise and speech noise are better maskers and more deleterious to efficient auditory processing. Amplitudes of later peaks are reduced in the older individuals possibly indicating the beginning of possible perceptual deficits. Significant correlation between N1, P2 latencies and SPIN scores were found, suggesting that measures of cortical potentials are sensitive to speech perception abilities of an individual.

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