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Psycho acoustical Measures in Individuals with Congenital Visual Impairment

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Abstract

Introduction: In congenital visual impaired individuals one modality is impaired (visual modality) this impairment is compensated by other sensory modalities. There is evidence that visual impaired performed better in different auditory task like localization, auditory memory, verbal memory, auditory attention, and other behavioural tasks when compare to normal sighted individuals. **Objective:** The current study was aimed to compare the temporal resolution, frequency resolution and speech perception in noise ability in individuals with congenital visual impaired and normal sighted. **Methods:** Temporal resolution, frequency resolution, and speech perception in noise were measured using MDT, GDT, DDT, SRDT, and SNR50 respectively. Twelve congenital visual impaired participants with age range of 18 to 40 years were taken and equal in number with normal sighted participants. All the participants had normal hearing sensitivity with normal middle ear functioning. **Results:** Individual with visual impairment showed superior threshold in MDT, SRDT and SNR50 as compared to normal sighted individuals. This may be due to complexity of the tasks; MDT, SRDT and SNR50 are complex tasks than GDT and DDT. **Conclusion:** Visual impairment showed superior performance in auditory processing and speech perception with complex auditory perceptual tasks.

Keywords: hearing loss, visual Impairment, auditory system.

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INTRODUCTION

The "neural Darwinism" theory predicts that when single sensory modality is not functioning, like congenital visual impairment, the target structures are taken over by the afferent inputs from other senses that will promote and control their functional maturation[1]. Individuals with congenital visual impairment have been found to show better performance in auditory perceptual task[2,3] and memory tasks[4]. The inter-aural time difference discrimination thresholds of blind individuals were significantly shorter than those with residual vision and controls[5].

Temporal processing is an ability of an individual to perceive and process the modulated stimuli at a rapid rate, which facilitates the localization and lateralization of sound, hearing discrimination, and auditory pattern recognition. Temporal processing deficits include difficulty in comprehending speech in the incidence of background noise, difficulties in auditory performance with competing signals, difficulty in auditory performance with degraded acoustic signals, and difficulty following verbal direction[6]. Frequency resolution refers to the ability of the auditory system to discriminate and detach the spectral components in a complex sound. Peripheral auditory system is composed of bank of over lapping band pass filters[7]. Spectral ripple tests are commonly used to measure frequency resolution[8]. Spectral ripple discrimination threshold is a reliable non-linguistic measure of spectral resolution[9].

Spectral processing and temporal processing is important to gather the available spectral information to understand the speech. In the presence of noise, normal hearing individuals have difficulty in understanding speech than in quite. This difficulty is due to the spectral overlying between the noise and speech, but this spectral overlapping is not completely overlapping so there is certain spectral information available for speech. If the visual input is absent, the person will rely upon one modality that is auditory modality. Few studies have suggested that localization and speech perception ability in individual with visual impairment are comparatively higher than the normal individuals[10,11]. There has been limited research done on temporal processing and frequency resolution in individuals with visual impairment. Hence the aim of the study was to assess the psychoacoustical measures (temporal processing & frequency resolution) and speech in noise score in individuals with congenital visual impairment.

METHODS

There were two groups of participants in the study. First group was congenital visual impairment with normal hearing and the second group was control group which included participants with normal vision with normal hearing status. The present study adopted a cross sectional comparative study design. Each group consisted of 12 participants in the age range of 18-40 years (mean age 29.5), a total of 24 participants were included for the study purpose. All the participants had pure tone thresholds within normal limits that is 15 dBHL with air-bone gap less than 10 dB at octave frequencies between 250 Hz to 8000 Hz with A type tympanogram and acoustic reflexes present. Participants with previously diagnosed hearing problem (any type of hearing loss), diabetics, comorbid psychiatric or neurological diseases, cognitive deficits were excluded. Individuals with acquired visual impairment were also excluded from the study.

To measure the hearing threshold, calibrated diagnostic LADIE audiometer was used and to evaluate the function of middle ear GSI Tympstar was used. Using MATLAB version 7 software psychophysical and speech perception tasks were carried out. Stimulus for the task was presented through calibrated headphones using personal computer dell inspiron N5050. The entire psychophysical tests were done at participant comfortable hearing level. The psychoacoustic measures were obtained using different tests like Gap detection test (GDT), Modulation detection threshold (MDT), Duration discrimination test (DDT) and Spectral Ripple Discrimination Threshold (SRDT). For above mentioned tests the participants were informed to respond verbally. For speech perception in noise task, the participants were asked to repeat the sentences that were presented to them. For all tests adequate training was given prior to the testing to eliminate the bias.

Spectral ripple discrimination threshold

SRDT stimuli with spectral ripples were created in MATLAB 7 environment. Amplitudes of the components were determined by a full wave-rectified sinusoidal envelope on a logarithmic amplitude scale. The ripple peaks were equally spaced on a logarithmic frequency scale. Bandwidth of the stimuli was in the100 to 5000 Hz range. Phase reversal test: Standard and inverted ripple stimuli were generated. For standard ripples, the phase of the full-wave rectified sinusoidal spectral envelope was created using 'sin' function; and for inverted ripples, it was 'cos' function. Two types of test stimuli were created using standard and reversed ripples; the 'standard-standard' ripple and the 'standard-inverted' ripple. For the standard-inverted ripple, there was a spectral change at 1s; whereas there was no spectral change for standard-standard stimulus. Participants were asked to identify the standard-inverted' ripple stimuli from the signals. In spectral ripple, depending on number of ripples the ripple density increased, and when ripple density was more space between two consecutive ripples were less. As the density increases discrimination between standard and inverted ripple spectrum becomes difficult. That means as the spectral ripple threshold gets better, the discrimination performance enhances.

Modulation detection threshold

MDT was projected by using 2 alternate forced choice (AFC) methods along with adaptive 2 down 1 up procedure, which corresponds to 70.7% psychometric function[12]. The carrier frequency was 500 Hz and carrier wave was amplitude modulated at 8 Hz, 16 Hz, 32 Hz, and 64 Hz rates separately. The modulation frequencies that are important for speech perception are 8 Hz, 16 Hz, and 32 Hz. Duration was 500 ms for the stimulus. Participant had to identify the target interval which contains the modulated tone by responding verbally.

Gap detection test

GDT was used to find the minimum gap needed to identify the signal as a two signals. The duration of the noise was 500 ms. Two signals were presented, one was standard and other was target signal, the standard signal duration was 500 ms and for target signals 500 ms with varying gap (20-1 ms) was presented. Duration of the gap in variable stimulus was adaptively varied using mlp procedure based on participant response. A two-interval alternative force choice procedure was used to track the threshold. Participant task was to identify the target signal containing gap by verbal response.

Duration discrimination test

DDT was used to identify the signal with longest duration. The standard signal duration was 250 ms, total three stimuli were presented with one having longer duration compared to other two. The participants were instructed to identify the longest signal. The duration of the variable stimulus was adaptively changed using mlp procedure based on participant response. To track the threshold two intervals alternate forced choice procedure was used.

Speech perception in noise (SPIN)

To identify the speech in noise quicksin protocol was used. This protocol had a list containing 7 sentences, with each sentence having varying signal to noise ratio (SNR) from 20 dB to -10 dB in 5 dB steps. Each sentence contained 5 key words presented with four talker babble noise. Participants were asked to repeat the keywords, the number of key words response was calculated. Quicksin is the standard method which gives information regarding SNR 50. In each participant SNR50 was calculated, that is minimum signal-to-noise ratio required for the participant to repeat 50% of the time words correctly.

$$SNR50 = i + \left(\frac{1}{2} \times d\right) - \left(\frac{d \times correct}{w}\right)$$

Where, i = initial presentation level, d = step size, Correct = No of keywords correctly identified, w = no of keywords per SNR.

Statistical analysis

SPSS 16 (Version) was used to perform the statistical analysis. Independent ‘t’ test was used to compare between participants with congenital visual impairment and normal sighted participants.

RESULTS

The current study was carried out to evaluate the performance of temporal processing, frequency resolution ability and speech perception in noise in participants with congenital visual impairment and normal sighted participants. MDT, GDT and DDT were done to evaluate temporal processing, SRDT were used to evaluate frequency resolution and SNR50 was used to evaluate speech perception ability.

Present study showed higher threshold in visually impaired participants than the normal sighted participants for SRDT. The mean threshold for SRDT in participants with visual impairment was 7.07 ± 1.40 (SD) and for normal sighted participants was 3.72 ± 1.20 (SD). The independent t test revealed a significant difference between SRDT threshold [t(22) = -6.252, p = 0.000] in visually impaired and normal sighted participants groups.

Independent ‘t’ test was performed to see the significant difference across the modulation rate for 500 Hz carrier frequency. Results revealed a significant higher mean threshold in congenitally visually impaired participants than the sighted participants at 500 Hz carrier frequency at 8 Hz [t(22) = 6.405, p = 0.000], 16 Hz [t(22) = 5.067, p = 0.000], 32 Hz [t(22) = 5.338, p=0.000], and 64 Hz [t(22) = 4.496, p = 0.000] modulation rate respectively. Mean and standard deviations of MDT thresholds for 500 Hz carrier frequency across four modulation rates is shown in the Figure 1.

The mean GDT threshold for normal sighted was 2.75 ± 0.72 (SD) and for visually impaired participants was 2.48 ± 0.54 (SD). The mean of DDT was 38.29 ms (SD = 12.77) in normal sighted and 34.80 ms (SD = 10.32) in visually impaired participants. The Independent ‘t’ test result revealed that there was no significant difference between normal sighted and congenital visual impaired participants for GDT [t(22) = 1.046, p = 0.307] and DDT [t(22) = 0.737, p = 0.469].

The mean score for congenitally visually impaired participants was -3.75 ± 1.35 (SD) and for normal sighted participants was -2.41 ± 1.31 (SD). Independent ‘t’ test showed a significant better SNR50 scores in visually impaired than the normal sighted participants [t(22)= 2.448, p = 0.023]. SNR50 results indicate that normal sighted participants have poor mean score compared to the congenitally visually impaired participants.

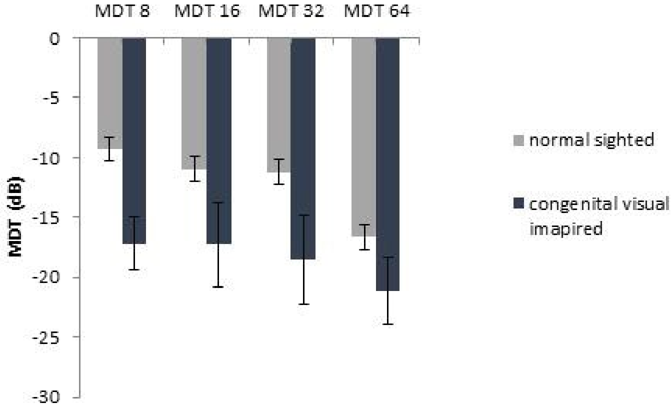

Figure 1. Represent mean and SD values for MDT at 8 Hz, 16 Hz, 32 HZ, and 64 Hz modulation rate in normal sighted and congenital visual impaired groups.

DISCUSSION

The present study, based on the SRDT score, reveals that the congenitally visually impaired participants have better frequency resolution ability than that of normal sighted participants. Spectral ripple task can predict spectral resolution ability[8]. Short term memory and other cognitive abilities are the most essential factors for the discrimination of the stimulus[13]. There is enhanced memory in visually impaired individuals as compared to sighted participants[14]. Hence, enhanced memory could be the reason for the superior performance of the visually impaired participants than the normal sighted ones in spectral ripple tasks.

The current study results indicated that for visually impaired participants MDT thresholds were better than that of normal sighted participants. However for GDT and DDT there was no significant difference seen between congenital visual impaired and normal sighted participants. This finding implies that there is a superior temporal processing ability in the participants with visual impairment. Studies have reported that inferior colliculus exhibits a huge variation in average spike rate depending on amplitude modulated rate. It depicted that information from auditory nerve reaches the cochlear nucleus, from cochlear nucleus it travels to higher level that this transformation completes at the level of inferior colliculus[15,16]. This superior performance in visual impaired participants might be due to neural plasticity at the level of the inferior colliculus.

There was no significant difference in GDT seen between sighted participants and visually impaired participants, concluding a similar processing taking place in visual impaired and normal sighted participants. Similar results were obtained in a study with no difference observed between age matched sighted participant and visually impaired participant[17]. According to the authors, the absence of significant difference in GDT might be suggestive of the fact that gap detection is not substantially altered in their sample of participants with early blindness and suggested that alterations in auditory perception in the participants with blindness reflect changes involving more complex auditory mechanisms than those tapped by gap detection. Literature also evidences that individuals with visual impairment do not have better discrimination abilities for pure tone audiometric thresholds than to sighted participants, as it is not a complex discrimination task5. No differences in GDT may also be due to simplicity of the tasks and lesser sample size in this study.

Results of current study indicates that there is no significant difference in DDT between congenitally visually impaired and normal sighted participants. Studies have proclaimed that based on complexity of the task, duration discrimination performance can vary[18]. The visually impaired participants having obtained excellent scores in perceptual auditory tasks, such as pitch discrimination or duration discrimination have been reported[3]. However, the simplicity of the task adopted in the present research would have resulted in contradictory observation.

Speech perception in noise was measured using SNR50 and the results revealed better score for congenitally visually impaired participants. There are studies proposing visual impaired participants having improved speech perception abilities when compared with age matched sighted participants. The speech discrimination scores were considerably greater in blind individuals in all semantic levels[19]. Visual impairment showed enhanced processing of speech sounds in especially congenital and early visual impairment[20]. There was improved speech perception ability in visual impaired participants with natural as well as synthetic ultra-fast speech. For ultra-fast speech, significant activation was seen in occipital cortex and left fusiform gyrus for visual impaired participants[21]. Hence the congenital visual impairment have superior speech perception in noise due to better frequency and temporal resolution.

CONCLUSION

The participants with congenital visual impairment showed better performance in MDT, SRDT and SNR50 in comparison with normal sighted participants. Participants with visual impairment displayed better performance in complex auditory perceptual tasks than simple tasks. In visually impaired participants as one modality is compromised, they rely more on other modalities.

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