Temporal Processing Abilities in Individuals with Blindness

V. Yamini

Registration No. 17AUD038

This Dissertation is submitted as part fulfillment

for the Degree of Master of Science in Audiology

University of Mysore, Mysuru

ALL INDIA INSTITUTE OF SPEECH AND HEARING

Manasagangotri, Mysuru 570 006

May 2019

CERTIFICATE

This is to certify that this dissertation entitled **'Temporal processing abilities in individuals with blindness'** is bonafide work submitted as a part for the fulfillment for the degree of Master of Science (Audiology) of the student Registration Number: 17AUD038. This has been carried out under the guidance of the faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysuru
May 2019

Dr. M. Pushpavathi
Director,
All India Institute of Speech nag Hearing
Manasagangothri, Mysuru-570006

CERTIFICATE

This is to certify that this dissertation entitled **'Temporal processing abilities in individuals with blindness'** is bonafide work submitted as a part for the fulfillment for the degree of Master of Science (Audiology) of the student Registration Number: 17AUD038. This has been carried out under my guidance and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysuru
May, 2019

Dr. Asha Yathiraj
Guide
Professor of Audiology
Department of Audiology
All India Institute of Speech and Hearing
Manasagangothri, Mysuru-570006

DECLARATION

This is to certify that this dissertation entitled **'Temporal processing abilities in individuals with blindness'** is result of my own study under the guidance of Dr. Asha Yathiraj, Professor of Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysuru and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysuru **Registration No: 17AUD038**

May, 2019

DEDICATED

TO AMMA

AND DADDY

ACKNOWLEDGMENT

I would like to express my deep sense of gratitude to my guide **Dr. A. Yathiraj** for constantly guiding and supporting me throughout this journey. Thank you ma'am for all the time you spent for me inspite of your tight schedules. Your sincerity, hard work, perfection, unique way of doing things had been an inspiration to me.

I extend my heartfelt thanks to Shubha tak mam, Shubhaganga akka, Shreyank sir, Amruthavarshini, Udhay sir, Suman and Amulya ma'am for your timely help.

Thank you, **Director** Ma'am for giving us this opportunity to conduct our study.

With respect and gratefulness, I thank the HODs, all the JRFs and the entire department of audiology for their valuable inputs.

This study would not have been completed without my subjects. Thank you Ajay and Priyanka mam for helping me to find my subjects. i am extremely grateful to all my subjects from JSS hostel as well as government blind school tilak nagar.

I would take a previlige to thank my friendly teacher and mentor Kranthi sir for being with me, helping me and guiding me .hope you will be there always. Thank youuuuu.

I would like to thank my friends (niharika, aruna, deepu, jyo) seniors(Chandan sir,Uday sir, Chitti sir,teju akka, Swaroopa mam) and juniors at AYJNIHH for making a memorable journey at Hyderabad.

Kavithaaaa thank you so much for being with me throughout this journey and without you definitely my dissertation would not be completed.

VAISHAL you are the only person who believed me to the core and encouraged me for whatever I do. Thank you and I really really miss you in my life.

Thanks would be a very small word to both of you for what you have done in my life rama mama and anu akka. I would be grateful to you.

I would like to thank my friends, who were always there supporting me and encouraging me throughout the journey especially Saisree, Sundar, Korani, Lyddu, Deepa akka, Saranya,abhi, Kriti, Kamala.

Here comes my posting partners Kishore, Faheema, Kavya, Ajay, Durga, Vishnu, Mohini had a great time with all of you. And thank you for everything.

My dearest audiology united thank you each and every one for being with me throughout this journey. And you people made my life at AIISH a memorable one.

I thank all those who helped me directly or indirectly in accomplishing this goal

THANK YOU...

Abstract

Aim: The aim of the study was to measure temporal resolution, temporal patterning, and temporal discrimination abilities in individuals with congenital blindness and comparing their performance with available normative values.

Method: The temporal processing abilities of thirty individuals with congenital blindness were studied. Temporal resolution, temporal patterning, and temporal discrimination were assessed using 'Gaps-In-Noise' test (GIN), developed by Musiek et al. (2005), 'Duration pattern test' (DPT), developed by Pinheiro and Musiek (1985), and 'Duration discrimination test' (DDT), in line with the recommendations of Starr et al. (1991) and Barman (2007), respectively. Prior to the administering of the temporal processing tests, it was confirmed that the participants had visual acuity of less than 3/60 or 10/200 (Snellen) in the better eye and normal hearing in both ears. GIN thresholds and percentage of correct scores, DPT scores, and DDT thresholds were measured. The scores obtained by the participants on GIN, DPT and DDT were compared with the norms of Prem Shankar and Girish (2012), Mohan and Yathiraj (2013), Barman (2007), respectively.

Results: The scores on GIN were found to be not significantly different from the available normative values. However, the scores on the other two tests were significantly poorer than the available norms. Additionally, the scores of the left and right ears of the participants were not statistically significant for 3 temporal processing tests. Further, no association and correlation were obtained between the 3 tests.

Conclusion: From the findings of the study it was inferred that individuals with blindness have similar temporal resolution abilities as that of normal sighted individuals. However, their temporal patterning and temporal discrimination abilities were poorer than existing normative values. Further, the findings of the study refute the notion that compensatory neuroplasticity occurs after visual deprivation, resulting in enhanced temporal abilities.

TABLE OF CONTENTS

List of Tables

List of Figures

Chapter 1

INTRODUCTION

Temporal processing of auditory signals has been reported to be important in identifying phonetic elements in speech, which help in speech perception. It was also noted that the difficulties found in temporal processing interfere with normal speech and phonemic recognition (Amaral et al., 2014). Besides speech perception, temporal cues are known to be utilized for localization (Goodman, Benichoux, & Brette, 2013).

Among the difficulties individuals with blindness have, mobility is an issue (Brambring, 1985). Those with blindness are known to use their hearing abilities to localize sounds and reduce their mobility difficulties (Simon & Levitt, 2007). It has been reported that when a single sensory modality is not functioning, such as the presence of a congenital visual impairment, afferent inputs from other senses promote their functional maturation (Edelman, 1993). It has been noted that the performance of individuals with blindness was superior to normally sighted individuals on some auditory tasks that include auditory memory and localization abilities (Doucet et al., 2005; Gori, Sandini, Martinoli, & Burr, 2013; Kellogg, 1962; Muchnik, Efrati, Nemeth, Malin, & Hildesheimer, 1991; Rice, 1969; Rokem & Ahissar, 2009; Yabe & Kaga, 2005).

Studies on temporal processing in individuals with visual impairment have observed varied findings. A few studies reported that those with visual problems have better temporal processing abilities compared to normal sighted individuals. This improvement in temporal processing abilities in individuals with blindness has been noted for temporal resolution abilities assessed through gap detection test and Gaps-In-Noise test (Muchnik et al., 1991; Sepehrnejad et al., 2011). Similarly, for temporal patterning tasks such as temporal order judgements, individuals with blindness performed better compared to normal sighted individuals (Stevens & Weaver, 2005). Based on such studies on temporal abilities of individuals with blindness it has been speculated that the perceptual consolidation or compensatory neuroplasticity occurs after visual deprivation, resulting in enhanced temporal abilities (Sepehrnejad et al., 2011; Stevens & Weaver, 2005).

In contrast, it has been noted by other researchers that those with blindness have similar temporal processing abilities as those with normal vision. This was observed in studies that assessed temporal resolution abilities in individuals with blindness (Boas, Muniz, Neto, da Silva, & Gouveia, 2011; Bross & Borenstein, 1982; Kumar, Thomas, Bhat, & Ranjan, 2017; Weaver & Stevens, 2006). Likewise, individuals with blindness were found to perform similar to normal sighted individuals on other temporal tasks such as temporal masking, and temporal patterning abilities (Boas et al., 2011; Stevens & Weaver, 2005). Hence, these groups of studies portrait that permanent loss of one sensory system such as vision does not result in enhancement of other sensory pathways, leading to better performance in tasks related to the other intact sensory systems.

Further, Kumar et al. (2017) claimed that less complex tasks such as Gap Detection Test and Duration Discrimination test are similar in those with blindness and those who have normal vision. On the other hand, they noted that for more complex tasks such as in the Modulation Discrimination test, SNR50, and Spectral Ripple Discrimination test the two groups are not alike. Similarly, other studies have demonstrated that relatively easy tasks such as auditory memory (Rokem & Ahissar, 2009), and inter-aural time difference (Yabe & Kaga, 2005) are better perceived in those with blindness.

1.1 Need for the Study

The review of the literature indicates that several studies claim that the temporal processing abilities of those with blindness are better than those who are sighted (Muchnik et al., 1991; Sepehrnejad et al., 2011; Stevens & Weaver, 2005). However, a few studies contradict this notion wherein they report that individuals with blindness having similar temporal processing abilities as that of individuals with normal sight (Boas et al., 2011; Kumar et al., 2017; Stevens & Weaver, 2005; Weaver & Stevens, 2006). Thus, in literature there is no consensus as to whether individuals with blindness have enhanced or similar temporal processing abilities as normal sighted individuals. Therefore, there is a need to confirm whether temporal processing in individuals with blindness is better or similar to that of normal sighted individuals.

It also needs to be studied as to whether the temporal processing abilities of individuals with blindness vary depending on the tests that are administered. This will provide information as to whether specific temporal processes are better perceived by them or not.

1.2 Aim of the Study

The study aimed to measure temporal processing (temporal resolution, temporal patterning, & temporal discrimination) abilities in individuals with blindness and compare their performance with available normative data.

1.3 Objectives of the study

The specific objectives of the study were as follows:

- To measure temporal resolution abilities in individuals with blindness by evaluating their gap in noise abilities and compare it with available normative values.
- To measure temporal ordering abilities in individuals with blindness using a duration pattern test and compare it with available normative values.

- To measure duration discrimination in individuals with blindness and compare it with available normative values and
- To determine the association/relation between the scores of the Gaps-In-Noise test, duration pattern test and duration discrimination test in individuals with blindness.

In order to design the method for to study the above objectives, a detailed review of literature was carried out. The review of literature majorly focuses on temporal processing abilities in individuals with blindness and other auditory processing abilities.

Chapter 2

REVIEW OF LITERATURE

It is reported in literature that individuals with blindness develop other abilities such as improved hearing due to their visual problems Niemeyer and Starlinger (1981). A few of the auditory skills reported to be better in individuals with blindness compared to those who have normal include sound localization abilities (Doucet et al., 2005; Kellogg, 1962; Muchnik et al., 1991; Rice, 1969), and speech discrimination abilities in the presence of noise Niemeyer and Starlinger (1981).

Contrary to the findings of the above studies, a few researchers have claimed that the auditory abilities of those with blindness are not better than those who are sighted. Kumar et al. (2017) claim that in less complex tests such as Gap Detection Test and Duration Discrimination test, similar responses are obtained in individuals with blindness and normal sighted individuals. However, for more complex tests such as Modulation Discrimination test, SNR-50 and Spectral Ripple Discrimination test, individuals with blindness obtain superior responses compared normal sighted individuals.

One of the major problems that individuals with blindness have is mobility (Brambring, 1985). To compensate for this difficulty, they are known to depend on their auditory localization abilities (Simon & Levitt, 2007). An important acoustical parameter that is known to help in localization is temporal cues. Several studies have evaluated the temporal abilities along with other acoustical parameters in individuals with blindness and compared them with sighted individuals. Details of such studies are provided below. Additionally, information regarding their localization, auditory discrimination, and auditory memory are also provided.

2.1 Temporal processing abilities in individuals with blindness

Muchnik et al. (1991) compared auditory temporal resolution in 20 individuals with blindness and 10 individuals with normal sight. The 20 individuals with blindness were divided in to two sub groups, 10 who had congenital blindness and 10 who had acquired blindness. The participants were required to perceive the presence or absence of a gap in a pair of noise bursts. This was used to measure the minimal time interval for all the 30 participants. The results revealed that the mean minimal time interval values did not differ significantly between the individuals with congenital and acquired blindness. It was also observed that those with blindness obtained a significantly lower mean minimal time interval score when compared to the normal sighted individuals.

Auditory perceptual consolidation was assessed by Stevens and Weaver (2005) in individuals blinded in early life and individuals with normal sight. Temporal-order judgment, auditory backward masking, single tone backward masking, and simultaneous masking tests were performed. The scores revealed that the individuals blinded in early life had significantly lower temporal order judgment thresholds than the individuals with normal sight. Discrimination performance was unaffected at all mask delays in the individuals blinded in early life than the individuals with normal sight. They needed a mask delay of 160 ms to perform comparably. On the backward masking task using single tone stimuli, they found no difference between the individuals with early blindness and individuals with normal sight groups at any mask delay. A simultaneous masking task demonstrated that the mask effectively impaired discrimination in individuals with early blindness at sensory stages. These results suggest that advantages in perceptual consolidation may reflect a mechanism responsible for the short response times.

Weaver and Stevens (2006) reported that for individuals with blindness, audition signals provide critical information for interacting with the environment. They assessed gap detection abilities in 30 participants who were divided in three groups. One group consisted of 10 younger individuals with normal sight, while the other groups consisted of 10 individuals blinded early in life and 10 age-matched individuals with normal sight. It was observed that the gap detection thresholds for individuals who were blinded early in life were nearly identical to the age matched individuals with normal sight but were slightly poorer relative to the younger individuals with normal sight subjects.

Boas et al. (2011) studied temporal resolution and temporal ordering abilities in 12 individuals with blindness. Temporal resolution was assessed using the original and modified version of a rapid gap detection test. Temporal ordering was evaluated using a duration pattern test, and frequency pattern test. The individuals with blindness were found to obtain normal scores on all the temporal tests.

Temporal resolution abilities of 22 individuals with congenital blindness (11 males & 11 females) was assessed by Sepehrnejad et al. (2011) using a gap in noise test. The responses were compared with that of 22 normal sighted individuals (11 males & 11 females). The mean age of the participants was 26.22 years and 24.04 years respectively. A significantly lower approximate threshold and high percentage of corrected answers was obtained by those with congenital blindness compared to the normal sighted control group. This was speculated to have occurred due to compensative neuroplasticity after visual deprivation.

Kumar et al. (2017) compared temporal resolution, frequency resolution and speech perception in noise of 12 individuals with congenital visual impaired and 12 normal sighted individuals. Modulation Discrimination Test, Gap Detection Test and Duration Discrimination test were measured to evaluate temporal processing. Spectral Ripple Discrimination Test was used to evaluate frequency resolution and SNR-50 was used to evaluate speech perception ability. No significant difference was found between the participants with normal sight and congenital visual impairment for gap detection test and duration discrimination test. However, the individuals with visual impairment showed superior threshold in the modulation discrimination test, spectral ripple discrimination test and SNR-50 as compared to normal sighted individuals. This was ascribed to the complexity of the tasks in the latter set of tests.

From the above review it can be noted that temporal processing abilities of individuals with blindness were comparable with normal sighted individuals. These findings were observed by most of the studies reported in literature although there were reports of those with blindness doing poorer than their sighted counterparts.

2.2. Auditory localization abilities in individuals with blindness

Sound localization and speech discrimination in noise abilities were compared in individuals with blindness and individuals with normal sight by Muchnik et al. (1991). For the sound localization experiment, 20 individuals with blindness and 20 individuals with normal sight were examined. For the speech discrimination in noise task, 16 individuals with blindness and 10 normal sighted individuals were tested. The results showed that the scores were significantly better for individuals with blindness when compared with the individuals with normal sight.

It was reported by Lessard, Pare, Lepore, and Lassonde (1998) that individuals with total blindness have better auditory ability than normal sighted individuals, enabling them to compensate for their loss of vision. A three-dimensional spatial mapping was carried out in individuals with total blindness and individuals with some amount of peripheral vision along with the individuals with normal sight. The participants were tested under monaural and binaural listening conditions. The individuals blinded early in life could map the auditory environment with equal or better accuracy than individuals with normal sight. They could also correctly localize sounds monaurally. It was also noted that individuals with residual peripheral vision localized sounds less precisely than individuals with normal sight or individuals with total blindness. This finding was considered to confirm that compensation varied according to the etiology and extent of blindness.

Vertical localization abilities were measured by Lewald (2002) in 6 individuals who were blinded from early life and normal sighted individuals. On a vertical elevation sound localization task, 4 out of the 6 individuals blinded early in life exhibited systematic deviations in locating the sound source. The remaining 2 individuals pointed accurately to the sound source, with similar accuracy as the individuals with normal sight. These results suggested that visual experience may be used to accurately calibrate the relation between the vertical coordinates of auditory space and body, but is not needed to develop sufficiently high resolution of spatial hearing.

Sound lateralization was measured by Yabe and Kaga (2005) on 37 adolescents with blindness (20 males & 17 females) who were aged 12 to 26 years (mean age = 15.0 years). The participants were divided into 4 groups consisting of 14 individuals with congenitally blindness (mean age = 15.2 years), 9 participants with acquired blindness (mean age = 15.3), 14 with residual vision (mean age = 14.9 years) and 10 normally sighted controls (mean age = 13.6 years). Pure-tone thresholds and inter-aural time difference discrimination thresholds were obtained for all the subjects. The mean pure-tone thresholds were not significantly different between the groups, and between the left and right ears. Inter-aural time difference discrimination was measured using an interrupted 500 Hz narrow-band noise at a constant rate of 50 µs/s. No statistically significant difference in inter-aural time difference discrimination threshold was observed between the individuals with congenital blindness and the individuals with acquired blindness. However, both groups of participants got statistically significantly lower thresholds than the other two groups. These findings were considered to suggest that individuals with blindness have better auditory spatial abilities than individuals with vision, and that some compensation in the normal senses occurred in the former to ensure that they accurate spatial cognition.

Gougoux, Zatorre, Lassonde, Voss, and Lepore (2005) investigated the neural basis for the behavioural differences in localization abilities in 12 individuals blinded early in life and compared them with 7 normal sighted individuals. Positron emission tomography and a speaker array that permitted pseudo-free-field presentations within the scanner were used. Initially, binaural and monaural sound localization tasks were performed in an anechoic chamber. Based up on the performance in the monaural tasks the subjects were divided in to 3 sub-groups (Group 1: Early blindness with superior performance; Group 2: Early blindness with normal performance; & and Group 3: Normal sighted individuals). The group with normal performance were those who were unable to localize the sounds any more accurately than the normal sighted controls. The positron emission tomography results indicated that during binaural sound localization, the normal sighted individuals (Group 3) showed decreased cerebral blood flow in the occipital lobe. This finding was not observed in individuals blinded early in life (Group 1 &and Group 2). During monaural sound localization, the subgroup of individuals blinded early in life, who were behaviorally superior at sound localization (Group 1) displayed two activation foci in the occipital cortex. This effect was not seen in individuals with blindness who did not have superior monaural sound localization abilities (Group 2), or in normal sighted individuals (Group 3). The degree of activation of one of these foci was strongly correlated with sound localization accuracy across the entire group of individuals with blindness (Group 1 &and Group 2). The results show that those individuals with blindness who perform better than normal sighted individuals recruited the occipital areas to carry out auditory localization under monaural conditions.

Gori et al. (2013) evaluated auditory spatial discrimination skills in 9 individuals with congenital blindness and 27 normal sighted individuals. A total of 5 tasks were performed in two sessions. In the first session, spatial bisection, and minimum audible angle were measured. The results revealed that the bisection thresholds were significantly poorer in individuals with blindness when compared with the individuals with normal sight. However, the minimal audible angle thresholds did not differ significantly in the two groups. In the second session, simpler spatial localization task, temporal bisection and a slower version of the spatial bisection were evaluated. Each of these tasks were performed on different number of participants. There were 7, 8 and 6 individuals from each participant group for the simpler spatial localization test, temporal bisection test, and the slower version of spatial bisection test, respectively. The performance of the individuals with blindness in the simpler spatial localization task, and the temporal bisection task were not significantly different from the individuals with normal sight. On the other hand, on the slower version of the spatial bisection task a significantly poorer performance was observed in the individuals with blindness. It was concluded that visual information was necessary for normal development of the auditory sense of space.

Nilsson and Schenkman (2016) measured discrimination thresholds for two binaural location cues (inter-aural level differences and inter-aural time differences) in 23 individuals with blindness (mean age = 54 years), 23 age matched individuals with normal sight, and 42 normal sighted young individuals (mean age = 26 years). The inter-aural level differences and inter-aural time differences were measured in three different conditions that included a single click condition, a lead-click condition and a lag-click condition. Two types of click stimuli were used, a click stimulus containing a interaural difference was considered as a signal and a click that did not contain any interaural difference was considered as a distractor. In the single click condition, the signal was presented alone. In the lead-click condition the signal was always presented 2 ms before the lagging distracter. In the lag-click condition, the signal was always presented 2 ms after the leading distracter. The results suggested greater inter-aural level differences sensitivity for those with blindness than both the sighted groups of listeners. In the individuals with blindness, better responses were particularly evident for the inter-aural level differences in lag-click condition compared to the other two conditions. This was considered to suggest not only enhanced inter-aural level difference sensitivity in general but also increased ability to un suppress lagging clicks. On the inter-aural time difference discrimination tasks, the individuals with blindness performed better than the sighted age-matched listeners, but not better than the sighted young listeners.

From the above studies mentioned it was clear that individuals with blindness had significantly better localization abilities when compared with normal sighted individuals. In the localization tasks, individuals with blindness had greater horizontal localization abilities. In case of vertical localization, individuals with blindness performed poorer when compared with normal sighted individuals.

2.3 Auditory discrimination abilities in individuals with blindness

Niemeyer and Starlinger (1981) compared speech discrimination ability, pure-tone integration, and late cortical evoked potentials in 18 individuals with blindness and 18 normal sighted subjects. The individuals with blindness were observed to perform better than the sighted individuals in all the skills. The better utilization of auditory information after the loss of the vision was attributed to the plasticity of the brain.

It was found by Wan, Wood, Reutens, and Wilson (2010) that the individuals with blindness performed better than individuals with normal sight on a range of auditory perception tasks. Pitch discrimination, pitch-timbre categorization and, pitch memory tests were measured in 33 individuals with blindness (11 congenital, 11 early-blind, 11 late-blind) and 33 age matched individuals with normal sight. The performance of individuals with blindness was better than that of normal sighted individuals on a range of auditory perception tasks, even when musical experience was controlled for. However, this advantage was observed only for individuals who became blind early in life, and was even more pronounced for individuals who were blind from birth. These results were considered to have implications for the development of sensory substitution devices, particularly for those who developed blindness later in life.

Frequency discrimination was assessed in individuals with blindness and individuals with normal sight by Gougoux et al. (2004) using a pitch discrimination test. The test was performed in 26 individuals out of which 7 had early onset of blindness, 7 were individuals with late onset of blindness and 12 were normal sighted individuals. The performance was significantly better in individuals with blindness than individuals with normal sight, only if the participants were blind at an early age. The authors concluded that the younger the onset of blindness, the better was the performance, which was in line with cerebral plasticity being optimal during the early years.

Chen, Liu, and Chen (2015) examined differences in auditory discrimination ability between individuals with blindness and normal sighted individuals under different surrounding sound and noise conditions. Their 24 participants were divided into 2 groups, 12 with normal sight and 12 with blindness. An auditory words-perception task was manipulated to investigate performance of individuals with blindness and individuals with normal sight on the discrimination of aurally presented words within different conditions.

The volume of background noise was increased by three levels 15%, 20% and 25%. The results showed that individuals with normal sight had a 0.8 accuracy with a 25% increment necessary in sound level. On the other hand, individuals with blindness had a 0.7 of accuracy and required a 15% increment in sound level.

Arnaud, Gracco, and Ménard (2018) investigated pitch processing enhancement in the individuals with blindness. This was tested on 15 individuals with congenital blindness and 15 individuals with normal sight. A set of personalized native and non-native vowel stimuli were used in an identification and rating task. An adaptive discrimination paradigm was used to determine the frequency difference limen for pitch direction identification of speech (native & non-native vowels) and non-speech stimuli (musical instruments & pure-tones). The results show that the individuals with blindness had better discrimination thresholds than individuals with normal sight for native vowels, music stimuli, and pure-tones. Whereas, within the individuals with blindness, the discrimination thresholds were smaller for musical stimuli than speech stimuli.

From the above review it is clear that the discrimination abilities are significantly better in individuals with blindness when compared to normal sighted individuals. Further, it was noted that earlier the onset of blindness the better was the discrimination abilities in individuals with blindness.

2.4 Auditory cognitive abilities in individuals with blindness

Auditory memory abilities of those with congenital blindness was assessed by Röder, Rösler, and Neville (2001) through the use of an electro physiological measure. An incidental memory paradigm was employed where 11 individuals with congenital blindness and 11 age matched sighted controls listened to 80 sentences that ended either with a semantically appropriate or inappropriate word. Event-related brain potentials were recorded from 28 electrode positions during both the encoding and the retrieval phase. Individuals with blindness were found to have superior memory performance compared to the normal sighted controls. This was concluded as the individuals with blindness resulted in larger positive amplitudes for previously presented words than new words.

Hugdahl et al. (2004) reported that enhanced processing of speech sounds was seen in individuals with congenital blindness and individuals blinded early in life when compared with the normal sighted individuals. They measured dichotic CV in 14 individuals with congenital or early onset of blindness and 129 individuals with normal sight. The dichotic listening procedure was carried out in three different conditions, with instructions to pay attention to the right ear stimulus, the left ear stimulus or no specific instruction. The results suggested that there was an overall significant improvement in scores of correct syllables in individuals with blindness than the normal sighted individuals. In specific, when instructed to pay attention to the left ear stimulus, the individuals performed significantly better than individuals with normal sight. These findings indicated the effects of hemispheric reorganization in individual with blindness at both the sensory and cognitive levels of information processing in the auditory sensory modality.

To determine the impact of congenital blindness on memory, a study was conducted by Rokem and Ahissar (2009). They found that those with congenital blindness (n = 16) showed significantly superior performance on a verbal memory span task compared to sighted individuals. In addition, it was found that those with blindness also had significantly better auditory frequency discrimination and superior speech reception thresholds in the presence of noise compared to age matched sighted individuals.

Episodic auditory recognition memory for environmental sounds after a short retention interval (8 to 9 min) was reported to be higher in individuals blinded in early life than the individuals with normal sight by Kärnekull, Arshamian, Nilsson, and Larsson (2016). They observed this finding after testing individuals blinded in early life (n = 15), individuals blinded in late life (n = 15), and individuals with normal sight (n = 30). The absolute threshold, discrimination, identification, episodic recognition, and metacognitive ability were measured in the participants. The results suggested that the individuals with blindness did not show superior performance in all the tests except the episodic auditory recognition memory test. Episodic sound recognition was better for individuals blinded early in life (M = 1.59, SD = 0.55) than individuals blinded late in life (M = 1.18, SD = 0.58) and individuals with normal sight (M = 1.05, SD = 0.46).

In a continuation to their earlier study, Kärnekull, Arshamian, Nilsson, and Larsson (2018) measured long term episodic memory in individuals with blindness. In this study, they followed-up participants (N = 57 out of 60) approximately 1 year after the initial testing and retested episodic recognition for environmental sounds and identification ability. They noted that the individuals blinded in early life (n = 14) performed at a similar level as the individuals blinded later in life (n = 13) and individuals with normal sight (n = 30). However, the effect of blindness on episodic memory for sounds varied as a function of retention interval, such that the individuals blinded early in life had an advantage over sighted individual across short but not long time frames. The authors suggested that blindness does not influence auditory episodic memory, when assessed after a long retention interval.

The above studies on cognitive skills in individuals with blindness indicate that their auditory memory abilities are better than the normal sighted individuals. This was mainly noted for short interval episodic memory auditory but not for long term episodic memory.

From the review of literature, it is evident that individuals with blindness perform better than normal sighted individuals on some auditory tasks. This better performance was mainly noted in those individuals who were blinded early in life. However, their temporal processing abilities were comparable with normal sighted individuals, but on other tasks localization, auditory discrimination and short-term auditory memory they were better than individuals with normal sight.

Chapter 3

METHODS

With the aim to measure temporal processing abilities in individuals with blindness, 30 adults with blindness were evaluated on 3 different tests. Temporal resolution, temporal patterning, and temporal discrimination were assessed using 'Gaps-In-Noise' test (GIN), developed by Musiek et al. (2005), 'Duration pattern test' (DPT), developed by Pinheiro and Musiek (1985), and 'Duration discrimination test', in line with the recommendations of Starr et al. (1991) and Barman (2007), respectively. The study was carried out using a standard comparison design, where the scores of those with blindness were compared with available norms.

3.1 Participants

Thirty individuals with congenital blindness were selected using a purposive sampling technique. All the participants were young adults aged 18 to 40 years. To be included in the study they were required to have total absence of sight or visual acuity for distance vision less than 3/60 or 10/200 (Snellen) in the better eye with best possible correction or limitation in the widest diameter of field of vision subtending an angle of less than 10 degree, as per the criteria mentioned in the 'Rights of Persons with Disability Act' (2016). It was ensured that all the participants had normal hearing sensitivity (≤ 15 dBHL) at the octave frequencies 250 Hz to 8000 Hz for air conduction and from 250 Hz to 4000 Hz for bone conduction. The participants also had 'A' type tympanogram with both ipsilateral and contralateral reflexes being present. Further, they were required to have no report of any otological problems, neurological problems, and speech and language problems. On the day of testing it was ascertained the participants had no illness.

3.2 Equipment

A calibrated dual channel diagnostic audiometer (Inventis piano) with TDH-39 headphones and B-71 bone vibrator were used to carry out pure-tone audiometry and speech audiometry, to rule out any hearing loss. A calibrated immittance meter (GSI Tympstar) was used to ensure normal middle ear functioning. Additionally, a laptop with Intel core i5 processor, was utilised to present the CD versions of the temporal processing tests.

3.3 Material

To select individuals with visual problems a Snellen eye chart was used. Speech identification scores were evaluated using the 'Phonemically balanced word test in Kannada', developed by Yathiraj and Vijayalakshmi (2005).

Duration pattern was measured using stimuli similar to the test developed by Pinheiro and Musiek (1985). A 1000 Hz pure-tone with two different durations (i.e., short 250 ms & long 500 ms) in six different combinations was used as the stimuli. Each sequence had three 1 kHz tones, with one tone that was different in duration from the other two. The tones were separated by a 250 ms gap. Thirty stimuli having six different combinations constituted the test material.

Duration discrimination was assessed using pairs of 1 kHz tones, with varying duration, as described by Starr et al. (1991) and Barman (2007). Within each pair, one served as an anchor tone and the other as a variable tone. The anchor tone had a duration of 500 ms and the variable tone had a duration that ranged from 1500 ms to 500 ms, in decrement of 50 ms.

Gaps-In-Noise test, developed by Musiek et al. (2005) was utilised to measure temporal resolution. The test was composed of a series of broad-band noise segments of 6 seconds in duration. Each 6 second segment of noise contained zero to three silent gaps, which vary in duration from as little as 2 ms to as long as 20 ms. The inter-stimulus interval between noise segments was 5 s. Ten different gap durations (i.e., 2, 3, 4, 5, 6, 8, 10, 12, 15, and 20 ms) were employed.

3.4 Test environment

All the audiological tests were carried out in an acoustically treated suite that met the specification of ANSI S3.1-1991 (R2010). The testing suites had optimum temperature and lighting and were free of any type of distractions.

3.5 Procedure

3.5.1 Procedure for Participant Selection. To confirm that the participants met the criteria for blindness mentioned in 'The Rights of Persons With Disability Act' (2016) their disability certificates, issued by qualified ophthalmologists, were verified. Additionally, the participants were evaluated using of Snellen eye chart to confirm that had visual acuity for distance vision that was less than 3/60 or 10/200 (Snellen) in the better eye. From those who had musically trained, information was noted regarding the number of years of training, and the type of music they received training (e.g. classical, folk, vocal, and instrumental).

The audiological assessment included obtaining pure-tone air conduction and bone-conduction thresholds using the modified Hughson-Westlake procedure. Air-conduction and bone conduction thresholds were established at octave frequencies between 250 to 8000 Hz and 250 to 4000 Hz respectively. Speech identification scores were obtained at 40 dB SL under head phones for each ear separately using the 'Phonemically balanced word test in Kannada' developed by Yathiraj and Vijayalakshmi (2005). To confirm normal middle ear functioning, tympanograms were obtained with a 226 Hz probe-tone and the presence of ipsilateral and contralateral reflex thresholds were determined at 500, 1000, 2000 and 4000

Hz. Those who met the participant selection criteria were further evaluated with 3 temporal processing tests. The order of the tests was randomized to avoid a test order effect.

3.5.2 Procedure For Administering Gaps-In-Noise (GIN) Test. To measure GIN, the test developed by Musiek et al. (2005) was used. The recorded stimuli were played through a laptop having a CD player. The output from the laptop was routed via a calibrated audiometer to headphones at 50 dB SL (ref. PTA). The test was presented monaurally and the participants were instructed to respond soon as they perceive a gap, by lifting a finger. Half of the participants were tested in their right ear first and half in their left ear first to avoid any ear order effect.

From the performance of the participants on the GIN test, their approximate gap threshold as well as percentage of correct gap identification was calculated. The approximate gap threshold was measured as the shortest gap identified on four out of six attempts. The percentage of correct gap identification was calculated from the sum of the gap intervals identified, divided by the number of gaps presented. The responses of the participants were compared with the norms given by to Prem, Shankar, and Girish (2012) determine if they passed or failed the test.

3.5.3 Procedure For Administering Duration Pattern Test. A duration pattern test, in line with that developed by Pinheiro and Musiek (1985) was used. The recorded stimuli were played through a laptop having a CD player. The output from the laptop was routed via a calibrated audiometer to headphones. Each ear was tested separately at 40 dB SL (ref. PTA). A three-interval force-choice technique was used, wherein the participants were asked to verbally repeat the pattern using the words, long or short. Every correct response was given a score of 1 and an incorrect response was given a score of 0. The maximum possible score for each ear was 30. To decide if the participants passed or failed the test, their scores were compared with the norms given by Mohan and Yathiraj (2013).

3.5.4 Procedure For Administering Duration Discrimination Test. This test was done to determine the smallest difference that can be discriminated between the two tones which are differed only in terms of duration. Duration discrimination as described by Starr et al. (1991) and Barman (2007) was used to measure this ability. A 500 ms anchor tone and the variable tone that increased in 50 ms steps, with a frequency of 1000 Hz was used. It was performed at 40 dB SL (ref PTA). The recorded stimuli were played through a laptop having a CD player. The output from the laptop was routed via a calibrated audiometer to headphones. The participants were instructed to respond verbally as to whether the stimuli in a pair were same or different. Initially, each participant was familiarized with the task at least three to four times. To familiarize the participants, they were made to hear two stimulus-pairs. In the first pair, there was maximum duration difference and in the second pair the duration difference was minimum. Once, it was assured that the participants understood the task, the actual test items were presented. All the test items were presented randomly. The stimulus-pair that was reported to be different on at least two out of the three trials was considered as the behavioral discrimination threshold for duration. The smallest discriminable difference was noted for each participant. To determine if the participants passed or failed the test, their scores were compared with the norms given by Barman (2007).

3.6 Statistical Analyses

The data obtained from the participants were statistically analyzed using the SPSS Software (Version 20). The descriptive and inferential statistics were done.

Chapter 4

RESULTS

The temporal processing abilities of thirty individuals (60 ears) with blindness were analyzed using SPSS software (Version 20). A Shapiro Wilk test of normality indicated that the scores of the three temporal processing tests were normally distributed ($p > 0.05$). Hence, parametric statistics were used to analyze the data. The analyses were done separately for the Gaps-In-Noise test, Duration pattern test and Duration discrimination test. The individual scores obtained for each ear on the temporal processing tests were compared with existing normative values to determine how many participants passed or failed the tests. Additionally, the mean scores obtained by the individuals with blindness were compared with existing normative data utilizing two-sample t-tests. The association between the temporal processing tests in individuals with blindness was checked using scatter plots, while the correlation was calculated using Pearson's product moment correlation. The results are provided for the 3 temporal processing tests (Gaps-In-Noise test, Duration pattern test, & Duration discrimination test) under the following sections:

4.1 Pass / fail findings of individuals with blindness

4.2 Comparison between left and right ears of the individuals with blindness

4.3 Comparison of individuals with blindness with normative data

4.4 Association between the temporal processing tests in individuals with blindness

4.5 Correlation between the temporal processing tests in individuals with blindness

4.1 Pass / fail findings of individuals with blindness

The pass / fail findings for the Gaps-In-Noise test, measured from the approximate thresholds and percentage of correct gap identification, are provided in Figure 1 and Figure 2. These are provided for each ear of the participants. The scores were compared with the normative values given by Prem, Shankar, and Girish (2012), depicted as a shaded band in the figures. From both the figures it is evident that the scores of all but one ear of an individual with blindness were within the normative range. Further, Table 1 provides information regarding the number of participants who passed and failed the test in each ear.

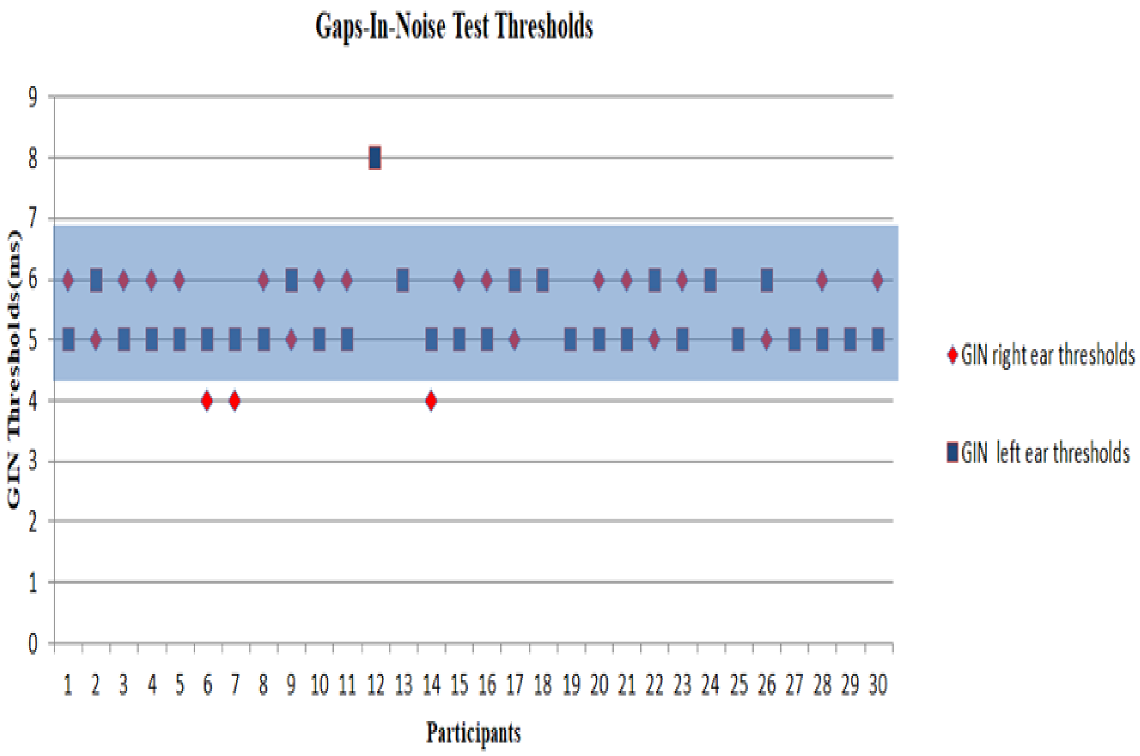

Figure 1: Ear-wise GIN thresholds (ms) of each of the 30 individuals with blindness. Shaded portion indicates the normative range given by Prem et al. (2012).

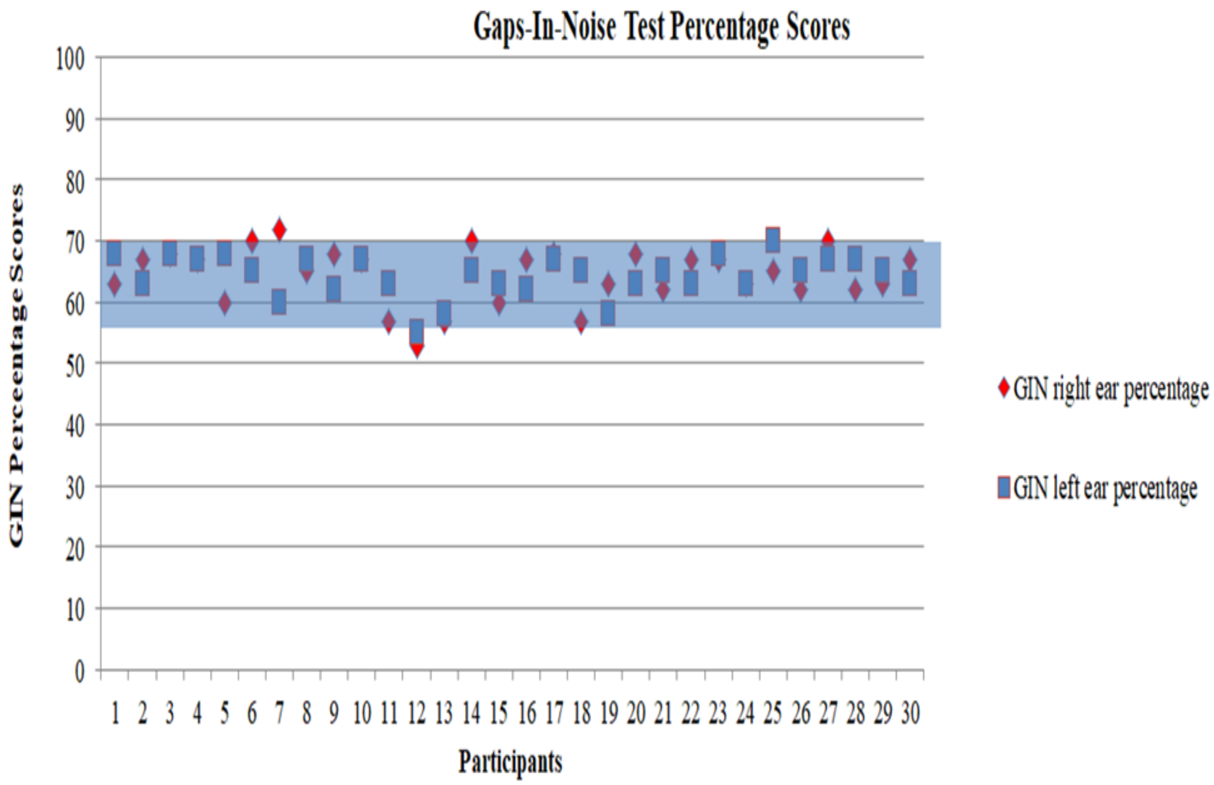

Figure 2: Ear-wise GIN percentage scores of each of the 30 individuals with blindness. Shaded portion indicates the normative range given by Prem et al. (2012).

The pass / fail findings for the Duration Pattern Test, obtained for the right and left ears of each individual were compared with the normative values given by Mohan and Yathiraj (2013). A graphical representation of the individual scores is depicted in Figure 3, with the shaded portion representing the normative values. As can be seen in the figure, several of the participants failed the test. Details of the number of participants who passed and failed the test are provided in Table 1.

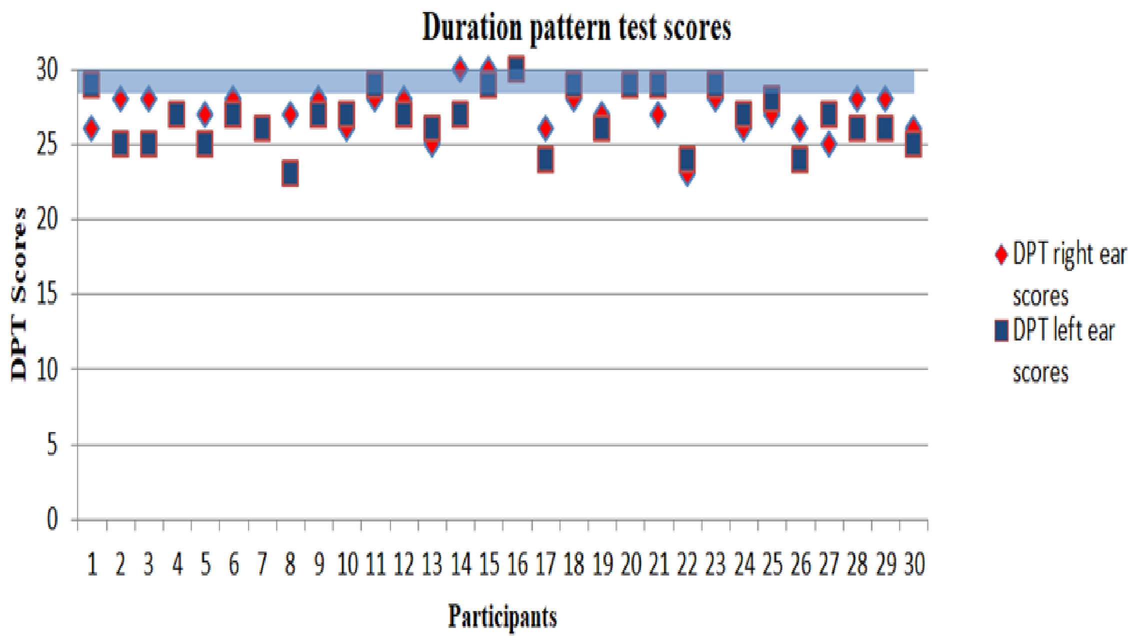

Figure 3: Ear-wise DPT scores of each of the 30 individuals with blindness. Shaded portion indicates the normative range given by Mohan and Yathiraj (2013).

The pass / fail findings for the Duration Discrimination Test for all 30 individuals was determined based on the normative scores given by Barman (2007). This was done for each ear separately. From Figure 4, it is evident that all but one ear of an individual failed the test. Additionally, the number of participants who passed and failed the test is given in Table 1.

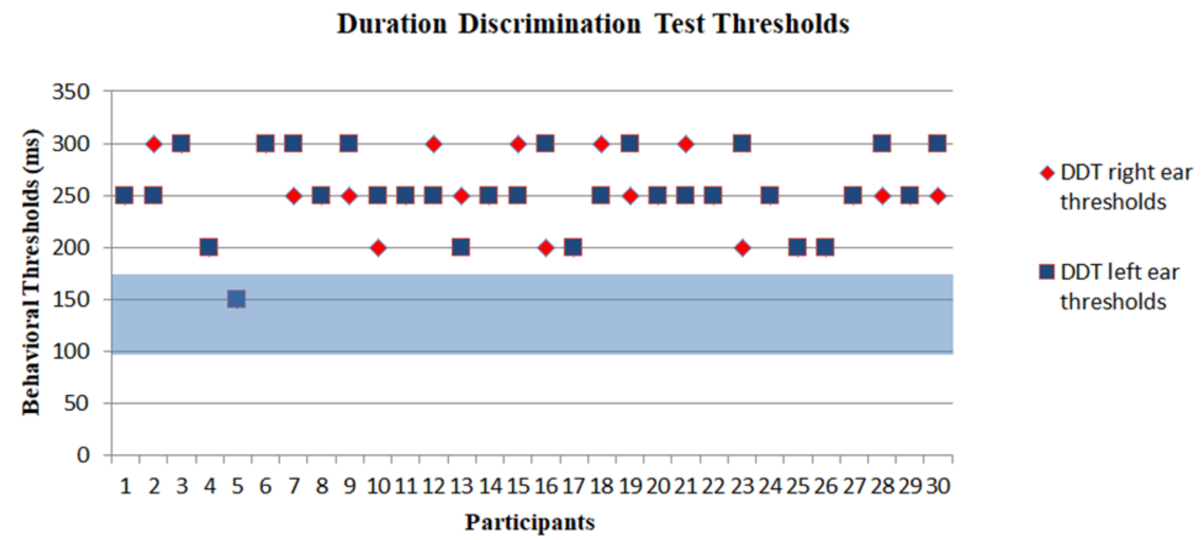

Figure 4: Ear-wise DDT thresholds of each of the 30 individuals with blindness. Shaded portion indicates the normative range given by Barman (2007).

Table 1 provides information regarding the number of participants who passed / failed the tests in one or both the ears. From the table it can be observed that the maximum number of individuals failed DDT, followed by DPT. Very few individuals failed GIN.

Table 1: Number of ears of individuals with blindness who passed or failed the three temporal processing tests (GIN, DPT, DDT) in those individuals with blindness

	Temporal Processing Tests		
	GIN	**DPT**	**DDT**
Right ear fail, Left ear pass	0	10	0
Right ear pass, Left ear fail	0	2	0
Both the ears pass	58	6	2
Both the ears Fail	2	42	58
Total number of ears	**60**	**60**	**60**

Note. GIN = Gaps-In-Noise Test; DPT = Duration Pattern Test; DDT = Duration Discrimination Test.

4.2 Comparison between the left and right ears of the individuals with blindness

A comparison of the left and right ear scores for the Gaps-In-Noise test indicated that the mean and standard deviation of the approximate thresholds and percentage scores of GIN (Table 2) varied only marginally. To check whether these differences were statistically different, paired samples t-test was done. It was observed that the difference was not statistically significant for the thresholds [t(29) = 1.29, p = .21] as well as percentage scores [t(29) = .07, p = .96].

Table 2: Mean, Standard Deviation (SD) of scores of individuals with blindness for Gaps-In-Noise, Duration Pattern, and Duration discrimination tests

Tests	**Right Ear**		**Left Ear**	
	Mean	**SD**	**Mean**	**SD**
GIN Threshold	5.56	0.81	5.36	0.66
GIN Percentage	64.40	4.50	64.30	3.30
DPT Scores	27.20	1.56	26.70	1.85
DDT Threshold	246.66	39.24	253.33	39.23

Note. GIN = Gaps-In-Noise Test; DPT = Duration Pattern Test; DDT = Duration Discrimination Test.

A comparison of the left and right ear scores for the Duration Pattern Test revealed that the mean and standard deviation were similar in the left and right ears (Table 2). A paired samples t-test, performed to confirm whether the scores of the two ears were statistically different or not, indicated that no significant difference was present [t(29) = 1.47, p = .15].

A comparison of the left and right ear scores for the Duration discrimination Test was done using the mean and standard deviation (Table 2). Like the other two temporal processing tests, the scores obtained in the two the ears were similar. A paired samples t-test confirmed that the scores of the left and right ears were not statistically significant for the Duration Discrimination thresholds [t(29) = -.89, p = .38].

4.3 Comparison of the individuals with blindness with normative data

As no significant difference was seen between the scores of the left and right ears for all three temporal processing tests, further evaluations were carried out with the responses of the two ears combined. The combined mean and standard deviation of the 60 ears of the individuals with blindness (Table 3) were compared with available normative data using two samples t-test. For GIN the scores were compared with the norms of Prem et al. (2012), while for DPT and DDT they were compared with the norms given by Mohan and Yathiraj (2013) and Barman (2007), respectively. It was noted that the difference for the GIN threshold [t(198) = .97, p = .33] and GIN percentage scores [t(198) = 0.04, p = .97] were not statistically significant from the normative data. However, the scores of DPT [t(98) = 7.91, p = .0001] and DDT [t(67) = 12.76, p = .0001] were statistically significant from the normative data, with those with blindness getting poorer scores.

Table 3: Mean, Standard Deviation (SD) of the left and right ear scores combined for Gaps-In-Noise, Duration Pattern and Duration discrimination tests in individuals with blindness, and normative data

	GIN Threshold		**GIN Percentage**		**DPT**		**DDT**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Individuals with blindness	5.46	0.74	64.46	4.06	27.03	1.69	250.00	39.05
Normative values	#5.62	1.18	#64.41	8.53	^29.30	0.80	♦133.33	36.87

Note. # Norms of Prem et al. (2012); ^ Norms of Mohan and Yathiraj (2013); ♦ Norms of Barman (2007).

4.4 Association between the temporal processing tests in individuals with blindness

The association between pairs of the temporal processing tests was checked using scatter plots. This was done for GIN approximate thresholds and DPT, GIN and DDT, as well as DPT and DDT. Scatter plots had to be used as the assumption for carrying out Chi square test was not met. For all three combinations of tests, it was observed from the scatter plots (Figures 5a, 5b, 5c) that there existed no association.

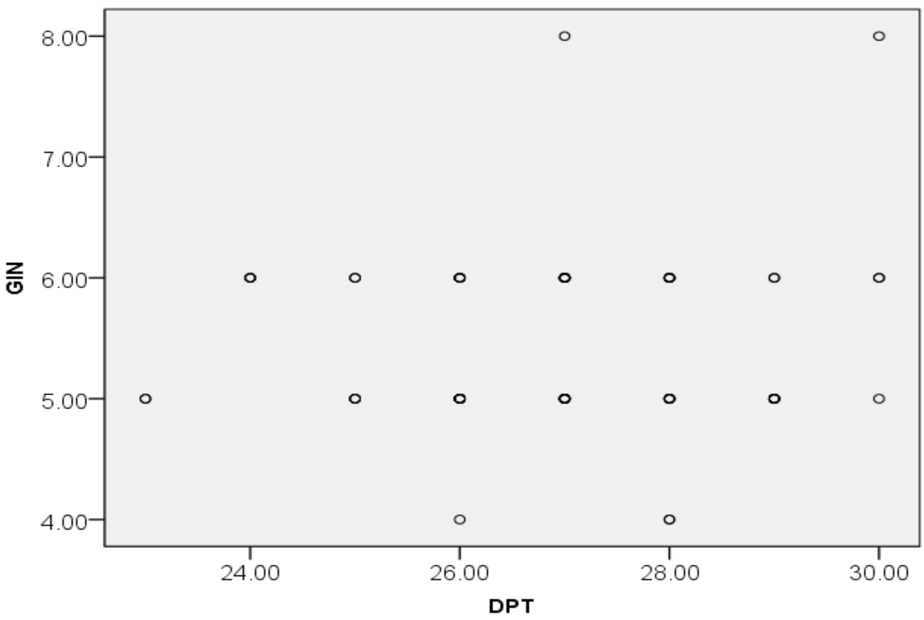

Figure 5a: Scatter plot of Gaps-In-Noise Test as a function of Duration Pattern Test.

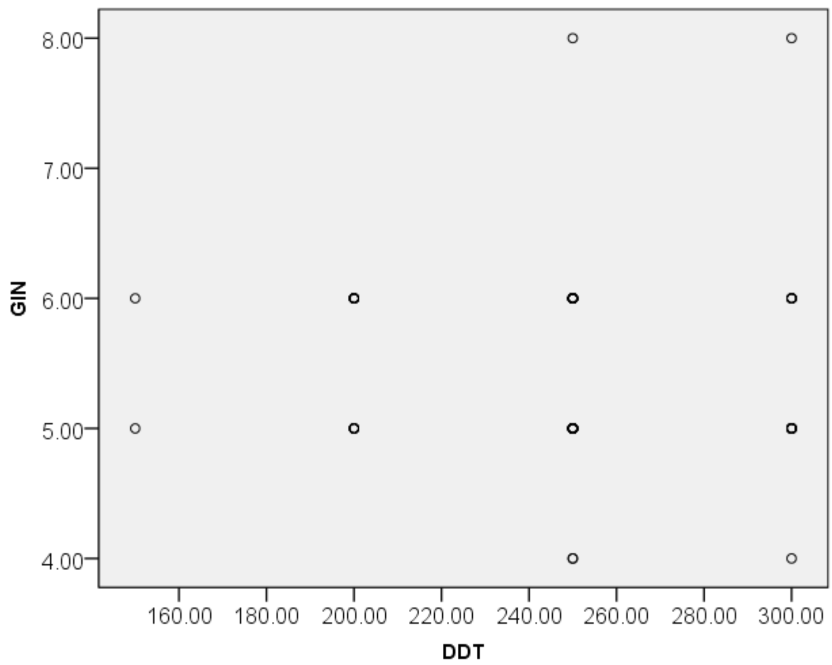

Figure 5b: Scatter plot of Gaps-In-Noise test as a function of Duration Discrimination Test.

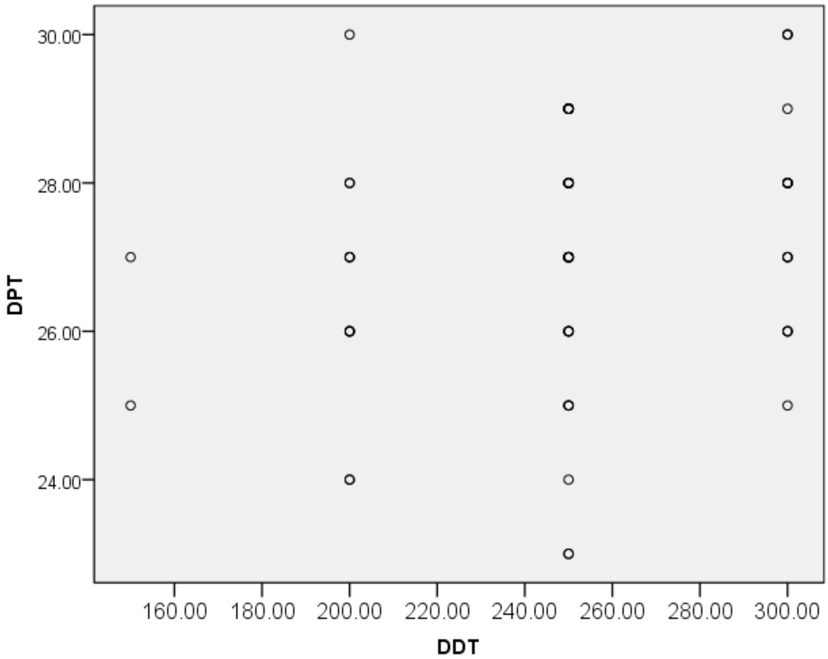

Figure 5c: Scatter plot of Duration Pattern Test as a function of Duration Discrimination Test.

4.5 Correlation between the three tests

To determine whether a correlation existed between pairs of temporal processing tests, Pearson's product movement correlation was calculated. This was done between GIN and DPT, GIN and DDT, as well as DPT and DDT. From Table 4 it can be seen that a low correlation existed between the tests. While the correlation was not significant for the first two combinations of tests, it was significant for the last combination.

Table 4: Correlation of three different tests

Tests	**Pearson's correlation (r)**
GIN and DPT	.07
GIN and DDT	-.06
DPT and DDT	.26*

Note. * $p < .05$

From the findings of the present study, it was observed that the temporal processing abilities of individuals with blindness were similar to the existing normative values for GIN but were significantly poorer compared to normative data for DPT and DDT. The scores of all 3 the temporal processing tests were not statistically different between the left and right ears of the participants. Further, there was no association or correlation found between the scores obtained by individuals blindness among the three temporal tests that were administered.

Chapter 5

DISCUSSION

The results of the 30 individuals with blindness on the 3 temporal processing tests that were administered (Gaps-In-Noise test, Duration pattern test, Duration discrimination test) are discussed. The results are discussed regarding the pass / fail findings of individuals with blindness in all the three tests; comparison of scores between the left and right ears of the individuals with blindness; and association / correlation between the temporal processing tests in individuals with blindness.

5.1 Pass / fail findings of individuals with blindness

The results of the present study showed that the performance of individuals with blindness varied depending on the temporal processing test that was administered. In the *Gaps-In-Noise test*, the responses of the individuals with blindness were comparable with that of the normative data provided by Prem, Shankar, and Girish (2012). This was seen for the approximate thresholds as well as the percentage of correct gap identification that were calculated. These findings were observed for the individual responses of the participants for each of their ears (Figures 1 & 2) as well as the group data.

These findings of the GIN test of the current study are in agreement with the reports published in literature. Kumar et al. (2017) found no significant difference between participants with normal sight and congenital visual impairment on a gap detection test. They claimed that the similar performance between their participant groups was due to the task being less complex compared to other tests performed by them (modulation discrimination test, spectral ripple discrimination test, & SNR-50). Likewise, Weaver and Stevens (2006) also reported that gap detection thresholds, measured in individuals blinded in early life, were similar to that of normal sighted individuals. Similar findings were also observed by Boas et al. (2011) using the original and modified version of a rapid gap detection test.

Thus, it can be construed that temporal resolution abilities in individuals with blindness are similar to those with normal sight. This conclusion can be made based on the findings of the current study as well as that mentioned in literature.

The performance of the individuals with blindness in the present study on the *Duration Pattern Test and Duration Discrimination Test* was poorer than the normative values given by Mohan and Yathiraj (2013) and Barman (2007), respectively. Among these two tests, a lot more individuals failed the Duration Discrimination Test when compared to the Duration Pattern test (Figures 3 & 4). This indicates that the former task was more difficult for almost all the participants compared to the latter task.

Unlike the findings of the current study, other researchers have reported that individuals with blindness perform better or comparable to those with normal vision on a variety of temporal processing tests. These processes included temporal resolution, temporal ordering and temporal discrimination (Boas et al., 2011; Hötting & Röder, 2009; Kumar et al., 2017; Muchnik et al., 1991; Sepehrnejad et al., 2011; Stevens & Weaver, 2005; Weaver & Stevens, 2006).

A reason as to why almost all the individuals with blindness found the duration discrimination task more difficult when compared to the other two tasks probably had to do with lack of visual cues obtained by them while the instructions were provided. Generally, when instructing individuals to do a discrimination task, in addition to the oral instructions, hand gestures as well as facial expressions are utilized to indicate that the participants should respond to small differences. These visual cues provide emphasis that the participants are required to respond to the smallest difference between the anchor and variable tones that are heard. Although the participants were required to respond similarly to the smallest difference while performing the GIN test, the levels of processing required while carrying out the two different tests were different. While two levels of processing were required to perform the DDT (perceive the duration of the anchor stimulus & compare it with the variable stimulus), only one level of processing was required for GIN (respond each time a gap was present). This could have led them to perform well on GIN but not on DDT. Thus, the difficulty in carrying out the DDT could have been due to the difficulty in them following instructions for the two levels of processing required execute the task. It needs to be studied as to whether changing the way oral instructions are given, such as the use of exaggerated suprasegmental cues to indicate smallness, would bring about improvement in their duration discrimination thresholds.

Likewise, two levels of processing are required while carrying out DPT wherein the individuals are required to perceive the durations of the 3 tones presented in each sequence and recollect as to which of them was different. The lack of visual cues to demonstrate this task could have resulted in the participants performing poorer than the existing normative values available for the test.

5.2 Comparison of the three test scores between ears of the individuals with blindness

The scores between the two ears of the participants of the current study were found to be similar and not statistically significant. This was observed in all the three temporal processing tests, indicating that ear similarity is seen in individuals with blindness for different temporal processes.

These results are in accordance with findings in normal sighted individuals reported in literature. Prem et al. (2012) found no ear effect for the Gaps-In-Noise test in 70 young normal individuals. Likewise, Zaidan, Garcia, Tedesco, and Baran (2008) found that there were no differences in performance between the right and left ears on the GIN test in 25 younger adults with normal hearing.

Similar findings regarding ear symmetry has been reported in literature for other temporal processes. Mohan and Yathiraj (2013), who studied temporal ordering skills in younger adults using a Duration Pattern test reported of no ear difference, as was obtained in the present study. In the same trend, Musiek (1994) observed temporal ordering skills in individuals with normal vision to have no difference between the ears for a duration pattern test.

5.3 Association and correlation between the temporal processing tests in individuals with blindness

The findings of the present study revealed that there was no association between the tests in individuals with blindness. This lack of association was observed from the scatter plots between GIN and DPT, GIN and DDT as well as between DPT and DDT. Similarly, a low correlation was obtained between the three temporal processing tests. This correlation was not statistically significant for the GIN and DPT, as well as GIN and DDT, but was significant between DPT and DDT.

The lack of association and correlation between the tests can be attributed to the varied responses obtained from the participants. While almost all the participants passed GIN, almost all failed DPT and DDT. Further, the lack of association and correlation between the tests indicates that each of the temporal processing tests assessed different aspects and the finding of one test cannot be used to make a judgement about the other.

From the findings of the study it can be concluded that the individuals with blindness performed similar to normal sighted individuals on a temporal resolution test, but poorer than the normal individuals on temporal patterning and temporal discrimination tests.

Thus, the assumptions made by Stevens and Weaver (2005) and Sepehrnejad et al. (2011) that compensatory neuroplasticity occurs after visual deprivation resulting in enhanced temporal abilities, is refuted.

.

Chapter 6

SUMMARY AND CONCLUSIONS

Temporal processing abilities in individuals with blindness have been reported to be higher or comparable with that of normal sighted individuals. A few studies have demonstrated enhanced temporal processing abilities in individuals with blindness (Muchnik et al., 1991; Sepehrnejad et al., 2011; Stevens & Weaver, 2005). In contrast, other studies contradict these findings and report of no difference between individuals with blindness and those with normal sight (Boas et al., 2011; Kumar et al., 2017; Weaver & Stevens, 2006). Some of the differences seen in the studies were due to variations in the type of temporal process that was evaluated. On other auditory abilities like localization, speech discrimination and auditory memory, individuals with blindness were reported to be better than normal sighted individuals (Kärnekull et al., 2016; Wan et al., 2010; Yabe & Kaga, 2005). Thus, in literature there is a lack of consensus regarding individuals with blindness having enhanced or similar temporal processing abilities as normal sighted individuals. Hence, the study was undertaken with the aim to measure 3 temporal processes (temporal resolution, temporal ordering, & temporal discrimination) in individuals with blindness and compare their scores with existing normative values.

A total of 30 individuals with congenital blindness, aged 18 to 40 years, were recruited for the study. Their hearing abilities were confirmed to be normal hearing after conducting audiological tests. All the participants were assessed using Gaps-In-Noise test developed by Musiek et al. (2005), Duration pattern test developed by Pinheiro and Musiek (1985) and Duration Discrimination test as recommended by Starr et al. (1991) and Barman (2007). The scores obtained by the participants were compared with existing normative values. The norms given by Prem et al. (2012), Mohan and Yathiraj (2013) and Barman (2007) were used to assess GIN, DPT and DDT, respectively.

The analyses were carried out using parametric tests as the data were found to be normally distributed on a Shapiro Wilk test of normality. On the GIN test all but one individual with blindness scored normal scores and the mean scores were not significantly different from the available norms, when measured using a two sample t-test. On the other two tests, two sample t-tests indicated that the scores secured by the individuals with blindness were significantly poorer than available normative data. The number of individuals who failed the temporal processing tests were more on DDT than DPT.

Further, the findings of paired t-tests indicated that the scores of the left and right ears of the participants were not significantly different in all 3 temporal processing tests. Additionally, no association and correlation were obtained between the 3 tests. This was construed from scatter plots and Pearson's product moment correlation.

Thus, it was inferred that individuals with blindness performed similar to normal sighted individuals on a temporal resolution test, but poorer than the normal individuals on temporal patterning and temporal discrimination tests. Further, the findings of the study refute the notion that compensatory neuroplasticity occurs after visual deprivation resulting in enhanced temporal abilities.

Implications of the study

1. The study indicates that the performance of individuals with blindness varies depending on the type of temporal process that is measured.

2. The study indicates that temporal processing abilities of individuals with congenital blindness do not become better than individuals with normal sight to compensate for their lack of vision.

Future directions

1. It needs to be seen whether with oral instructions having exaggerated suprasegments, the performance of the participants with blindness becomes better.
2. Other auditory processes could be evaluated in individuals with blindness.
3. Auditory processing abilities could be compared in those with congenital blindness with those having acquired blindness.

REFERENCES

Amaral, M. I. R., Casali, R. L., Boscariol, M., Lunardi, L., Guerreiro, M. M., & Colella-Santos, M. F. (2014). Temporal Auditory Processing and Phonological Awareness in Children with Benign Epilepsy with Centrotemporal Spikes. *BioMed research international, 2015,* 9.

Arnaud, L., Gracco, V., & Ménard, L. (2018). Enhanced perception of pitch changes in speech and music in early blind adults. *Neuropsychologia, 117*, 261-270.

Barman, A. (2007). *Psycho-Acoustical Profile in Normals and Individuals with Auditory Dys-Synchrony.* (Doctoral Thesis), University of Mysore, All India Institute of Speech and Hearing, Mysuru.

Boas, L. V., Muniz, L., Neto, C., da Silva, S., & Gouveia, M. D. C. L. (2011). Auditory processing performance in blind people. *Brazilian journal of otorhinolaryngology, 77*(4), 504-509.

Brambring, M. (1985). Mobility and orientation processes of the blind *Electronic spatial sensing for the blind* (pp. 493-508): Springer.

Bross, M., & Borenstein, M. S. (1982). Temporal Auditory Acuity in Blind and Sighted Subjects: A Signal Detection Analysis. *Perceptual and Motor Skills, 55*(3).

Chen, M., Liu, J., & Chen, W. (2015). *Different performance on auditory discrimination between sighted and blind individuals.* Paper presented at the Proceedings of the 5th International Asia Conference on Industrial Engineering and Management Innovation (IEMI2014).

Doucet, M. E., Guillemot, J. P., Lassonde, M., Gagne, J. P., Leclerc, C., & Lepore, F. (2005). Blind subjects process auditory spectral cues more efficiently than sighted people. *Experimental Brain Research, 160*(2), 194-202.

Edelman, G. M. (1993). Neural Darwinism: selection and reentrant signaling in higher brain function. *Neuron, 10,* 115-125.

Goodman, D. F., Benichoux, V., & Brette, R. (2013). Decoding neural responses to temporal cues for sound localization. *Elife, 2,* e01312.

Gori, M., Sandini, G., Martinoli, C., & Burr, D. C. (2013). Impairment of auditory spatial localization in congenitally blind human subjects. *Brain, 137*(1), 288-293.

Gougoux, F., Lepore, F., Lassonde, M., Voss, P., Zatorre, R. J., & Belin, P. (2004). Neuropsychology: pitch discrimination in the early blind. *Nature, 430*(6997), 309.

Gougoux, F., Zatorre, R. J., Lassonde, M., Voss, P., & Lepore, F. (2005). A functional neuroimaging study of sound localization: visual cortex activity predicts performance in early-blind individuals. *PLoS biology, 3*(2), e27.

Hötting, K., & Röder, B. (2009). Auditory and auditory-tactile processing in congenitally blind humans. *Hearing research, 258*(1-2), 165-174.

Hugdahl, K., Ek, M., Takio, F., Rintee, T., Tuomainen, J., Haarala, C., & Hämäläinen, H. (2004). Blind individuals show enhanced perceptual and attentional sensitivity for identification of speech sounds. *Cognitive Brain Research, 19*(1), 28-32.

Kärnekull, S., Arshamian, A., Nilsson, M. E., & Larsson, M. (2016). From perception to metacognition: Auditory and olfactory functions in early blind, late blind, and sighted individuals. *Frontiers in psychology, 7*, 1450.

Kärnekull, S. C., Arshamian, A., Nilsson, M. E., & Larsson, M. (2018). The effect of blindness on long-term episodic memory for odors and sounds. *Frontiers In Psychology, 9*.

Kellogg, W. N. (1962). sonar system of the blind. *science, 137*(3528), 399-404.

Kumar, K., Thomas, T., Bhat, J. S., & Ranjan, R. (2017). Psycho acoustical Measures in Individuals with Congenital Visual Impairment. *The international tinniitus journal, 21*(2), 185-189.

Lessard, N., Pare, M., Lepore, F., & Lassonde, M. (1998). Early-blind human subjects localize sound sources better than sighted subjects. *Nature, 395*(6699), 278-280.

Lewald, J. (2002). Vertical sound localization in blind humans. *Neuropsychologia, 40*(12), 1868-1872.

Mohan, S., & Yathiraj, A. (2013). Central Auditory Processing Skills in Older Individuals. *Student Research at A.I.I.S.H Mysore (Articles based on Dissertation done at AIISH), XI*.

Muchnik, C., Efrati, M., Nemeth, E., Malin, M., & Hildesheimer, M. (1991). Central Auditory Skills in Blind and Sighted Subjects. *Scandinavian audiology, 20*(1), 19-23.

Musiek, F. E. (1994). Frequency (pitch) and duration pattern tests. *Journal-American Academy Of Audiology, 5*, 265-265.

Musiek, F. E., Shinn, J. B., Jirsa, R., Bamiou, D., Baran, J. A., & Zaida, E. (2005). GIN (Gaps-In-Noise) test performance in subjects with confirmed central auditory nervous system involvement. *Ear and Hearing, 26*(6), 608-618.

Niemeyer, W., & Starlinger, I. (1981). Do the blind hear better? Investigations on auditory processing in congenital or early acquired blindness II. Central functions. *Audiology, 20*(6), 510-515.

Nilsson, M. E., & Schenkman, B. N. (2016). Blind people are more sensitive than sighted people to binaural sound-location cues, particularly inter-aural level differences. *Hearing research, 332*, 223-232.

Pinheiro, M. L., & Musiek, F. E. (1985). *Assessment of central auditory dysfunction: Foundations and clinical correlates*: Williams & Wilkins.

Prem, G., Shankar, N. S., & Girish, N. (2012). Gaps In Noise (GIN) test–normative data. *Amrita Journal of Medicine, 8*(1), 24-27.

Rice, C. E. (1969). perceptual enhancement inn the early blind. *The Pschychological Record, 19*(1), 1-14.

Röder, B., Rösler, F., & Neville, H. J. (2001). Auditory memory in congenitally blind adults: a behavioral-electrophysiological investigation. *Cognitive Brain Research, 11*(2), 289-303.

Rokem, A., & Ahissar, M. (2009). Interactions of cognitive and auditory abilities in congenitally blind individuals. *Neuropsychologia, 47*, 843-848.

Sepehrnejad, M., Mohammadkhani, G., Farahani, S., Faghihzadeh, S., Khoshk, N., & Hossein, M. (2011). Comparison of gap in noise test results between congenital blind and sighted subjects with normal hearing. *Bimonthly Audiology-Tehran University of Medical Sciences, 20*(2), 22-29.

Simon, H. J., & Levitt, H. (2007). Effect of dual sensory loss on auditory localization: Implications for intervention. *Trends in amplification*, *11*(4), 259-272.

Starr, A., McPherson, D., Patterson, J., Don, M., Luxford, W., Shannon, R., . . . Waring, M. (1991). Absence of both auditory evoked potentials and auditory percepts dependent on timing cues. *Brain*, *114*(3), 1157-1180.

Stevens, A. A., & Weaver, K. (2005). Auditory perceptual consolidation in early-onset blindness. *Neuropsychologia*, *43*(13), 1901-1910.

The Rights of Persons With Disability Act. (2016). *The Gazette of India (Extraordinary).* Controller of Publications, New Delhi. Retrieved from http://www.disabilityaffairs.gov.in/upload/uploadfiles/files/RPWD%20ACT%202016.pdf

Wan, C. Y., Wood, A. G., Reutens, D. C., & Wilson, S. J. (2010). Early but not late-blindness leads to enhanced auditory perception. *Neuropsychologia*, *48*(1), 344-348.

Weaver, K. E., & Stevens, A. A. (2006). Auditory gap detection in the early blind. *Hearing research*, *211*(1-2), 1-6.

Yabe, T., & Kaga, K. (2005). Sound lateralization test in adolescent blind individuals. *Neuroreport*, *16*(9), 939-942.

Yathiraj, A., & Vijayalakshmi, C. S. (2005). *Phonemically balanced word identification test in Kannada.* Department of Audiology, All India Institute of Speech and Hearing, Mysuru.

Zaidan, E., Garcia, A. P., Tedesco, M. L. F., & Baran, J. A. (2008). Performance of normal young adults in two temporal resolution tests. *Pró-Fono Revista de Atualização Científica*, *20*(1), 19-24.