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Original Research Article

A comparative study of simple auditory reaction times in congenitally blind and normally sighted children

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Abstract

Abstract:

Background: Congenitally blind individuals are deprived of visual input from an early age. In congenital blind people, cross-modal plasticity strengthens other sensory modalities. Simple auditory reaction time (SART) measures the response time to single auditory stimuli, reflecting the overall efficiency of sensory, neural, and motor processing pathways. There is a paucity of literature on simple auditory reaction time (SART) measurements in blind children across different age groups. Therefore, the present study was undertaken to evaluate the simple auditory reaction time (SART) in blind children aged 8–16 years and to compare it with age- and sex-matched normally sighted children.

Materials and Methods: The study was conducted in children aged 8-16 years old. The study population involved 58 congenitally blind children, and 58 age- and sex-matched normal-sighted children. The study was conducted after obtaining institutional ethical clearance. The participants' simple auditory reaction time was measured using a response analyzer. Statistical analysis was performed using SPSS version 23 software.

Results: SART was faster among congenitally blind children. No statistically significant sex difference was observed in congenitally blind students and normal sighted students. No statistically significant sex difference was observed in congenitally blind students and normal sighted students. There was significant negative correlation between age and mean SART in the blind group indicating older blind children exhibited faster auditory reaction times.

Conclusion: The faster SART among blind children can be explained on the basis of cross modal plasticity.The study showed a statistically significant negative correlation between age and mean ART in the blind group.

Keywords: Simple auditory reaction time, Blind children, Normal sighted children

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1. Introduction

Reaction time provides valuable information on central nervous system processing time and is defined as the time interval between the stimulus and response. It includes sense organ time,central processing time, nerve time, and muscle time. Simple auditory reaction time (SART) measures the response time to single auditory stimuli, reflecting the overall efficiency of sensory, neural, and motor processing pathways.It is a simple test for measuring the speed of information processingwithin the central nervous system.[1]

Sighted people use vision to navigate and interact with the external world, whereas blind individuals depend on their remaining sensory systems to compensate for the absence of visual cues. Congenital blindness, which deprives individuals of visual input from birth, prompts profound neuroplastic adaptation. Two theories explain the effect of sensory deprivation on remaining sensory modalities. According to disability theory, sense modalities complement each other, and maximum performance occurs when all sensory systems are complete; the lack of one sense leads to the generalized impairment of othersensory systems.In contrast,the compensatory theory states that if conditions are favorable, the negative defects ofone modality will change into positive compensationsof the remaining senses.[2]

Congenitally blind people are deprived of their vision from an early age. In such cases, cross-modal plasticity strengthens other sensory modalities.This leads to a connection between the visual and auditory cortices, increasing the ability of the auditory system to function in the blind.[3] It is implied that blind people have better sensitivity for touch and hearing than normal-sighted people.[4] Children deprived of visual experience and mental imagination have been shown to develop compensatory mental representations based on auditory cues.[5]

Previous studies have predominantly investigated simple auditory reaction times among adults and adolescents with congenital blindness, with mixed results.One study showed better auditory reaction times in congenitally blind participants than in blindfolded sighted participants[2], whereas another study showed no such difference.[4] There is a paucity of literature on simple auditory reaction time (SART) measurements in blind children across different age groups.Early visual deprivation during sensitive developmental periods may produce distinct patterns of neuroplasticity compared to adults.Therefore, the present study was undertaken to evaluate the simple auditory reaction

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time (SART)in blind children aged 8–16 years and to compare it with age- and sex-matched normally sighted children.

2. Aim and Objectives

1. To measure SART in congenitally blind children.
2. To compare SART between children with congenital blindness and healthy control subjects.
3. To evaluate the effect of age and sex on SART.

3. Materials and Methods

1. Study design: Cross-sectional observational comparative study.
2. Sample size: with reference to the article[2]
3. Sample size is calculated by using formula

n=2(Zα+Zβ)2 x S2/ d2

Zα=alpha error 99%=2.58

Zβ=power 90%=1.28

S=average S.D. from reference article=0.06

d=difference of means from reference article=0.08

n=17 in each group.

The minimum required sample size was set at 17 participants per group.

To enhance statistical power and improve representativeness, the sample size was increased to 58 participants per group.

3.1. Source of data

The study population involved two groups: 58 congenitally blind children of 8-16 years recruited from the Maheshwari Blind School, Belgaum, and 58 age- and sex-matched normal-sighted children recruited from NPET's English Medium School, Belgaum.

3.2. Inclusion criteria for the congenitally blind group

Children aged 8–16 years with total blindness were included in the study.Congenital blindness was defined as the total loss of light perception from birth, as confirmed by school records.

3.3. Inclusion criteria for normally sighted group

Age and sex matched Children with normal vision

3.4. Exclusion criteria

Children with any degree of hearing impairment or ear disease, history of head injury, use of medications that could affect reaction time, and known psychiatric disorders or sensorimotor deficits of the hands in the form of leprosy, neuropathy, or neuritis were excluded from the study.

The study was conducted after obtaining institutional ethical clearance. The details, such as the purpose of the study, nature of the study, and methods used, were explained to the participants and controls in their own understandable language. Written informed consent was obtained from the guardians of the participants and controls.

3.5. Measurement of simple auditory reaction time

Everyone was explained about the test and sufficient trials were given for proper understanding. The participants' simple auditory reaction time was measured using a response analyzer in the morning from 9 a.m. to 12 p.m. under similar conditions an hour after a light breakfast. Testing was done in controlled school settings, minimizing noise via quiet rooms The participants were instructed to press the response key by dominant hand as soon as possible after hearing a beeping sound. Hand dominance was confirmed by self-report. The mean of the three readings was calculated for all participants. No warning signals were provided. Three readings were taken to achieve high test-retest reliability.

3.6. The instrument: Response analyzer

Simple auditory reaction time was measured using audio visual reaction time apparatus (RTM-608) response analyzer manufactured by 'Medicaid Systems, Chandīgarh. This instrument works with a power of "220AC,50 Hz "and is equipped with a very sensitive quartz clock. The maximum reaction time ranged from 0 s to 999.9999 s. The display accuracy was $\pm$1 digit. The auto-display unit counts the time elapsed between the presentation of the stimulus and the response in seconds. The auto display unit initially shows 000 s. In RTM-608 series three different types of audio and visual stimuli are provided. A simple auditory reaction measures the reaction to a sound stimulus. The audio mode was selected to measure the simple auditory reaction time, and the participants were instructed to press the response switch with the index finger of their dominant hand as soon as they heard the sound. The reading on the display indicates a simple auditory reaction time.

3.7. Statistical analysis

The basic data of the simple auditory reaction time of the participants were presented as the mean $\pm$ SD. Statistical analysis was performed using SPSS version 23 software.The SART scores between congenitally blind children and normally sighted controls were compared using an unpaired t-test. An intra-group comparison of SART scores between males and females was also performed using an unpaired t-test. The relationship between SART and age was assessed using non-parametric test Spearman's rank correlation. A p-value of < 0.05 was considered statistically significant.

4. Results

A total of 116 children were enrolled in the study, comprising 58 children with congenital blindness (36 boys, 22 girls) and 58 age-matched sighted children (38 boys, 20 girls). The mean age of children with congenital blindness was 12.98 $\pm$ 2.23 years, while the mean age of sighted children was 12.34 $\pm$ 2.05 years. No significant age difference was observed between the two groups, ensuring comparability. The mean BMI of blind children was 17.57 $\pm$ 5.89 kg/m^2 compared to 18.48 $\pm$ 4.16 kg/m^2 in sighted children. Descriptive statistics for both groups are presented in Table 1.

4.1. Comparison of auditory reaction time between blind and sighted students

Unpaired test was used to compare the mean ART between blind and sighted children's groups, as the data were normal. There was a significant difference of mean SART between blind and sighted groups. Unpaired t-test showed t = 5.768, p< 0.001indicating SART was faster among congenitally blind children.The results are shown in Table 2

Table 1. *Descriptive statistics*

Variable	Mean+SD	Confidence interval for mean		Median	IQR
		Lower limit	Upper limit		
Age					
Blind children	12.98+2.23 milliseconds	12.39	13.57	13.5	4.0
Sighted children	12.34+2.05 milliseconds	11.81	12.88	12.0	4.0
BMI					
Blind children	17.57+5.89	16.02	19.12	16.5	4.0
Sighted children	18.48+4.16	17.39	19.58	17.0	4.25
ART					
Blind children	237.17+43.5 milliseconds	225.72	248.63	240	72.75
Sighted children children	281.45+38.9 milliseconds	271.2	291.69	276.5	57.75

ART = Auditory Reaction Time; BMI = Body Mass Index; CI = Confidence Interval; IQR = Interquartile Range.

Table 2. *Comparison of mean ART between blind and sighted children*

Variable	Mean + SD	Confidence interval for mean		Median	IQR	Test statistic	P value
ART							
Blind students	237.17 + 43.57	225.72	248.63	240	72.75	t=5.768	< 0.001
Sighted students	281.45 + 38.97	271.2	291.69	276.5	57.75		

The normality of all SART values was assessed using the Shapiro–Wilk test, which showed a normal distribution of values. The right-hand mean auditory reaction times among congenitally blind students was 237.17 ± 43.57 millisecond, whereas it was 281.45 ± 38.97 millisecond among sighted students.

4.2. Sex-wise differences in auditory reaction time

Within the blind group, males recorded a mean ART of 235.38 ± 42.96 milliseconds compared to 240.33 ± 45.53 millisecond in females. No statistically significant sex difference was observed (p = 0.785), indicating that sex does not significantly affect auditory reaction time in congenitally blind students. Among sighted students, males demonstrated a mean ART of 274.29 ± 39.74 millisecond compared to 294.05 ± 34.98 millisecond in females. No statistically significant difference (p = 0.063) was observed among sighted students. The results are presented in Tables 3 and 4.

Table 3. *Comparison of mean SART between male & female students among blind children*

Variable	SART Mean + SD	Confidence interval for mean		Median	IQR	Test statistic	P value
Male	235.38 + 42.96	221.06	249.7	242	74.5	0.413	0.785
Female	240.33 + 45.53	219.61	261.06	230	77		

Table 4. *Comparison of mean ART between male and female students in the sighted children group*

Variable	SART Mean + SD	Confidence interval for mean		Median	IQR	Test statistic	P value
Male	274.29 + 39.74	261.05	287.55	267	60.5	1.897	0.063
Female	294.05 + 34.98	278.12	309.97	296	43		

No significant difference was observed in the mean SART values between males and females.

4.3. Correlation between age and auditory reaction time

Non-parametric Spearman's rank correlation was used to assess age-ART associations. Spearman's rank correlation analysis revealed a statistically significant negative correlation between age and mean SART in the blind group (ρ = −0.450, p = 0.0004;) This indicates that older blind students exhibit faster auditory reaction times. In the sighted group, a weak negative correlation was observed between age and ART (ρ = −0.194, p = 0.144;)., indicating that age is not a significant predictor of auditory reaction time in sighted students. The results are shown in table 5.

Table 5. *Correlation between age and auditory reaction time*

Group	Measure	ρ (rho)	p-value
Blind children	Age vs ART	−0.450**	0.0004
Sighted children	Age vs ART	−0.194	0.144

** p< 0.05; ** p < 0.001.*

5. Discussion

In the present study, simple auditory reaction time among blind children was significantly faster than normally sighted children. The mean auditory reaction times among congenitally blind students was 237.17 ± 43.57milliseconds, whereas it was 281.45 ± 38.97 milliseconds among sighted students (t = 5.768, p< 0.001). Our results are consistent with those of previous studies.[2,6] Bhirud and Chandan observed a significant reduction in auditory reaction time compared to blindfolded sighted individuals[2]Collignon and De Volder found that congenitally blind participants exhibited shorter reaction times than sighted controls when detecting spatial targets in both auditory and tactile modalities[6]. Patel et. al observed decreased simple auditory reaction time in congenitally total blind people as compared to normal-sighted people.[7] Another study among children with congenital blindness shown better auditory processing than children in the reference group with enhanced behavioural and neurophysiological responses.[8] Our results contrast with those of Gandhi et al., who showed no statistical difference between congenitally blind and normally sighted individuals for different types of sounds.[4] The faster ART among blind children can be explained on the basis of cross-modal plasticity.The primary sensory areas, typically responsible for processing information from a deprived sensory modality, may adapt to process information from remaining senses.[3] Visual deprivation results in cortical reorganization that facilitates the processing of non-visual information. Functional imaging studies in late-onset blind (LB) and congenitally blind (CB) subjects have shown consistent activation of brain areas such as the lateral surface of the lateral occipital cortex (LOC) during auditory and/or tactile sensory tasks regardless of task and age of onset.[9] Strnad et al. (2013) demonstrated that the occipital cortex of blind participants encodes stimulus-specific auditory motion information in spatially distributed patterns.[10]

Our study showed a significant negative correlation between age and mean SART in the blind group ($\rho = -0.450$, p = 0.0004;). This indicates that older blind students exhibit faster auditory reaction times. Faster ART in older children could be explained by auditory neurophysiological development in early childhood. Subcortical auditory maturation develops linearly from 3 to 8 years, with frequency following responses (FFRs) becoming faster, more robust, and more consistent. Neural timing response stability and spectral coding improves over time with age.[11] The study by Alhamdan et al.(2022)showed that the decrease in speeded motor reaction time for multisensory facilitation in children aged 5–10 was primarily due to reduced timed motor responses with age.[12] In addition to general neurodevelopmental maturation, the statistical significance of the age-SART correlation in the blind group may reflect an additional, blindness-specific mechanism explained by cross-modal neuroplastic reorganization. Bedny et al. (2015) demonstrated that occipital brain regions in blind individuals respond to spoken language in the absence of visual input, highlighting the developmental timing and mechanism of this plasticity.Age significantly influences occipital activity in blind children, with responses to non-language sounds increasing from ages 4 to 17.[11] The data suggested that the increase in occipital activity is linked to age which highlighted the role of age in shaping occipital plasticity in blind individuals.[13]

Jiang et al; compared the responses to auditory motion in sighted controls, early blind, late blind, and sight-recovery subjects which showed enhanced responses in hMT+ and reduced functionality in right planum temporale(rPT). Alterations in auditory motion processing in early-blind individuals are predominantly shaped by the lack of visual experience early in life[14]. A study using high-density electrical mapping of event-related potentials (ERPs) and behavioral measures to investigate the developmental trajectory of audiovisual (AV) integration revealed a gradual enhancement in multisensory facilitation, culminating in mature levels around the age of 14[15].

No significant sex difference was observed in the congenitally blind and sighted students indicating that sex does not significantly affect auditory reaction time. Our results contrast with those of a previous study, which showed that males had significantly faster auditory reaction times than females.[16,17]

The findings of this study carry practical implications for education and rehabilitation of congenital blind children. Congenitally blind people must rely on the second most important human sense, the sense of hearing. To prevent them from social exclusion they should be taught how to safely and independently navigate in an urban environment. Therefore, they should be taught to focus auditory attention on small differences in parameters of acoustic waves. The acoustic training improved the abilities of lateralization of the moving sound sources, which is directly connected to improved safety of blind or visually impaired people in urban environment.[18] Blind individuals show impairments in auditory spatial skills that require a complex spatial representation of the environment.The audio-motor training can recalibrate the auditory space perception in blind individuals.[19] Perceptual development in the case of blindness can be enhanced with naturally associated auditory feedback to body movements. Therefore the early introduction of a tailored audio-motor training could potentially prevent spatial developmental delays in visually impaired children.[20] Congenitally blind individuals can further improve their spatial skills with the use of sensory substitution devices (SSDs), either visual-to-tactile or visual-to-auditory.[21]

6. Conclusion

In the present study simple auditory reaction time among blind children was significantly faster than that among normally sighted children. The mean auditory reaction times among congenitally blind students was 237.17 ± 43.57 milliseconds whereas it was 281.45 ± 38.97 milliseconds among sighted students($t = 5.768$, $p < 0.001$). The faster ART among blind children can be explained on the basis of cross modal plasticity. The statistically significant negative correlation between age and mean ART in the blind group ($\rho = -0.450$, p = 0.0004;) indicates that older blind students exhibit faster auditory reaction times could be explained on the basis of auditory neurophysiological development in early childhood. No statistically significant sex difference was observed in congenitally blind students and sighted students indicating that sex does not significantly affect auditory reaction time.The enhanced auditory processing capacity underscores the importance of structured audio motor training and the use of sensory substitution devices to enhance spatial orientation in congenitally blind children.

6.1. Limitations of the study:

This study used a cross-sectional design. The observed age-related improvement in SART among blind children cannot be definitively attributed to progressive neuroplastic reorganization. A longitudinal follow-up of data is required for this purpose. The study did not incorporate neurophysiological or neuroimaging assessments, such as electroencephalography (EEG) and event-related potentials (ERPs), to demonstrate occipital cortex recruitment during auditory processing. The study has limitation of small sample size and single center study.

6.2. Future research

Longitudinal studies of the same cohort of blind children over time could map the developmental trajectory of auditory reaction time and establish when cross-modal plasticity reaches its maximum functional benefit. The effect of structured auditory training on further improving SART in congenitally blind children could be studied to determine the direct educational and rehabilitation implications.

Conflicts of Interest: None

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8. Source of Funding

None.

9. Conflict of Interest

None.

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