

Spatial Localization of Sound in Early Blind During Spatial Bisection Task and Minimum Audible Angle Task

Sowmya Rajaram¹, Ganesh Prasanna²

¹Assistant Professor, Department of Physiology, ²Student, Third year MBBS, Department of Physiology, Bangalore Medical College and Research Institute, Fort, KR Road, Bangalore

Abstract

Background: Research has shown that early blind have supra-normal localization abilities in the azimuthal plane while performing a minimum audible angle task which is based on egocentric paradigm. An opposing view has been proposed that the early blind have a deficit in spatial localization of sound in the horizontal plane during an allocentric based task such as spatial bisection of sound. The objective of our study was to assess spatial localization of sound in the early blind by means of minimum audible angle task and spatial bisection task.

Methods: A total of ten early blind and ten normal sighted blind folded controls were subjected to minimum audible angle task and spatial bisection task in the azimuthal plane.

Results: The early blind subjects performed significantly poorer than controls in the spatial bisection task which was based on the allocentric model. However, they performed as well as the controls in the Minimum audible angle task which was based on egocentric model.

Conclusion: The minimum audible angle task based on the egocentric paradigm does not require a metric representation of auditory space whereas allocentric paradigm based task would require the same. However the spatial bisection task which is based on the allocentric paradigm taxes the retinotopic maps. Hence the poor performance in this task

Key words: *spatial bisection task, Minimum audible angle task, early blind, cross sensory calibration*

Background

The consequence of blindness in the development of sound localizing abilities in the early blind has been a subject of research in the last decade. The research work in this area of neuroscience has yielded two different and opposing viewpoints. One set of research studies has proved that early blind are blessed with supra-normal abilities in the azimuthal plane ¹. An opposing view is that the early blind have a deficit in the spatial localization of sound in the horizontal plane ².

At this point, we need to consider the reference frames that are used to localize sounds. The frames of reference are the means of representing the location of entities in space ³. The two dominant ones include the egocentric frame of reference which uses the subject as the centre of environment ⁴ and the allocentric frame of

reference, which is centred on external objects or the environment itself ⁵.

The objective of our research study was to study spatial localization of sound in the early blind during minimum audible angle task which is an egocentric task and during spatial bisection task which is an allocentric task.

Subjects, Materials and Method

Subjects:

Ethical approval was obtained from the institutional ethical clearance committee as part of an ICMR short term studentship 2017 project. Ten early blind subjects and ten age and gender matched controls were recruited for the study based on the inclusion and exclusion criteria. Early blind were defined as those who had complete

blindness by eleven years of age. Of the ten early blind subjects, eight were blind since birth and the remaining two had lost vision completely by the age of five years. Blindness was defined by World Health Organization criteria as visual acuity of less than 3/60 in both eyes. Inclusion criteria were: age more than nineteen years and normal hearing as screened by hearing test @audiologia 1.1.2. Exclusion criteria were: history of occupational exposure to loud sounds, history of consumption of ototoxic drugs, history of neurological impairment, ear diseases or any acute or chronic ailments other than blindness.

A total of twenty subjects included in the study were screened for deafness by 'Hearing Test version 1.1.2'. They were explained about the procedure of the test and each of them gave their informed consent. The blind gave their left thumb impression upon reading the informed consent in Braille.

Instrument:

The Audiometer mobile application 'Hearing Test version 1.1.2' (by developer: hearingtest@e-audiologia.pl), calibrated according to the default headphones of the phone was used which gives a result as (i) 'Normal hearing', or Hearing loss in increasing degrees as (ii) 'Mild', (iii) 'Moderate' or (iv) 'Severe' hearing loss and (v) 'Deafness'.

The horizontal arrangement of Generic Passive 5-Volt Speaker modules, compatible with Arduino microcontroller board was placed on a table 150 cm away from the height-adjustable chair where the subjects took their seat. An angle of 2° was maintained between neighbouring speakers such that a total of 21 speakers covered the total angular distance from +20° to -20° with respect to the position of the subject. 'Arduino' is an open-source platform based on easy-to-use hardware and software that provides a programming tool, Arduino IDE (Integrated Development Environment), for writing code and uploading it to the Arduino board and was used in the study. The duration of sound production and the intervals between successive sounds were programmed on the IDE software on the laptop to which the microcontroller was connected.

Method

The study was carried out in an anechoic room, in the Department of Physiology, Bangalore Medical

College and Research Institute. Each subject sat on a height adjustable chair and the row of twenty one 5-Volt speakers was placed such that the subject's ears and speakers were at the same horizontal level. The central speaker was placed in front of subject 150 cms away.

Minimum audible angle task:

Two sounds each of 1.5 kHz frequency and of 75ms duration which were separated by a gap of 500msec duration were produced: The first from central speaker and the second sound from the speakers to the left of central speaker for 5 trials and from the speaker to the right of central speaker for 5 trials. During each trial, the subject had to say whether the two sounds were from same speaker or two different speakers. The angular separation between the 2 sounds was noted in each trial. The data was noted as the minimum angular separation between the 2 speakers.

Spatial bisection task:

The subject was seated as for the minimum audible angle task. The same instrument was used for this test. Three sounds of 75ms duration and 1.5 kHz frequency were presented from the speakers to each subject. The first sound was produced from -20° speaker, the third sound from + 20° speaker and the second sound from any other speaker except the central speaker. The subject had to say whether the second sound was closer to the first or third sound. The number of correct responses was noted. A total of 30 trials were done for each subject and their responses were noted. The angular distance of the second sound from the central speaker was noted from the computer programme.

Statistical Analysis

Descriptive statistics were performed and data were expressed as mean and standard deviation. Inferential statistics were done to compare the means between early blind and age and gender matched controls. P-value less than 0.05 was considered to be significant. Graph was plotted using Microsoft excel.

Observations and Results

Table 1: Descriptive Statistics for age and gender matching of the subjects

| | Early blind n = 10 | Sighted controls n = 10 | P - value |
|----------------|-----------------------|----------------------------|-----------|
| Age (in years) | 22 ± 4 | 20 ± 1 | 0.2 |
| Gender (M : F) | 7 : 3 | 7 : 3 | 0.6242 |

Table 2: Minimum audible angle expressed as mean and Standard deviation from minimum audible angle task in the early blind and blindfolded sighted controls

| | Early blind n = 10 | Sighted Controls n = 10 | P-Value |
|--|-----------------------|----------------------------|-----------|
| Minimum audible angle (°) (left of the central speaker) (Mean ± SD) | 3 ± 1 | 3 ± 1 | P = 0.06 |
| Minimum audible angle (°) (right of the central speaker) (Mean ± SD) | 3 ± 1 | 3 ± 2 | P = 0.134 |
| Minimum audible angle (°) (mean of both sides) (Mean ± SD) | 3 ± 1 | 3 ± 1 | P = 0.672 |

Table 3: Mean and Standard Deviation (SD) of the number of correct responses out of 30 trials per subject in the spatial bisection task

| | Early blind n = 10 | Sighted controls n = 10 | P - Value |
|---|-----------------------|----------------------------|-----------|
| Number of correct responses (Mean ± SD) | 25 ± 4 | 26 ± 2 | 0.0095* |
| Percentage of correct responses | 82% | 87% | |

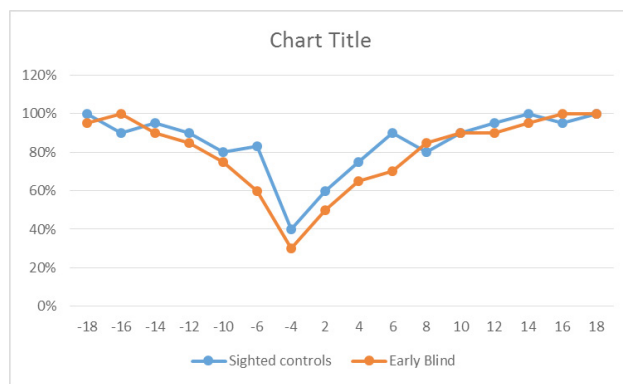
* P<0.01: hence highly significant

Graph 1: Angular position of the 2nd sound in spatial bisection task in X-axis and the percentages of correct answers in the Y-axis

Table 1 shows the descriptive statistics of the subjects in each group expressed as mean and standard deviation. There was no significant difference in means of age in years between the two groups. The two groups were gender matched and male to female ratio was 7:3

Table 2 shows that there was no significant difference between the 2 groups with respect to their performance in the minimum audible angle task. This means that the early blind performed this task as good as the blindfolded sighted controls.

Table 3 shows that the comparison of mean of correct responses during spatial bisection task between two groups was significant. The early blind performed the task significantly poorly compared to the controls.



Graph 1 shows the angular position of the second sound during spatial bisection task in X-axis and the percentages of correct answers in the Y-axis.

Discussion

In this study, table 1 shows that there is no significant difference between the two groups with respect to age and gender. This emphasizes that the two groups were age and gender matched.

Table 2 shows minimum audible angle task performance of both groups. There was no significant difference between the two groups. This means that the early blind were as good as controls. Gori et al had conducted a study on minimum audible angle in congenital blind and found similar results in the minimum audible angle task² This task is based on the egocentric frame of reference. In this task the subject localizes the sound with respect to himself and hence

does not require a metric representation of auditory space which an allocentric paradigm requires.

Table 3 shows the performance of the subjects on spatial bisection task. The P-value of 0.0095 shows that early blind performed significantly worse than the controls. This task is based on allocentric frame of reference. To perform this task successfully, the subject needs to have had intact vision in his childhood. To visualize space, a person needs to have intact vision in childhood when utilizing the retinotopic mapping to calibrate their sound localization skills. In the retinotopic blind, this development would not have taken place as the visually impaired lacked visual calibration of the ability to localize sound in space⁵.

There is sufficient evidence that the visual system plays a major role in calibrating auditory localization. Owls reared with distorting prisms show persistent and systematic biases in auditory localization. A study has shown that visually deprived ferrets show impaired development of auditory spatial map in the superior colliculus. The above cited examples indicate that vision is very important for the formation of auditory spatial maps^{2,7}. Gori et al described that cross sensory calibration is a general property of the sensory system especially during the early years when the sensory apparatus is still developing². They explained that while the sensory systems are still developing and have not yet reached complete maturity, the more accurate and robust sensory system calibrates the other sensory system. In these ten early blind subjects, lack of visual calibration of the developing spatial localization of sound in their childhood resulted in their poor localization abilities.

Strengths and limitations of the study:

The strength of this study was its adequate sample size and thorough age and gender matching of the subjects of the two groups. Another feature in this study was utilization of the Arduino microcontroller board to control the speakers. This removed bias by enabling the sound stimuli to be completely identical for each subject.

In our study, the tasks were performed only in the horizontal plane and not in vertical plane. This was chosen as it is the more commonly used plane during way finding in the blind. For a more thorough understanding of spatial localization of sound, the vertical plane should also be studied. Also, further insight can be gained by examining localization in different directions other than

the front as was done in this study.

Future directions look at studying spatial bisection and minimum audible angle in the vertical plane in early blind and late onset blind and at finding out whether sensory motor feedback training will improve spatial localization of sound in early blind⁵.

Conclusion

The early blind group performed poorer than the normal sighted blindfolded controls in the spatial bisection task. However their performance in minimum audible angle task was as good as the controls. This means that they did well on the egocentric task which does not require a metric representation of auditory space which an allocentric paradigm-based spatial bisection task would require. In the early blind, the absence of vision when the sensory systems were developing results in lack of visual calibration of auditory spatial localization skills. Hence this supports the cross sensory calibration hypothesis.

Conflict of Interest: Nil

Source of Funding: Nil

Ethical approval: Obtained as part of ICMR Short Term Studentship project from the Institutional Ethical Clearance Committee.

Acknowledgement: We acknowledge the Indian Council of Medical Research for selecting Ganesh Prasanna for the ICMR- Short Term Studentship-2017.

We also wish to express our gratitude to all the blind subjects who were recruited for the study. We thank 'Premaanajali Educational Trust', JP Nagar, Bangalore and 'The Karnataka Welfare Association for Blind', Sampangirama Nagar, Bangalore for their sincere cooperation.

References

1. Voss P, Lassonde M, Gougoux F, Fortin M, Guillemot J-P, Lepore F. Early-and late-onset blind individuals show supra-normal auditory abilities in far-space. *Current Biology*. 2004; 14(19):1734–8.
2. Gori M, Sandini G, Martinoli C, Burr DC. Impairment of auditory spatial localization in congenitally blind human subjects. *Brain*. 2014 Jan; 137(Pt 1):288–93.

3. Kosslyn SM. Seeing and imagining in the cerebral hemispheres: a computational approach. *Psychol Rev.* 1987 Apr; 94(2):148–75.
4. Klatzky RL. Allocentric and egocentric spatial representations: Definitions, distinctions, and interconnections. In Springer; 1998. p. 1–17.
5. Voss P. Auditory spatial perception without vision. *Frontiers in Psychology.* 2016; 7.
6. Gori M, Sandini G, Martinoli C, Burr D. Poor haptic orientation discrimination in nonsighted children may reflect disruption of cross-sensory calibration. *Current Biology.* 2010 Feb 9; 20(3):223-5.
7. Witten IB, Knudsen EI. Why seeing is believing: merging auditory and visual worlds. *Neuron.* 2005 Nov 3; 48(3):489-96.