

# Gender Differences in Spatial Localization of Sound in the Azimuthal Plane in Normally Sighted Young Adults

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## Abstract

**Background:** Research studies have shown that there are differences in the neuroanatomy of males and females. The aim of our study was to find whether there are any gender differences in the spatial localization of sound.

**Method:** A total of eighteen blindfolded subjects, consisting of nine males and nine age-matched females with normal hearing, were subjected to the spatial bisection task where they had to localize the second sound, whose location varied from  $-20^\circ$  to  $+20^\circ$  in the azimuthal plane, while the first and third sound were fixed at  $-20^\circ$  and  $+20^\circ$  respectively. The Minimum audible angle task was administered, where the subjects had to say whether the 2 sounds presented were from same location or from two different speakers.

**Results and Conclusion:** There was no significant difference between the males and females with respect to their performance of spatial bisection task and minimum audible angle task.

**Keywords:** gender difference, spatial bisection task, Minimum audible angle task, spatial localization of sound

## Background

Men and women are equal in intelligence but differ in their skills and capacities. There are papers that support the view that there are differences between the neuroanatomy of males and female. The size of the male brain is on an average 8-10% larger than the female brain<sup>1</sup>. The hemispheric asymmetry in the cerebral hemispheres is more in males than in females<sup>2</sup>. This is supported by the fact that in the male brain, the functions are lateralized to one hemisphere<sup>3</sup>. Ruytjens et al explained that there is gender difference in the regional cerebral blood flow in the left and right primary auditory cortex when responding to music or noise<sup>4</sup>.

Localization of sound is defined as a listener's ability to identify the location or origin of the detected sound in direction and distance. The human auditory system uses several cues to localize sound. One such mechanism is the inter-aural time difference used in sound localization in the azimuthal plane. For sounds less than 2 kHz, the sound reaches the ear closer to the origin of sound first and then goes around the head and enters into the other ear. Using this cue, the human brain can identify the

location of sound source<sup>5</sup>.

An essential consideration is of the reference frame which is used to localize sounds. The frame of reference is defined as the means of representing the location of entities in space<sup>6</sup>. The dominant ones are egocentric and allocentric frames of reference. The egocentric frame uses the subject as the center of the environment whereas the allocentric frame is centered around external objects or the environment itself. The spatial bisection task assesses the spatial localization of sound in the allocentric frame while the minimum audible angle task is based on the egocentric frame<sup>7</sup>.

The Objective of our study was to find out whether there was any gender difference in spatial localization of sound assessed by the spatial bisection task and minimum audible angle task in the azimuthal plane.

## Subjects, Materials and Method

### Subjects:

Ethical approval was obtained from the Institutional ethical clearance committee as part of a larger ICMR

Short Term Studentship - 2017 project. Nine males and nine age matched females, who were in the age group between 20 and 29 years were recruited for the study from the staff and student population of Bangalore Medical College, based on the inclusion and exclusion criteria. Inclusion criteria: healthy young adults with normal hearing. Exclusion criteria: history of any past or present ear disease, any neurological illness, usage of ototoxic drugs and occupational exposure to loud sounds. Informed consent was obtained from each of the participants. The hearing threshold of all the subjects had to conform to the normal range and this was tested by the audiometry. Only those with 'Normal Hearing' were recruited.

### Materials

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 to assess hearing by pure tone audiometry.

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

### Methodology

All experiments were conducted in an anechoic room in the department of physiology, Bangalore medical college and research institute. The subjects were informed of the procedure before the start of the experiment and all doubts adequately clarified. Informed consent was taken from each subject before the procedure. All subjects were blindfolded to rule out any visual distractions.

### Spatial Bisection Task:

In this method, the blindfolded subject was made to sit on the height-adjustable chair whose height was adjusted such that the subject's ears were in the same horizontal plane as the speakers. Three sounds each of 1.5kHz frequency, lasting 75 ms were successively presented at 500ms intervals, the first sound from -20°, third sound at +20°, and the middle sound from an arbitrary point in between the first and last sounds. The subject was required to verbally indicate whether the second sound source was closer in space to the first or the third sound. Thirty such trials were performed for each subject

### Minimum Audible Angle Task:

For this task, the same setup was used as for the spatial bisection task. Two 75 ms sounds were presented successively with a 500 ms interval, first on the central speaker (0°), and the second sound from the point adjacent to the central speaker. After every trial the subject was required to indicate whether the two sounds seemed to arise from the same point or not. Trials were repeated with successive increase in angular distance of the second sound from the central speaker till the subject was able to distinguish the two sounds sources as from 2 different speakers. 5 sets of such trials were done on each side of the central speaker alternately for each subject<sup>7</sup>. The data collected for each subject consisted of the 10 values of Minimum Audible Angles (correct to 2°) and their means.

### Statistical Analysis

Descriptive statistics were done and data expressed as Mean  $\pm$  Standard deviation (SD). Inferential statistics for the spatial bisection task was done and the two groups were compared using student's t-test.  $P < 0.05$  was considered to be significant. The proportion of the total number of correct responses to the number of wrong responses in each group was compared using Chi-square test. Similarly, the mean of the two groups were compared during the minimum audible angle task by student's t test when the second sound fell to the left and the right of the central speaker individually.

## Observations and Results

**Table 1: Baseline characteristics of the male and female group**

	Males n = 9 (Mean ± SD)	Females n = 9 (Mean ± SD)	P - value
Age (years)	23 ± 4	23 ± 4	0.631

**Table 2: Mean and Standard Deviation (SD) of the number of correct responses out of 30 trials per subject in the spatial bisection task**

	Males (n=9) Mean ± SD	Females (n=9) Mean ± SD	P - value
Number of correct responses	26 ± 2	27 ± 2	0.63

**Table 3: Comparison of proportion of right to wrong responses in the 3 groups for Spatial Bisection task:**

	Males (n = 9)	Females (n = 9)
Number of correct responses	236	240
Number of wrong responses	34	30
Total	270	270

P = 0.6892 (by chi squared test); Chi square – 0.16

**Table 4: Angular separation of the 2 sounds to denote Minimum audible angle:**

	Males (n = 9)	Females (n = 9)	P - value
Right of central speaker (°) (Mean ± SD)	3 ± 2	3 ± 1	0.745
Left of central speaker (°) (Mean ± SD)	3 ± 1	3 ± 1	0.259
Mean of both sides (°) (Mean ± SD)	3 ± 1	3 ± 1	0.464

## Results

Table 1 shows that there was no difference between the means of the 2 groups with respect to the age of the subject.

Table 2 shows that the mean and standard deviation of the number of correct responses out of 30 trials done by each of the 9 participants in each group. While the males showed a mean and standard deviation of 26 and 2 respectively, the females showed a better response of 27(mean) and 2(standard deviation). However there was no significant difference between the means of the two groups.

Table 3 shows the proportion of correct to wrong responses compared between the two groups by Chi square test which showed a P value of 0.689. There was no significant difference between the two groups

Table 4 shows the mean and standard deviation in either group with respect to minimum audible angle when the second sound was to the left of median speaker or to the right of the median speaker. When the mean of both groups were compared, it yielded a P value which was not significant.

## Discussion

There was no significant difference between the mean ages of the two groups. This supports the fact that the two groups were age matched.

Of the 30 trials of spatial bisection task for each subject, the number of correct responses in each group was 26 and 27 in the male and female groups respectively. At this point, we can say that not all could score 30 out of 30 correct responses as blindfolding itself put them at a disadvantaged position. What the subjects had been doing with their eyes open all their life, they had to do after blindfolding. They had only a few minutes to adapt themselves to this situation. We blindfolded them to rule out any visual distractions during the task. Tabry et al compared the effect of blind folding of normal sighted subjects to the not blindfolded condition. They stated that blindfolding put them at a disadvantage compared to the not blindfolded controls<sup>8</sup>.

Ruytjens et al described that there is a difference between males and females in brain activation in the primary auditory cortex in response to different types of acoustic stimuli. They concluded that there was a significant sexual dichotomy in auditory gating. Males

showed inhibition of acoustic stimuli by corticofugal networks. This put them in an evolutionarily advantageous position, where in their role as hunters, they could focus on relevant acoustic stimuli and they could ignore the irrelevant acoustic stimuli. However, in our study, we could not find any significant difference between males and females in spatial localization of sound during the spatial bisection task and minimum audible angle task.

Sound localization can be studied in 3 dimensions - Azimuthal plane or horizontal plane, elevation or vertical plane, distance of stationary sound or the velocity of moving sound. In our study, we have studied sound localization in the azimuthal plane.

The medial superior olivary nucleus, which is a component of superior olivary complex, helps in localizing sound in the azimuthal plane at the ear level. When the source of sound is in the azimuthal plane, it reaches the two ears at different times. The ear closer to the sound receives first. The sound then has to travel around the head (takes 700 microseconds) and reaches the other ear. This difference in time is used by the medial superior olivary nuclei to localize sound in the azimuthal plane<sup>5</sup>. Sexual dichotomy in localization of sound in the azimuthal plane has not been studied much. Our study where we found that there is no gender difference in spatial bisection task and minimal audible angle task in spatial localization of sound is one of the few studies conducted on this topic.

**Strength and limitations:** An important strength of the study was the age matching. There are some studies which explain how the ability to localize sounds varies with age<sup>9</sup>. Another important aspect was the use of Arduino micro controller board. These scientific advancements eliminated the noise that would have been produced had it been necessary to shift the speakers during each trial manually.

**Limitations of the study:** Inclusion of a wider age group including middle aged and the elderly would have provided a complete answer as to whether there is any gender difference in middle aged and elderly.

### Conclusion

This study showed that there was no significant difference in sound localization between males and females during spatial bisection task and minimum audible angle task.

Future directions should focus on gender dichotomy in spatial localization of sound in the vertical plane.

**Conflict of Interest:** Nil

**Source of Funding:** Nil

**Ethical Approval:** Obtained as part of the ICMR Short Term Studentship-2017 project from Institutional Ethical clearance committee

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