Hearing Practicals, Sound Localization and the Psychometric Function: Overview

In this practical, you should:

1. Watch introductory presentation/video 1.1 [if you are doing the practical in person, this just repeats the introductory presentation given by your instructor. So you only need to watch it if you didn't understand the instructor's introductory presentation]
2. Read the introduction and aims
3. Measure someone's sensitivity to one of the most important sound localization cues (Interaural Time Differences), then plot the data and answer some related questions.
4. Listen to sound localization cues (Interaural Time Differences and Interaural Level Differences) and experience how your sensitivity to these cues varies with frequency. Then answer some related questions.

1.1. Introductory Presentation on Sound Localization

Watch introductory video 1.1 on sound localization [if you are doing the practical in person, this just repeats the introductory presentation given by your instructor. So you only need to watch it if you didn't understand the instructor's introductory presentation]

2.1. Introduction to Sound Localization (summary of key points)

Sound Localization Cues

Sounds can be located using a variety of different 'acoustical cues' (i.e. aspects of the sound that provide information about its location). These include:

- **Interaural Time Differences (ITDs):** a sound on one side of the head will arrive at the nearer ear first, producing a timing difference between the two ears (because of differences in path length between the sound source and each ear).
- **Interaural Level Differences (ILDs):** a sound on one side of the head will be louder in the nearer ear, producing a difference in sound level between the two ears (because the head blocks sound by casting an acoustic shadow).
- **Spectral cues:** when sound hits the pinna, it bounces around inside it in a way that amplifies some frequencies and attenuates others. This changes the spectrum of the sound (i.e. the amount of energy at different frequencies), but does so in a way that depends on the direction of the sound.

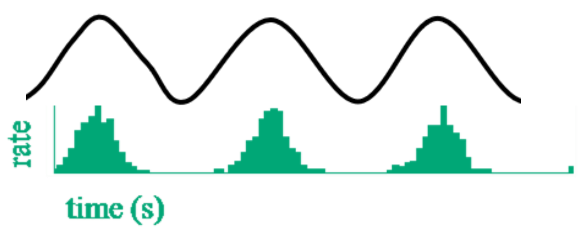
Horizontal and Vertical Sound Localization

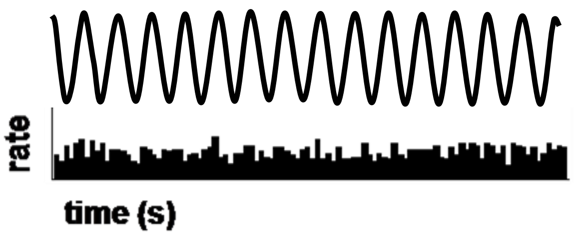
- by using ITDs and ILDs, the brain can tell whether a sound is on the **left or right**.
- by using spectral cues (i.e. comparing the amount of energy at different frequencies), the brain can tell the **elevation** of a sound as well as whether it is in **front or behind**.

Locating Sounds at Different Frequencies

- At **low frequencies** (<2000 Hz), the brain primarily relies on ITDs because ILDs and spectral cues are very small.
- At **high frequencies** (>2000 Hz), the brain primarily relies on ILDs and spectral cues because the brain is not very sensitive to high-frequency ITDs. This is because phase-locking in the auditory nerve provides crucial information about the precise timing of sounds. But at high frequencies, phase-locking fails (because auditory nerve fibres can't keep up with the extremely rapid peaks and troughs in the sound, although the auditory nerve may still keep track of the envelope)

2. Introduction to Sound Localization (more advanced concepts)

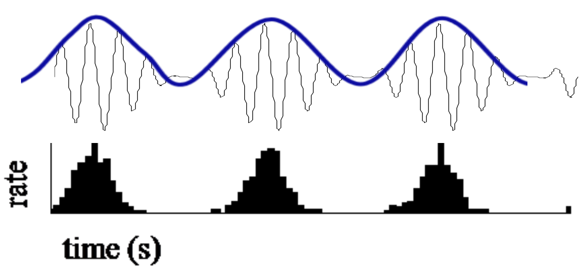




Timing Cues

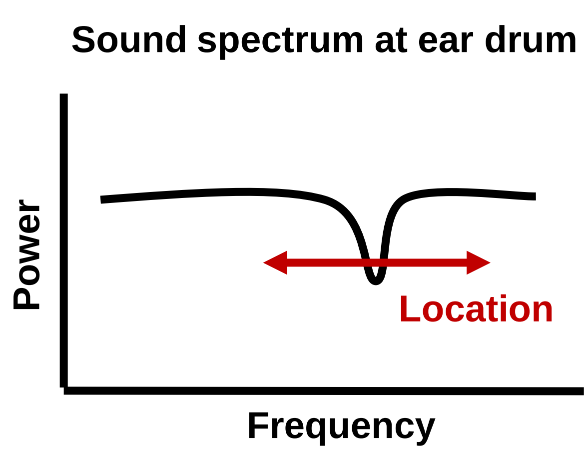
- **Phase Locking:** in auditory nerve fibres, action potentials are locked to a particular phase of the waveform. In other words, neurons fire whenever there is a peak in the waveform.

- **Envelope of a Sound:** refers to slower fluctuations in the overall intensity of a sound. Can be used to compare timing of input to ears at high frequencies, which is evidence against the Duplex Theory (Duplex theory says only ILDs are used at high frequencies).



Spectral Cues

- **Spectral notch:** sound energy at one frequency is much lower than at all other frequencies (i.e. it looks like there is a notch in the spectrum). When a sound is presented, the acoustical properties of the pinna can produce a spectral notch. But the location of the sound determines the frequency at which the spectral notch occurs.



2.2. Aims of Practical

Aim 1: How can we measure sensitivity to Interaural Time Differences (ITDs)? What is an ITD threshold? And how are ITDs affected by head size?

[note: very similar methods are used to measure sensitivity to many other aspects of perception in hearing as well as vision and touch etc.]

Aim 2: How and why does sensitivity to Interaural Time Differences and Interaural Level Differences vary with frequency?

To present test sounds, and find instructions on how to record and plot your data, go to: www.auditorybrain.com/hearing-practicals/Aim1

[note: you should be able to just click on the link above and other links throughout]

Copy of online instructions

1. **Initial Setup:** Ask your participant to wear earphones (making sure the left earphone is on the left ear and vice versa). Then ask them to face away from the screen so they cannot see which stimuli you are presenting. Present a sound to check the volume and adjust the volume on your computer if the sound is either too loud or too quiet.

2. **Test Procedure:** Present a sound with a particular ITD. Then ask your participant whether the sound was on the right or left. If they are not sure, they must make their best guess. Record their response using a table similar to that below. Present each ITD once, making sure that you present different ITDs in a quasi-random order. Then repeat this process until you have at least 5 responses for each ITD tested.

3. **Preliminary Data Analysis:** for each ITD, calculate the percentage of times the sound was heard on the right. Make a note of these results for use in the next step.

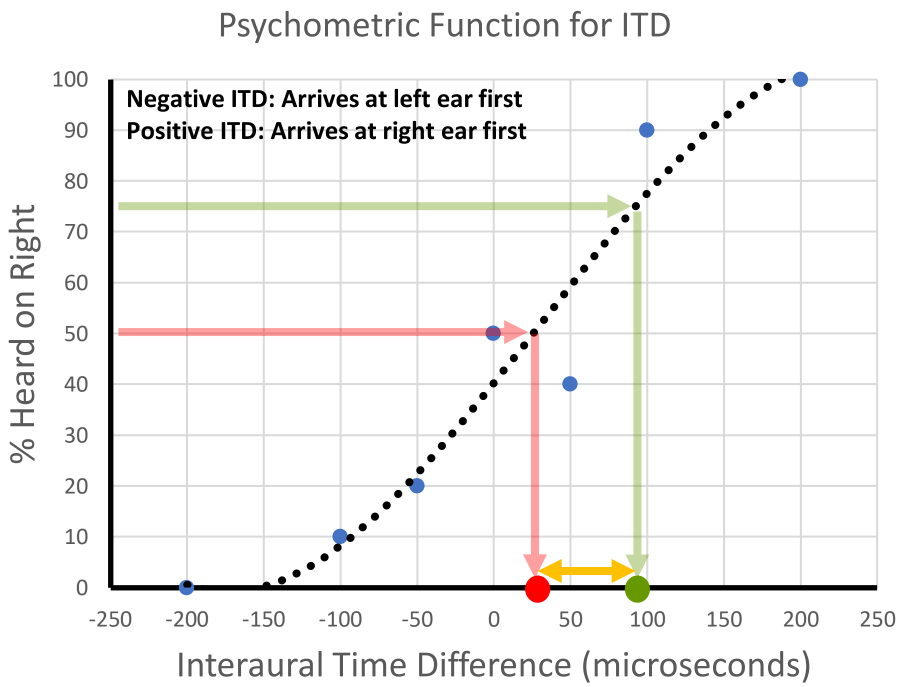
Heard on Right = R
Heard on Left = L

Example of Partially Complete Response Table

ITD:	-200	-100	-50	0	50	100	200
	L	L	L	R	L	R	R
	L		L	R	R		R
% Heard on Right	0	0	0	100	50	100	100

3.2. Aim 1: Calculating ITD thresholds to measure ITD sensitivity

1. **Plotting Data:** For each ITD you tested, plot the percentage of times that the subject heard the sound on the right (blue circles). Then, fit an S-shaped curve to your data (black dotted line).
2. **50% Point:** Identify the ITD that the subject hears on the right 50% of the time (red dot). This is the ITD that causes participants to guess randomly (i.e. 50% of the time they guess right and 50% of the time they guess left).
3. **75% Point:** Identify the ITD that the subject hears on the right 75% of the time (green dot). This is deemed to be a reliable rightward response because it is too consistent to reflect random guessing.
4. **Threshold:** Identify how much you have to change the ITD to go from random guessing (50% Point) to a consistent rightward response (75% Point). This is the threshold.



Worked Example:

50% Point (red dot; random guessing): 25 µs (microseconds)

75% Point (green dot; consistent rightward response): 90 µs

Threshold = 75% Point – 50% Point
= 90 µs – 25 µs
= 65 µs

ITD threshold: Smallest change in ITD that can be reliably detected.

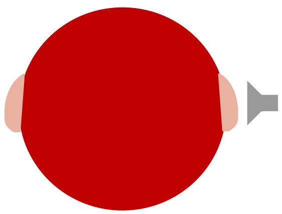
3.3. Aim 1: Questions on the measurement of ITD sensitivity

1. If an ITD of 0 is presented, what percentage of responses would you expect to be made to the right? What might affect this?

2. What is your participant's ITD threshold? If you want to locate sounds, is it better to have a small ITD threshold or a large ITD threshold? If someone were perfect at the ITD task, what would their data look like? If someone couldn't do the ITD task at all, what would their data look like? Given that an action potential is 1ms long, is the ITD threshold you measured surprisingly small or surprisingly large? Could the 75% point sometimes reflect random guessing?

3. What impact does head size have on the magnitude of ITDs experienced? Does having a bigger head make it easier or harder to locate sounds? What implications might this have if you compare sound localization abilities in adult humans with either children or animals?

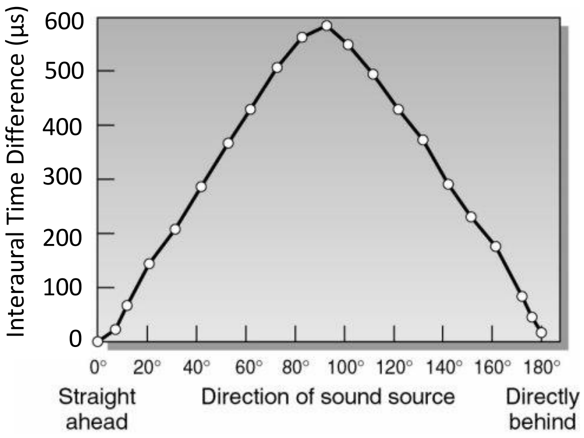
4. Using the following pieces of information, can you work out the largest ITD experienced by Bunsen?
    1. Bunsen has a perfectly circular head with a radius of 0.09m.
    2. The circumference of a circle is equal to $2\pi r$
    3. The speed of sound in air is 343 m/s
    4. Time taken = distance travelled divided by speed
    5. Work out the ITD in seconds, then multiply it by 1,000,000 to express it in microseconds

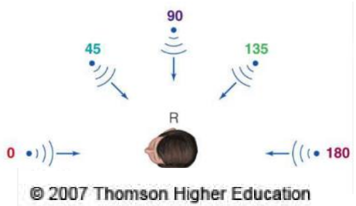


5. Using tiny microphones inserted into Edison's ears, we have measured the Interaural Time Differences that Edison experiences when sounds are presented at different directions (see plot →).

   If Edison has an ITD threshold of 250 μs, what is the smallest change in direction that Edison can detect? Using your own ITD threshold, what is the smallest change in direction that you can detect?

ITDs experienced by Edison





4.1. Aim 2: How does ITD and ILD sensitivity vary with frequency?

To listen to ITDs and ILDs at different frequencies, go to:
www.auditorybrain.com/hearing-practicals/Aim2

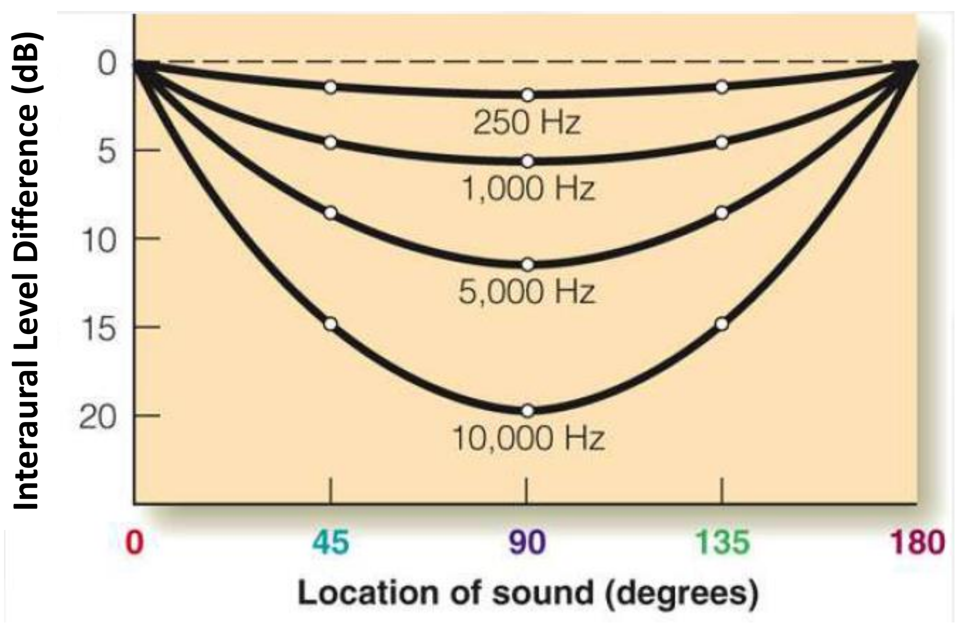
6. When you listen to ITDs using either 500 Hz tones or 4000 Hz tones, can you easily tell when sounds are on the right or left? Which frequency do you find easier to locate using ITDs? Why do you think this is the case?

7. When you listen to Interaural Level Differences (ILDs) using either 500 Hz tones or 4000 Hz tones. Which frequency do you find easier to locate using ILDs?

8. Using tiny microphones, we have recorded the Interaural Level Differences experienced by Edison at different locations (see plot). What happens to ILDs at lower frequencies and why do you think this happens?

9. If Edison has an ILD threshold of 5 dB for both 1000 Hz and 5000 Hz tones, what is the smallest change in location that Edison can detect at each of these frequencies?

10. Overall, is it easier to locate sounds using ITDs or ILDs or does it depend on the frequency of the sound?



4.1. Aim 2: Multiple frequencies together are more effective

To listen to a virtual haircut (created using sound localization cues over headphones), go to: www.auditorybrain.com/listen and scroll toward the end.

[Note: because of time constraints, only listen to 2.40-3.20 in the virtual haircut video]