PSY-2007S

Auditory Experimentation

week 10 – Spatial sound perception

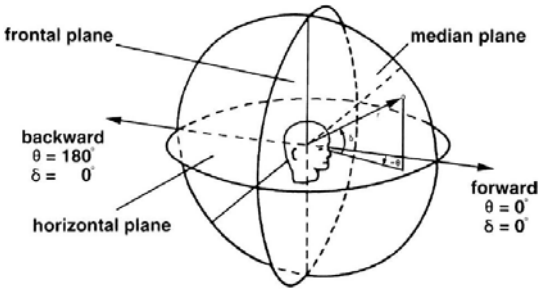
Auditory localization

Auditory spatial cues

Interaural Time Differences (ITDs)
Interaural Level Differences (IIDs) (Head Shadow)
Monaural Level (Head Shadow)
Binaural/Monaural Spectral Shape (Pinna)
Binaural/Monaural Spectral Shape (Shoulder/Torso)
Dynamic cues from head or source movement
Distance (Level, Floor Echoes, Direct-to-Reverberant Ratio, Vocal Effort)

Roles of these cues change for near-field sources

Coordinates for localization in 3D space



Moore, 1997

Auditory spatial cues: ITD and ILD

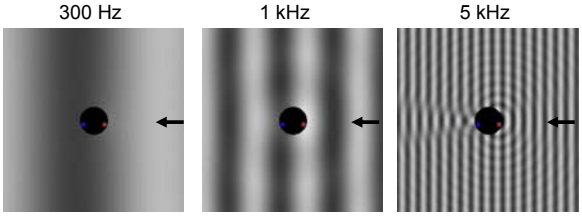
In humans, sound localisation mainly relies on the analysis of differences in sound level and sound arrival time at the two ears.

Interaural level and interaural time differences: ILDs, ITDs

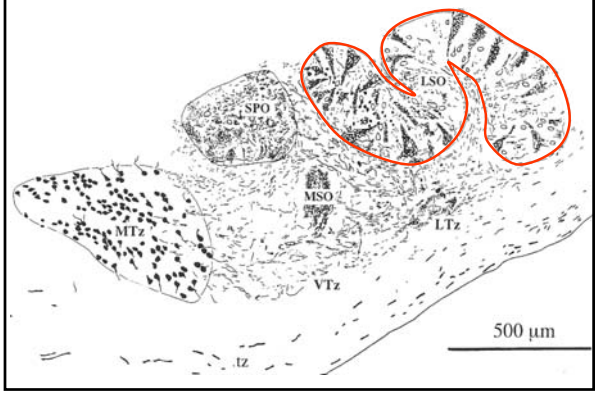
In a sound originating from a lateralised source, ILDs are produced by the head casting a shadow on the farther ear -> ILDs more prominent in high-frequency sounds, because low frequency sounds travel around the head (sound wave length same or larger than head diameter).

Duplex theory of sound lateralization (Lord Rayleigh, 1907)

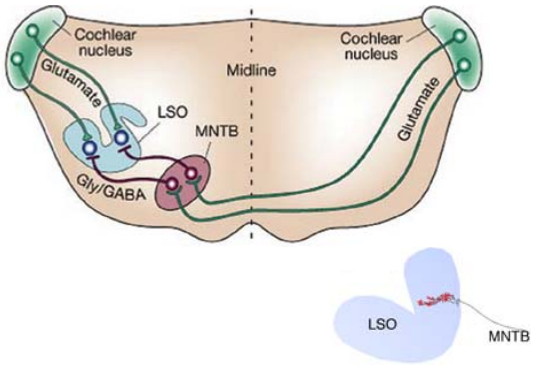
ILDs



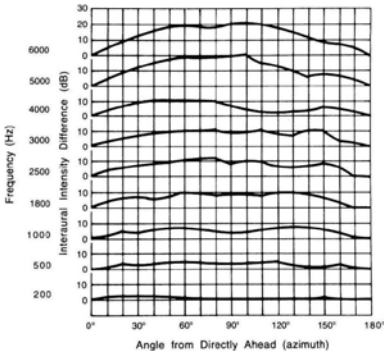
The superior olivary complex



The LSO



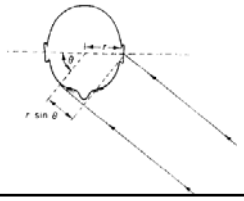
measured IIDs



Moore, 1997

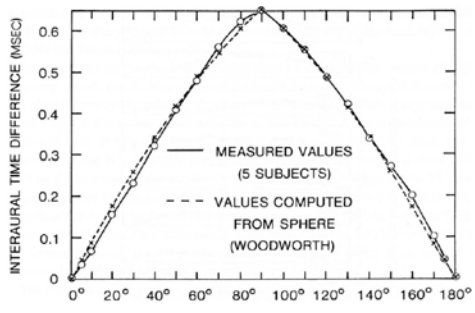
ITDs

ITDs are produced by the path length differences between the sound source and the two ears -> ITDs are of the order of a few tens to a few hundreds of microseconds, thus neural processing of ITDs requires a phenomenal temporal accuracy.
ITDs are more important at low frequencies, because phase locking works only up to about 1500 Hz.



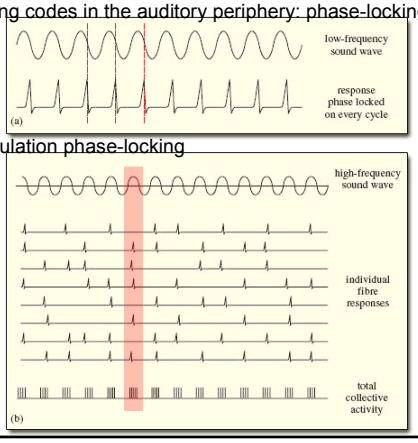
Moore, 1997

ITD: measured vs. predicted



Warren, 1999

Timing codes in the auditory periphery: phase-locking



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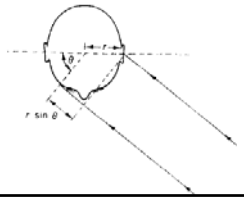

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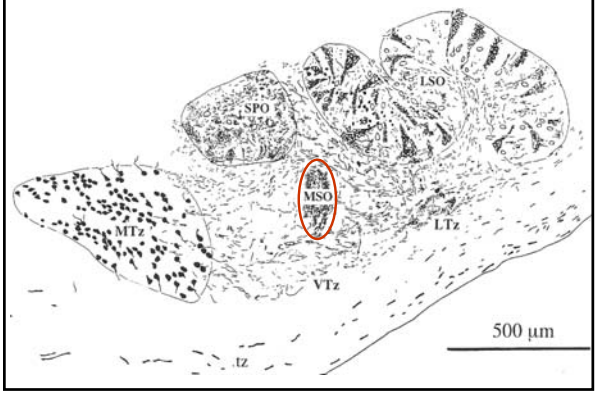
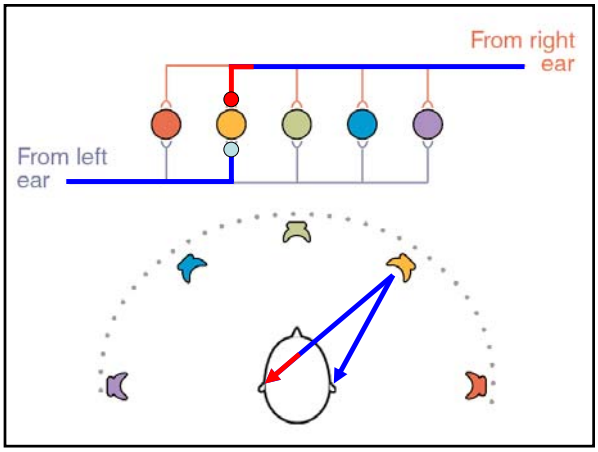
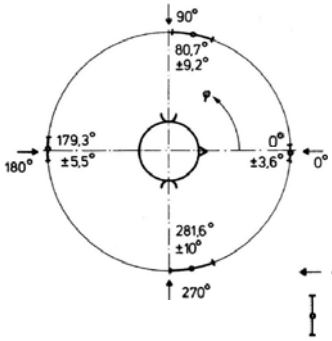




Horizontal directional acuity



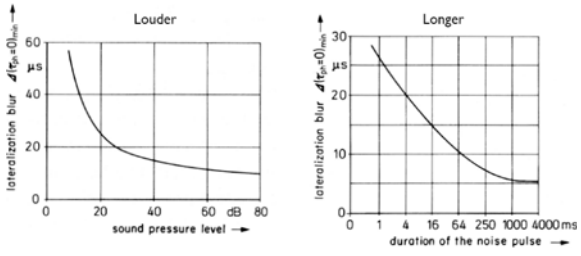
Blauert, 1997

Sound shift acuity: minimum audible angle

Signal Type	Acuity
clicks	0.75° - 2°
sinusoids	1° - 4°
tone bursts	0.8° - 3.3°
speech	0.9° - 1.5°
noise	3.2°

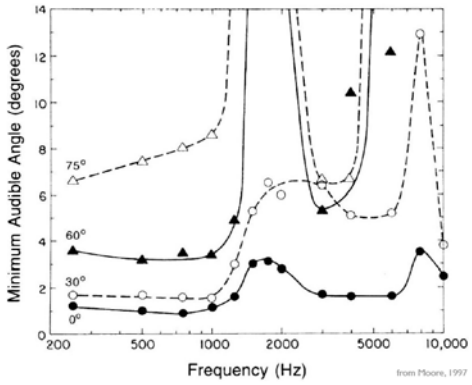
Measuring minimal perceivable displacement from forward direction, under “ideal” conditions.

More signal improves localization accuracy



Temporal integration of information.

MAA vs frequency for different azimuths



ITD and IID

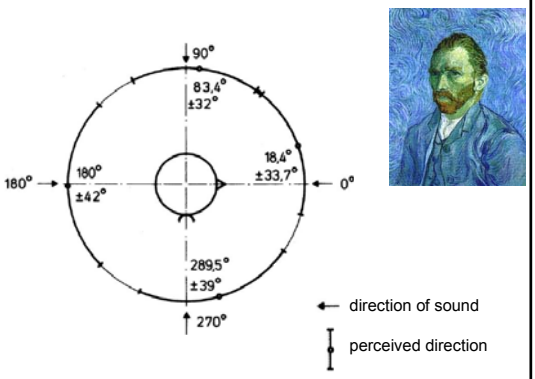
ITD:
- most sensitive at 0°
- smallest detectable change is ~10 μs or 1°
- when f > 900 Hz, ITD sensitivity drops dramatically

IID:
- most sensitive at 0°
- smallest detectable change is ~1 dB
- real world IIDs are small at f < 1800 Hz but still perceptible.

Limitations of the Duplex Theory

- limited to lateralization
- doesn't do front-back discrimination
- doesn't explain why are sounds are outside your head
- doesn't account for acoustic environment (echoes)
- can't handle multiple sound sources

Can we localize sound with one ear?



Blauert, 1997

Function of the Pinna revised

Older theories:
- sound gathering
- Darwin (1800s) evolutionary coincidence, no role in sound localization
- Lord Rayleigh (1907) front and back distinction

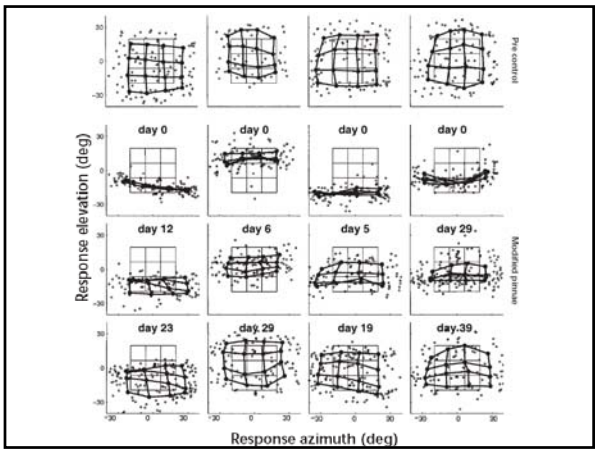
Batteau's theory (1967)

Echos produced by the pinna provide lateralization and elevation cues.

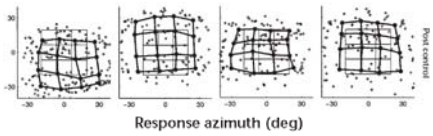
used microphones in pinna casts:

The key experiment - listening through casts caused externalization.

Freedman and Fisher (1968): Not necessary to use subject's own pinnae
- subjects can localize with other pinnae, but with less accuracy
- Only a single pinna (monaural) is needed for localization



HRTFs are learned



Subjects localized sounds with both normal and modified pinnae. Learning new spectral cues does not interfere with the neural representation of the original cues.

Hofman et al., 1998

Vocabulary

ILD
ITD
phase-locking
Superior olivary complex (LSO and MSO)
HRTF
pinna
head shadow
localization
lateralization
externalization