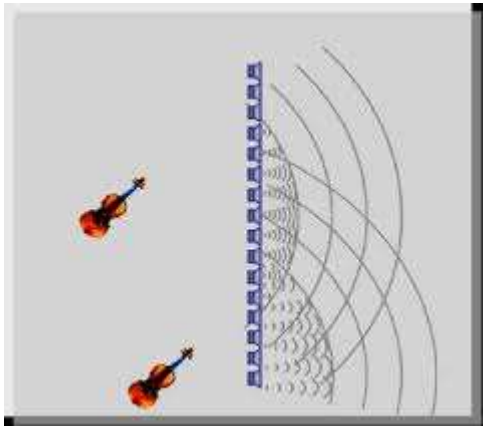
Jogos e Simulação – Audio

Spatialized Audio
and
Sound Localization

3D Sound and Surround Sound

- Mono
- Stereo
- Surround sound
- Sound field synthesis
  - Ambisonics
  - Wave field synthesis



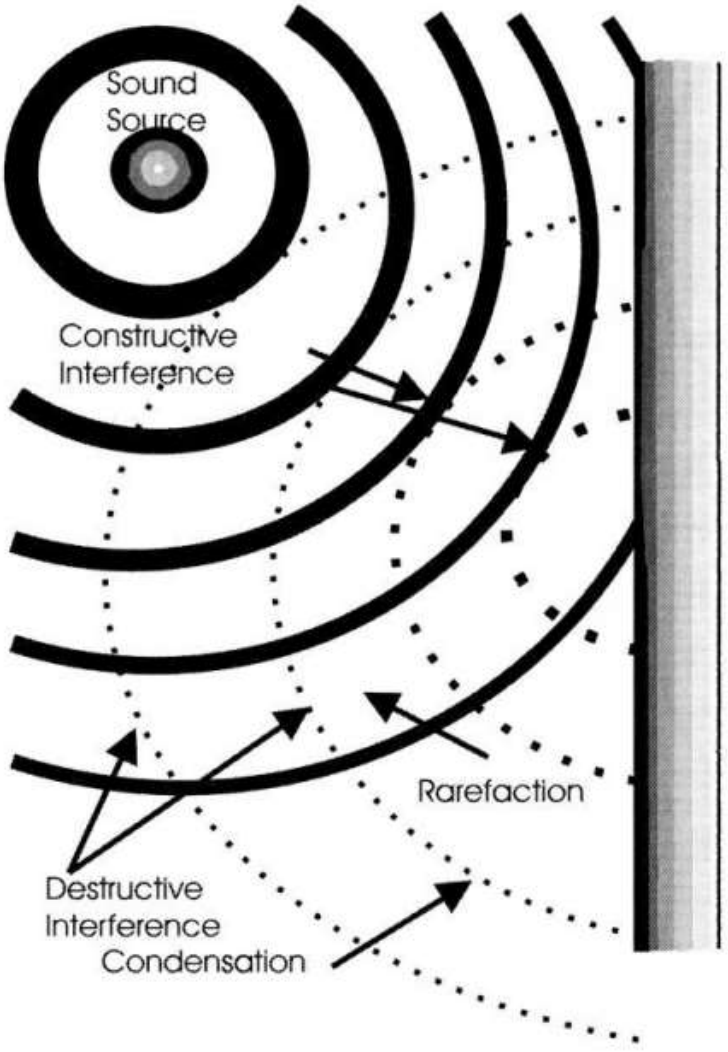
3D Sound vs Surround Sound

- Sound in the real world is 3D – because sound sources' positions are 3D

- Mono – one channel
- Stereo – two channels
- Surround sound – several speakers (several audio channels), perception depends on speakers positioning and listener position
- Ambisonics – speakers above and below (in a sphere), signal in B-format (instead of several channels)
- Wave field synthesis – it creates wave fronts to simulate the sound coming from different locations

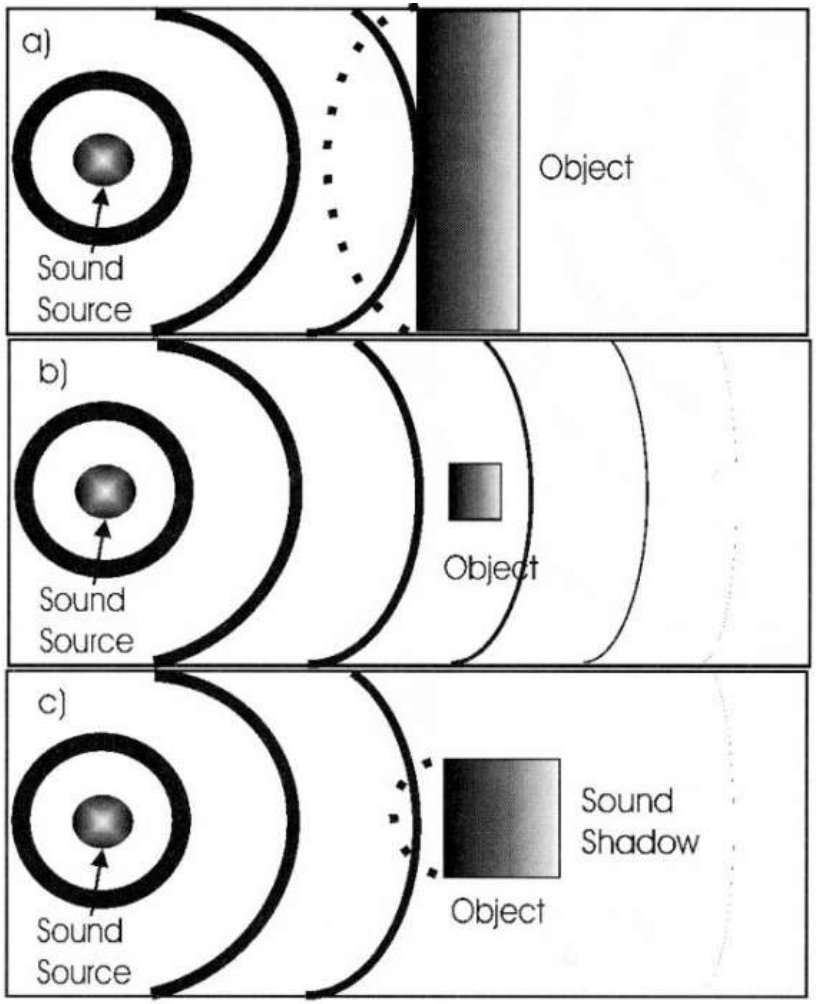
Sound reflection

- Reverberation



From Yost

Sound propagation



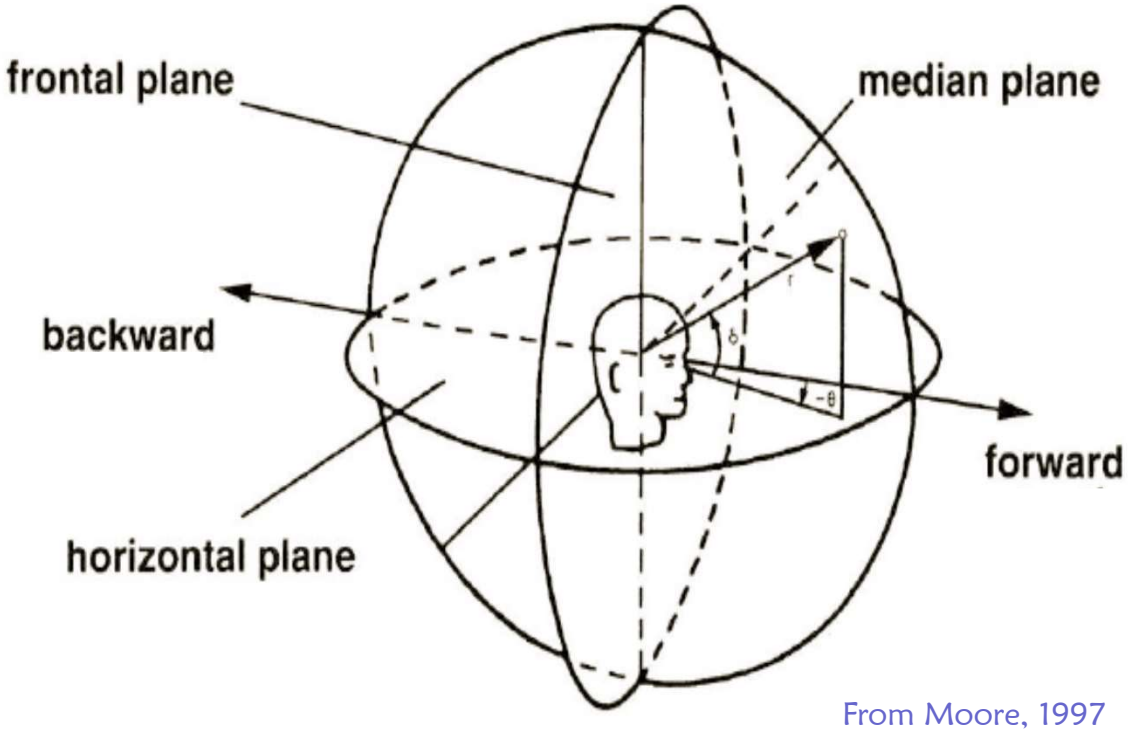
From Yost,

Anechoic and reverberation rooms

- https://www.youtube.com/watch?v=cvr-TRuOzqM

3D localization

- Azimuth (left – right)
- Elevation (up – down)
- Distance



From Moore, 1997

Passive/active localization

- Active localization – estimate position, size, and texture of silent bodies by means of reflected sound waves.
  - Eg. Blind people (use sounds with a wide range of frequencies to discriminate surfaces), and trained sighted people.

- Echolocation – ability to use echoes to do localization.
  - Eg. Shrews, oil-birds, Himalayan cave swiflet, dolphins, bats.

Echolocation

- https://www.youtube.com/watch?v=xATIyq3uZM4

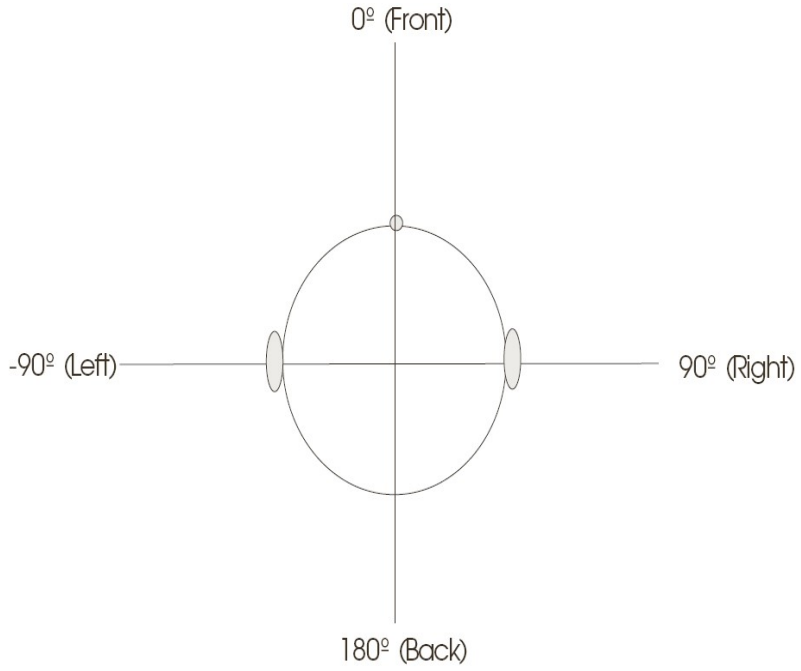
Passive/active localization

- Passive localization – localizing sound sources by means of the sound waves they emit.

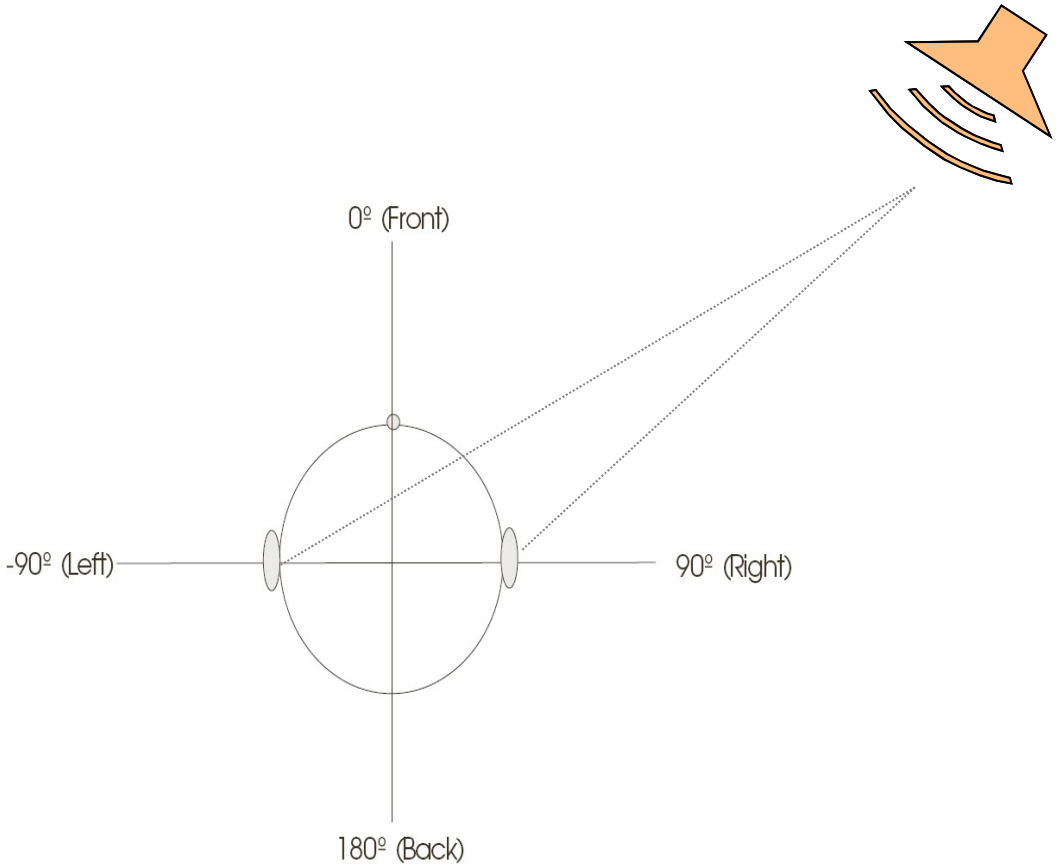
Lateralization

- Lateralization – determining if the sound comes from the left or right of the frontal-medial plane of the head.

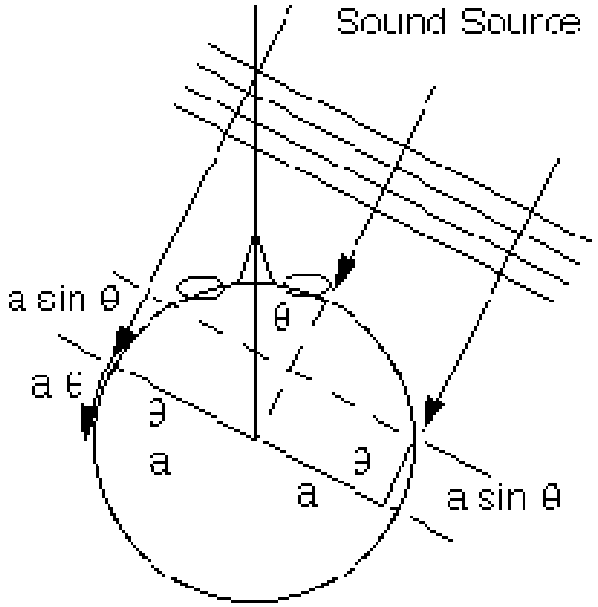
- What cues are used for lateralization?
  - Interaural differences



Interaural time difference (ITD)



Interaural time difference (ITD)



$\Delta t = a/c\ (\theta + \sin\theta)$

$\Delta t_{max} = a/c\ (\pi/2 + 1)$

- a – head radius
- c – sound velocity

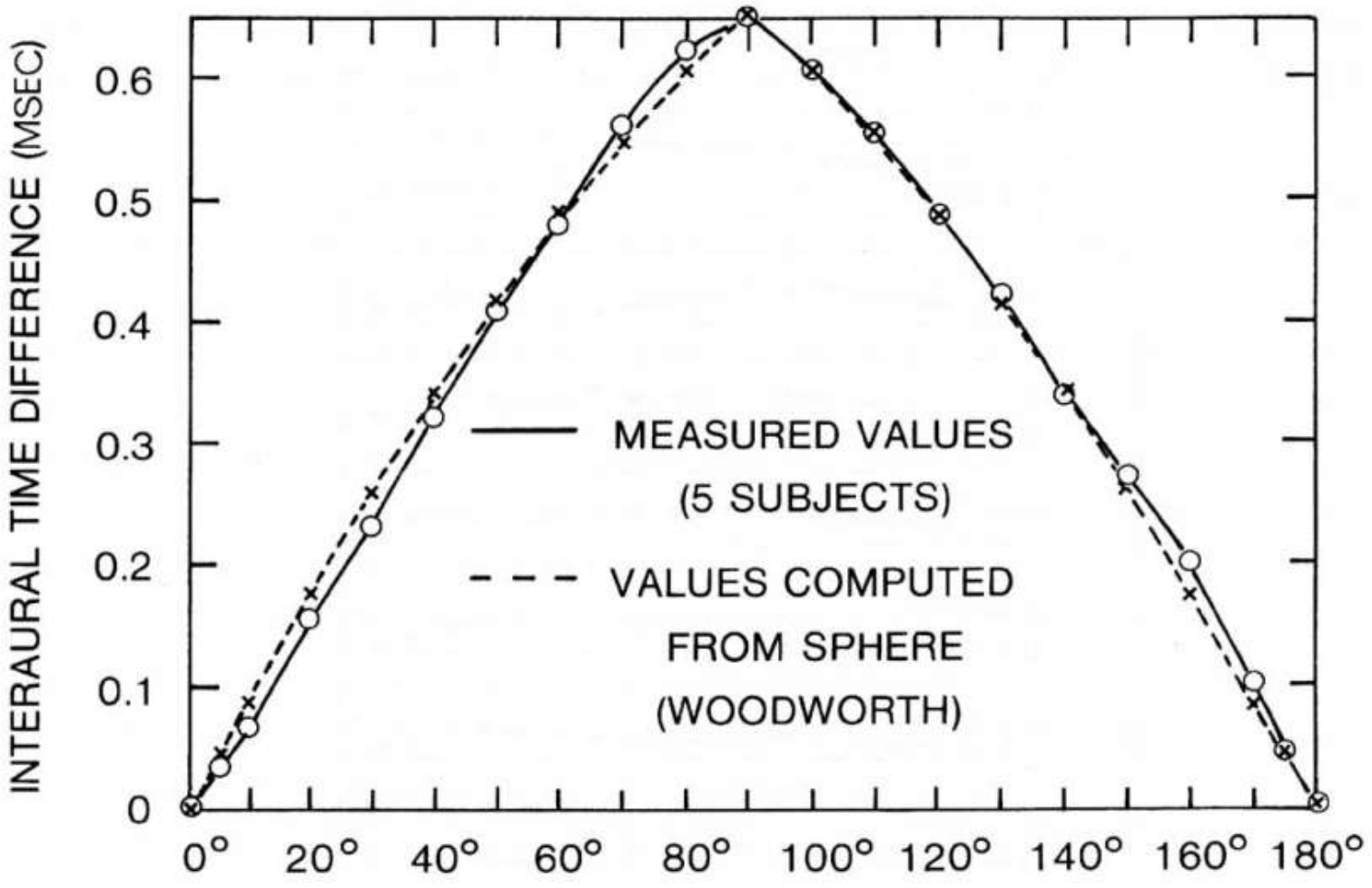
$$\Delta t_{max} = \frac{a}{c}\left(\frac{\pi}{2} + 1\right)$$

$a \approx 0.09\ m$

$c = 343.2\ m/s$

$$\Delta t_{max} = \frac{0.09}{343.2} \times 2.57 = 0.674\ ms$$

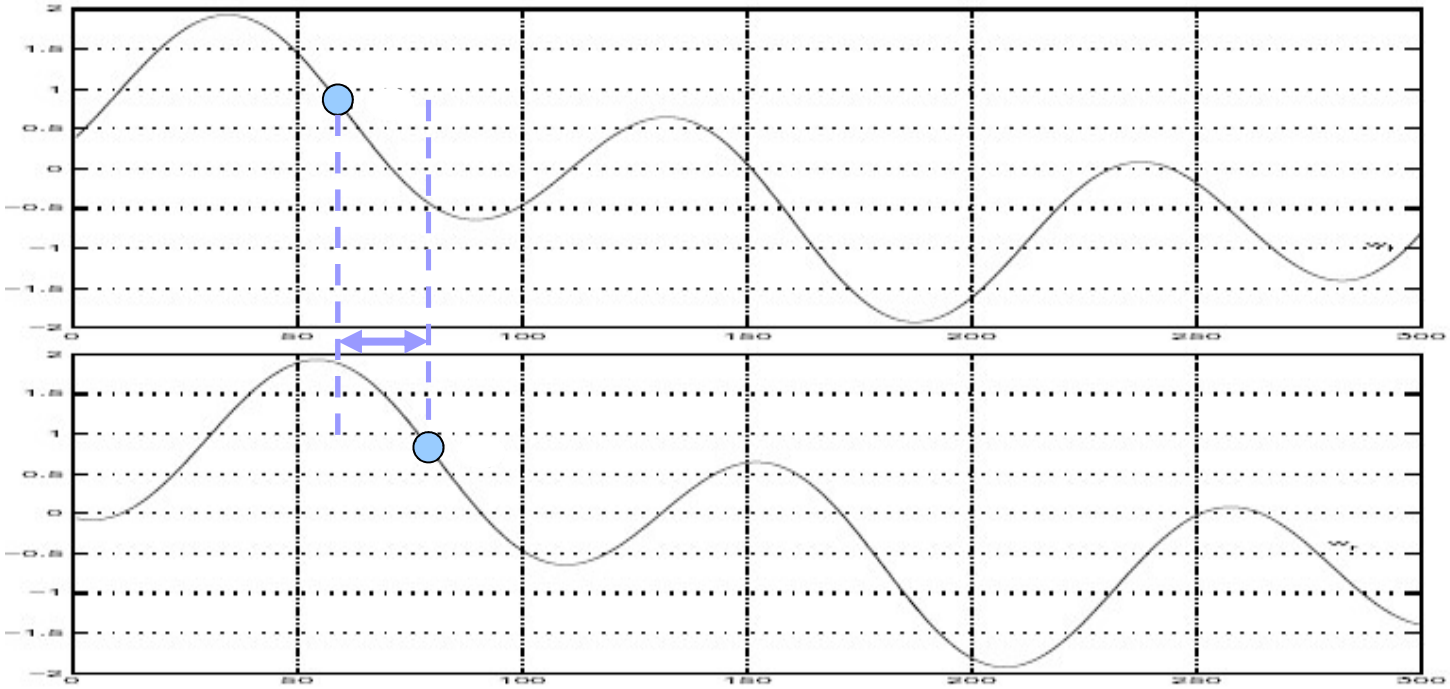
ITDs



From Warren,

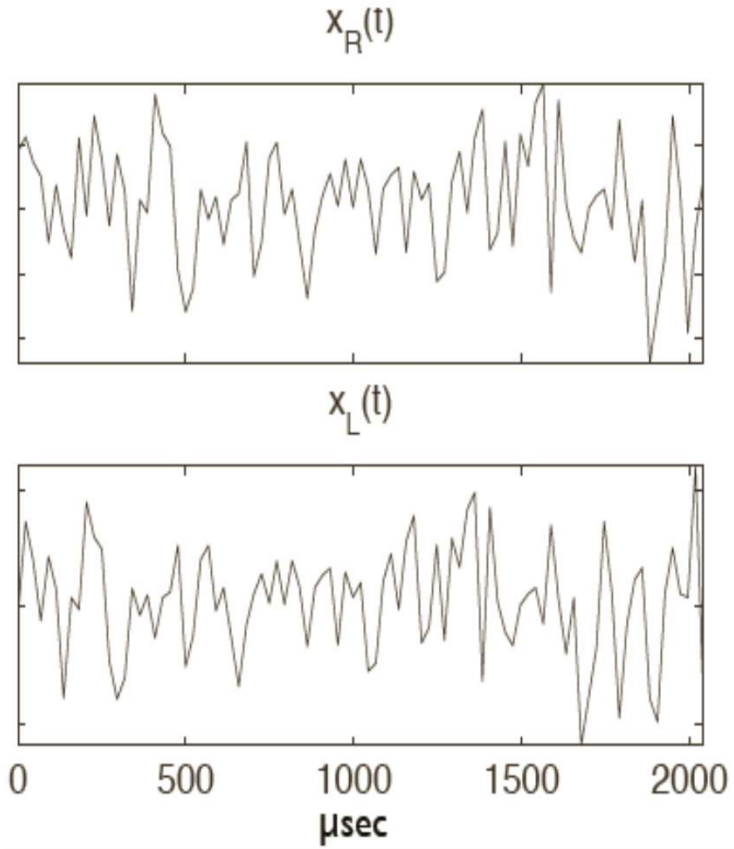
Computing ITDs

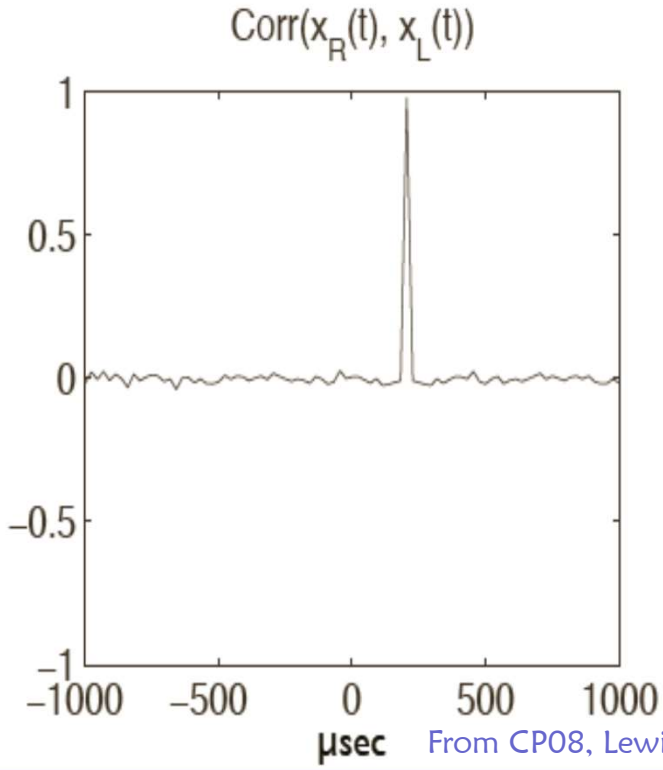
- Matching left and right signals:
  - Zero crossings (sample difference that can easily be converted to time difference)



Computing ITDs

- Matching left and right signals:
  - Zero crossings
  - Cross-correlation

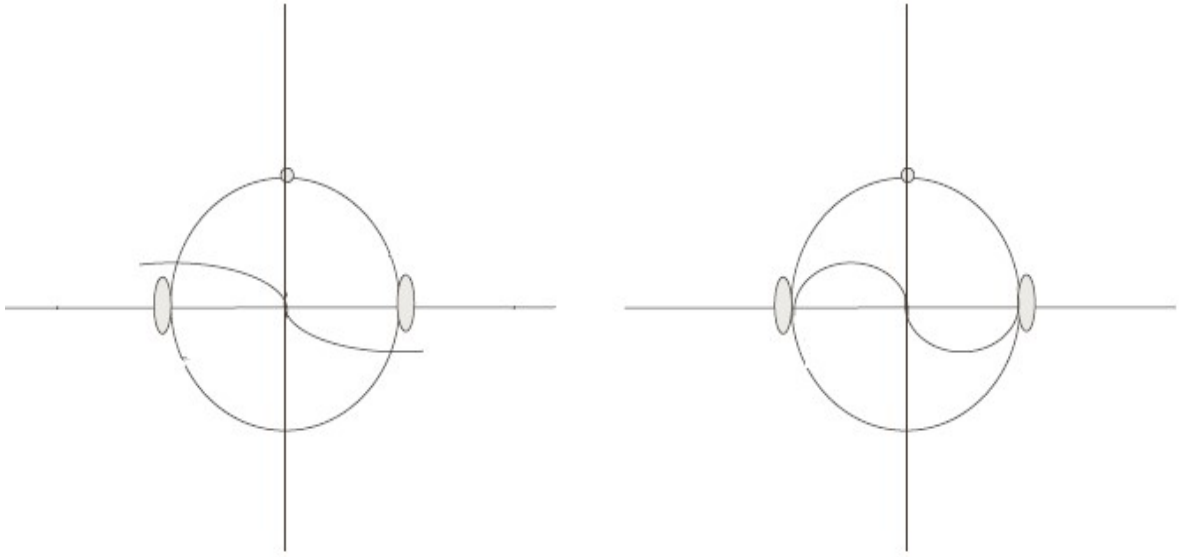




From CP08, Lewicki (CMU)

ITDs limitations

- wavelength ≤ distance between ears ⇒ azimuth ambiguity



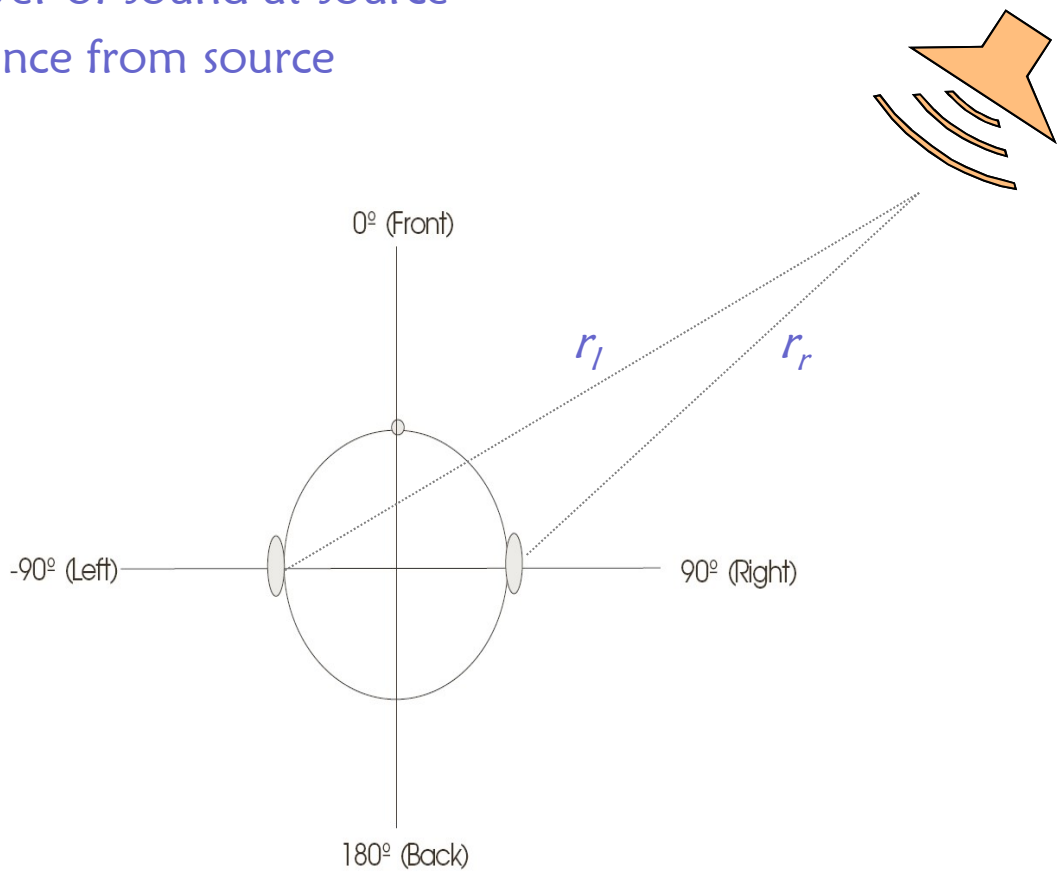
- ITDs limitations –
  - work only for low frequencies
  - (Cannot distinguish front from back.)

Interaural intensity (level) difference (IID/ILD)

- Sound is more intense at ear where it arrives first
  - Inverse square law:

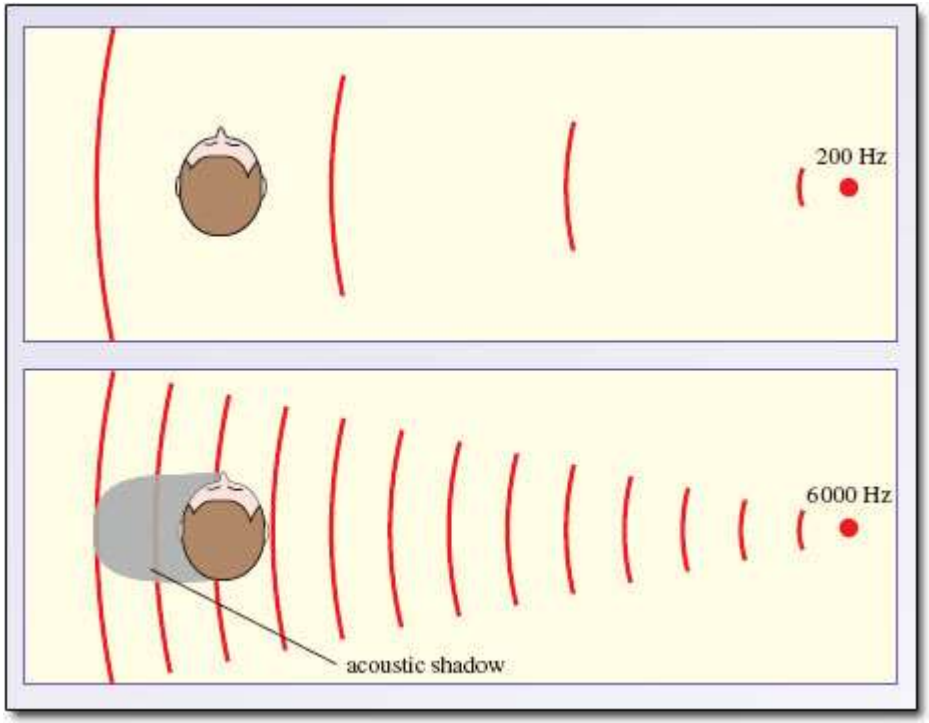
    $I \propto P / (4 \pi r^2)$, P – power of sound at source

    r – distance from source

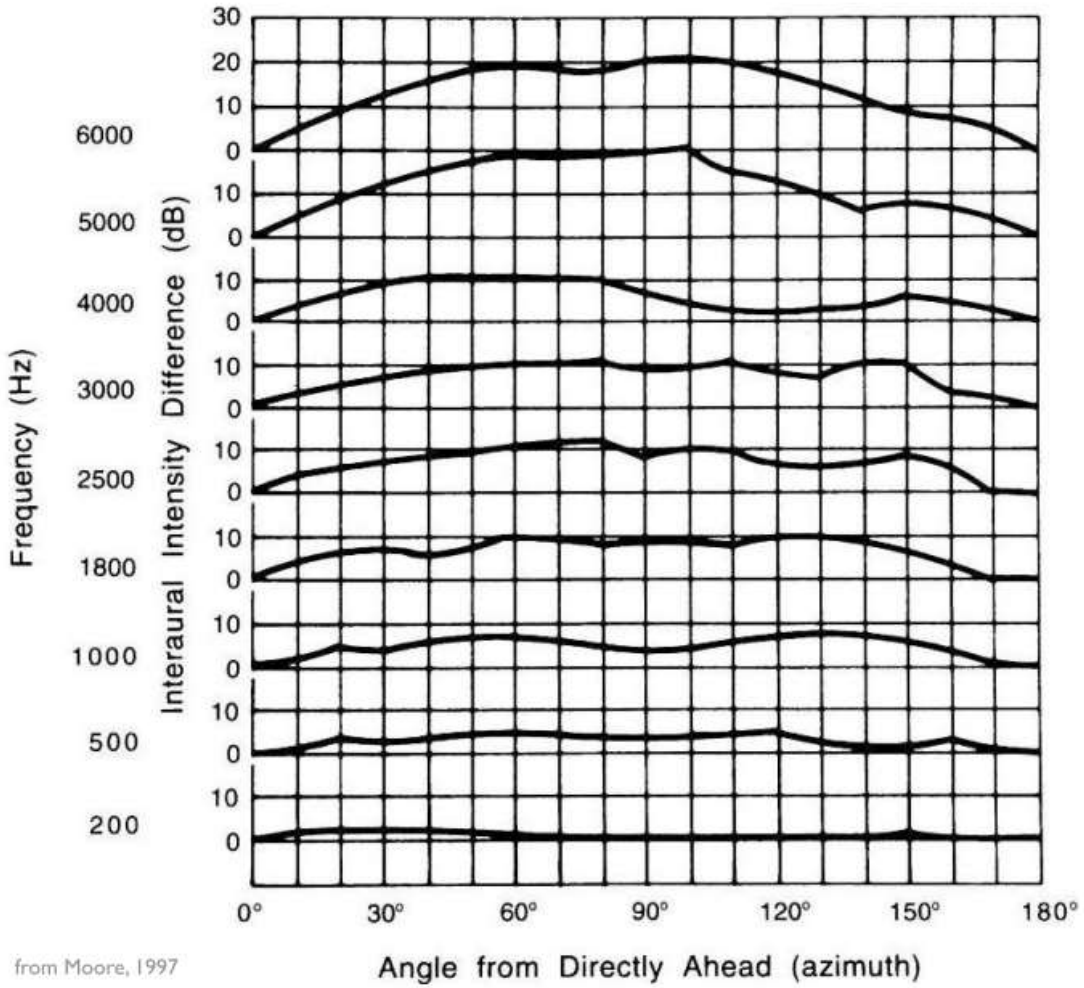


IIDs

- Head shadow (for short wavelengths)
  - IID can be as large as 20 dB for high frequencies.



Measured IIDs



from Moore, 1997

Duplex theory

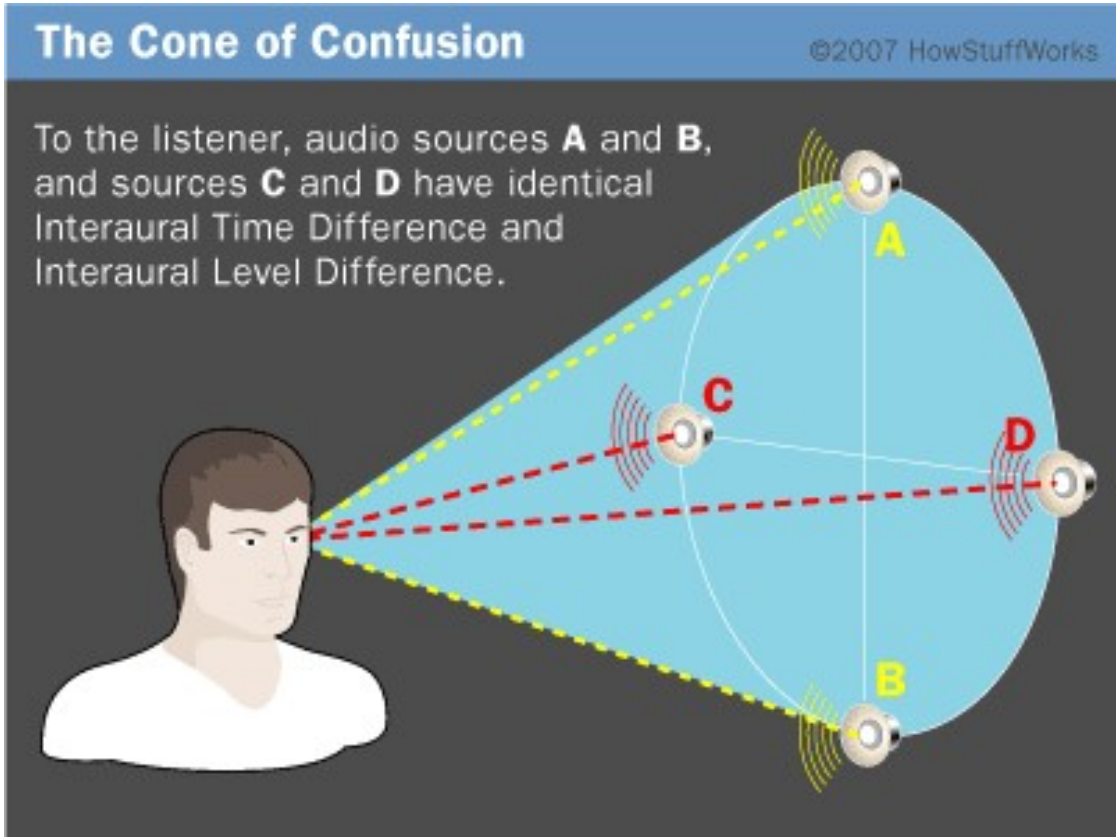
- ITDs limitations – work only for low frequencies
- IIDs limitations – work only for high frequencies

- Duplex theory (Lord Rayleigh, 1907) –

ITDs are used for low frequencies and IIDs for high frequencies.

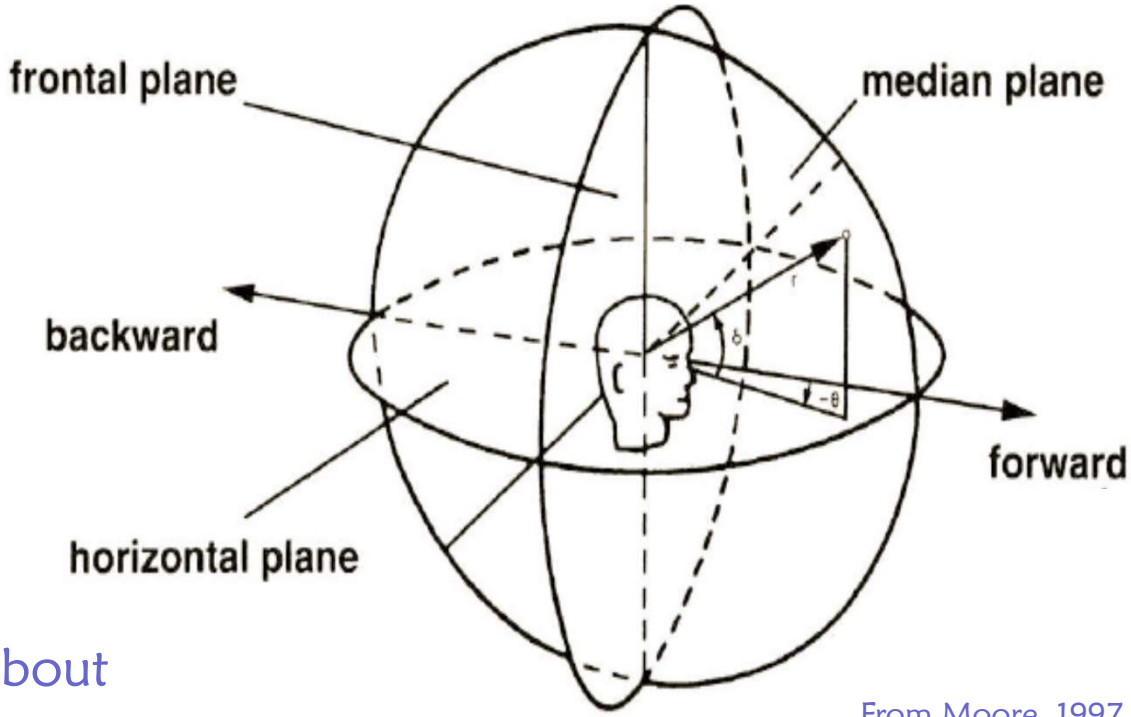
Cone of confusion

- So far we have seen front (or back) azimuth localization only!



- All points on the cone are at the same relative distance to the ears.
- All points on the cone produce the same interaural differences.

3D localization

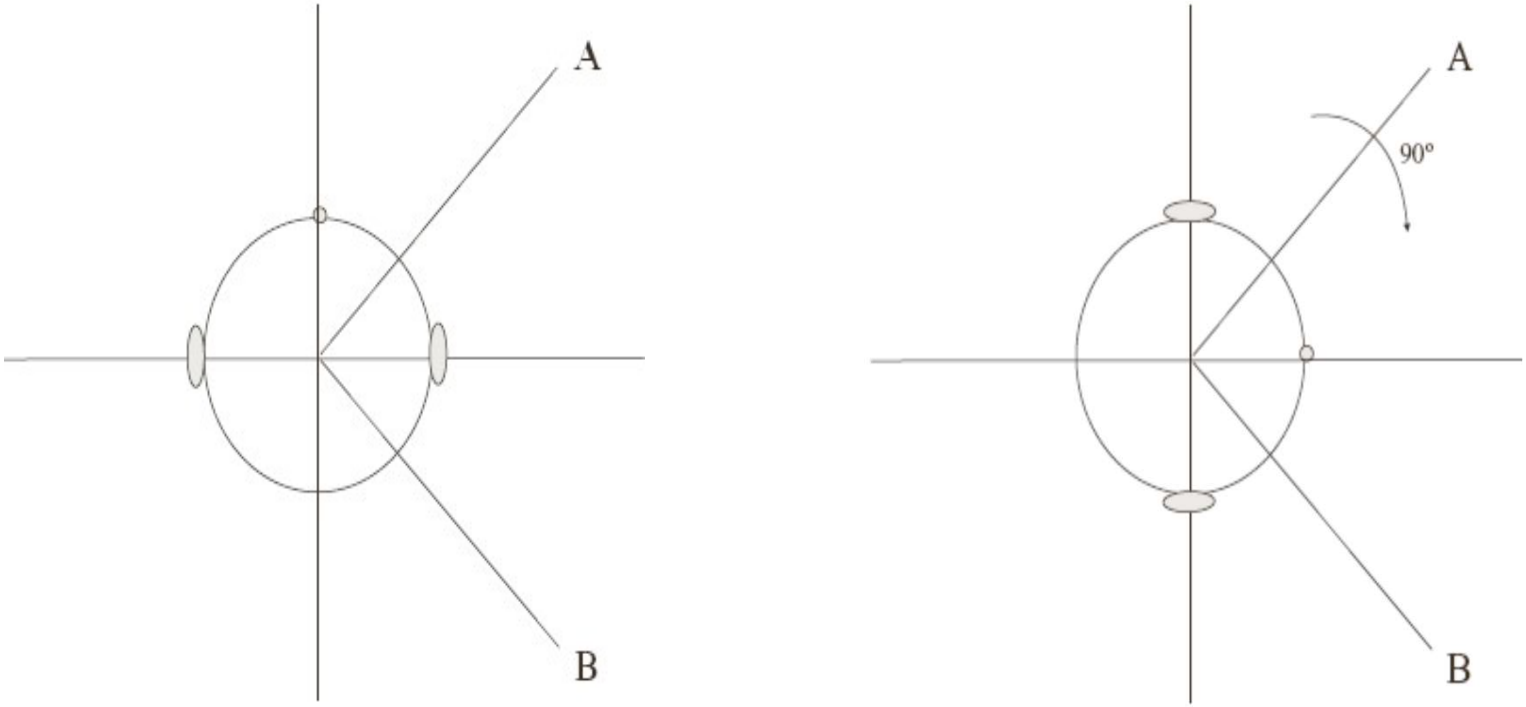


From Moore, 1997

- What about
  - front/back,
  - elevation,
  - distance,
  - monaural localization, and
  - externalization (sounds come from outside the head)?

3D localization

Head movements



- Head movements allow:
  - front/back discrimination, and
  - monaural localization.

Pinna

- Pinna – why do we have pinnae?
- Darwin (1800s) – vestigial form of animal ear and no functional significance.
- Lord Rayleigh (1907) – for front/back auditory discrimination.
- Batteau (1960s) – give externalization and elevation cues.
- Freedman and Fisher (1960s) – monaural localization.

Pinna

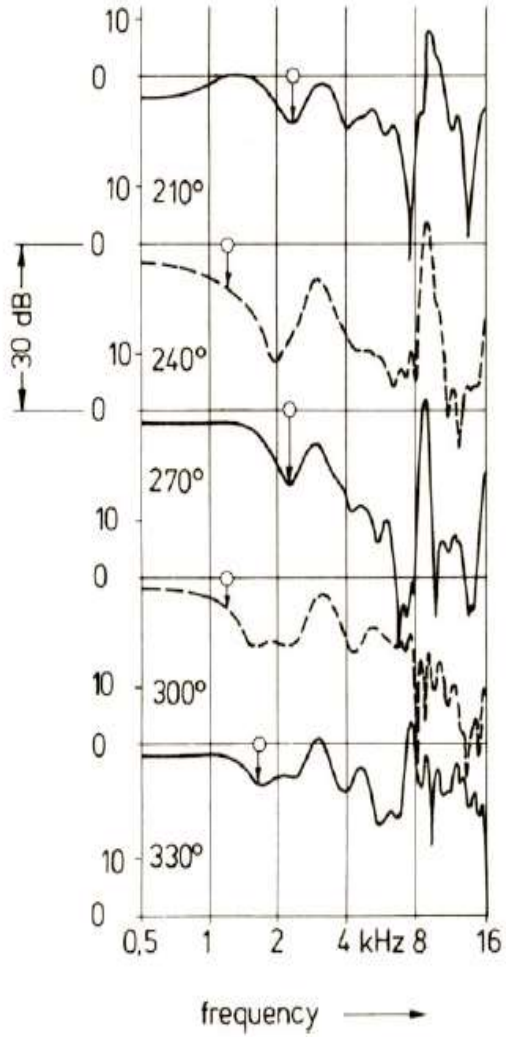
- Still more functions:
  - Give distance cues.
  - Give cues used in determining the direction of motion of sound sources.

Spectral cues

- External parts of our head and body, especially the pinna cause sound shadows, delays (phase shift) and reflections that affect the received sound wave.
- The strange shape of the pinna generates a series of reflected waves. The result is a new waveform whose components have different intensities.
- Different frequencies (especially higher frequencies) suffer different delays and attenuation. In other words, the pinna acts as a filter that changes the intensity of the high frequency components.
- The direction from where the sound is coming also affects how sound is shaped. (The phase difference between direct and reflected waves depends on the source's position.)

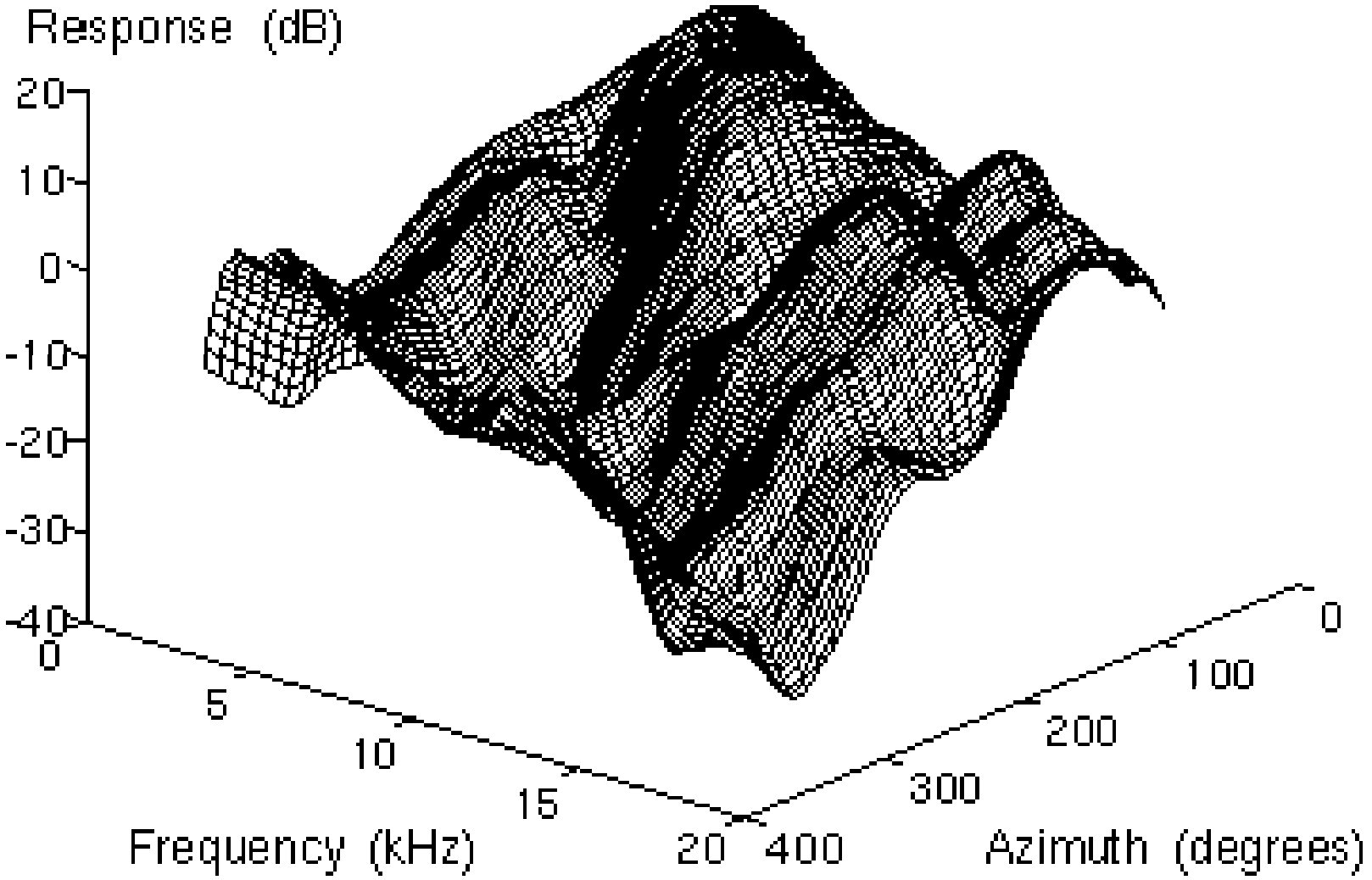
Spectral cues

- Head-related transfer function (HRTF) – describes how the sound is affected by torso and head (especially by the pinna).
- HRTFs – depend on subject.
- Notches and spatial maxima – The spectrum acquires some sharp minima (notches). The frequencies at which the notches appear vary with the source's position.
- Eg. When first notch frequency increases (between 6 and 12 kHz) the apparent elevation increases.

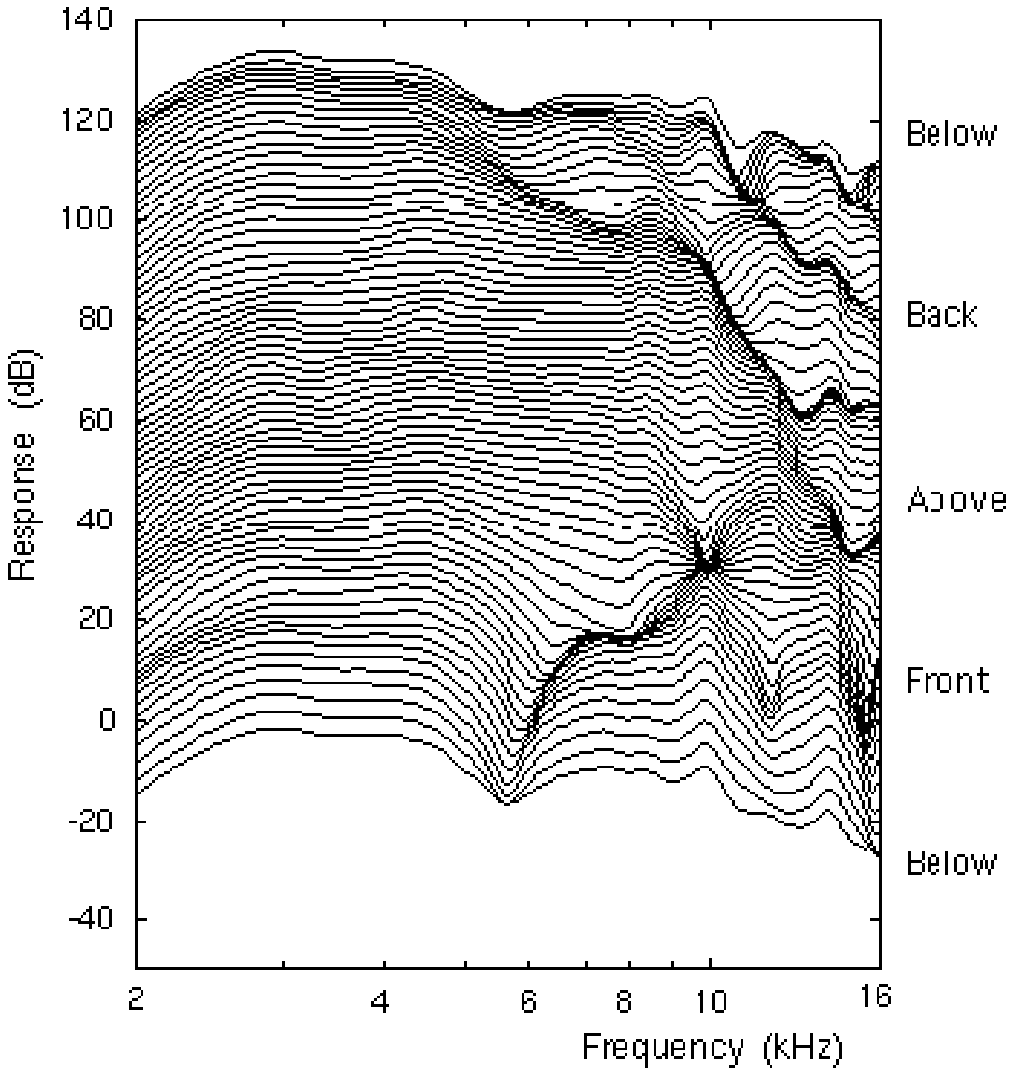


From B

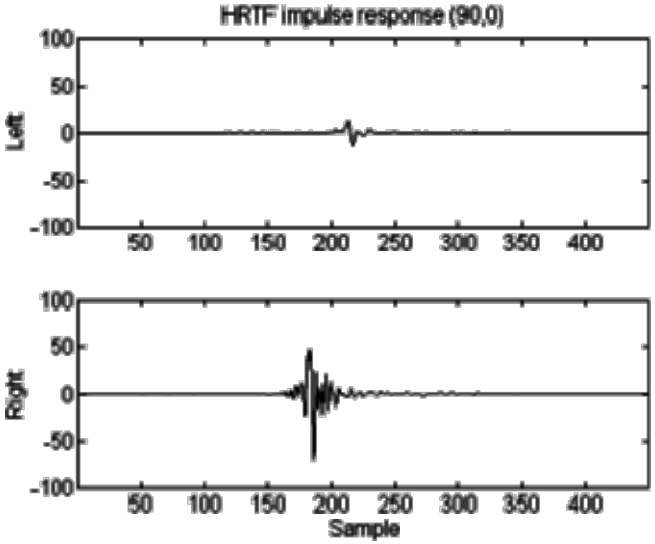
HRTF


Response (dB)
20
10
0
-10
-20
-30
-40
0
5
10
15
20
Frequency (kHz)
0
100
200
300
400
Azimuth (degrees)

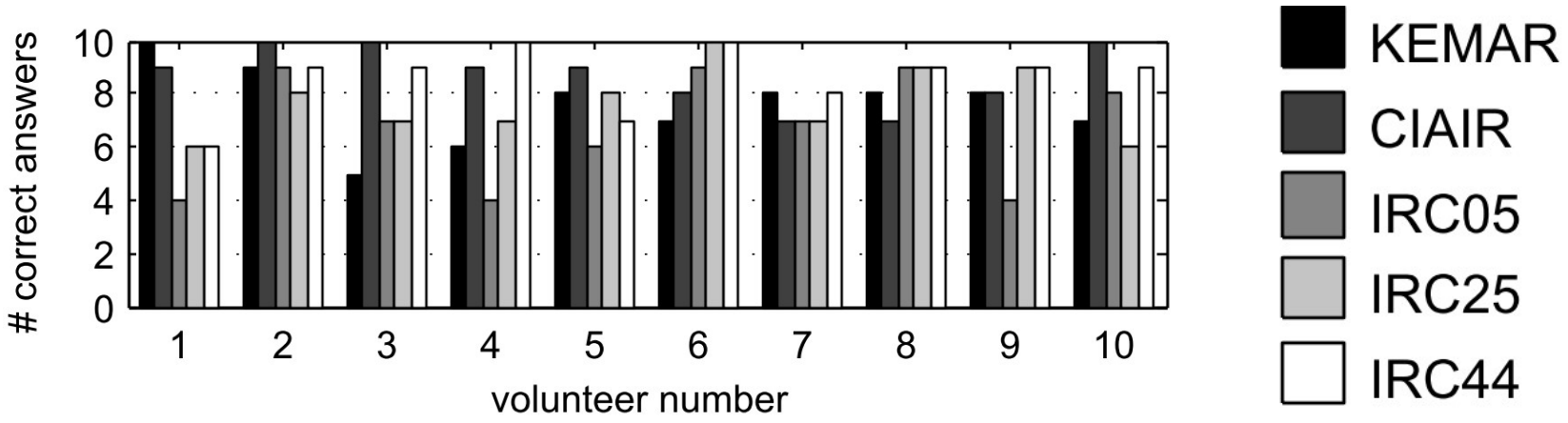
HRTF


140
120
100
80
60
40
20
0
-20
-40
Response (dB)
2
4
6
8
10
16
Frequency (kHz)
Below
Back
Above
Front
Below

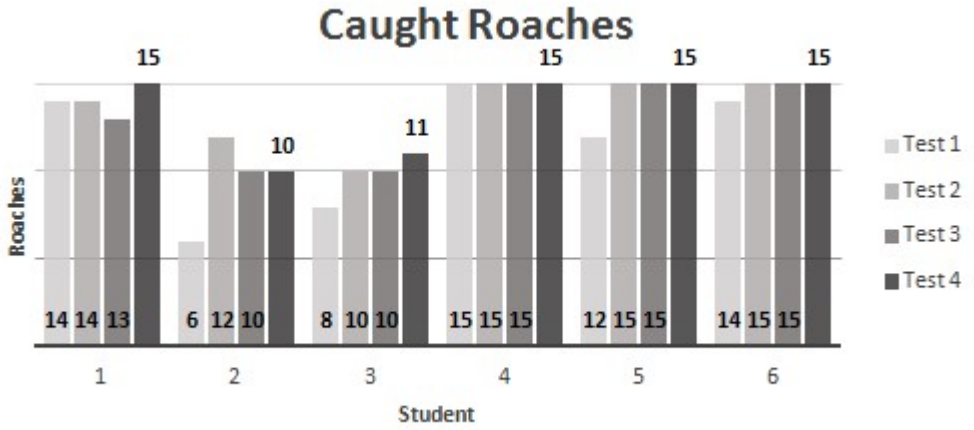
Measuring HRTFs



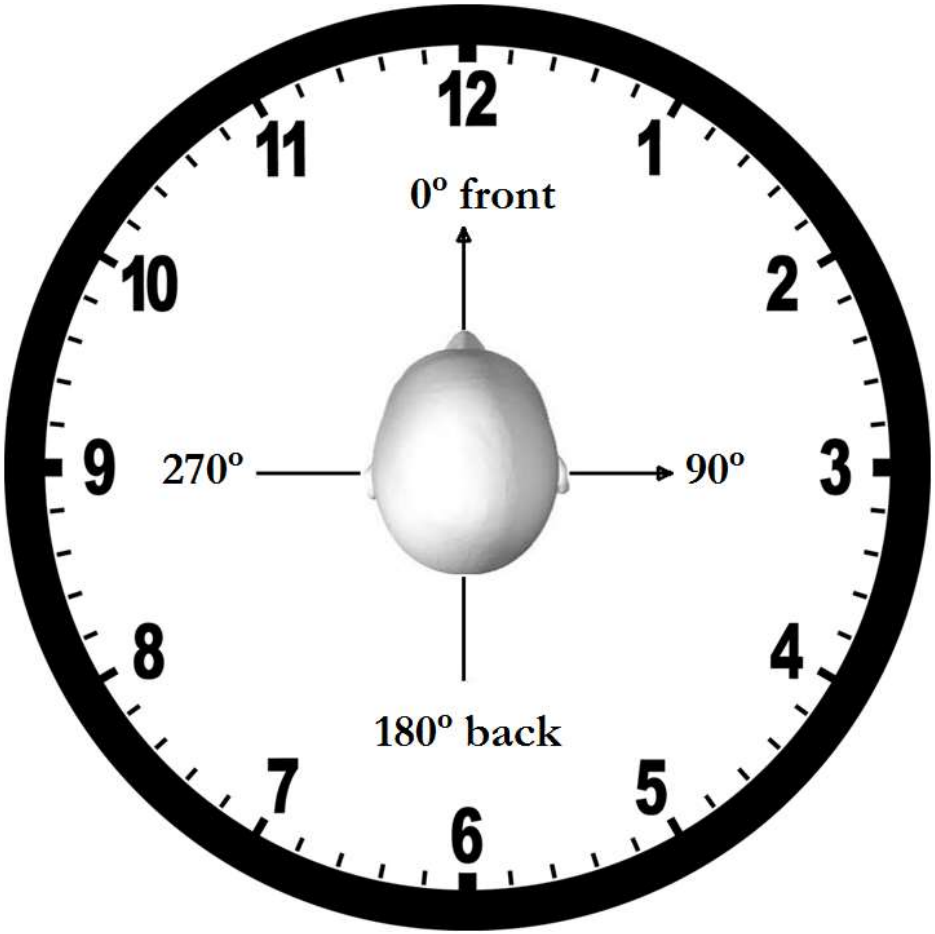
Measuring HRTFs



Games with 3D audio with HRTFs



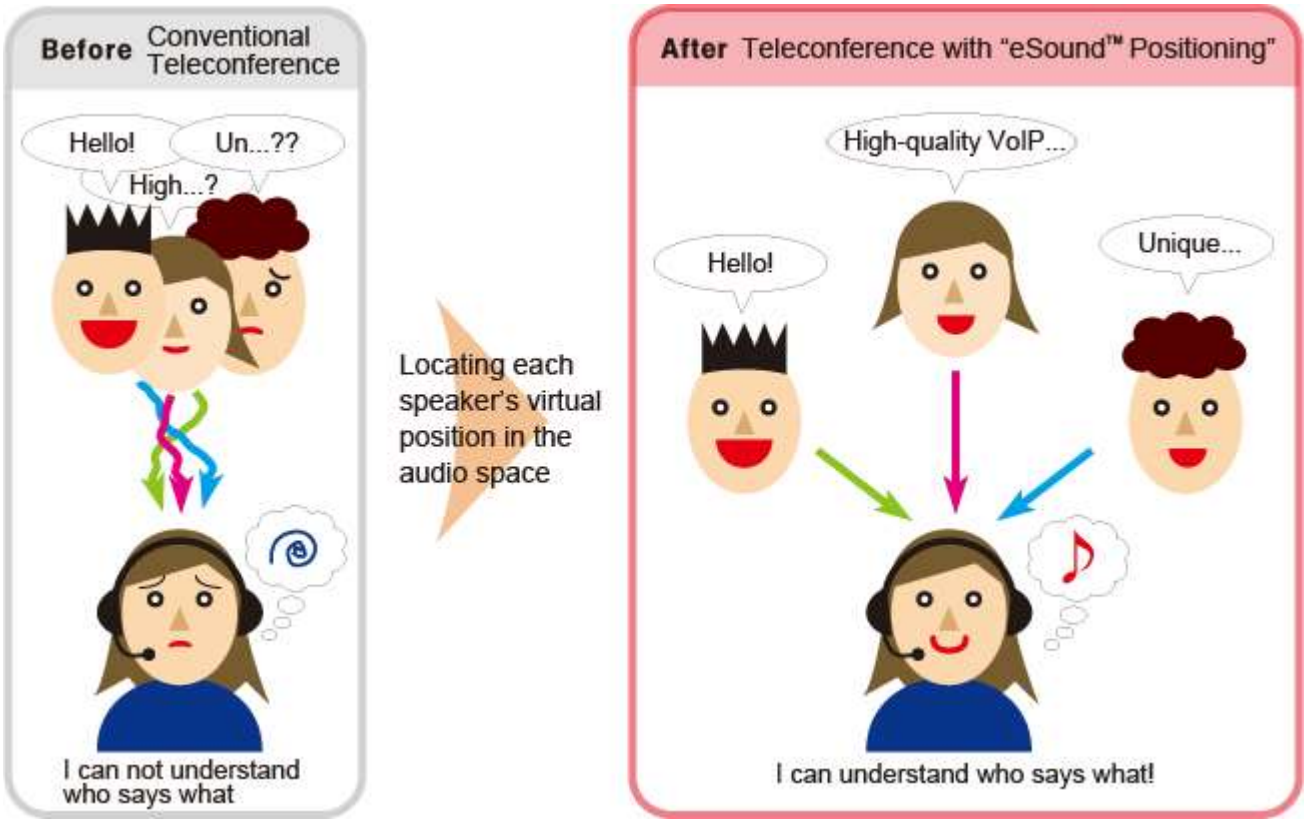
Applications with 3D audio with HRTFs



Auditory Scene Analysis

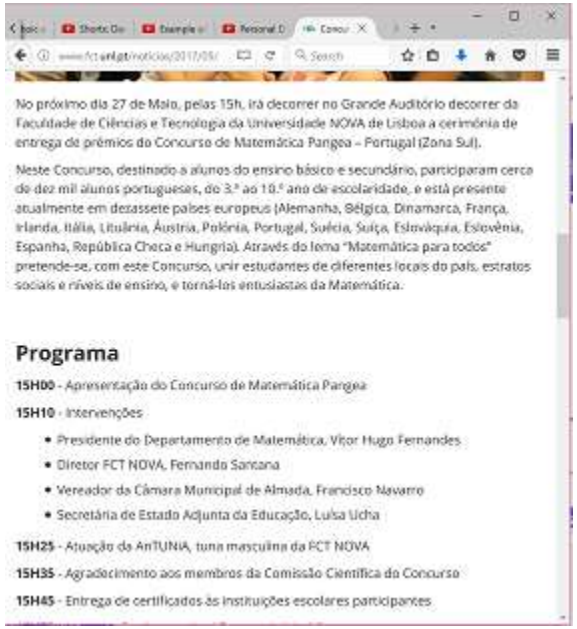
- Cocktail party effect – ability to concentrate on what one person is saying in the presence of noise and voices from other people.

Cocktail party effect



Cocktail party effect

Cocktail party effect in application with HRTFs for the blind



No próximo dia 27 de Maio, pelas 15h, irá decorrer no Grande Auditório decorrer da Faculdade de Ciências e Tecnologia da Universidade NOVA de Lisboa a cerimónia de entrega de prémios do Concurso de Matemática Pangea – Portugal (Zona Sul).

Neste Concurso, destinado a alunos do ensino básico e secundário, participaram cerca de dez mil alunos portugueses, do 3.º ao 10.º ano de escolaridade, e está presente atualmente em dezassete países europeus (Alemanha, Bélgica, Dinamarca, França, Irlanda, Itália, Lituânia, Áustria, Polónia, Portugal, Suécia, Suíça, Eslováquia, Eslovénia, Espanha, República Checa e Hungria). Através do lema "Matemática para todos" pretende-se, com este Concurso, unir estudantes de diferentes locais do país, estratos sociais e níveis de ensino, e torná-los entusiastas da Matemática.

Programa

15H00 - Apresentação do Concurso de Matemática Pangea

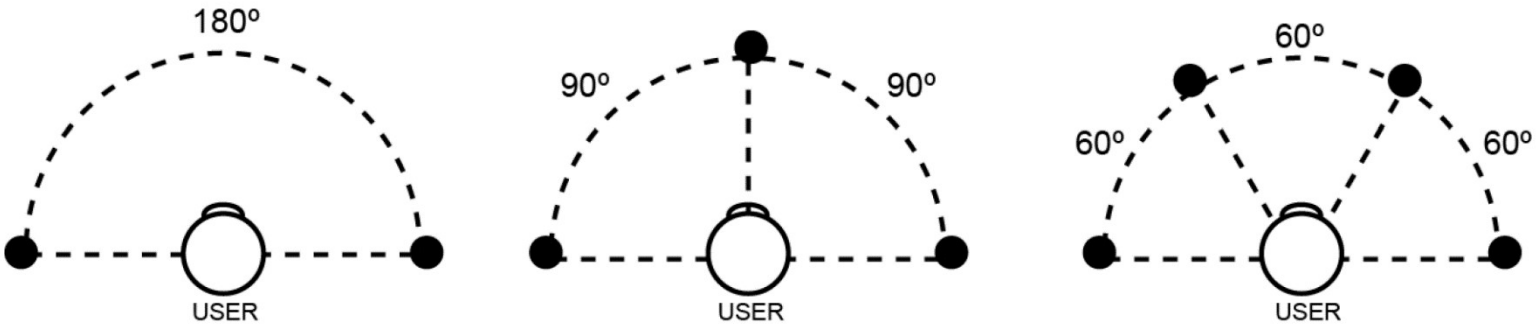
15H10 - Intervenções

- Presidente do Departamento de Matemática, Vítor Hugo Fernandes
- Diretor FCT NOVA, Fernando Santana
- Vereador da Câmara Municipal de Almada, Francisco Navarro
- Secretária de Estado Adjunta da Educação, Luísa Lícha

15H25 - Atuação da AnTUNIA, tuna masculina da FCT NOVA

15H35 - Agradecimento aos membros da Comissão Científica do Concurso

15H45 - Entrega de certificados às instituições escolares participantes

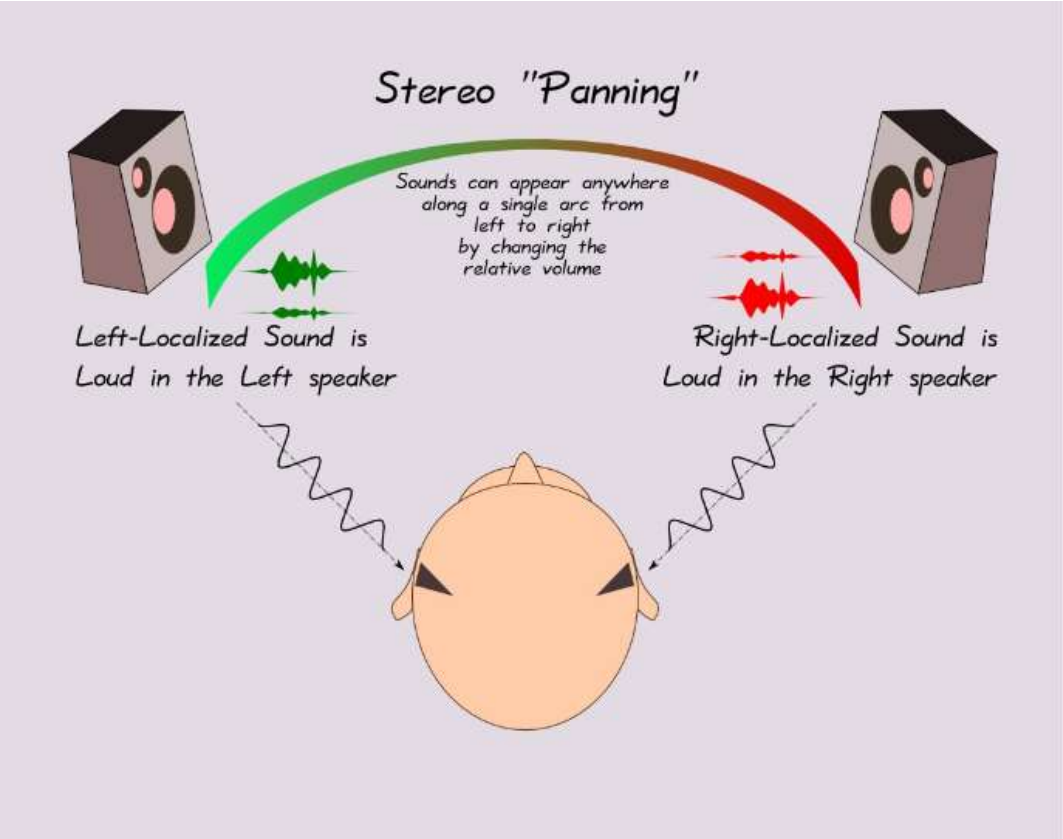


Auditory Scene Analysis

- Cues:
  - Frequency
    - fundamental frequency,
    - autocorrelation,
    - amplitude modulation,
    - frequency modulation,
    - timbre…
  - Time
    - tempo,
    - rhythm,
    - onset…
  - Spatial cues
    - ITDs,
    - IIDs…

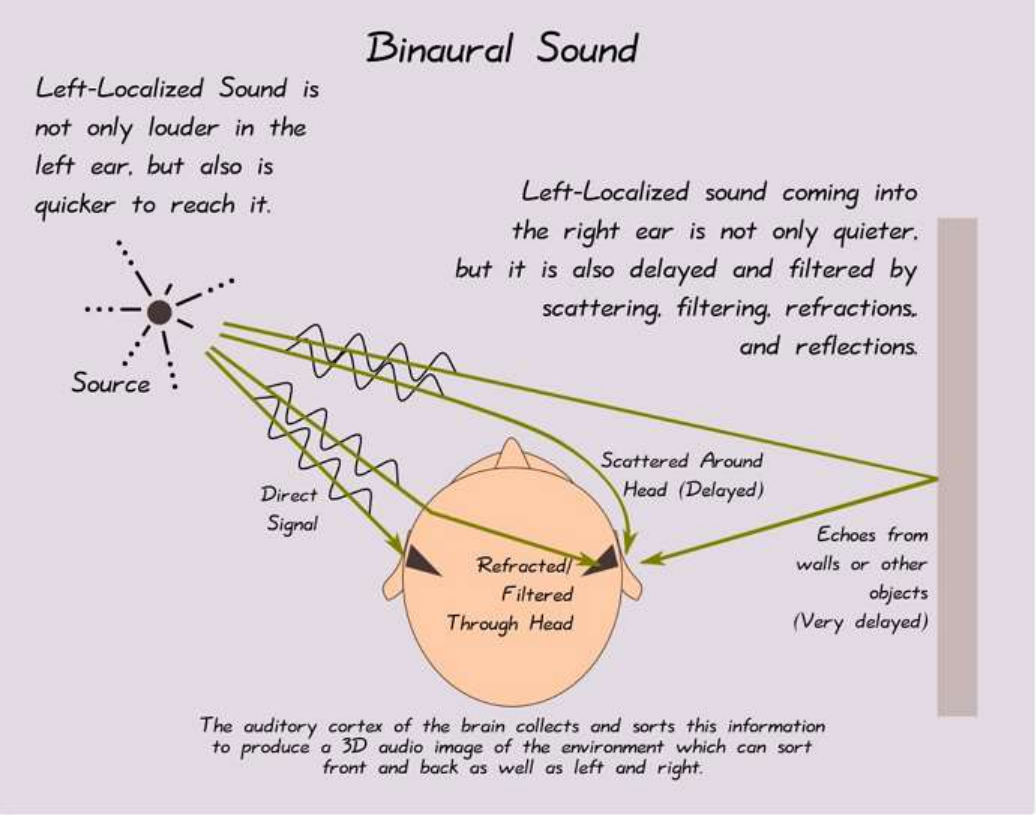
Sound panning vs binaural sound

- Sound panning – distributes the signal between left and right channels. (IIDs)



Sound panning vs binaural sound

- Binaural 3D sound – left and right channels have different signals.



Cues for distance

- Cues for distance:
  - sound pressure and frequency spectrum (amplitude of high frequency components attenuates faster)
  - reverberation (room acoustics)
  - experience

Doppler effect

- https://www.youtube.com/watch?v=a3RfULw7aAY
- https://www.youtube.com/watch?v=FyU6-cg5EW0

Doppler effect