Approaching Sound Localization by Top-Down and Bottom-Up Methods

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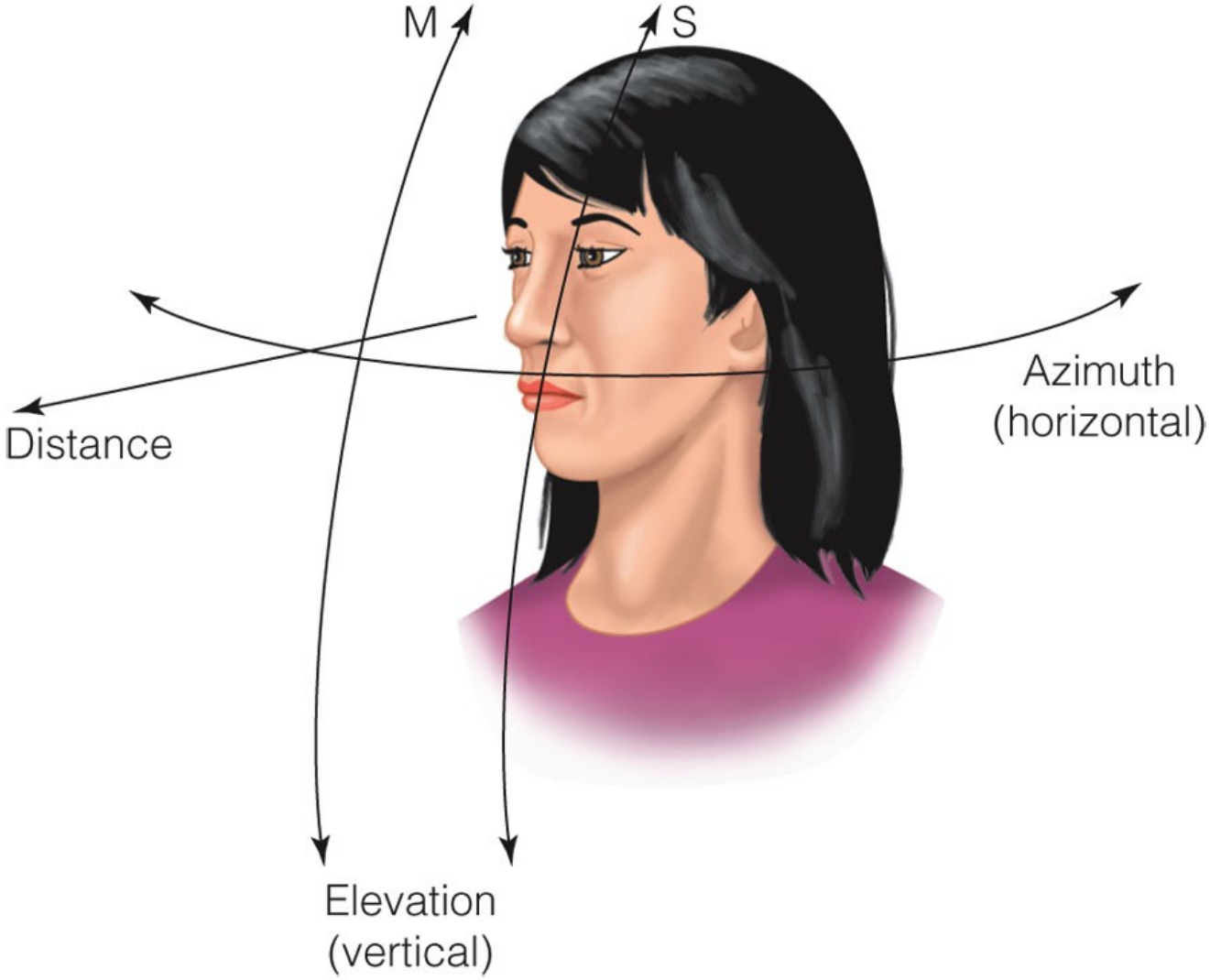
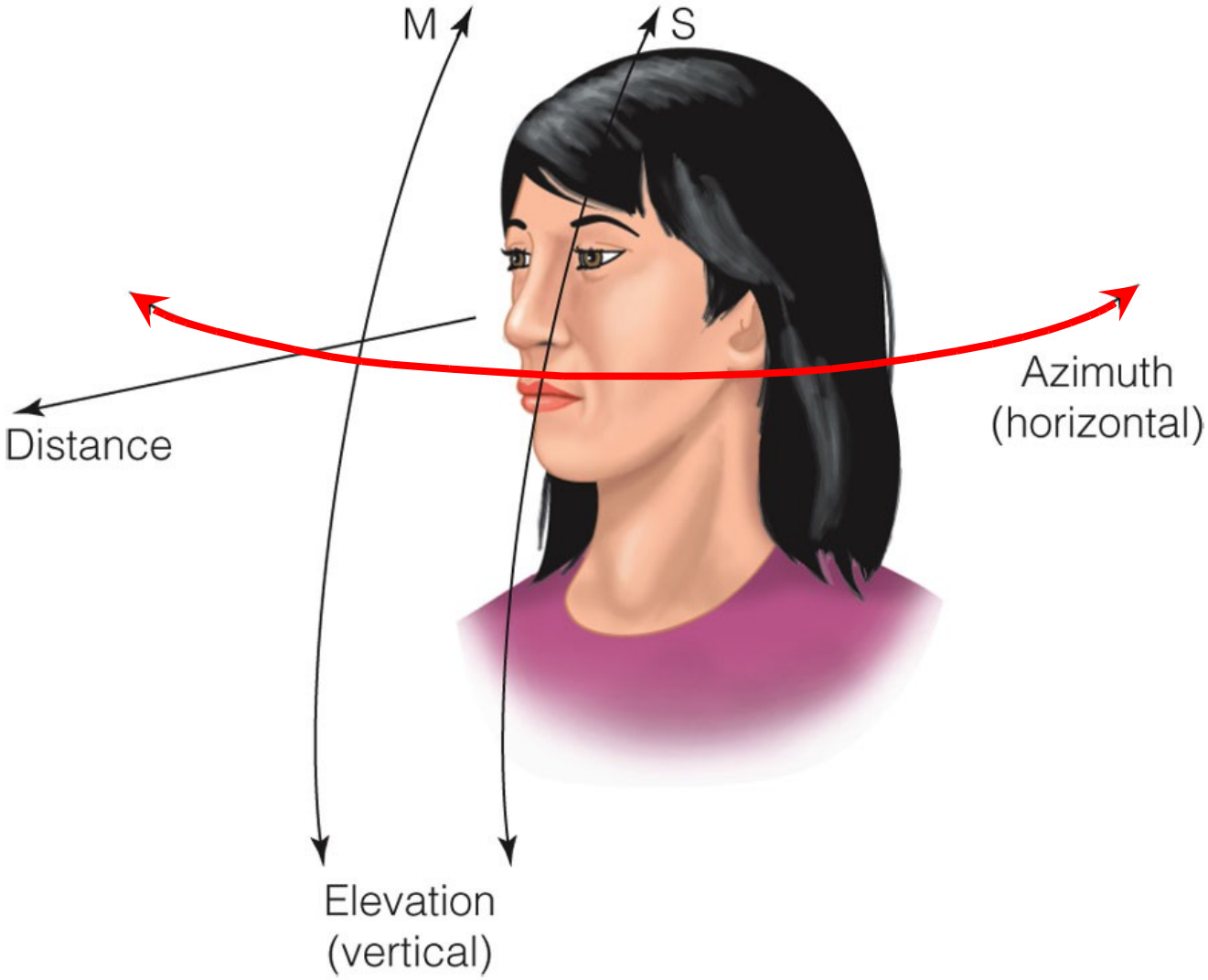
Overwiew

- Problem: “Understanding auditory spatial localization in normal and cochlear-implant hearing”
- Scope of the project „BEKECI“
  - Concept and objectives
  - Methodology and work plan
  - Impact & long term vision in ICT domain

Auditory spatial localization in normal hearing

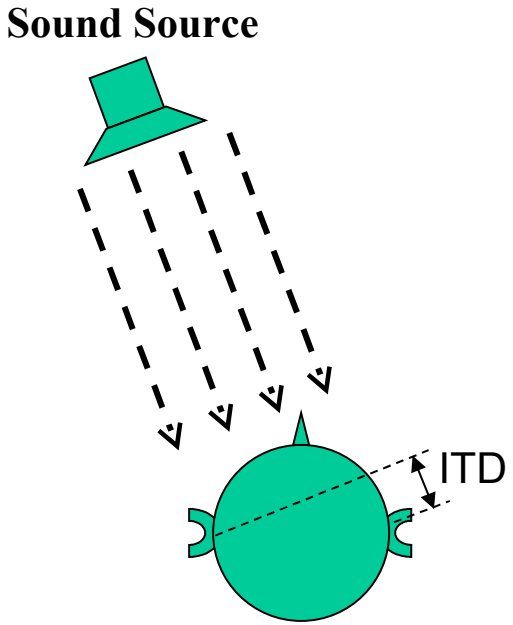


Auditory spatial localization in normal hearing



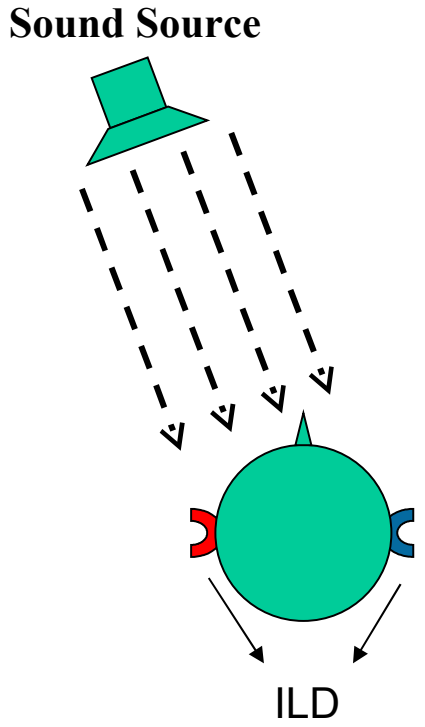
Main cues for localization in the horizontal plane

- Interaural Time Difference (ITD)



Main cues for localization in the horizontal plane

- Interaural Time Difference (ITD)
- Interaural Level Difference (ILD)



Both cues are also important for speech understanding in noise!

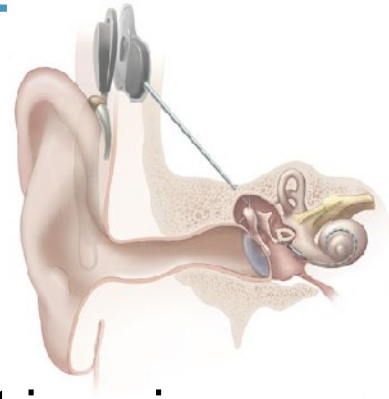
Some Properties of Sound Localization in horizontal plane

- Very high accuracy: minimum detectable angle in horizontal plane: ≈ 1-2° (frontal sources)
- Importance/weighting of ITD and ILD cues depends on Bottom-Up factors:
  - Frequency content of sound
  - Temporal properties of sound (AM, FM)
  - Course of signal (onset/ongoing portion)

Some Properties of Sound Localization in horizontal plane II

- Importance/weighting of ITD and ILD cues depends also on Top-Down factors:
  - Learning/Training
  - Context (preceding/subsequent sound)
  - A priori knowledge (Expectation)
  - Acoustic environment (reverberation, background noise, etc.)
  - Cross-modal effects (audio-visual interaction)

Cochlear Implants and Spatial Hearing



- Neuroprosthetic device that restores hearing in the deaf or hard of hearing
- Direct stimulation of auditory nerve via electrical stimulation
- High speech intelligibility in quiet, but not in noise
- More than 100.000 implantations worldwide (2005): ≈ 50% children)
- Bilateral CI:
  - Moderate left/right localization, mainly based on interaural level differences
  - Current clinical CI systems not designed for binaural hearing
  - Large room for improvements

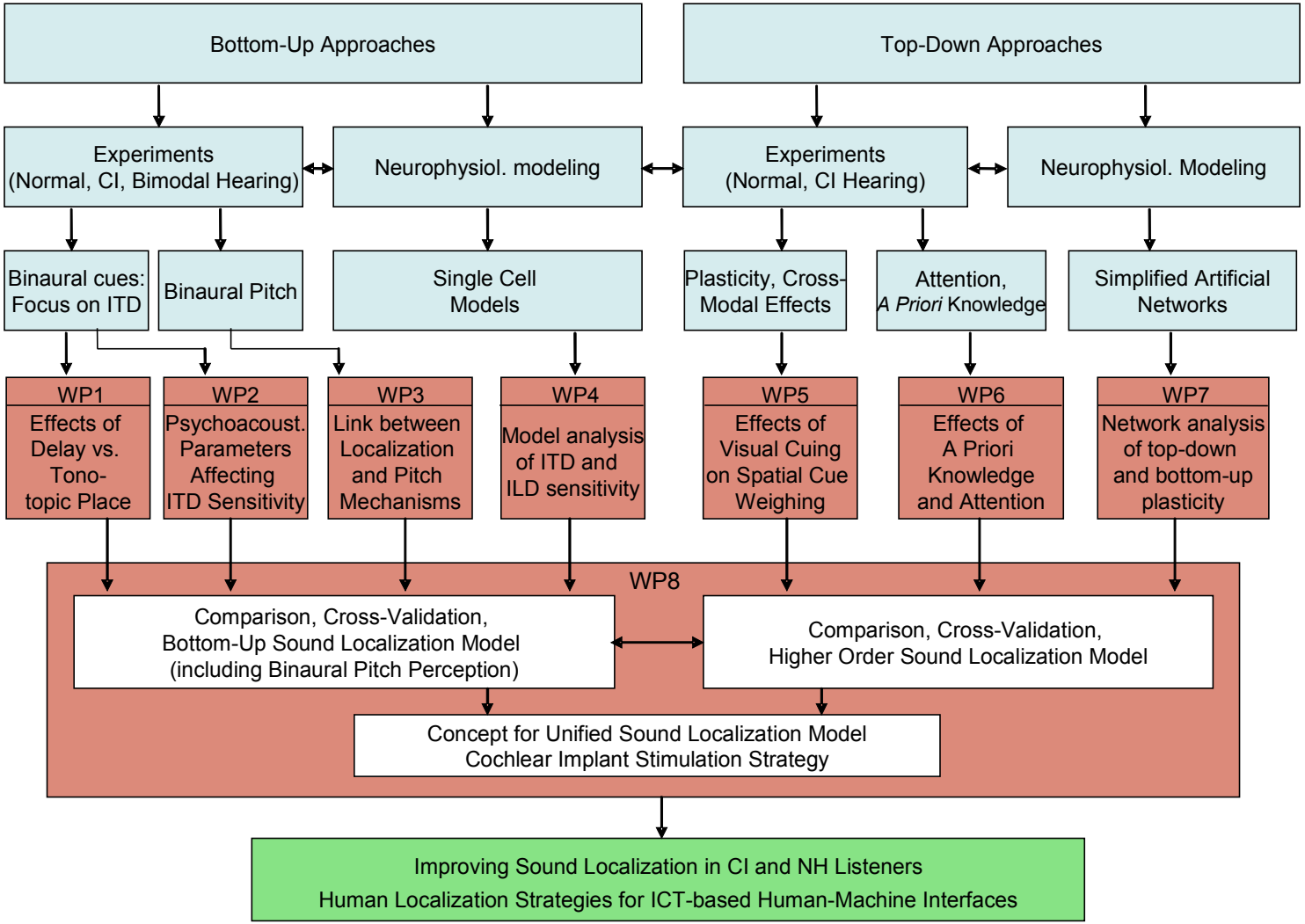
The BEKECI Project: Aim

- Better understand information processing mechanisms underlying spatial perception in
  - normal-hearing (NH) listeners
  - cochlear-implant (CI) listeners
- Focus on interaural time differences

The BEKECI Project: Concept

- Combine psychoacoustic (experimental) and neurophysiologic (modeling) approaches
- Study bottom-up and top-down factors

Methodology and Work Plan



Work Packages 1-3: Bottom up factors in CIs and NHs

- WP1: Role of cochlear dispersion in ITD perception in electric and normal hearing
  - Effect of traveling wave delay on ITD perception?
- WP2: Origins for low ITD sensitivity in CI listeners and methods for perceptual improvements
  - Which are limiting factors? How to remove them?
- WP3: Link between localization and “binaural pitch” mechanisms

Work Packages 5-6: Top-Down Factors in CIs and NHs

- WP5: Effects of visual cueing on spatial cue weighting
  - Is reduced ITD sensitivity in electric hearing due to too strong weighting of ILD cues?
  - Can weight be modified by visual feedback re-enforcing ITD cues?
- WP6: Effects of a priori knowledge and attention
  - How do CI and NH listeners use central factors (a priori information and attention) in sound localization?

Work Packages 4 & 7: Bottom-Up & Top-Down Models

- WP4: Neural analysis of ITD and ILD sensitivity
  - Build simplified model of ascending auditory pathway
  - Test and validate model with data from WPs 1 &2
- WP7: Network analysis of bottom-up and top-down plasticity
  - Develop abstract model of plasticity
  - Model neural plastic reconstruction processes by novel sensory inputs (e.g. CIs)
  - Exploitation of plasticity in design of bilateral CIs

Final Work Package

- Assessment and cross-validation of results from
  - NH and CI studies
  - Experimental and theoretical approaches
  - Bottom-up and top-down approaches
- Development of unified sound localization model
- Cochlear-implant stimulation strategy
  - Based on unified model

Implementation

- Five partners, each 2-4 researchers
- 480 man-months in total
- Partner states: Austria, Czech Republic, Hungary, Germany, Slovakia,
- Consultant partner: USA

Expected Impact & Long Term Vision

- Advancement in understanding of spatial processing mechanisms in acoustic and electric hearing
- New CI stimulation methods
- Human-machine interfaces maximizing information transfer
- Future ICT systems (e.g. virtual auditory environments) that mimic human sound localization strategies