Directional Microphone Technology for Children

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Problem …

- Background noise remains one of the primary nemeses of children with hearing loss
- FM systems are the most effective technology for improving the signal-to-noise ratio in most educational environments
However...

Multiple environments exist in which FM technology is currently not feasible or desirable
Can directional microphones be beneficial?

- Benefit in background noise when listening in specific laboratory environments (Gravel et al., 1999; Kuk et al., 1999)
- Effective because of attenuation of sounds behind and to the sides of the listener
What we don’t know…

- Even if young children CAN localize sound accurately, DO they orient to sound in the real world?
- Do the orientation abilities of children with HL differ from those of NH children?
What we don’t know…

- Do children orient with their eyes instead of turning their heads?
- Do they look up while listening & taking notes?
- Is a lot of instruction given while students are not oriented toward speaker?
What we don’t know…

- Where are the noise sources relative to the microphone placement in real-world environments for children?
  - Source and noise angle relative to the hearing aid interacts with directional hearing aid performance!

- What are the potential positive and negative aspects of directional microphones?
Two Phase Study

- Phase 1: Examine children’s position and head angles while listening at school relative to the sound source of interest and noise sources.

- Phase 2: Examine directional and omnidirectional hearing aid performance in listening environments identified from Phase 1 and the impact on self perceived, parent perceived and teacher perceived listening performance.
Phase One – Design

- 40 children
  - Young group between 4-8 years of age (n = 20)
    - 10 NH (Threshold ≤ 10 dB HL), 10 HI (PTA = 34 dB HL)
  - Older group between 11-17 years of age (n = 20)
    - 10 NH (Threshold ≤ 10 dB HL), 10 HI (PTA = 40 dB HL)
Phase 1 – Design

- Measure head angle and position of children in educational environments
- ~20 minutes of video recording with 3 cameras in child’s classroom
  - Camera 1: Position of child relative to teacher and other sound sources
  - Camera 2: Head Angle
  - Camera 3: Head elevation
- The three video streams are time locked for analysis using video editing software
Camera Position Example
Teacher Position Camera
Angle Analysis Example: Measured angle once per second
Phase 1 – Design continued…

- In classroom physical measurements of class size, object and person position, etc.
  - Goal to enhance accuracy of measurements (approximately +/- 3 degrees)
- Classroom observer records primary and secondary talkers, their positions, other noise sources and other sound sources that may be missed by the camera
Phase 1 - Outcome Measures

- Horizontal and vertical deviation from target angle as a function of time
  - Head angle relative to the angle of the source was plotted in 1 second increments.
- Number and duration of brief and sustained utterances made and attended
Teacher spoke for 69% of the analyzed time in the older children classrooms.
- Range 46-98%

Teacher spoke for 80% of the analyzed time in the younger children classrooms.
- Range 73-100%

More talkers, interruptions and silent time in older classrooms.
RMS Deviation: Impact of Hearing Impairment and Age?

![Bar chart showing RMS deviation in degrees for different conditions: HI-O, NH-O, HI-Y, NH-Y.](chart.png)
Individual RMS Deviation Data: Older Children Horizontal Plane
RMS Deviation: Most Accurate 1/3 of Listening Time: Active Listening

![Graph showing RMS deviation in degrees for horizontal and vertical directions for different conditions.](image)
Average Deviation: Slight Constant Downward Bias?

![Diagram showing average deviation with horizontal and vertical directions.](image-url)
What is This Nine y.o. Doing? (6 minute window)

Constant horizontal bias, averaged out by seating position.
Attention to Briefs

- Children with HI look around significantly more.
- Only 4/18 NH attended more than 25%, 14/18 HI
  - Visual scanning?
- More briefs in older classrooms
  - Consistent with significantly greater rms deviation in Overall data
Impact of Age?

- Age is at best very weakly correlated with accuracy.
- No consistent effect of sex either.
Phase 1 Conclusions

- Children can accurately orient their head toward the sound source of interest
  - Age (~4-17) was not a factor.
  - Sex was not a factor
  - Hearing loss (over the range examined) was not a factor when examining maximum accuracy.
  - Hearing loss was a factor when examining overall accuracy in the horizontal plane in older children.
    - Searching for visual information?
  - Importance of message, other demands, difficulty of listening situation are the primary factors impacting accuracy.
Phase 1: Implications For Phase 2 and Directional Microphone Use in Kids

- The environment must allow for “looking at sound source”. Directional hearing aids are expected to have a negative impact on off axis “over hearing”.

- Desk work and FM systems
  - Some help from DM if FM system not available?

- Multiple talkers of interest are present (lunch - group discussion - bus)
Phase 2: Subjects

- 24 Children aged 10 to 17 years old (mean 14).
- Two could not complete all tasks and were excluded.
- Of the remaining 22, 18 were past hearing aid users (none previously used directional HAs).
Average Hearing Thresholds

Frequency (Hz)

Threshold (dB)

- Right ear
- Left ear
Bilateral BTE - 17 Oticon Gaia - 5 Phonak Supero –DSLv4.1 Targets

![Graph showing hearing aid performance](image-url)
Phase 2 Test Environment

- Moderate (800 ms) RT – 6M X 8M X 3M classroom
- Children seated in the center of the room at a table
- 4 uncorrelated noise sources placed in the corners of the room
- All noise sources approximately at ear level

Source Conditions:
- Simulated classroom Front: “Teacher” at 2 M front
- Simulated classroom Rear: “Teacher” at 2 M behind
- Simulated classroom Desk Work: “Teacher” at 2 M front – 1st grade math work
- Simulated lunch room/group discussion: 3 random talkers across table (1.25 meters) – 0 and +/- 45 degrees
- Simulated lunch room – private conversation: talker 0.5 meters directly to the side
Phase Two Design - Continued

- Counterbalanced assignment to directional or omnidirectional mode
- One month of experience with microphone Condition #1 – evaluated in 5 test environments using same microphone mode
- One month of experience with microphone Condition #2 – evaluated in 5 test environments using same microphone mode
- 2 weeks in a switchable mode - evaluated using recorded nonsense syllables
Phase 2 Evaluation Methods

- Hearing in Noise Test – (Children HINT-C)
- Parent, Child and Teacher Questionnaires.
- Performance for “Front” and “Rear” source locations was further evaluated using 36 nonsense syllables recorded at +6 dB SNR in the test environment (KEMAR).
  - Omnidirectional, directional, directional above 1500 Hz only – presented monaurally (Etymotic ER-4 Earphones)
Impact of Speaker to Listener Distance

Listening Condition

HINT Threshold (dB SNR)

- Speaker Front
- Speaker Rear
- Head Down
- 3 Speaker
- 2 Speaker Close

HINT- C Performance

omni Directional
HINT- C Directional Benefit: Effect of Port Angle, Behavior?

- Figure shows a bar chart with the following conditions:
  - Speaker Front
  - Speaker Rear
  - Head Down Speaker Front
  - 3 Speaker
  - 2 Speaker Close

- Y-axis: Directional Benefit (dB SNR HINT)

- The chart indicates that the most common condition is the Head Down Speaker Front, with a directional benefit of approximately 3 dB SNR HINT.
HINT- C Individual Directional Benefit: Fully Sorted

- Speaker Front
- Head Down Speaker Front
- 3 Speaker
HINT- C Individual Directional Benefit - Unsorted

![Graph showing directional benefit in terms of dB SNR HINT relative to the subject number.](image-url)
HINT- C Individual Directional Benefit – Negative or No Impact

Directional Benefit (dB SNR HINT)

Relative Subject Number

- Speaker Rear
- 2 Speaker Close
NST Directional Benefit: The Impact of Reduced Low Frequency Directivity
16 questions which focused on situations in which the directional microphone was expected to beneficial or detrimental.

- 10 point scale from easy to very difficult

Completed by both children and parents separately.

Only two questions came out significantly different (approximately 1 rating point) – though they were consistent across parent and child.

- Both involved listening to someone behind - the directional mode was rated as poorer.
The SIFTER was given to all teachers along with a self-addressed stamped envelopes – Teachers were paid $10 for every SIFTER returned.

Received complete data on two children.
General Implications

- As with adults significant directional benefit is evident when the head is generally “pointed” at the sound source of interest and away from the noise.
- Conditions exist for which the DM will provide no advantage or a potential disadvantage (overhearing/not facing source).
- Hardware and processing design aimed at improved SNR, as well as fitting decisions relative to directional microphones must include consideration of ALL potential environments.
  - “Typical classrooms” do not really exist.
Clinical Implications

- Directional advantage in some noisy environments and disadvantage in others provides additional support that full time directional use is **NOT** appropriate.
  - Limiting the frequency response of directionality while limiting detriment will also limit benefit.

- Can kids switch appropriately?
  - Age limited even with training
  - Automatic switching? Won’t always work appropriately.
  - “Asymmetrical” fitting?

- Consider directional for schools age? Yes, but with close monitoring.

- Low frequency roll-off and gain – potential audibility issues.