Directional effects on young children

In real life

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Why directional microphone technology for young children?

• Auditory maturation (Werner, 2008)
  – sensitivity is adult-like by 6 months
  – Resolution and attention continue to develop over first decade

• Children have difficulty listening to speech in noisy situations (Crandell, 1993; Finitzo-Hieber & Tillman, 1978)
Why directional microphone technology for young children?

• Children have difficulty listening to speech in noisy situations (Crandell, 1993; Finitzo-Hieber & Tillman, 1978)
• Younger children have greater difficulty than older children (Ching et al, 2008)

Improve SNR for children

• Proximity-based technology (Lewis, 1991; Madell, 1992)
  – Multiple talkers
  – Incidental and directed learning
  – Cosmetic and social concerns
• Directivity-based technology
  – Listener-talker orientation
  – Listener-talker distance
  – reverberation
Research on school-aged children in a laboratory,

- Directionality improved speech perception when target speech came from the front (Gravel et al., 1999; Ricketts et al., 2007)
- Directionality decreased speech perception when target speech originated from behind (Ricketts et al., 2007)

Do children look ahead at the talker?
Yes, school-aged children do so in classrooms (Ricketts & Galster, 2007).

Do young children look at the talker in real life?

Subjective rating of school-aged children

After 1-month trials, subjective rating of school-aged children

In real-life situations, effectiveness of directional microphones are affected by
- listener-talker distance
- reverberation

- when directionality was compared in same hearing aids, children (26) reported no significant difference (Ricketts et al., 2007)
When there is noise and reverberation, a directional microphone lifts the speech in front, but not the noise. Directional mics increase SNR. If a child looks ahead.

Survey

When do you fit directional microphones to children?

- When they are infants?
- Above 3 years of age?
- When they are school age?
- When they are adolescents?
- When they are adults?
Research questions

• How often do young children look at the talker in real-life situations?
• What proportion of a child’s everyday life would he/she benefit from directional microphone technology?

Aim

• To determine the extent to which directionality in hearing instruments is advantageous for young children in everyday natural environments
Subjects

- 27 Children
  - 11 normal hearing
  - 16 hearing-impaired
- Age: 0;11 to 6;6

Method

1. Video-record listening behaviour

Four scenarios:
- Child interacts with parent/caregiver in the child’s home
- Child plays, with a parent elsewhere in the same room
- Child with a small number of children and adults around, and speech is not always directed to the child (e.g. mothers’ group)
- Child plays outdoors with other children and adults
Video recording

During recording, the closest ("best") and furthest ("worst") distances between child and talker were estimated, and speech levels were measured at these locations.

Video analysis

• Videos “stitched” together and analyzed for:
  – Time “target speech” present
  – Proportion of time “target speech” is present that child is facing:
    • frontward
    • sideward
    • rearward
Listening behaviour - frontward

Listening behaviour: sideward
Method: 2. Directional benefits - Speech Transmission Index

- Dirac software for STI measurement
- Talker’s head substituted by loudspeaker
- Child’s head substituted by KEMAR’s head
- Hearing aid dummy behind KEMAR’s ear
- Stereo recordings of STI stimuli at 0, 90, 180 and 270° KEMAR azimuth
- Post-processing ->
  - omni and directional response
- Benefit = $\text{STI}_{\text{directional}} - \text{STI}_{\text{omni}}$

Method
3. Diary of everyday situations

- Parents described up to 10 situations in which their child spends most of their waking hours over a one-week period
Diary analyses

- Real-life situations categorized into:
  - One-to-one situations
  - Group situations
  - Solitary play
### Averaged effect across “best” and “worst” estimates

<table>
<thead>
<tr>
<th>Scenario</th>
<th>dB Advantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front 0°</td>
<td></td>
</tr>
<tr>
<td>Sc 1</td>
<td>1.69</td>
</tr>
<tr>
<td>Sc 2</td>
<td>1.99</td>
</tr>
<tr>
<td>Sc 3</td>
<td>3.04</td>
</tr>
<tr>
<td>Sc 4</td>
<td>2.72</td>
</tr>
<tr>
<td>Average</td>
<td>2.36</td>
</tr>
<tr>
<td>Side 90°/270°</td>
<td></td>
</tr>
<tr>
<td>-1.57</td>
<td>-1.28</td>
</tr>
<tr>
<td>-1.51</td>
<td>-2.78</td>
</tr>
<tr>
<td>-1.78</td>
<td></td>
</tr>
<tr>
<td>Back 180°</td>
<td></td>
</tr>
<tr>
<td>-1.48</td>
<td>-1.39</td>
</tr>
<tr>
<td>-1.27</td>
<td>-1.65</td>
</tr>
<tr>
<td>-1.44</td>
<td></td>
</tr>
</tbody>
</table>

### Directional advantage
(averaged across “best” and “worst” estimates)

- **Front**
- **Side**
- **Back**

![Graph showing directional advantage](image)
If the child looks ahead
→ directional microphones increase SNR

…. But how often does the child look ahead?

How often do children look at the talker?

Effect of age: p = 0.4
Effect of hearing: p = 0.09
**Effect of scenario: p < 0.001**
Proportion forward-looking vs age

Weighted advantage in real life

Weighted adv = dBfront*%front + dBside*%side + dBback*%back
Daily activities as reported by parents

Current effect: F(5, 110)=2.3405, p=.04627
Vertical bars denote 0.95 confidence intervals

Diary

- Indoors - HI children engaged in more one-to-one and less group situations than NH children (p < 0.001)
- Outdoors - HI children engaged in more solitary play and less group situations than NH children (p < 0.001)
Summary

• Physical measurements of directional advantage up to 3 dB in different scenarios
• Age (11 m – 6.5 yrs) does not affect proportion of time children look at the talker.
• Both NH and HI children look at the talker >50% of the time during child-directed speech
• On average, weighted directional advantage varied between -0.4 dB to 0.2 dB across scenarios
• HI children engaged in more one-to-one and solitary play situations but less group situations than NH children

Caveat

• HI children in this study had no experience in directional microphone technology
• Those with directional mics may look more at the talker
  – Talker attracts their attention
  – They are taught to look at the talker
  – They learn to look at the talker
• Hence, potential for greater weighted advantage than we found.
Interaction of compression and directional microphones

- Dominant speech signal from rear →
- Directional mic decreases sensitivity →
- Level decreased re an omni →
- Compression in hearing aid increases gain

- Therefore net effect of directional mic and compression for rearwards wanted speech is a decrease in ratio of direct signal to (noise + reverberation) of around 3 dB, but a decrease in actual signal level of only around 1.5 dB.

Impact on side-by-side interaction

- For side by side interaction, do not want a figure-eight pattern, so adaptive polar patterns would not be optimal.
Message for hearing aid companies

Auto-selection of directional microphones should be dependent on the direction of the dominant speech signal.

Message for clinicians

- Directional microphone technology does not significantly disadvantage children of any age
- Counsel caregivers and professionals on making the most of directional advantage
  - by facing the child when talking
  - by teaching the child to look at the talker

Thanks for listening

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Free Field Omni directional (5.2 sec)

Free Field Directional (5.2 sec)
Kemar mounted Omni directional, Full 5.2 second data

Kemar mounted Directional, Full 5.2 second data
Reverberation time

- Pure tone sweeps
- Stimulus peak at 40 dB above ambient noise
- Frequency specific values for $T_{20}$ (time for stimulus intensity to fall by 60 dB, based on the first 20 msc of decay curve) calculated by Dirac software

Ching, NAL