Effects of Hearing Aid BW on Speech Perception, Production, and Complex Auditory Skills

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BW Effects: Adult Studies

- **Degradation in performance**
  - Hogan & Turner, 1998; Ching et al., 1998)

- **Little improvement, but *no degradation* in performance**
  - Turner & Cummings, 1999; Baer et al., 2002; Vickers et al., 2001

- **Some improvement in performance**
Effect of stimulus BW on the perception of /s/

Stelmachowicz, Pittman, Hoover, & Lewis (JASA, 2001)
Importance of /s/ in language development

- 3rd or 4th most frequently occurring consonant in English
- Multiple linguistic uses
  - Plurality of nouns (cat; cats)
  - Third person present tense (I eat; she eats)
  - Present vs. past tense (She put it on; She puts it on)
  - To show possession (That is Mike’s)
  - Possessive pronouns (Is that Beth? Is that Beth’s?)
  - Contractions (that’s, let’s, it’s, what’s)
Methods

- **Stimuli**
  - /s, f, th/ in an /iɪ/ context (VC & CV)
  - 3 talkers (male, female, child)
  - LP filtered at 2, 3, 4, 5, 6, & 9 kHz
Bandwidth of /s/
Effect of Low-Pass Filtering

Stelmachowicz, et al.

(E & H, 2001)
Aided Perception of /s/ & /z/

Stelmachowicz, Pittman, Hoover, & Lewis
(Ear & Hearing, 2002)
Hearing-Impaired Children (5-13 yrs)

N= 40

Male talker
  - performance correlated with HL & SL at 2-4 kHz

Female talker
  - performance correlated with HL & SL at 2-8 kHz

Plural Score
Male talker
  87%
Female talker
  79%
To explore the effects of BW on four different auditory skills and to determine if the developmental trends observed for NH children differ from those of HI children.

- **Subjects**
  - 32 NH and 24 HI Children in 4 age groups: (7-8 yrs, 8-10 yrs, 11-12 yrs, & 13-14 yrs)

- **Methods**
  - Stimuli were filtered at either 5 or 10 kHz
  - Stimuli were frequency-shaped for HI listeners based on DSL targets and presented via wideband earphones
  (Stelmachowicz et al., Ear & Hearing, 2007)
Monosyllabic Word (PBK) Recognition

SNR = +8 dB
Fricative Perception (9 VCs)

SNR = +10 dB
BW effects on /s/ & /z/

![Bar graph showing the phoneme recognition of /s/ and /z/ for NHC and HIC with 5 kHz and 10 kHz frequencies.](image)
BW effects on /f/ & /v/
Listening Effort (Dual Task Paradigm)

SNR = +8 dB
Novel Word Learning Paradigm
Novel Word Learning

SNR = +10 dB
BTNRH Longitudinal Study

Speech & Language Development in Children w/ HL

● Purpose:
  - To compare phonetic and lexical foundations in normal-hearing and hearing-impaired children from 4 to 24 months of age

● Subjects
  - 21 children with normal hearing
  - 12 children aided before 12 months (Early)

Moeller et al., Ear & Hearing (2007)
Methods

Videotaped 30-minute sessions

- 6 to 8 week intervals starting at 4 mos
- Wireless lapel microphone worn with a baby vest
- Broad transcription using the International Phonetic Alphabet (3 transcribers)
Normal Hearing – 24 mos.

### Place

- **Flosive**: p, b, t, d, k, g
- **Nasal**: m, n
- **Fricative**: f, v, ð, s, z, j, ʃ, ʒ, h
- **Approximant**: ð, ʃ, ʒ, j
- **Lateral Approximant**: ð, ʃ

### Manner

- **Labiodental**
- **Dental**
- **Alveolar**
- **Post Alveolar**
- **Palatal**
- **Velar**
- **Glottal**

### Hearing Level (dB)

<table>
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<th>Frequency (Hz)</th>
<th>250</th>
<th>500</th>
<th>1000</th>
<th>2000</th>
<th>4000</th>
<th>8000</th>
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<td></td>
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</table>
ID at birth, aided at 5 mos. - 24 mos.

<table>
<thead>
<tr>
<th>Manner</th>
<th>Bilabial</th>
<th>Labiodental</th>
<th>Dental</th>
<th>Post Alveolar</th>
<th>Alveolar</th>
<th>Palatal</th>
<th>Velar</th>
<th>Glottal</th>
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<tbody>
<tr>
<td>Plosive</td>
<td>p b</td>
<td></td>
<td>t d</td>
<td>k g</td>
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<tr>
<td>Nasal</td>
<td>m</td>
<td></td>
<td>d</td>
<td></td>
<td>n</td>
<td></td>
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<td></td>
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<tr>
<td>Fricative</td>
<td>f v θ ɔ s z j ʒ ǳ ʃ h</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Approximant</td>
<td>r</td>
<td></td>
<td>j</td>
<td></td>
<td></td>
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<tr>
<td>LaterApproximant</td>
<td>n</td>
<td></td>
<td>l</td>
<td></td>
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</tbody>
</table>

Hearing Level (dB)

-20
-10
0

Frequency (Hz)

100
200
500
1000
2000
4000
8000
Results: Phonetic Development

![Graph showing phonetic development across age groups.

- Non-Fricatives (13): NH and HL groups show a trend of increasing percentage of sounds produced with age.
- Fricatives/Affricates (11): Similar trend observed for NH group, while HL group remains relatively constant.

Age Group (Months): 10-12, 14-16, 18-20, 22-24.

% Sounds Produced: 0, 20, 40, 60, 80, 100.

Legend: NH (filled circle), HL (open circle).]
Summary

- Despite early intervention and amplification, fricative acquisition for HI children is more delayed than other classes of phonemes & is delayed relative to children with normal hearing.
- The gap between NH and HI children is still apparent at 24 months.
- It is possible that the limited BW of hearing aids has contributed to these delays.
Bandwidth Problem

Possible Solutions:

– Extension of the high-frequency response of hearing aids – some devices in development

– Frequency compression/transposition – three devices are commercially available
Research Needs

- Improved methods for extending the high-frequency response of hearing aids
- Studies to evaluate the efficacy of extended HF bandwidth vs. frequency compression/transposition.
- Development and validation of clinically-feasible methods to assess and monitor speech development in infants and young children with hearing loss
Collaborators

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The End