Pediatric Auditory Training: Improving Perception of Speech in Noise

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Aural Habilitation

Technology

Communication Options

Auditory Training

Psychosocial Issues
The Problem

Poor speech recognition in noise can affect for children with HI:

- Academic performance
- Language development
- Reading achievement
- Psychosocial development

(Finitzo-Hieber & Tillman, 1978; Eisenberg et al., 2000; Elliot et al., 1979; Litovsky, 2005; Talerico et al., 2007; Jamieson, 2005)
Strategic Areas for Perceptual Learning

- Language
- Audibility
- Cognitive Factors
Current Solutions

Hearing Assistive Technology

Pictures courtesy of www.phonak.com
Current solution

Otto’s World of Sound
Awareness
Discrimination
Identification

Earobics
Awareness
Discrimination
Identification

Laureate Learning Systems
Identification
Comprehension

Fastforward
Reading
comprehension
SPEECH RECOGNITION IN NOISE
What We Know About Speech Recognition In Noise

• Children with hearing impairment have poorer speech recognition in noise due to deficits in:
  
  Temporal Resolution
  
  Language Abilities
  
  Reduced Audibility
  
  Auditory Experience
How do HI children listen in noise?

Strategies used by HI children in speech recognition in Noise

- Jerger (2007) suggest the HI Children use a different “listening Strategy” than NH Peers
Picket Fence Effect
Miller & Licklider (1950)
Glimpsing

- Glimpsing involves perceiving the speech signal in the gaps in noise to combine a series of brief speech cues to get meaning
Glimpsing Model
(Cooke 2006)
Glimpsing
Glimpsing
AUDITORY TRAINING
Current Solutions

• Auditory Training
  – Numerous researchers have investigated the benefit of auditory training for individuals with hearing impairment
    (Burk et al 2006; Burk & Humes 2007; Kricos & McCarthy 2007; Fu et al., 2005; Nogaki et al., 2007; Stacey & Summerfield, 2007; Sweetow 2006; Schopmeyer et al., 2000; Tremblay & Kraus, 2002; Tremblay, Kraus, Carrell, & McGee, 1997; Walden et al., 1981; Zwolan et al., 2000)
  
  _ Few have investigated benefit of auditory training in noise._
    (Burk et al 2006; Burk & Humes 2007; Sweetow 2006; Milward et al 2011)
AUDITORY TRAINING

We know...

• Auditory training in noise can be effective in improving speech recognition in noise

• Auditory training can lead to a generalization of trained skills

• Short-term auditory training is beneficial in improving speech recognition

We need to know...

• Can auditory training in interrupted noise improve speech recognition in noise for children with HI

  – Can this lead to improvements in glimpsing skills

  – Are the improvements long-term
“Benefits of such training have been demonstrated in terms of improvement on trained tasks and talkers, generalization to untrained tasks and talkers, improvements in self perceived competence, and reduction of self-perceived handicap.

So far, however, we lack information on which aspects of training are responsible for benefit, which aspects of perception are changed....”

Can auditory training in interrupted noise result in improved speech recognition in noise?
Learning Effect in Interrupted Noise

Interrupted noise may train listeners to “glimpse” into the gaps in the noise

- SRTs in interrupted noise were 11 dB better than SRTs in continuous noise.
- After 5 replications, SRTs in interrupted noise improved 3 to 4 dB.

(Rhebergen, Versfeld, & Dreschler, 2008)
• Individuals with normal hearing have a perceptual advantage in interrupted noise even at -18 dB SNR

• Individuals with hearing impairment and younger–normal hearing children have not demonstrated an advantage of speech recognition abilities in interrupted noise

(Festen & Plomp 1986, 1990 Stuart, 2005)
Top-down Processing

Long-term Memory

Short-term Memory

Neural Processes

Glimpsing

Habituation to background noise

Bottom-up Processing

Perceptual Training

Word identification in interrupted noise

Word identification in continuous noise
The Purpose

• Compare speech recognition in noise of children with hearing impairment before and after short-term auditory training in:
  - Interrupted noise
  - Continuous noise

• Determine if speech recognition benefits are maintained 3-months following short-term auditory training in:
  - Interrupted noise
  - Continuous noise
Computer-based Training

ATI
N=8
• Auditory training
• Word identification
• Interrupted noise

ATC
N=8
• Auditory training
• Word identification
• Continuous noise

Control
N=8
• Visual training
• Memory/analytic puzzles
• Ambient noise
Participants

– Children ages 6-16 years
– Moderate-severe bilateral sensorineural hearing loss
– Bilateral hearing aid users for at least 1-year
– Native English speakers
– Language ability ≥ 6 years
Mean Group Demographics (N=24)

- **ATI**
  - 12 yrs
  - 53 dB PTA
  - 9.46 dB SNR
  - Interrupted

- **ATC**
  - 11 yrs
  - 54 dB PTA
  - 10.44 dB SNR-Interrupted

- **Control**
  - 11 yrs
  - 50 dB PTA
  - 7.33 dB SNR-Interrupted
Training Timeline

- Screening: 1.5 hrs
  - OWLS Goldman-Fristoe
- Baseline Testing: 1.5 hrs
  - SRT Interrupted Continuous
- Training: 7 hrs
- Post-training Testing: 1.5 hrs
  - SRT Interrupted Continuous
- 3-months Post-training Testing: 1.5 hrs
  - SRT Interrupted Continuous

Sullivan, Assmann, & Thibodeau  Submitted JASA
AUDITORY TRAINING

Critical Elements

Short-Term Auditory Memory

Noise

Detection & Audibility

Time

Delay

Rehearsal in Memory
Auditory Training Stimuli

- Corpus of 3000 sentences
  - Male and female talkers
    - Young-normal hearing adults

- Carrier phrase followed by
  - Adjective, adjective, and noun
  - Possessive noun, adjective, and noun
    - He ate four green beans

- Recorded Digitally
  - Manually processed using Wave Surfer
  - Gated into individual files using MATLAB
Noise Generation

- **Speech-shaped noise**
  - Based on the long-term average spectrum (LTAS) of speech stimuli
  - Interrupted randomly
    - 5-95 ms, .5 duty cycle

![Graph showing Male and Female LTAS in dB](image)
Sentence Themes

• Zoo
  – He saw Number + Color + Animal

• Mall
  – Mother bought Name + Color + Clothing

• Grandmother (Food 2)
  – Grandmother gave Name + Color + Food

• Food
  – We ate Number + Color + Food

• Toys
  – I saw Name’s + Number + Toy

• Transportation
  – We saw Number + Color + Vehicle
Presentation of Stimuli for Auditory Training

- A block consisted of 3 runs
- Each run consisted of 10 sentences
- Across runs changes:
  - SNR (0, 6, 12 dB)
  - Critical elements (1, 2, or 3)
  - Time delay (0, 2, or 4 seconds)

- Block average performance determined by $80\% \geq$ change in difficulty

- Timing
  - Each run takes about 3-5 minutes
  - 4-12 blocks completed per session
HINT: Hearing in Noise Test

• Adaptive speech-recognition in noise test
  – Automated presentation of stimuli
  – Speech recognition threshold (SRT) in noise reported as the SNR at which 50% of speech was repeated correctly

(Nilsson et al. 1996)

• Two testing conditions that were counterbalanced
  – SRT-Interrupted noise
  – SRT-Continuous noise
Speech-recognition Testing Set-up

PC

HTD

Amplifier

CD Player

Light

Speech

Soundbooth

Noise
Video of Auditory Training
Initial Starting Level
Progression of Difficulty Within a Block
Results

A 1 dB change on the HINT is equal to 8.9 % possible improvement in speech intelligibility (Nilsson et al. 1996)

Pre-training

14.10 dB SNR

Post-training

4.10 dB SNR

10.00 dB SNR

Difference Score
Pre vs. Post Difference Scores

Difference Scores in Signal-to-Noise Ratio (dB)

ATI ATC Control

Sullivan, Assmann, & Thibodeau Submitted JASA
Pre vs. 3-months Post Difference Scores

Difference Scores in Signal-to-Noise Ratio (dB)

Training Groups

ATI
ATC
Control

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ANCOVA of Difference Scores, Better-ear PTA & Age

- Better-ear PTA
  - Significant

- Age
  - Significant

- Group
  - (ATI, ATC, & VTQ)
  - Significant

- Time
  - (Pre vs. Post & Pre vs. 3-months post)

- Noise
  - (Interrupted & Continuous)
  - Sullivan, Assmann, & Thibodeau Submitted JASA
Main Effect of Group with Better-ear PTA and Age held Constant

ATI 5.67 dB

ATC 1.99 dB

Control .81 dB

Significant

Sullivan, Assmann, & Thibodeau Submitted JASA
SUMMARY

– No effect of SRT noise condition

– The greatest improvement in speech recognition in noise abilities was by the group that trained in interrupted noise

– All improvements were maintained 3-months post training for ATI and ATC
IMPLICATIONS

The improvement by the ATI group suggest that:

• Glimpsing skills may be enhanced because speech cues in the gaps are better utilized

• Auditory attention may be enhanced because of the uniqueness of interrupted noise

• Auditory processing of the acoustic trace held in memory is enhanced because it is may be resistant to competing noise
FUTURE DIRECTIONS

• Two lines of research have emerged:
  – Evaluation of developmental effects of auditory perception strategies utilized in speech recognition in noise by children with hearing impairment
  – Further development of computer-based auditory training methods and the evaluation of outcomes following training
    • Academic performance
    • Self-report of hearing function
Future Solutions

Language

Audibility

Cognitive Factors

Auditory Strategy Training:
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