The Impact of Unilateral Hearing Loss on Children's Speech Understanding in Complex Environments

Dawna Lewis, Ph.D.
Center for Hearing Research
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dawna.lewis@boystown.org

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One Ear or Two; Does it Matter?

Benefits of Binaural Hearing

- Binaural summation
- Head shadow/better ear effect
- Sound localization
- Spatial release from masking
- Precedence effect in reverberant enclosures

(for reviews, see Akeroyd, 2006; Stecker & Gallun, 2012)

How does binaural hearing benefit children's speech understanding in the real world ?

- Locate signals/talkers
- Segregate talkers/sounds
- Selectively attend to talkers of interest
- Reduce masking effects from other sounds/talkers

Effect of UHL on Auditory Localization

- Poorer localization for tones and noise when compared to peers with NH (Humes et al., 1980; Newton, 1983; Bess et al., 1986; Bovo et al., 1988; Kenworthy et al., 1990)
- In some studies participants were aware that they had difficulties and in others they were not
  - 83% in Bovo et al. (1988) reported difficulties
  - 57% in Newton (1983) were not aware of any difficulties prior to the study

Locating Talkers with both Auditory and Visual Cues

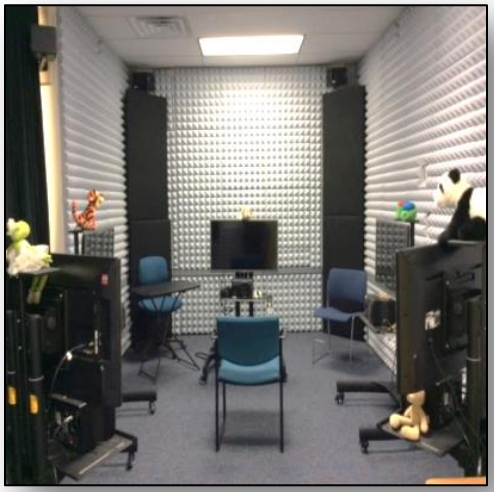
Research with adults has shown that

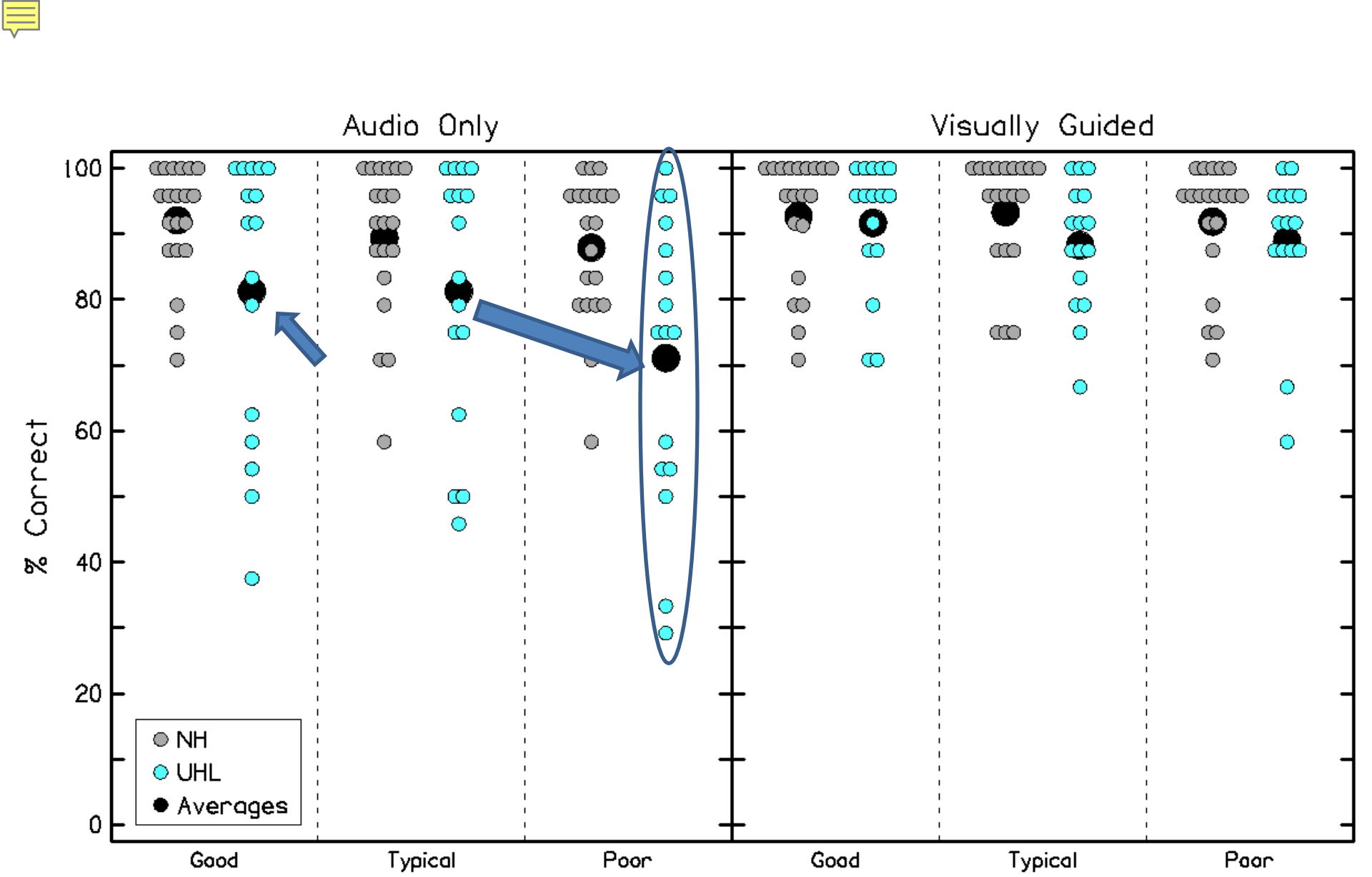
- Being able to see talkers can improve localization (Shelton & Searle 1980)
- Visual cues often more salient than auditory cues in determining location of audiovisual sources (Bertelson & Radeau 1981)
- Visual cues for the location of sounds can enhance their identification for adults with NH and HL when the visual stimulus can be easily located (Best et al. 2007; Best et al. 2009)

Effect of UHL on Ability to Locate Talkers

(Lewis et al, in preparation)

- Children with UHL or NH (8-12 yrs)
  - 20 NH, 16 UHL
- Sentences presented from 5 locations around listener (65 dBA)
- 2 presentation conditions:
  - auditory only
  - visually guided
- 3 acoustic environments:
  - *favorable* (38 dBA noise, 0.5 sec RT)---27 dB SNR
  - *typical* (55 dBA noise, 0.7 sec RT)---10 dB SNR
  - *poor* (65 dBA noise, 1.2 sec RT)---0 dB SNR
- Participants were asked to locate the talkers as they spoke
  - A head-tracker monitored looking behaviors





Preliminary Results

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Effect of UHL on Speech Perception

- Perform more poorly than peers with NH on speech perception in noise with speech to poor ear and noise to good ear

  (Bess et al., 1986; Kenworthy et al., 1990; Ruscetta et al., 2005)
- Demonstrate poorer speech perception even when speech is presented from the front or toward good ear

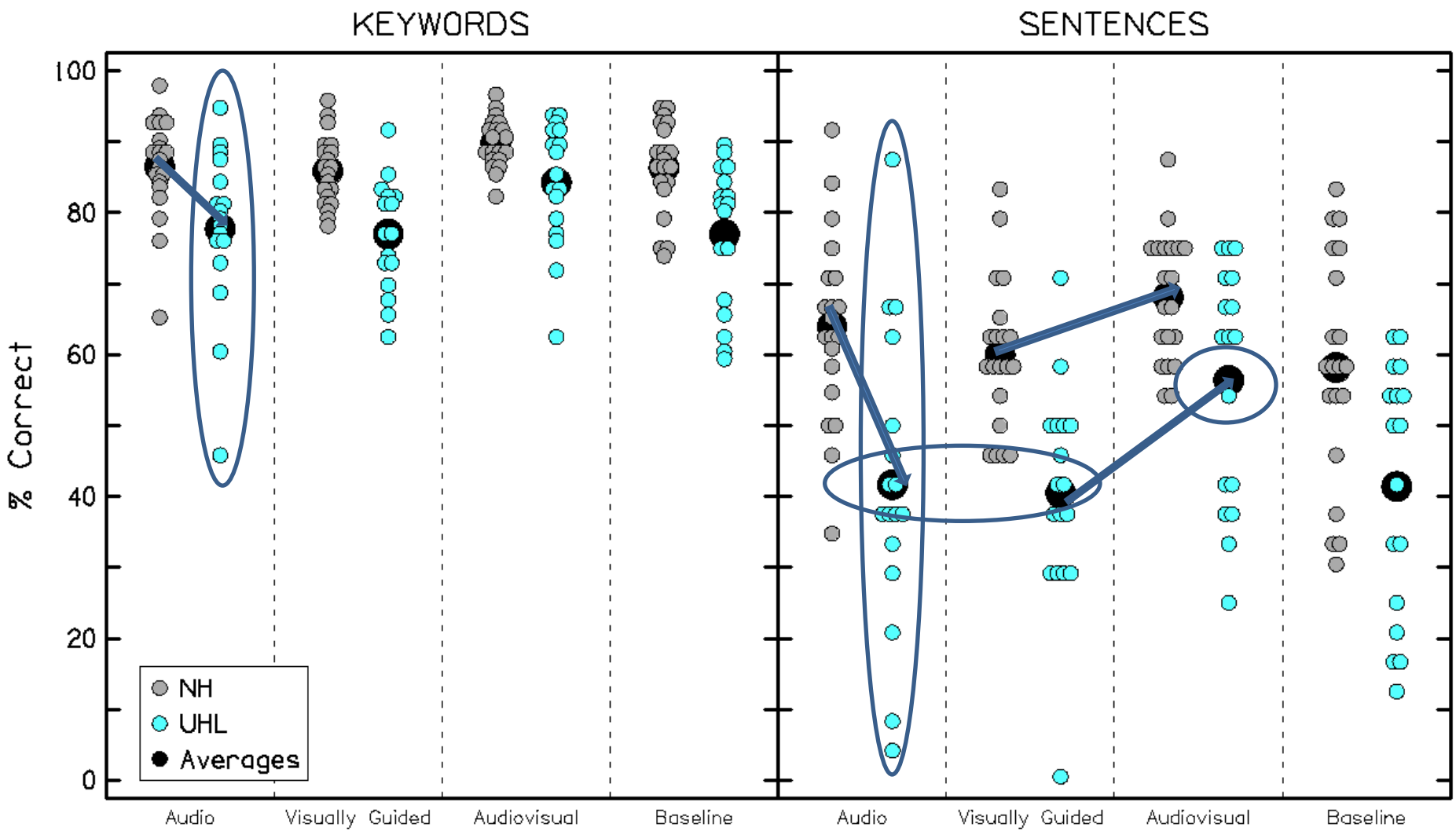
  (Bess et al., 1986; Bovo et al., 1988; Ruscetta et al., 2005)
  - Suggests that other factors play a role
    - Language and cognition
- Differences in cortical processing of speech in noise as well as during multi-modal processing of speech and noise in children with severe-profound UHL compared to children with NH

  (Probst et al., 2010; Schmithorst et al., 2014)

Localization and Speech Recognition

(Lewis et al, in preparation)

- Children with UHL or NH (8-12 yrs)
  - 20 NH, 17 UHL
- Same set-up as in previous study but had to locate and repeat low-predictability sentences
- SNR = 3 dB; RT = 0.6 sec
- 4 conditions
  - Audio only; visually-guided; audiovisual; baseline



Preliminary Results

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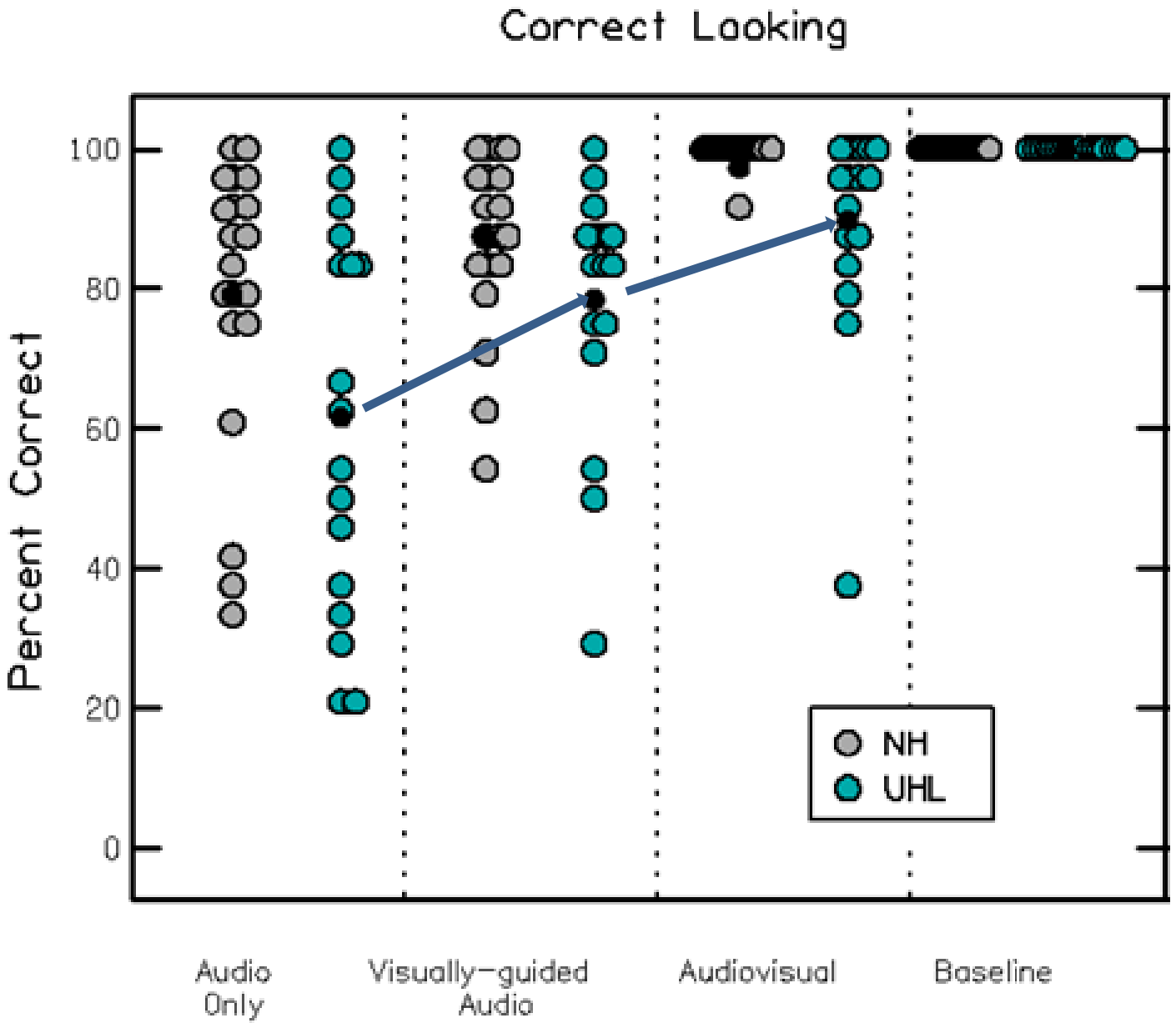
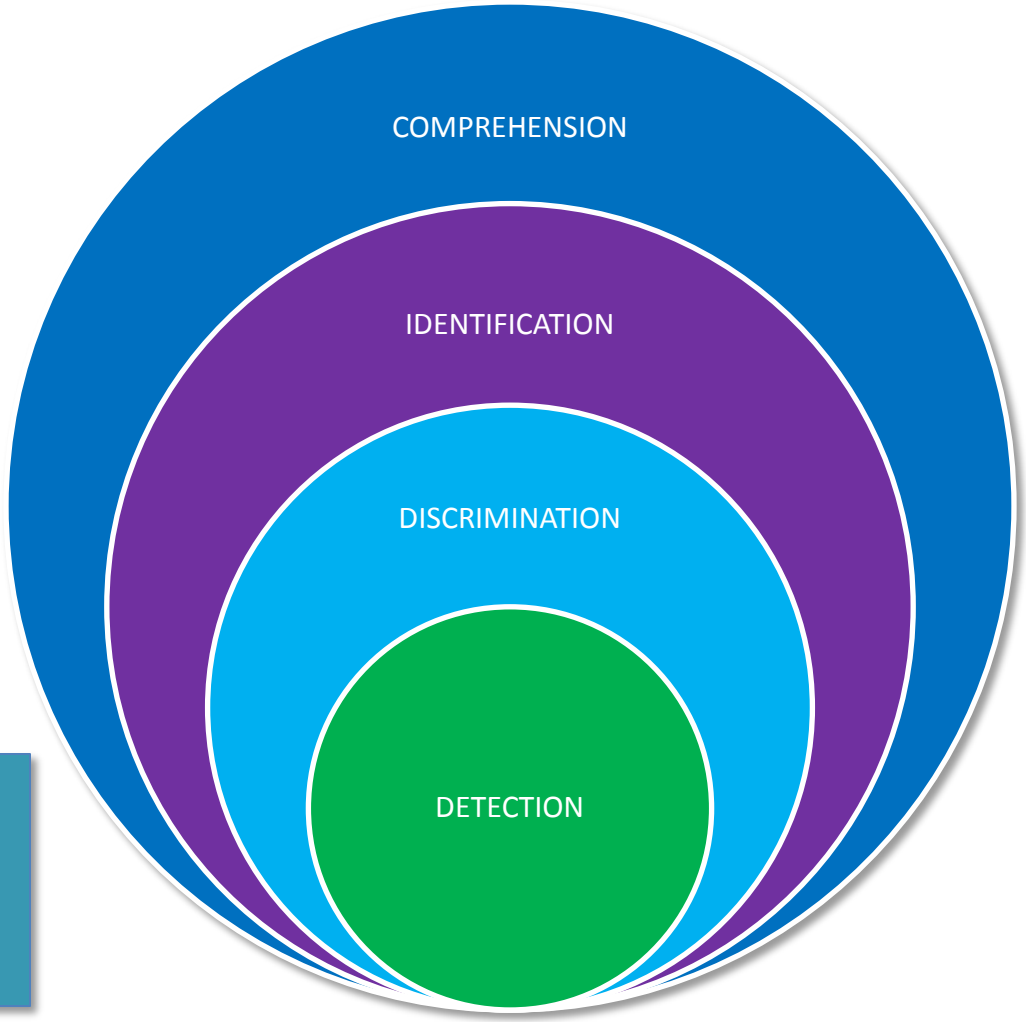


Preliminary Results

- Together, these studies suggest
  - Visual information improves the ability to locate talkers for children with UHL
  - When asked to find talkers and repeat what they say, children with UHL
    - May take longer to find the talker than peers with NH
    - May benefit more from seeing the talker
  - It is possible that the effort required for these processes may impact ongoing speech understanding

Task Complexity and Speech Understanding



Categories from Erber (1982) re: Auditory Skill Development

Complex Listening Tasks

- Recent studies evaluating children with HL have used a variety tasks to more closely assess the cognitive demands of real-world speech understanding

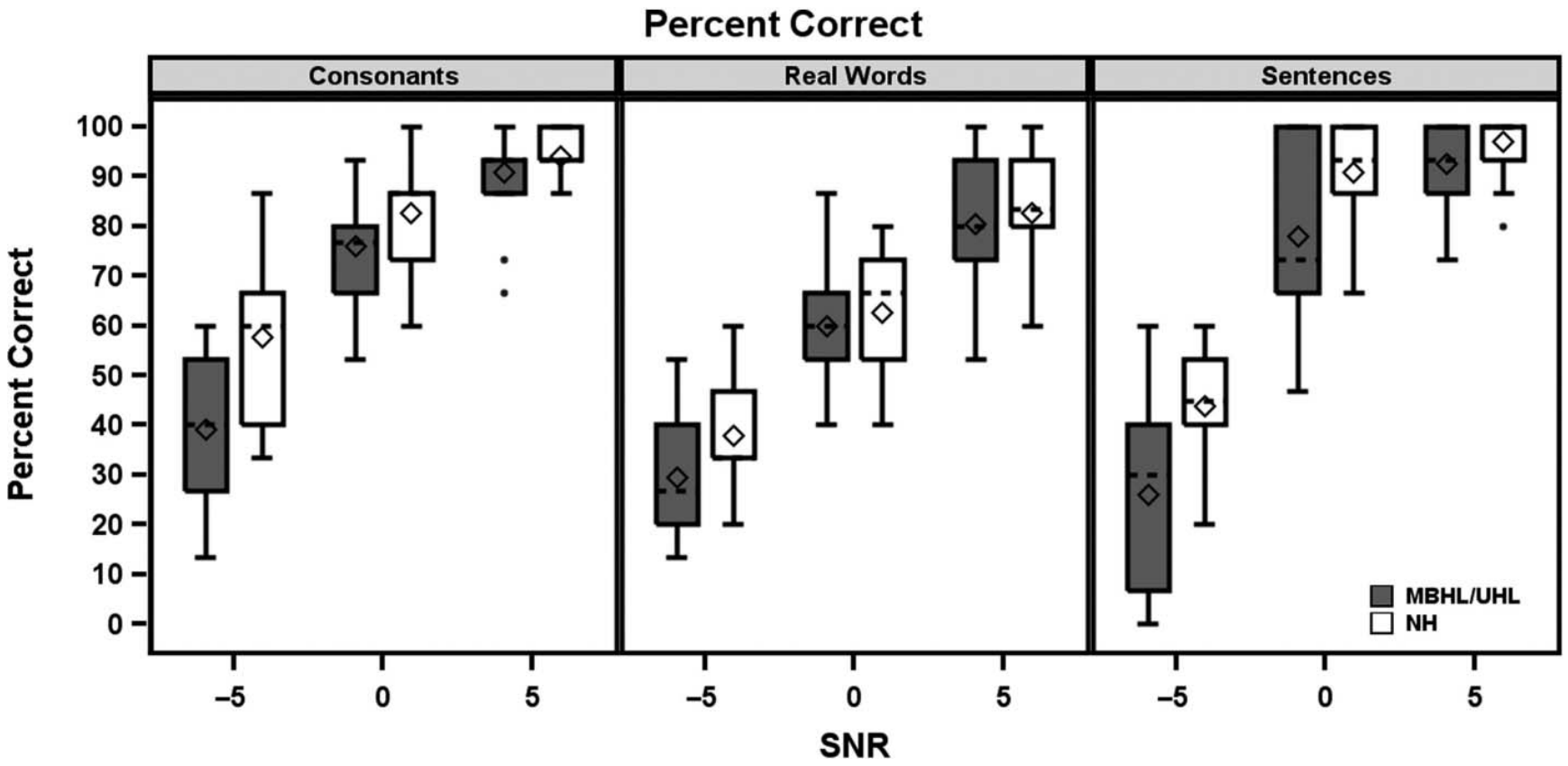
- Dual-task paradigms
  (Hicks & Tharpe, 2002; McFadden & Pittman, 2008)
- Verbal processing time measures
  (Lewis et al., 2017; McCreery & Stelmachowicz, 2013)
- Comprehension tasks
  (Lewis et al., 2015; Lewis et al., accepted for publication)
- Measures of Fatigue
  (Bess et al., 2016; Hicks & Tharpe, 2002; Hornsby et al., 2014)

Speech Recognition and Listening Effort in Children with NH or MBHL/UHL

(Lewis et al. 2016)

- 18 children (8-12 yrs) with NH and 18 with MBHL/UHL
  - 8 with bilateral HL
  - 10 with unilateral HL
- Three SNRs and three levels of linguistic complexity
  - speech at 65 dB SPL, noise at +5, 0, -5 dB SNR
  - VCVs (e.g., aCa), real words, sentences
    - 15 tokens of each stimulus were presented at each SNR
- Children were instructed to repeat the stimuli as heard

- Percent correct was measured for each stimulus
- Listening effort was assessed using measures of Verbal Response Time (VRT)
  - Onset time is the delay from the end of the stimulus to the initial vocalization
  - Total duration is onset time + length of utterance
    - Length of utterance is the time from the initial vocalization to the end of the response



- Performance increased with increasing SNR
- Children with NH performed better than children MBHL/UHL for consonants and sentences but not words

Why might we expect group differences for some stimuli and not others?

- Children with NH would have had history of consistently better access to information in speech signals. May have been better able to
  - perceive the acoustic–phonetic information in the consonants
  - use acoustic–phonetic information, supplemented by linguistic and contextual information to assist in sentence recognition
- For single real words, linguistic and contextual information is more limited than for sentences, and the acoustic–phonetic content is greater than in consonants
  - Possible that limited amount of both types of information was not sufficient to bolster their scores relative to the children with hearing loss for these stimuli

Assessing Listening Effort using Measures of VRT

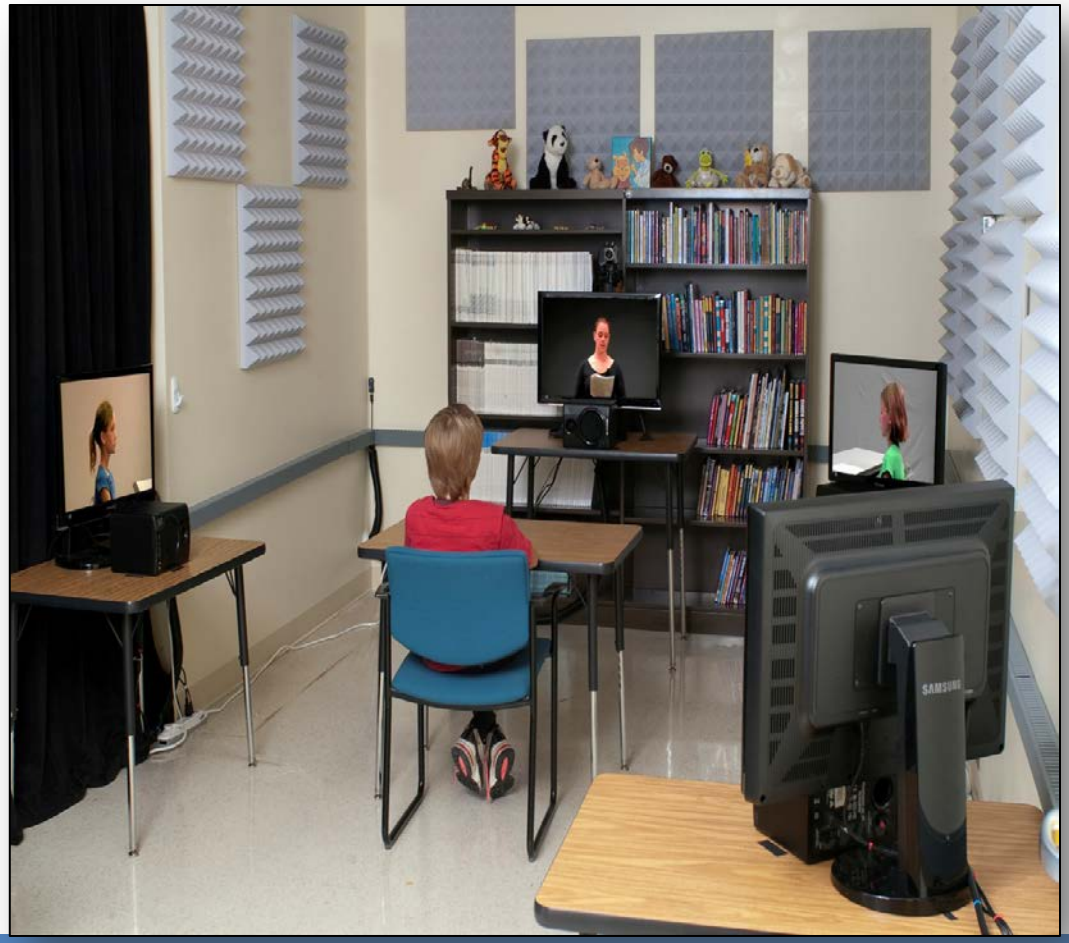
- Onset time
  - Longer for incorrect than for correct responses
    - Differences greatest for sentences
  - Overall increase with decreasing SNR
  - No effect of hearing status
- Total duration (correct responses only)
  - No main effect of hearing status

What might explain the absence of a hearing-status effect on VRT?

- Chose measures of VRT to attempt to obtain additional information beyond that provided by percent correct scores alone
- Speech recognition tasks commonly used in clinical settings
  - May not have created enough cognitive load to differentiate the populations using VRT
- Tasks that are higher in the listening hierarchy (Erber, 1982) may be necessary to differentiate listening effort for this population
  - Tax more of the cognitive resources available for speech understanding

Comprehension and sentence recognition in a simulated classroom environment

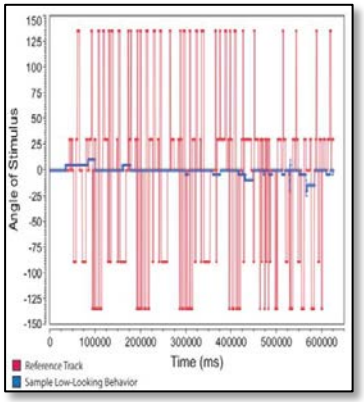
(Valente et al., 2012; Lewis & Wannagot, 2014; Lewis et al., 2015)



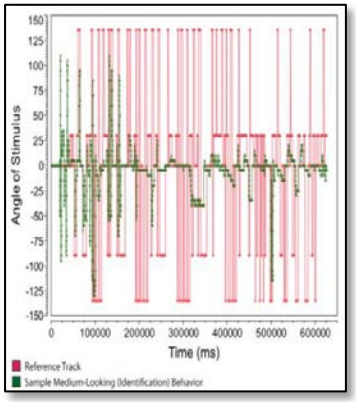
- ***Realistic classroom comprehension task***
  - Video recordings of talkers positioned around the subject, reading lines from a play
  - Teacher + 4 Students
  - Answered a series of questions about the story at its completion
- ***Speech recognition task***
  - Sentence repetition by single talker
  - Auditory-only from 5 loudspeakers

Looking Behavior

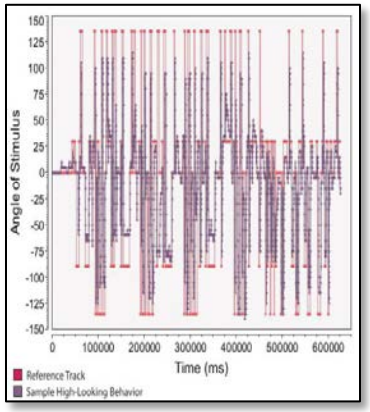
- Proportion of Events Visualized
  - How often listeners looked directly at the talker as he/she was speaking during the classroom learning task
- Overall Looking Behavior



Low
<20



Medium
20<SD<45



High
>45

Acoustical environment

- Talkers presented at 60 dBA
- SNR and RT varied across tasks/studies
  - 5, 7, 10 dB SNR
  - 0.6, 1.5 sec RT
- Neutral spectrum background noise, HVAC systems

Adults and Children with NH

- *Valente et al., 2012*
  - Children performed more poorly than adults on the comprehension task despite similar performance in speech recognition
  - Children looked around more on average, despite lower comprehension scores
- *Lewis & Wannagot, 2014*
  - Sentence Recognition: Adults performed better than 8- and 11-yr olds. No effect of required looking.
  - Comprehension: Adults and 11-yr olds performed better when looking was not required. This was not the case for younger age groups.
  - Suggest that looking behavior can impact comprehension differently depending on the task and age of the listener, with potential implications for learning

Children with MBHL/UHL

(*Lewis et al. 2015*)

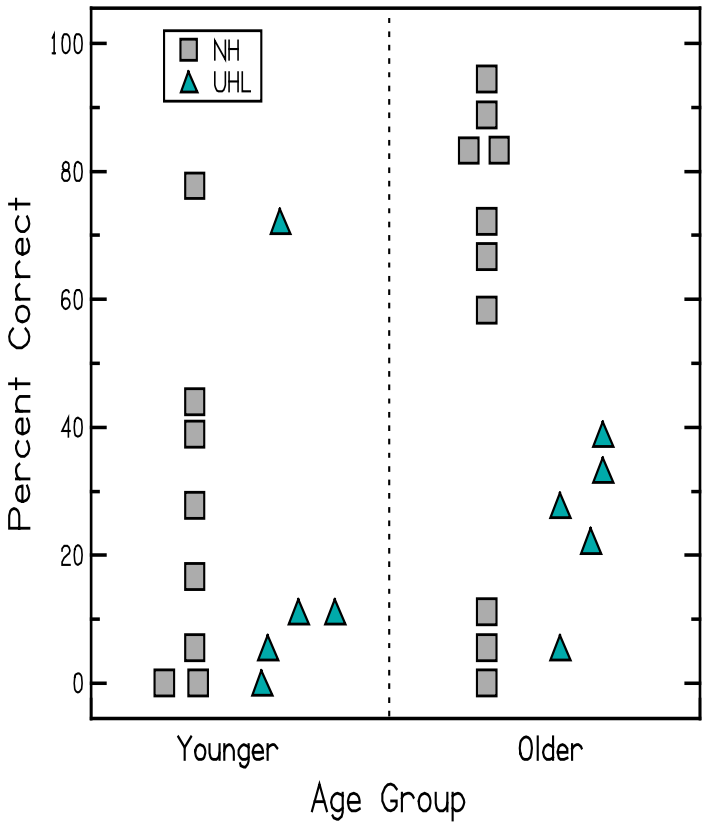
- 18 children (8-12 yrs) with NH and 18 with MBHL/UHL
  - 8 with bilateral HL
  - **10 with unilateral HL**
- Age-matched
- WASI 2FSIQ within 1.25 SD of mean
- All testing completed without amplification

Speech Recognition

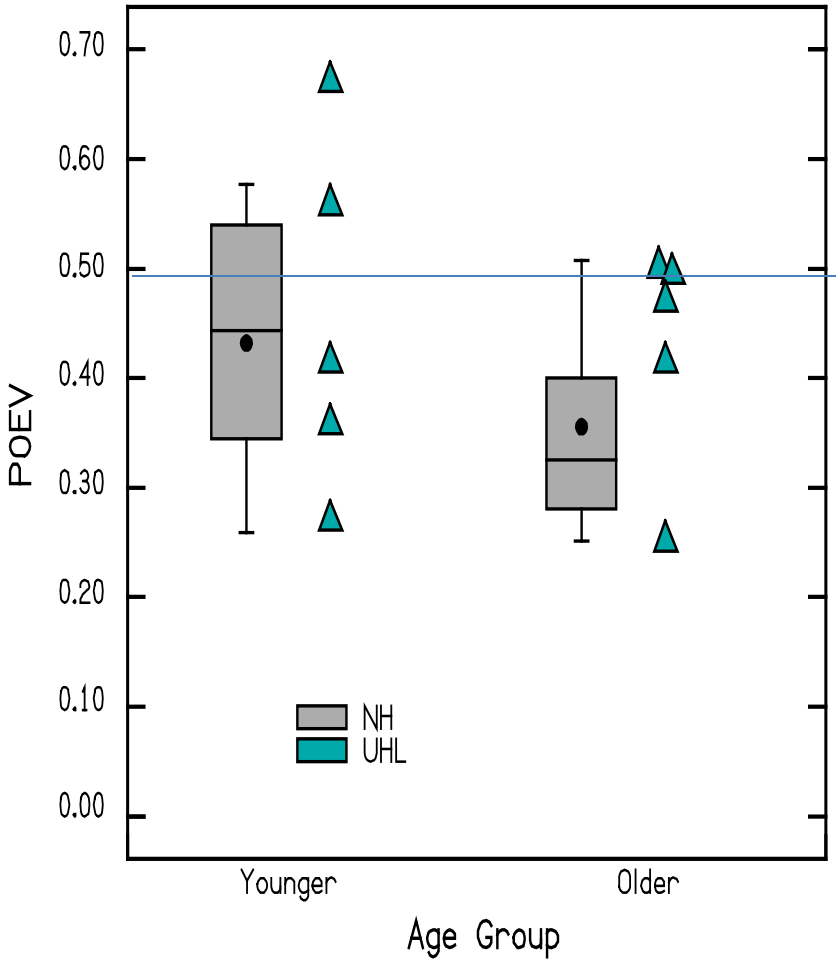
NH mean = 99.33

UHL mean = 96.74

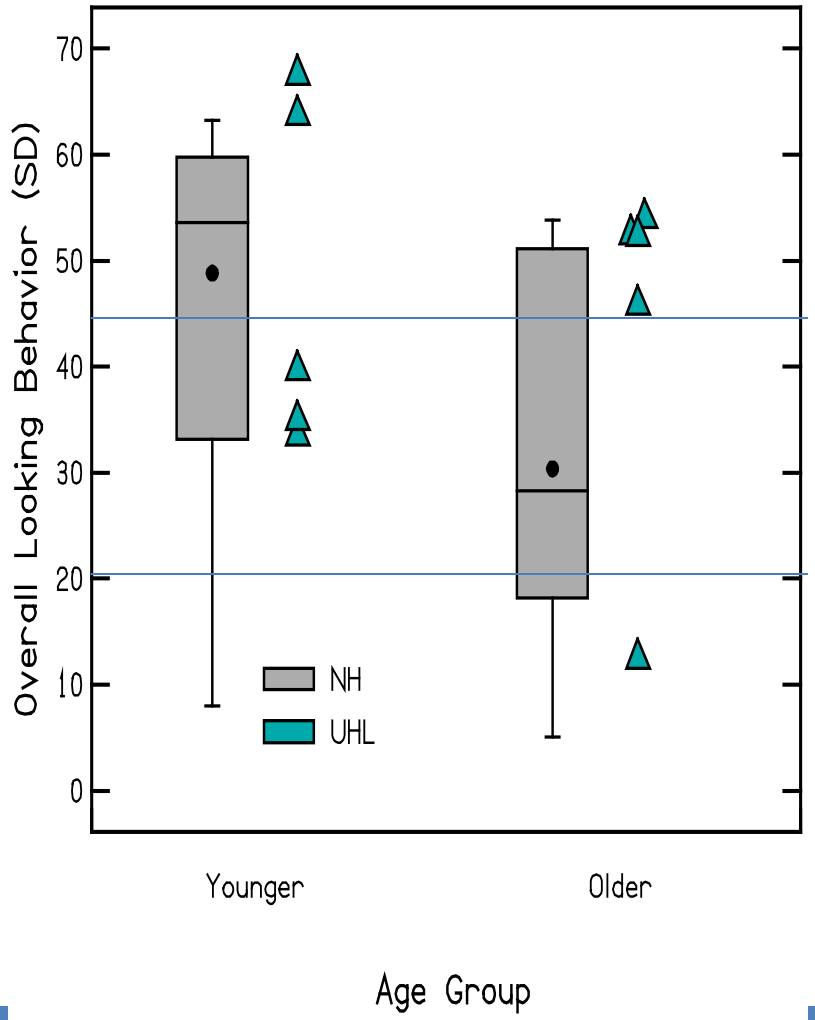
Comprehension



Proportion of Events Visualized



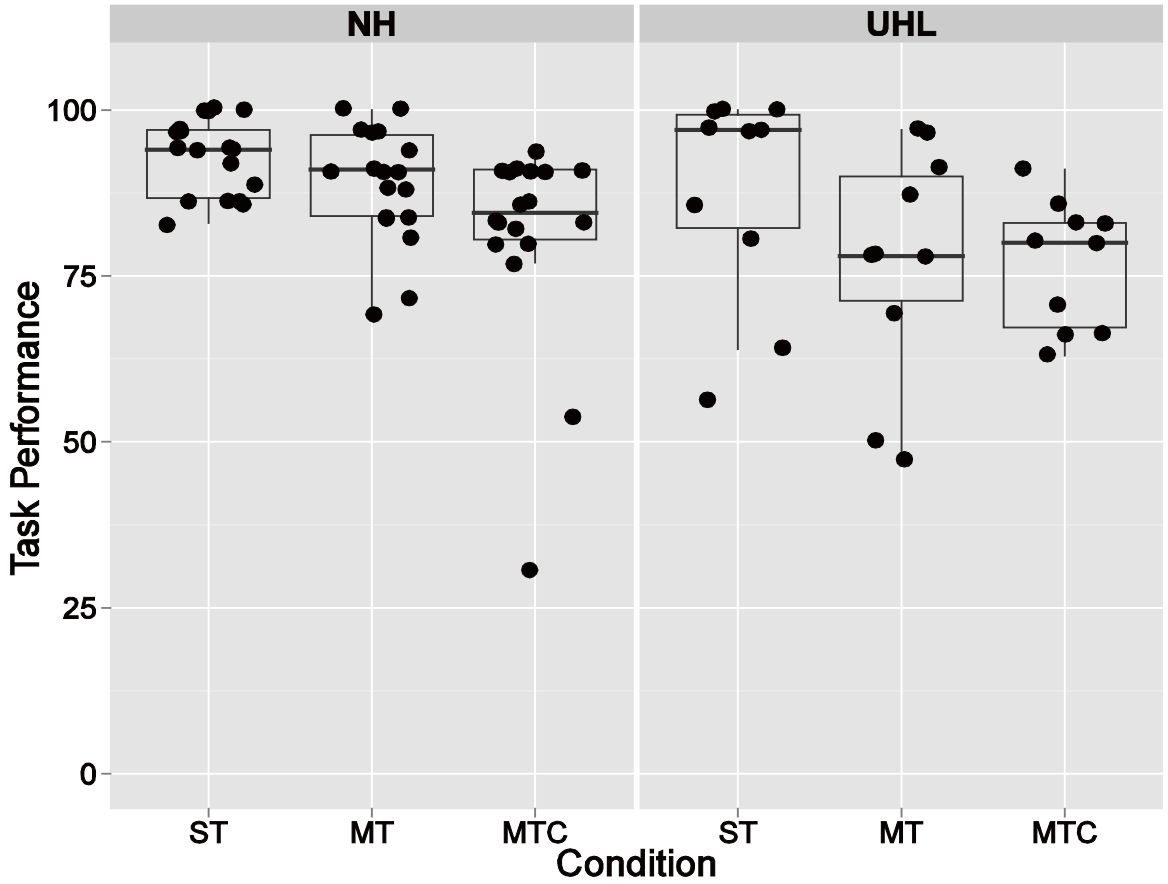
Overall Looking Behavior

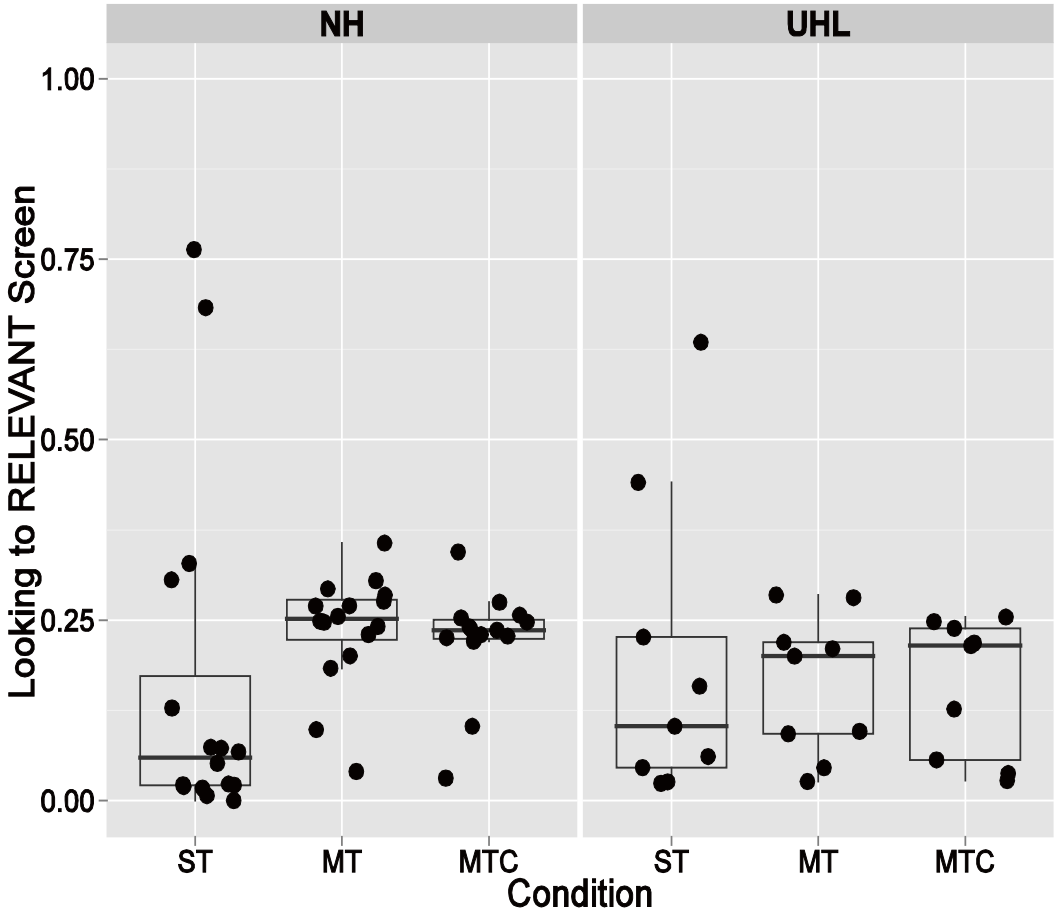


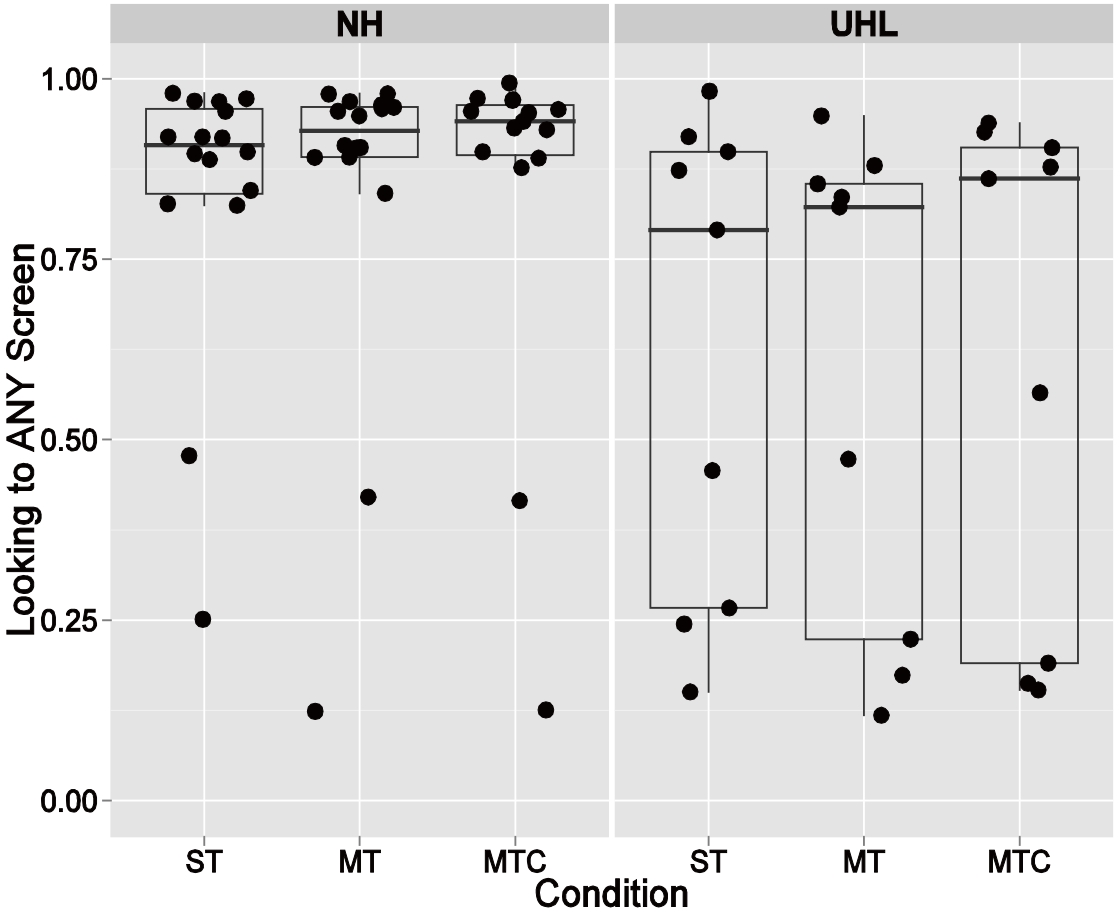
Looking Behavior and Audiovisual Speech Understanding in Noise

(Lewis et al., accepted for publication)

- Same subjects
- Participants instructed to follow verbal directions for placing objects on a mat
- Speech = 60 dB SPL; multi-talker babble = 55 dB SPL
- Video recordings of children (8-12 years) providing instructions
  - Single-talker (ST)
  - Multi-talker (MT)
  - Multi-talker with comments (MTC)
- Eye-tracking was used to monitor looking behaviors


NH
UHL
100
75
50
25
0
Task Performance
ST
MT
MTC
ST
MT
MTC
Condition


NH
UHL
1.00
0.75
0.50
0.25
0.00
Looking to RELEVANT Screen
ST
MT
MTC
ST
MT
MTC
Condition


NH
UHL
1.00
0.75
0.50
0.25
0.00
Looking to ANY Screen
ST
MT
MTC
ST
MT
MTC
Condition

What do results from these comprehension studies tell us?

- Children with UHL perform more poorly than peers with NH during complex tasks with multiple talkers
  - Even when they demonstrate similar performance on less complex tasks
- Patterns of looking behaviors may vary by task
- Patterns of looking behaviors may differ across the two populations, suggesting potential differences in use of visual information to supplement degraded auditory input

In Summary

- Children with UHL represent a complex and diverse population
- Despite research over more than 30 years, there are many questions that still need to be answered to ensure their communication access and academic access
- Speech understanding may vary depending on the complexity of the listening environment and task
  - Need to understand the types of real-world environments these children encounter in their daily lives
  - How might those environments affect performance?
- Considering complex, multi-talker audiovisual environments in our research and clinical evaluations can enhance our understanding of the effects of UHL on speech understanding in real-world settings
  - Improve communication access


Thank
you!