Evaluation of a soundfield + virtual environment for listening outcome assessment

Isabel Martin, Rose Pérez, & Jani Johnson
School of Communication Sciences and Disorders, University of Memphis, Memphis, TN

INTRODUCTION

Hearing loss can have detrimental effects on an individual's communicative behavior, social-emotional wellbeing, earning power, and quality of life (e.g., Kochkin, 2007; Nachtegaal, 2009). Behavioral researchers often rely on outcome measures in 3 domains to describe auditory performance: speech understanding, localization accuracy, and listening effort. Typically, researchers use independent auditory tasks to assess each outcome, which is time-consuming and cumbersome for listeners. For those with reduced cognitive abilities and auditory attention spans, longer task durations can reduce performance over time. Further, prior research has repeatedly documented discrepancies between laboratory and real-world measures of auditory performance in many of these areas (e.g., McGarrigle et al 2014; Johnson et al 2017). We worked with an interdisciplinary team to develop a virtual reality (VR) assisted behavioral task with greater ecological validity that simultaneously assessed performance in each of these domains. This research evaluated the measure's feasibility of use with older adults and sensitivity to changes in listening difficulty.

Research Questions:

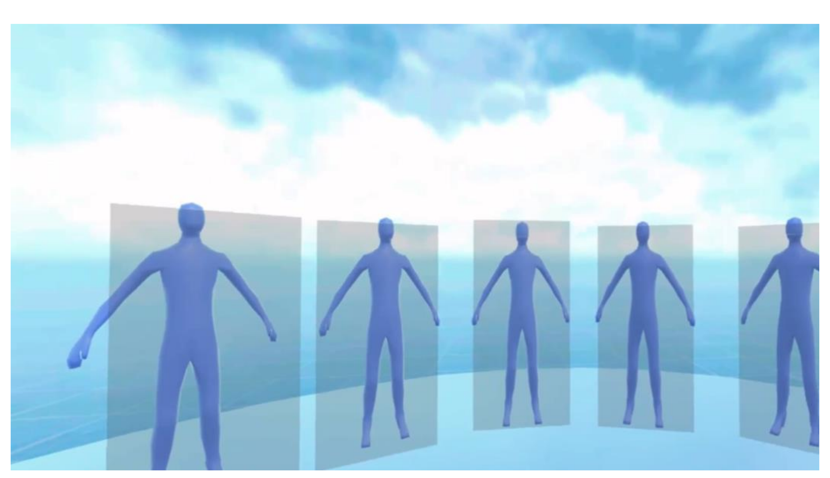
1. Is this measure adequately sensitive to detect changes in performance due to differences in listening-related challenges in the following domains:

a. Speech understanding
b. Localization accuracy
c. Listening effort

2. Is this simultaneous assessment of speech understanding and localization performance feasible for use with older adults?

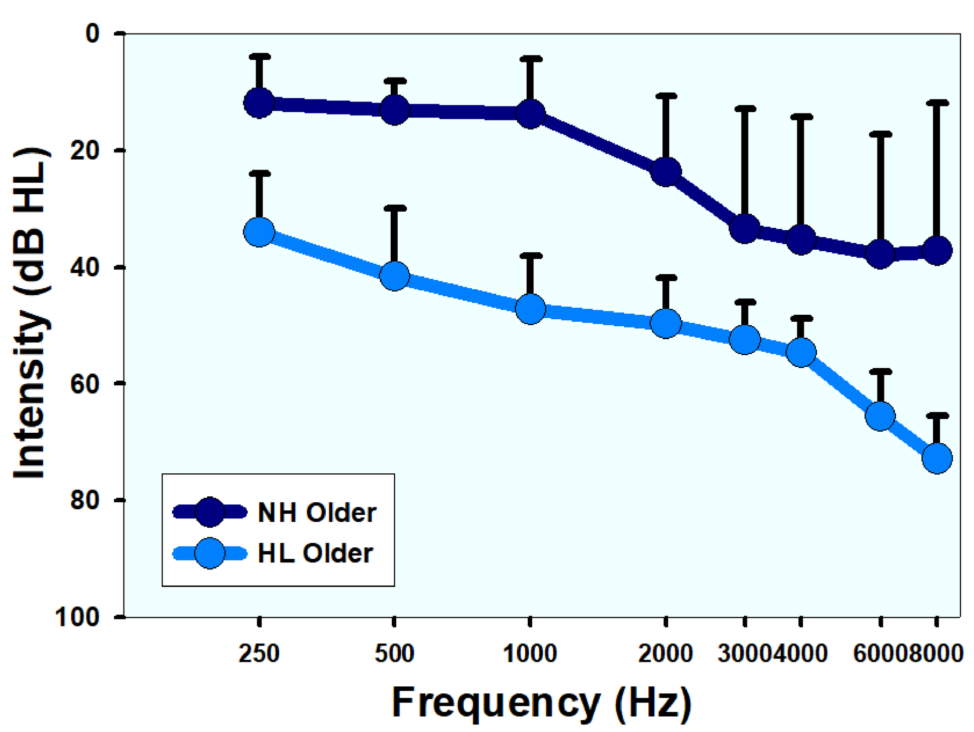
METHODS

While seated in an anechoic chamber, participants listened to a roving speech signal presented at ear-level in the front hemifield with varying levels of competing noise presented from behind the listener. Twenty passages of a modified version of the Connected Speech Test materials (recorded by 8 voice actors) served as speech tokens. Participants experienced a virtual environment with avatars represented in visual space corresponding with nine soundfield loudspeakers ranging from +/- 90 degrees azimuth to the front of the listener as the competing multitalker babble was decreased in 2dB steps, varying the signal-to-noise ratio (SNR) from -10 to +8. Participants used a VR controller to indicate the avatar from which they thought the speech arrived. Localization accuracy (degree of error) served as the localization outcome. Response time served as the measure of listening effort. Simultaneously, as the intensity of the competing noise varied, participants indicated the level at which they could just follow the conversation and identify the topic of the speech passage (JFC). The JFC threshold served as the measure of speech understanding performance.



PARTICIPANTS

The present study contained two phases. Phase 1 developed and piloted the measure on 4 young adults (3 female, age 23-24) with typical hearing (all thresholds < 25 dB HL, **NH Younger**). Phase 2 validated the measure with older adults. Eight had age-adjusted "normal" hearing (4 female, age 60-75, **NH Older**), and 8 with hearing loss, (6 female, age 63-81, **HL Older**). As the measure involved multiple simultaneous tasks and use of a virtual reality headset and controllers, the second phase specifically explored whether the measure was feasible for use with older adults as well as sensitive to detecting differences in listening performance based on hearing-related challenges. Data were evaluated statistically using mixed-model ANOVAs and Holm Bonferroni corrected post-hoc pairwise comparisons.



RESULTS

1. Was the measure adequately sensitive to detect changes in performance due to differences in listening-related challenges in the following domains:

a. Speech understanding: HL older struggled more with understanding speech in background noise compared to NH younger (p = .002, d = 2.78) and NH older (p = .017, d = .68). A large group effect was demonstrated when comparing NH younger and NH older (d = 1.36). However, this difference did not reach statistical significance.

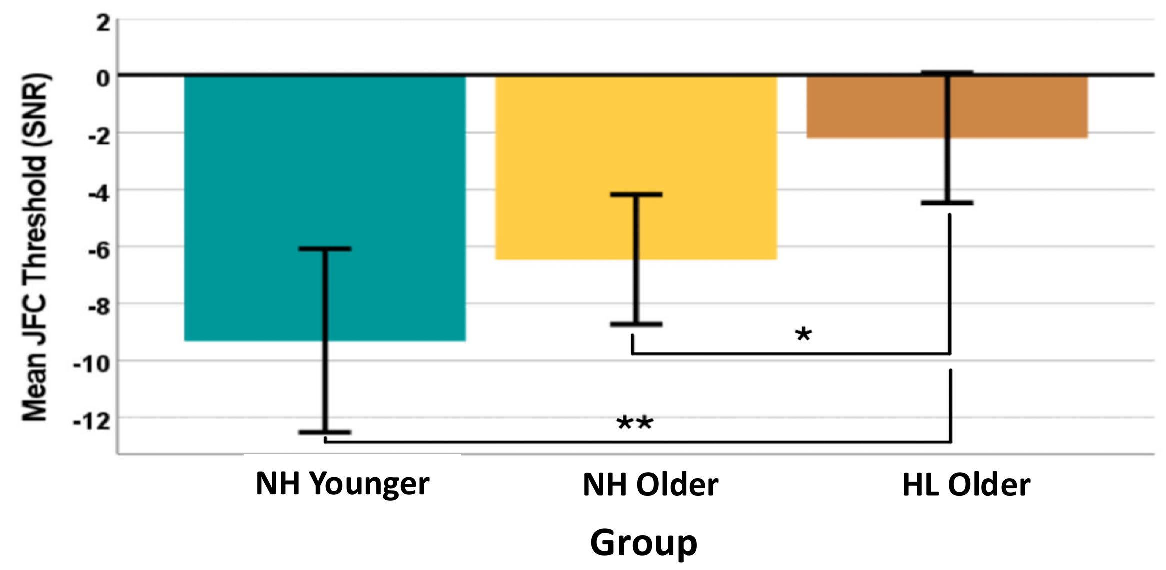
b. Localization accuracy: Similarly, large effects of group were seen when comparing localization performance for HL older and NH younger (p = .028, d = 1.47) and NH older (p = .041*, d = 1.11), and a small to moderate nonsignificant group effect was seen when comparing NH younger and NH older (d = .38). All groups demonstrated poorer localization accuracy in the worst SNR condition (p < .001 for all comparisons), but performance plateaued at easier SNRs.
*nonsignificant after correction for familywise error

c. Listening effort: Similarly, different reaction times were demonstrated across groups and SNRs. HL older had significantly increased reaction times compared to NH younger (p < .001, d = 3.06) and NH older (p = .003, d = 1.74). A large group effect was also seen when comparing NH younger and NH older (d = 1.32) but was not statistically significant after correction (p = 0.047). Reaction times were significantly higher at the worst SNR across groups (p < .001 for all comparisons) but plateaued at easier SNRs.

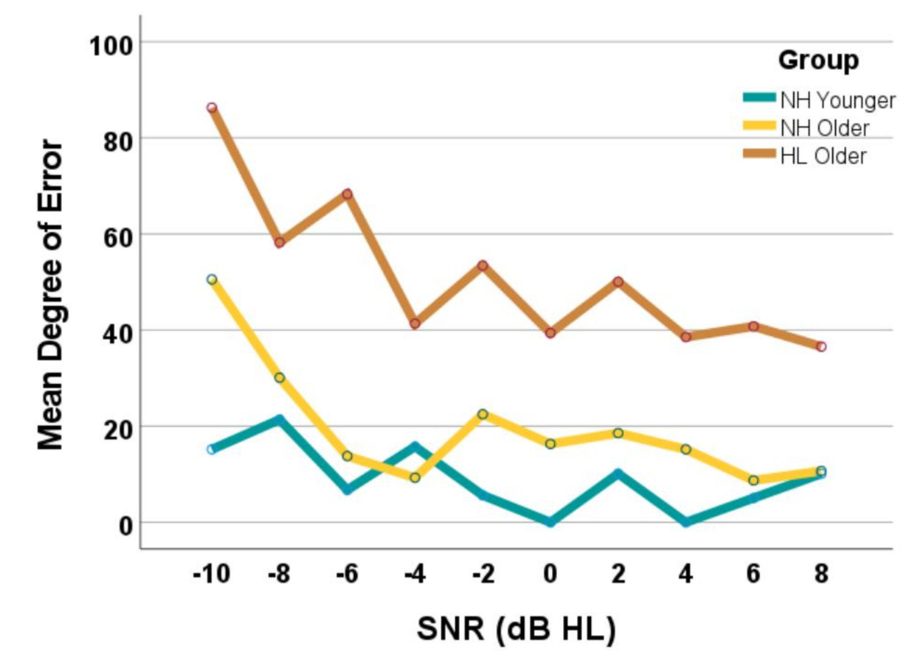
2. Was this simultaneous assessment of speech understanding and localization performance feasible for use with older adults?

Average test time was approximately 15 minutes, with 5-10 minutes of instruction. Almost all participants were able to perform the tasks required, with minimal need for reinstruction. One participant required substantial reinstruction and resulting data were of questionable validity. Participants indicated that the tasks were relevant and easily navigated with no negative experiences.

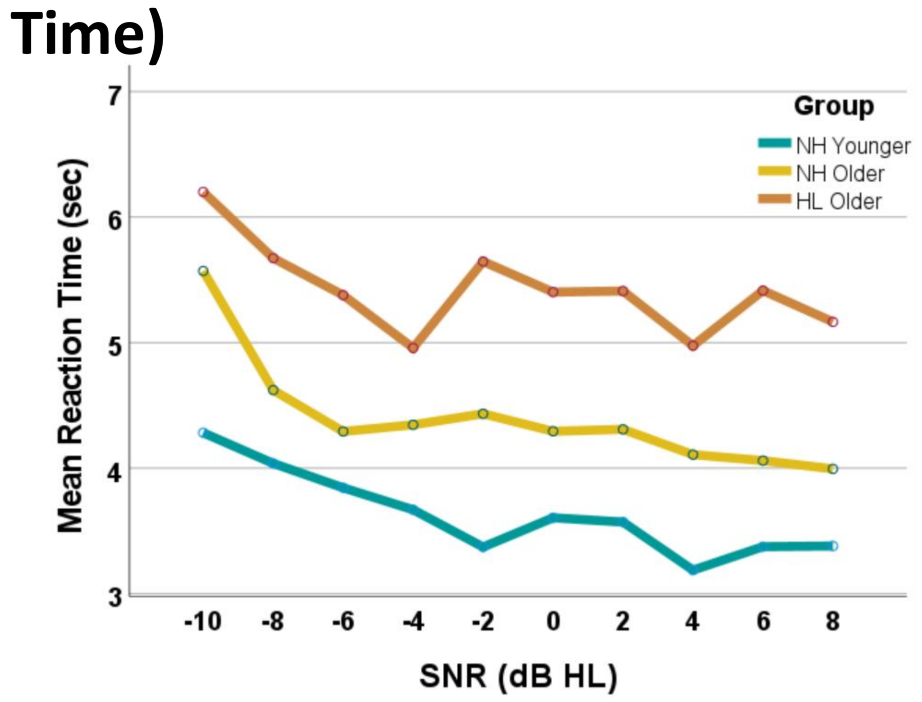
1a. Speech Understanding



1b. Localization Accuracy



1c. Listening Effort (Localization Reaction Time)



Q & A

1. Was this measure adequately sensitive to detect changes in auditory outcomes due to listening-related challenges?

A. Yes, especially for speech understanding. Measurable differences were detected between participant groups in expected directions in speech understanding and across listening conditions in localization and listening effort domains, despite the small sample. This suggests sufficient sensitivity to detect meaningful existing differences in listening-related difficulty. It was noted that incremental benefits to localization and effort at easier SNRs were subtle. Future research using these measures should take small effect sizes into account when determining sample sizes.

2. Was this measure feasible for use with older adults?

A. Mostly. With instruction, most older adults were able to simultaneously navigate the listening tasks and utilize the VR technology. However, it was noted that one participant with a passing but low score on a cognitive screener required substantial reinstruction and support to complete the task. It is possible that older adults with poorer cognitive abilities may struggle to produce reliable data.

CONCLUSION

Simultaneous assessment of speech understanding, effort, and localization abilities for roving speech presented in background noise can be accomplished using a virtual environment and response system synced to sound field presentations developed for this purpose. This procedure allows for more efficient data collection and an evaluation method that has greater ecological validity compared to traditional behavioral measures of these outcomes.
It is hoped that this measure can provide insights into the detriments of hearing difficulties and relative benefits of different hearing interventions (e.g., wearing different types of hearing aid technologies). Using just one task to simultaneously evaluate multiple listening outcomes could not only reduce testing time and physical and mental burden on participants but also could be a better representation of how these listening domains interact in daily listening to impact listeners' perceptions of real-world auditory performance. Thus, we anticipate that such a laboratory measure will better correlate with self-reported daily life listening outcomes in future studies. Future research should explore this hypothesis.

ACKNOWLEDGMENTS

This work was funded by a grant to the third author from the School of Communication Sciences and Disorders at the University of Memphis. Kevin McKenzie, Arturo Pérez, and his team in the Department of Computer Science at the University of Memphis assisted in the development of the VR environment and data recording software.

REFERENCES

1. Johnson, J., Xu, J., & Cox, R. (2017). Impact of hearing aid technology on outcomes in daily life, III: Localization in quiet and in noise. Ear & Hearing, 38(6), 746-759. doi:10.1097/AUD.0000000000000473.
2. Kochkin, S. (May, 2007). The impact of untreated hearing loss on household income. Better Hearing Institute.
3. Nachtegaal, J., et al. (2009). The association between hearing status and psychosocial health before the age of 70 years: results from an internet-based national survey on hearing. Ear Hear. 30(3): 302-12.
4. McGarrigle, R., et al. (2014) Listening effort and fatigue: What exactly are we measuring? A British Society of Audiology Cognition in Hearing Special Interest Group 'white paper', International Journal of Audiology, 53:7, 433-445, DOI: 10.3109/14992027.2014.890296

This poster is available for download at [*www.harlmemphis.org*](http://www.harlmemphis.org)