Effects of Hearing Loss on Selective Attention from Childhood to Adulthood

Shreya Sriram, Kristi Ward, & Tina Grieco-Calub

[1]The Roxelyn & Richard Pepper Department of Communication Sciences & Disorders, Northwestern University, Evanston, IL

email: shreyasriram2022@u.northwestern.edu

Background & Objectives

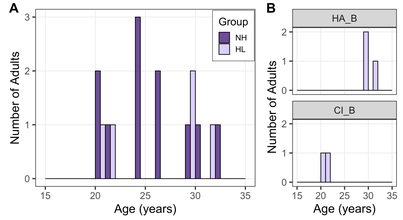
- Listeners have difficulty understanding speech in environments that have multiple sound sources (i.e., background noise). To improve speech perception in these scenarios, listeners must allocate more of their attention to the speech signal and inhibit their attention to the background noise. Thus, the inability to selectively attend to speech would likely further impair speech recognition accuracy.
- This is especially important for listeners with hearing loss, who have difficulty understanding speech even with the use of hearing devices (e.g., hearing aids or cochlear implants). In considering the proposed role of selective attention in speech recognition, it is possible that part of the reason listeners with hearing loss experience poor speech understanding is due to impaired selective attention.
- Previous research has demonstrated this relation in children with hearing loss. However, the extent of this relation in adulthood remains unknown. As selective attention is known to improve with age, the maturation of attentional processes may compensate for differences that are seen in children.

This preliminary study investigates whether adults with hearing loss demonstrate greater difficulty attending to a target stream than adults with normal hearing.

Participants

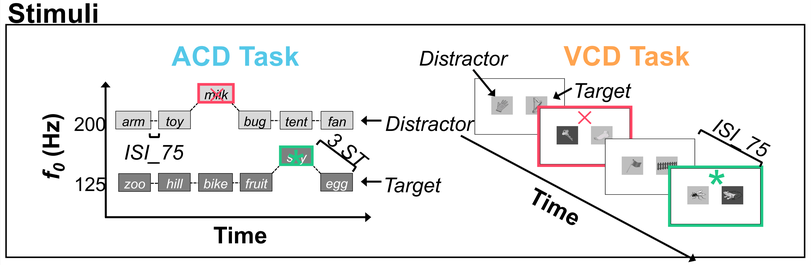
Participants

- Participants included 18-to-35 year-old adults with normal hearing (NH; *N* = 10) or hearing loss (HL; *N* = 5).
- Adults with HL wore bilateral hearing aids (HA_B; *N* = 3), or bilateral cochlear implants (CI_B; *N* = 2).



Methods

Stimuli



- Stimuli consisted of single-syllable words (ACD; *left*) or illustrated images (VCD; *right*). ISI_75 is the amount of time between each presentation of stimuli, a value based on performance in pre-testing.
- Participants were simultaneously presented with two auditory streams (ACD) or two visual streams (VCD). In the ACD task, the two streams were a male voice (F0 = 125 Hz) and female voice (F0 = 200 Hz). In the VCD task, the two streams were a right and left stream.
- Each stream contained standard stimuli (90% occurrence) and deviant stimuli (10% occurrence). Adults were instructed to respond (via keypress) to deviants in the target stream (*), but not the distractor stream (X). Responses were registered as either a target or distractor hit if within 2 sec of stimuli presentation.
- Deviant stimuli were derived from standard stimuli by transposing the F0 by +3 semitones (ACD) or increasing the saturation of the background by 40% (VCD).
- Performance was quantified by the dependent variables in **Figures 2 and 3**:
  - hit rate and speed of responses to deviants in the target stream (% target hits)
  - hit rate and speed of responses to deviants in the distractor stream (% distractor hits)
  - relative proportion of responses to deviants in the target and distractor streams (response sensitivity)
  - responses to non-deviant stimuli (false alarms)

Audiometric Profiles of Participants with Hearing Loss

Table 1: Unaided high-frequency pure tone average (HFPTA), aided HFPTA, and speech recognition (SR) scores in quiet for participants with hearing loss.

Unaided HFPTA values represent participants' residual hearing thresholds (i.e., how much they can hear without the use of their hearing devices). The results indicate high levels of variability in degrees of hearing loss across participants.

Aided HFPTA values represent the participants' hearing thresholds with the use of their hearing devices. This measure reflects their audibility on a day-to-day basis. Subjects C and A demonstrated the best aided hearing ability.

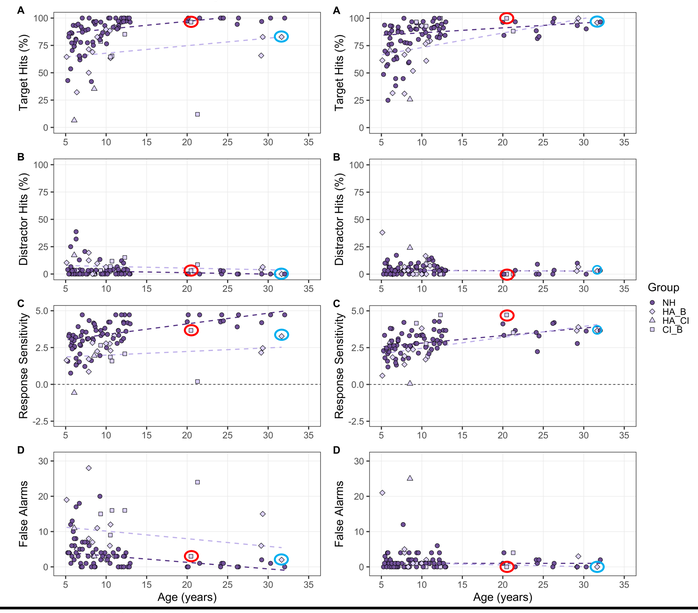
	Unaided HFPTA (dB HL)		Aided HFPTA (dB HL)		SR in Quiet	
Subject	L	R	L	R	Control	Low Reverb
A	55.00	53.75	27.50	27.50	92%	90.3%
B	70.00	75.00	37.50	37.50	72%	67.7%
C	CI	CI	18.75	18.75	100%	90.3%
D	75.00	81.25	NA	NA	NA	NA
E	CI	CI	28.75	28.75	76%	67.7%

SR in Quiet scores represent the proportion of words the participant was able to correctly identify in a sound-treated room (i.e., Control) and a room with low reverberation. This measure represents the functionality of their aided hearing. The relations between unaided HFPTA, aided HFPTA, and SR scores are not necessarily linear. However, participants with lower (i.e., better) aided HFPTAs demonstrated better speech recognition (e.g., A and C).

Performance on the ACD and VCD Tasks

Figure 2: Figure includes data from a previous related study investigating the relationship between selective attention and aging in children with HL and NH. ACD data for adults with HL revealed that subject C performed most similarly to normal hearing peers, followed by subject A. Subjects C and A had, respectively, the two lowest aided HFPTAs and highest SR scores in quiet, suggesting more robust access to the auditory stimuli of the task.

Figure 3: Figure includes data from a previous related study investigating the relationship between selective attention and aging in children with HL and NH. VCD data shows similar performance across all adults regardless of hearing status. As expected, adults with hearing loss were able to selectively attend to a target speech stream similarly to their peers with normal hearing.



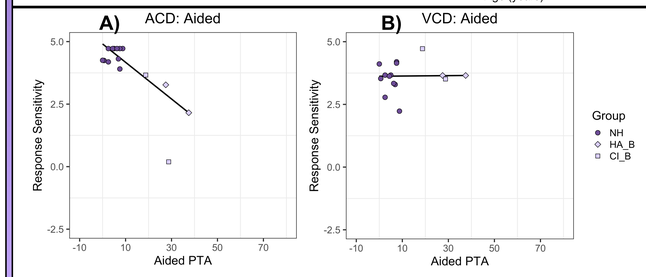


Figure 4: Correlations between participants' response sensitivity and aided HFPTA on the ACD (**A**) and VCD (**B**) task. Visual inspection of the figures revealed that adults who demonstrated poorer aided hearing sensitivity had greater difficulty selectively attending to the target stream during the auditory, but not visual change detection task. The difference in findings between the ACD and VCD tasks suggests that inadequate access to the auditory stimuli—rather than group differences in selective attention—may have driven performance in the auditory domain.

Summary & Conclusions

This was a preliminary study in which we did not have sufficient power to execute statistical analyses. Therefore we depended on visual inspection of the data to discuss some early findings:

- We observed differences in the adults' performance in the ACD task where adults with HL had more difficulty selectively attending to the target stream than NH adults. (**Figure 2**).
- All adults demonstrated similar ability to selectively attend to the target stream and inhibit the distractor stream in the VCD task. (**Figure 3**)
- With this limited data set, it is difficult to say whether adults with NH and HL are similarly able to selectively attend to a target stream. Performance on the ACD task in the present study appears to have been influenced by aided hearing sensitivity in adults with HL, which may have resulted in inadequate access to the stimuli's acoustic characteristics.
- Overall, the ability to selectively attend to the target stream and inhibit the distractor stream in both ACD and VCD tasks is seen to improve from childhood to adulthood. (**Figure 2 & 3**) This suggests that the developmental trajectory of selective attention is positive, but the present results do not indicate whether these attentional capabilities have matured enough in adults with HL to overcome deficits induced by hearing loss.
- **Figure 4** shows the relationship between aided hearing sensitivity and response sensitivity for each task. A relationship between audibility, measured by aided HFPTA, and response sensitivity is only seen in the ACD task. As audibility decreased, the participant demonstrated increased difficulty in selectively attending and responding to the target stream deviants over the distractor stream. Unexpectedly, no relationship between aided hearing sensitivity and performance is seen in VCD.
- Selective attention is a domain-general cognitive resource and, as such, was expected to be reflected similarly in performance across the ACD and VCD tasks. Based on the relations displayed in **Figure 4**, it is possible that the performance of adults with HL on the ACD task is more reflective of impaired audibility than their selective attention, per se.
- Ultimately, it can be concluded that audibility is a key component in the ability of adults with HL to selectively attend to a target stream and inhibit a distractor stream.

Future Directions

- Future research is needed to delineate these possibilities. Testing this phenomenon with adults with less severe hearing loss or with better aided hearing functionality would allow distinction between audibility and selective attention.
- Furthermore, using a larger sample size would allow for more quantitative conclusions to be drawn.

References

- Crandell, C. C., & Smaldino, J. J. (2000). Classroom Acoustics for Children With Normal Hearing and With Hearing Impairment. *Language, Speech, and Hearing Services in Schools*, *31*(4), 362–370.
- Leibold, L. J., & Buss, E. (2013). Children's identification of consonants in a speech-shaped noise or a two-talker masker. *Journal of Speech, Language, and Hearing Research*.
- Oberfeld, D., & Klöckner-Nowotny, F. (2016, August 31). Individual differences in selective attention predict speech identification at a cocktail party. *eLife Journal.*
- Ruggles, D., Shinn-Cunningham, B. Spatial Selective Auditory Attention in the Presence of Reverberant Energy: Individual Differences in Normal-Hearing Listeners. *JARO* **12,** 395–405 (2011).
- Shinn-Cunningham, B., Best, V., & Lee, A. K. (2017). Auditory object formation and selection. In The auditory system at the cocktail party (pp. 7-40). Springer, Cham.

Acknowledgments

- Shreya Sriram would like to thank the Northwestern Hearing and Language Lab for the support in data collection and guidance, especially from her mentors Dr. Tina Grieco-Calub and Kristi Ward and members of the lab, especially Natalie Sliskovich. Shreya is incredibly grateful for the opportunity to spearhead this related initiative and for the time and effort of the participants in this study. Lastly, Shreya would like to extend her gratitude to the Northwestern Office of Undergraduate Research for the chance to present her research.