VISUAL-AEROTACTILE PERCEPTION AND HEARING LOSS

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1 Introduction

Previous research on multimodal speech perception with hearing-impaired individuals has focused on audiovisual integration, with mixed results. Some evidence suggests cochlear-implant users integrate audiovisual cues better than perceivers with normal hearing when perceiving congruent [1] but not incongruent cross-modal cues [2], leading to the suggestion that early auditory exposure is required for typical speech integration processes to develop [3]. If a deficit of one modality leads to a general deficit in multimodal processing, then hard-of-hearing perceivers should show atypical patterns of integration in other modality pairings.

To test this, the current study builds on evidence that aerotactile information influences the perception of English stop consonants in normal hearing (NH) individuals. When perceiving auditory [4] or visual cues [5] to English stops, subjects are more likely to judge tokens as aspirated when they feel a simultaneous puff of air on the skin. These additional modality pairings (audio-aerotactile and visual-aerotactile) provide an opportunity to assess previous claims regarding the effects of impaired audition on sensory integration in speech perception. To better understand how individuals with hearing loss process multimodal information more generally, an integration task is required that does not rely on auditory input. Thus, a visual-aerotactile task such as that used by [5] is particularly well suited for hearing-impaired individuals who have normal perceptual experiences with both the visual and aerotactile modalities. If atypical auditory access in development leads to atypical integration processes across the board, then individuals with hearing loss should show different patterns of integration from individuals with typical hearing, regardless of the modality pairing.

2 Method

11 participants with hearing loss (HL) and 14 native English speakers with normal hearing (NH) were recruited from the Greater Vancouver area. The HL participants varied in the cause of hearing loss: 8 reported congenital hearing loss and the remaining 3 reported losing their hearing before the age of 10. The HL group further differed in the type of hearing loss. Nine HL participants reported sensorineural hearing loss, 1 participant reported mixed hearing loss, and 1 additional participant was unsure. Finally, participants varied in the severity of their hearing loss. Four participants reported profound hearing loss; 3 severe; 4 moderate; and 1 mild/moderate. All participants wore hearing aids and reported English as their principal communication method. No NH participants reported a history of speech or hearing issues.

Participants were seated in a sound-attenuated booth with their heads resting against a headrest and told they would feel puffs of air throughout the experiment. Participants completed a two-alternative forced-choice response task while listening to babble over headphones. During the task, participants were presented with 240 silent video clips of a male speaker producing the syllables /pa/ and /ba/. After each clip, participants used the keyboard to indicate what they thought the talker had said (i.e., /pa/ or a /ba/). Half of the clips were accompanied by a 100 ms duration puff of air directed at the participant's suprasternal notch (see [5] for details regarding the air flow apparatus and stimuli creation).

Following the perception task, HL participants completed both a language background questionnaire and a hearing history questionnaire. NH participants completed the language background questionnaire only.

3 Results

For both groups, participants showed increased accuracy for /pa/ tokens and decreased accuracy for /ba/ tokens during VT trials (Figure 1) – aerotactile cues facilitated aspirated syllable identification and interfered with unaspirated syllable identification. A generalized linear mixed effects model was fit by maximum likelihood using the lme4 [6] packaged in R [7]. Response served as the dependent variable; visual (/ba/ or /pa/), condition (visual-only or visual-tactile), group (HL or NH) and their interaction were fixed effects; and participant and a by-participant random slope for the interaction of visual, condition, and group were the random effects. The formula is as follows:

*Response ~ visual * condition * group + (1 + (visual * condition * group) | subject)*

To find the optimal model, model fitting was performed in a stepwise backward iterative way. The Akaike information criterion (AIC) was used to measure quality of fit. We found no significant difference of hearing group on response. In fact, the optimal model was one that excluded hearing group. Thus, the following results reflect a model that does not consider hearing ability. The model indicated that

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participants were most likely to respond correctly for /pa/ in a visual-tactile condition than all other conditions ($\beta = 1.95$, $SE = 0.49$, $z = 3.96$, $p < 0.001$) regardless of hearing group (see Figure 1). That is, aerotactile information facilitated identification of /pa/ for all participants.

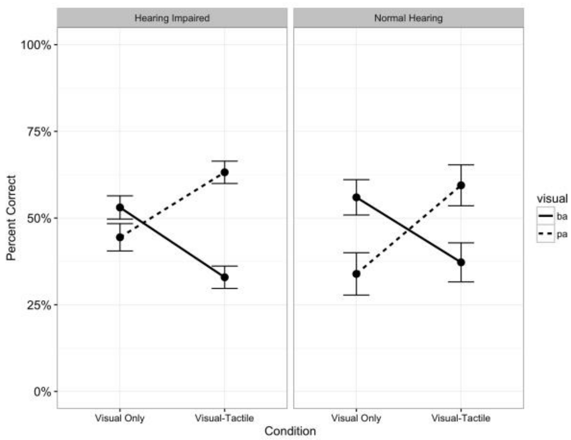

Figure 1: Percentage of correct responses in each condition (e.g., responding /ba/ when presented with a /ba/-visual cue). Accuracy for visual-only vs. visual-tactile conditions for both the hearing loss group (left) and the normal hearing group (right) are shown.

Given the high confusability between the articulations of /p/ and /b/, we predicted that participants would perform at chance at identifying the visual cues. However, both NH and HL participants were better at identifying /ba/ than /pa/ ($\beta = -0.75$, $SE = 0.3$, $z = -2.46$, $p = 0.01$), consistent with the ba-bias found in [5].

4 Discussion

This study investigated whether HL individuals show different multimodal integration patterns from NH perceivers during using a speech perception task without an auditory component. Our results show that HL participants are able to use aerotactile information when identifying visual bilabial articulations, demonstrating their ability to integrate cross-modal speech cues. More to the point, we found no significant difference between HL and NH individuals suggesting that reduced auditory access may not affect the development of typical speech integration processes. While we were unable to conduct in-house audiometry for each participant and therefore cannot make strong claims about what kind of acoustic information each participant would be exposed to, the strength and uniformity in the performance of the HL group in visual-tactile integration reaffirm that the development of multimodal integration processes is not contingent on hearing ability. This evidence that individuals with hearing loss have normal multimodal speech processing suggests that previous atypical performance at audiovisual integration tasks may be attributed to the degraded quality of audio input given their hearing loss and a subsequent reliance on visual cues.

However, there are some limitations to our study. The HL participants in this experiment may not be representative of previous research given that they differed greatly in hearing ability. Many had residual hearing and used hearing aids to communicate orally. This is a very different population from the cochlear implant users in previous research [1, 2, 3, 8, 9], who were mostly congenitally deaf individuals with profound hearing loss. It is possible that the residual hearing ability of the HL participants in the current study may provide enough auditory input for them to develop speech experiences similar to normal hearing participants. Given this variability, future directions should extend the research to the profoundly deaf.

5 Conclusion

The present study examined multimodal speech perception in individuals with hearing loss through a visual-tactile integration task. Results showed that participants used aerotactile stimuli as a cue to aspiration and integrated visual and aerotactile speech cues as in [5]. In addition, there were no differences in the integration pattern between normal hearing subjects and subjects with hearing loss suggesting that HL individuals can make use of the same visual and tactile cues to stop discrimination in English and have normal multimodal processing for speech information.

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References

[1] Rouger, J., Lagleyre, S., Fraysse, B., Deneve, S., Deguine, O., & Barone, P. (2007). Evidence that cochlear-implanted deaf patients are better multisensory integrators. *Proc. of the Nat. Acad. of Sci.*, *104*(17), 7295-7300.

[2] Rouger, J., Fraysse, B., Deguine, O., & Barone, P. (2008). McGurk effects in cochlear-implanted deaf subjects. *Brain research*, 1188, 87-99.

[3] Schorr, E. A., Fox, N. A., van Wassenhove, V., & Knudsen, E. I. (2005). Auditory-visual fusion in speech perception in children with cochlear implants. *Proc. of the Nat. Acad. of Sci.*, *102*(51), 18748-18750.

[4] Gick, B., & Derrick, D. (2009). Aero-tactile integration in speech perception. *Nature*, *462*(7272), 502-504.

[5] Bicevskis, K., Derrick, D., & Gick, B. (2016). Visual-tactile integration in speech perception: Evidence for modality neutral speech primitives. *JASA*, 140(5), 3531-3539.

[6] Bates, D., Maechler, M., Bolker, B., & Walker, S. (2015). Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software*, 67(1), 1-48. doi: <10.18637/jss.v067.i01>.

[7] R Core Team (2013). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. <http://www.R-project.org/>.

[8] Huyse, A., Berthommier, F., & Leybaert, J. (2013). Degradation of labial information modifies audiovisual speech perception in cochlear-implanted children. *Ear and hearing*, *34*(1), 110-121.

[9] Lane, H., & Perkell, J. S. (2005). Control of voice-onset time in the absence of hearing: a review. *Journal of Speech, Language, and Hearing Research*, *48*(6), 1334-1343.