

Visual Perception of Gravity: Effect on Speech Tongue Posture

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1 Introduction

Visual perception of gravity change may impact tongue posture during speech production. Shamei et al. [1] established that returning astronauts show compensatory postural behaviour of the speech articulators after extended exposure to microgravity. Previous studies [2] report anticipatory visual disturbances to induce compensatory postural behavior in the human body [3]. Furthermore, existing literature demonstrates that the magnitude of such postural responses is dependent on the velocity and direction of one's visual perception [4]. The existing literature provides insight into cross-modal experiments between body posture and visual perturbations; e.g., Assländer et al. [4] described the impact of visual perception on body posture balance in virtual reality (VR). However, there is a gap in research on speech posture. An earlier VR pilot study on tongue posture [5] found that posture significantly differed between visually perceived falling vs. rising, and levelled vs. rising gravitational conditions; however, there was inter-participant variation in the direction of tongue posture change with no generalizable directional change across participants.

The current study expands on Chernets et al's [3] preliminary findings by further using VR as a tool to observe tongue posture changes in an environment with altered gravitational visual input with a larger sample size and a refined virtual reality environment. This research investigates tongue posture in speech production during perceived gravity changes in an immersive VR plank-walk experience. Based on the limited existing literature [1], we predicted that visual perturbations from a VR environment may impact tongue height due to compensatory behaviour for the visual perception of gravity. We further anticipate the level of immersion to affect postural behavior.

2 Methods/Analysis

11 participants were recruited via UBC's Linguistics Outside the Classroom (LOC) SONA System. To control for confounding variables, criteria regarding experience with VR and heights were applied. One participant was omitted due to data collection issues. The remaining seven (6 females, 1 male) participants all had a basic history of VR experience and reportedly had no acrophobia.

Prior to the experiment, participants were shown an instructional video to maintain a consistent and replicable VR experience. Participants were fitted with an ultrasound probe headset, the VR headset and earbuds to listen to the stimuli. Ultrasound imaging was used to measure tongue posture changes during speech production while experiencing a VR plank-walk in gravitationally stable and

free-falling conditions. Using the stimulus audio track, participants were prompted to first complete one block of mouth breathing as they walked off the plank at the top of a skyscraper and following their revival to return to the elevator to restart the simulation. Participants then completed 3 separate blocks of speech production following the same instructions. The 3 speech blocks cued production of low back, high front, and low front vowels situated within real (e.g., "hot", "heave", and "hoot") and nonsense words (e.g., "hok", "heeb", and "hoob"). Following the VR experience, participants were asked to complete the Immersive Experience Questionnaire (IEQ) [6] to test for predicted correspondence between reported level of VR immersion and degree of tongue posture compensation, as well as for acoustic and articulatory analyses.

The articulatory analysis was conducted using the tongue tracing software DeepEdge [7], while the acoustic analysis was completed using a Praat Autotrack Formants script. The articulatory and acoustic data were unified and visualized using R [8].

3 Results

Figure 1 presents the tongue contours for each of the three vowels for both level and falling conditions. The x-axis shows the tongue frontness (within-speaker z-score values) of the tongue in the oral cavity (positive values indicate a fronter position) while the y-axis indicates the vertical position of the tongue. The lines in the figure represent contours smoothed across all speakers using the loess method (`geom_smooth()` in R) [8]. The shades around the lines indicate 95% confidence intervals.

As Figure 1 indicates, the production for the vowel /a/ (AH) shows the largest difference in tongue body contour between the falling and level conditions, with the two contours being slightly, but consistently different in the front of the tongue. For vowel /i/ (EE), the height of the tongue middle was slightly lower, with no difference in the root and blade; there was no indication of differences for /u/ (OO) vowel.

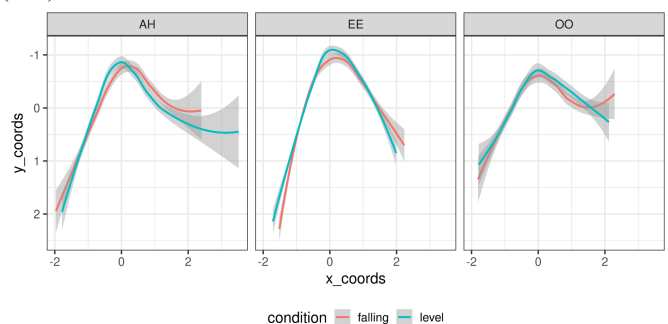


Figure 1: Falling vs. level tongue contours for target vowels

The results in Figure 2 further indicate that there are no significant differences for all of the elicited words between the level and falling conditions. However, similar to the leftmost graph in Figure 1—the “AH” vowel—“hok” and “hot” show some tongue body posture variation between the falling and level conditions with the tongue height being slightly lower and slightly higher, respectively. Further, the word “heave” exhibits a lower tongue body height for the falling condition in comparison to the level.

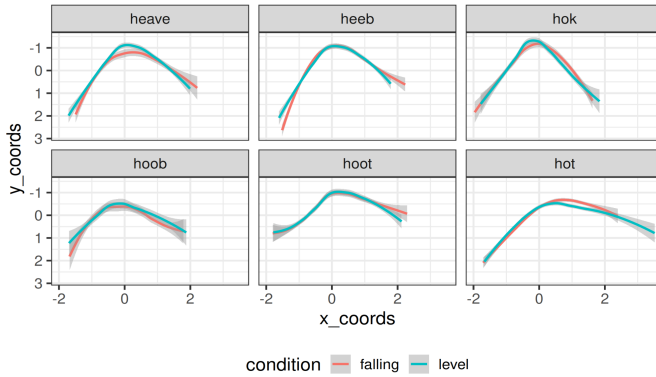


Figure 2: Falling vs. level tongue contours for target words

In order to investigate the role of VR immersion in the effect of visual perception of gravity, the IEQ scores were filtered for the immersion factor of cognitive involvement. 4 participants had a high level of immersion and the other 3 had a low level of immersion. Figure 4 illustrates the tongue contours of the participants who scored at a high level of immersion. These results indicate a lowered tongue body for the falling condition for /a/ and /i/ and vice versa for /u/.

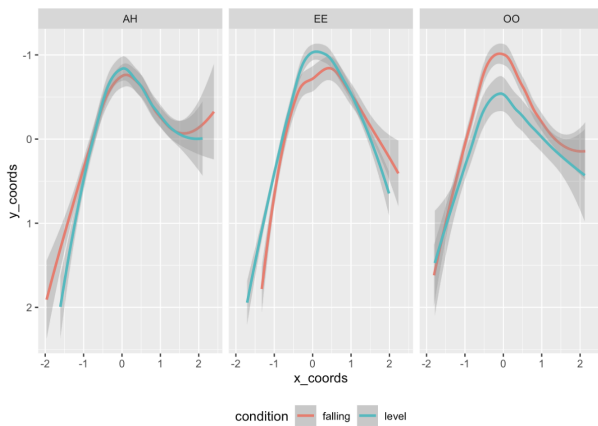


Figure 3: Tongue contours plotted for participants reporting a high level of immersion.

4 Discussion and Conclusion

While visual perturbations of perceived gravity (falling vs. level) produced only subtle and inconsistent changes in group-averaged tongue contours for target vowels and words, the pattern aligns with prior observations of high inter-participant variability [5]. It is evident that each

participant, when compared against themselves as a baseline for the level condition, shows large differences in tongue body posture between the two conditions, and that the direction of tongue posture differences varies greatly across participants, indicating varied speaker-specific strategies.

The IEQ results provided insight into a potential explanation for the previously observed high degree of inter-participant variability. Figure 4 shows a clear difference between the falling and level conditions for the vowel /u/ in the rightmost graph. This may be representative of compensatory behaviour of the tongue posture as a response to the visual perception of gravity. The highly immersed participants may have visually perceived the force of gravity as they fell and raised their tongue bodies in compensation. The tongue contours of the participants that reported a low level of immersion showed little variability between the target vowels and words.

To expand upon these findings, further investigation with a larger sample of participants would aid in establishing whether the effects of visual perception of gravity on tongue posture are generalizable to the tongue.

Acknowledgments

This project was funded by an NSERC Discovery grant. We would like to acknowledge the contributions to data collection from Zoë Cheng and Tiana Ho.

References

- [1] Shamei, A., Sósokuthy, M., Stavness, I., & Gick, B. (2023). Postural adaptation to microgravity underlies fine motor impairment in astronauts' speech. *Scientific Reports*, 13(1), 8231-8231. <https://doi.org/10.1038/s41598-023-34854-w>
- [2] Chander, H., Kodithuwakku Arachchige, Sachini N K, Hill, C. M., Turner, A. J., Deb, S., Shojaei, A., Hudson, C., Knight, A. C., & Carruth, D. W. (2019). Virtual-reality-induced visual perturbations impact postural control system behavior. *Behavioral Sciences*, 9(11), 113. <https://doi.org/10.3390/bs9110113>
- [3] Phillips, D., dos Santos, F. V., & Santoso, M. (2022). Sudden visual perturbations induce postural responses in a virtual reality environment. *Theoretical Issues in Ergonomics Science*, 23(1), 25-37. <https://doi.org/10.1080/1463922X.2020.1870052>
- [4] Assländer, L., Albrecht, M., Diehl, M., Missen, K. J., Carpenter, M. G., & Streuber, S. (2023). Estimation of the visual contribution to standing balance using virtual reality. *Scientific Reports*, 13(1), 2594-2594. <https://doi.org/10.1038/s41598-023-29713-7>
- [5] Chernets, M., Hong, A., Wong, V., Ferguson, A. S., Islam, J., Liu, Y., & Gick, B. (2024). Effects of visual perception of gravity on tongue posture. *The Journal of the Acoustical Society of America*, 156(4_Supplement), A49-A49.
- [6] Jennett, C., Cox, A. L., Cairns, P., Dhoparee, S., Epps, A., Tijs, T., & Walton, A. (2008). Measuring and defining the experience of immersion in games. *International journal of human-computer studies*, 66(9), 641-661.
- [7] Yamansavaschilar, B., Baktir, A. C., Sonmez, C., Ozgovde, A., Ersoy, C. (2022). DeepEdge: A deep reinforcement learning based task orchestrator for edge computing. *Transactions on Network Science and Engineering*, 10(1), 538-552. <https://doi.org/10.1109/TNSE.2022.3217311>
- [8] R Core Team (2025). R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Austria. <https://www.R-project.org/>.