# REGISTER SHIFTS IN WHISTLING: INVESTIGATING THE INFLUENCE OF TONGUE SHAPE

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## 1. Introduction

Whistling relies on the modulation of airflow through the oral cavity. This interplay between airflow and the constriction size contributes to whistle production, resulting in an increase in pitch as the tongue moves anteriorly [1]. rtMRI imaging from previous studies suggests that tongue differentiation, indicated by movement between two degrees of freedom [2], occurs at the higher frequencies of an individual's range [3]. Differentiated tongue shapes are observed in sounds such as the English /ɹ/ [4], and in certain types of throat singing [5]. However, the presence of register shifting, which has been explored in singing [6], remains unknown for whistling. This study aims to examine the existence of register shifts as indicated by specific tongue shapes during whistling, as well as their relation to wide whistling ranges. We hypothesize that participants with larger whistling ranges will demonstrate register shifts indicated by differentiated tongue shapes.

## 2. Method

### 2.1. Participants

The study analyzed 11 participants selected through convenience sampling from the University of British Columbia, all with varying linguistic backgrounds. Of these participants, 2 of the 11 were authors of this paper. All of the individuals participating in the study had experience in music theory and were capable of whistling a minimum of one octave.

### 2.2. Procedures

Ultrasound imaging was used to obtain and observe tongue shaping and movement during four distinct whistling tasks. An ophthalmic examination chair was used alongside a Sonosite Titan ultrasound machine to ensure a standard midsagittal probe placement and full dorsal tongue view across all participants. Audio was captured through the use of a microphone simultaneous with the ultrasound video.

Tasks one and two consisted of participants whistling a continuous siren, and then a chromatic scale beginning at their lowest possible note, up to their highest note and back down. Tasks three and four involved /ɹ/ production in both casual speech, as in the Rainbow Passage [7], and formal speech, as in a minimal pair list of various /ɹ/ sounds.

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### 2.3. Analysis

Audio of one continuous siren from each participant was input into Praat [8] for frequency analysis and used for semitone identification. Every semitone identified in a participant's range was timestamped and aligned with the corresponding frame in VLC [9]. Each semitone image was then compiled into an image stack for each participant's individual range. The image stacks from each participant were imported into GIMP [10], where the upper (dorsal) edge of the tongue in every second semitone was traced and overlaid.

## 3. Results

Figure 1 demonstrates the individual range of each participant, with color-coded semitones, according to the key. Figure 1 illustrates the individual range of each participant with the specific semitones from within their range, colour-matched according to the key.

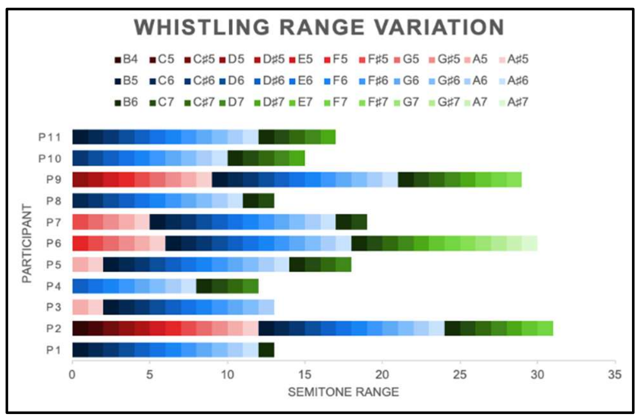


**Figure 1**: Total Whistling Range Variation

Figure 2 presents overlaid images of the tongue shape of participants exhibiting ranges from one octave (12 semitones) to greater than two octaves (>24 semitones). The x-axis demonstrates the distance on the tongue surface from the posterior side towards the anterior side, while the y-axis represents variation in the tongue's dorsal surface.

Images a-h, illustrate participants with ranges less than two octaves (<24 semitones), show a lack of significant alteration in tongue shapes, illustrating no identifiable manipulation of both degrees of freedom, indicating that no register shift occurred. Participants with ranges greater than 2 octaves (>24 semitones), images i-k, demonstrated a range spanning within B4 to A#7, and a shift between G6-A6. Participants 6 and 9 (images j and k) exhibited a distinctive shift in tongue shaping during whistling, a phenomenon not observed in the preceding images. Both individuals transitioned from their initial undifferentiated tongue shape to the bunched differentiated shape [4]. P2 (image i), who displayed the largest whistling range, demonstrated a significant register shift in the constriction location, albeit with less pronounced changes in tongue shape differentiation. Thus, while all of the greater than two-octave whistlers show a register shift, the complexity of tongue shape does not consistently accompany this transition.

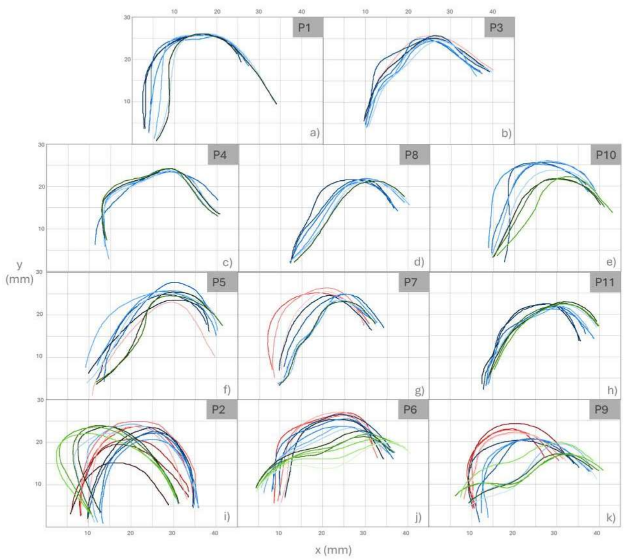


**Figure 2**: Overlayed images of all participants.

## 4. Conclusion

The results of this study demonstrate insight into pitch variation during whistling tasks. The differentiation of patterning was revealed by grouping participants according to their whistling ranges: less than two octaves or greater than two octaves, with each individual displaying varied degrees of tongue movement. Participants with wider whistling ranges exhibited greater and varied tongue shapes and constriction locations, suggesting a relationship between the ability to manipulate degrees of freedom in tongue movement to expand whistling range. Future studies could further examine broader ranges of language backgrounds.


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## References


[1] Shadle, C. H. (1983). Experiments on the acoustics of whistling. *Phys. Teach.* 21, 148-154. https://doi.org/10.1119/1.2341241

[2] Belyk, M., Schultz, B. G., Correia, J., Beal, D. S., & Kotz, S. A. (2019). Whistling shares a common tongue with speech: Bioacoustics from real-time MRI of the human vocal tract. *Proceedings of the Royal Society B: Biological Sciences,* 286(1911), 20191116. https://doi.org/10.1098/rspb.2019.1116

[3] Kaburagi, T., Shimizu, T., & Uezu, Y. (2018). A morphological and acoustic analysis of the vocal tract during the Act of Whistling. *Acoustical Science and Technology, 39*(3), 198–206. https://doi.org/10.1250/ast.39.198

[4] Delattre, P. & Freeman, D. (1968). A Dialect Study Of American R's By X-Ray Motion Picture. *Linguistics*, 6(44), 29-68. https://doi.org/10.1515/ling.1968.6.44.29

[5] Bergevin, C., Narayan, C., Williams, J., Mhatre, N., Steeves, J. K., Bernstein, J. G., & Story, B. (2020). Overtone focusing in biphonic tuvan throat singing. *eLife, 9*, e50476. https://doi.org/10.7554/eLife.50476

[6] Bengtson, G., Massing, E., Zhao, C., Samarskaya, M., Islam, J., & Gick, B. (2023). Tongue Adjustments in the Chest-Head Register Transition of Operatic Singers. *Canadian Acoustics*, *51*(3), 216–217.

[7] Fairbanks, G. (1960). *Voice and articulation drillbook* (2nd ed.). Harper & Row.

[8] Boersma, Paul & Weenink, David (2024). *Praat: doing phonetics by compute*r [Computer Program]. Version 6.4.11, retrieved from http://www.praat.org/

[9] VideoLan. (2006). *VLC media player* (3.0.20). https://www.videolan.org/vlc/index.html

[10] The GIMP Development Team. (2019). *GIMP: GNU Image Manipulation Program* (2.10.36). https://www.gimp.org