

Reduced Acoustic Contrasts of Speech Productions from Mandarin-speaking Adults with Prelingual and Postlingual Deafness

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Cochlear implants (CIs) help listeners with severe hearing loss restore hearing and gain oral speech production abilities. However, since CI devices cannot effectively transmit fine-grained speech frequencies, auditory feedback provided by CIs is largely degraded, leading to atypical speech production. Relative to children with normal hearing (NH), Mandarin-speaking children with CIs exhibit reduced vowel space [1], shortened voice onset time (VOT) for aspirated stops [2], and flattened tone contours [3]. While such deficits have been well documented in children, little is known about Mandarin-speaking adults with CIs. Unlike children with CIs who are mostly prelingually deafened (deafened before language acquisition), adults with CIs include both prelingually and postlingually deafened individuals. However, it remains unclear whether Mandarin-speaking adults with CIs exhibit similar deficits to those observed in children and whether these deficits differ by deafness onset.

Therefore, this study examined speech production from prelingually and postlingually deafened Mandarin-speaking adults with CIs, focusing on vowel, stop consonant, and tone production. Based on previous findings, we predicted that both prelingual and postlingual CI groups would demonstrate smaller vowel space, reduced aspiration contrasts, and flatter tone contours compared to NH adults, with greater deficits particularly for the prelingual CI group.

Seventeen Mandarin-speaking adults with CIs (6 prelingual: mean age = 31.50 years, mean deafness onset age = 1.83 years, mean implantation age = 31.00 years; 11 postlingual: mean age = 48.36 years, mean deafness onset age = 29.18 years, mean implantation age = 48.00 years) and 14 NH controls (mean age = 40.71 years) participated in this study. To elicit three corner vowels /a, i, u/, six stops /p, p^h, t, t^h, k, k^h/, and four lexical tones (T1-T4), 27 Mandarin monosyllables were selected as the stimuli, including (1) 15 syllables consisting of six stops /p, p^h, t, t^h, k, k^h/ and three vowels /a, i, u/, all in T1; (2) 12 syllables with the stop /t/ paired with vowels /a, i, u/ across all four tones. Each syllable was produced three times by each participant. F1 and F2 of vowels, VOT of stops, and F0 of vowel portions were extracted to analyze vowels, stop consonants, and tones respectively. To normalize individual differences in articulation rate, VOT was analyzed as a ratio relative to syllable duration.

Vowel analysis showed that the prelingual CI group exhibited significantly smaller vowel space than the NH group, while the postlingual CI group showed intermediate values that did not differ from either group (Fig. 1a). Furthermore, relative to the NH group, both CI groups showed lower F1 for /a/ and lower F2 for /i/ (Fig. 1b). **Consonant analysis** demonstrated that all three groups showed expected VOT contrasts (Fig. 2). However, both CI groups produced significantly shorter VOT ratios for aspirated stops than NH adults. **Tonal analysis** revealed that both CI groups showed flatter T3 contours than the NH group, with no difference between the two CI groups (Fig. 3). Additionally, prelingually deafened adults exhibited a less rising contour for T2 and a less falling contour for T4 compared to both the NH and postlingual CI groups. No group differences were found for T1.

Our findings indicate that Mandarin-speaking adults with CIs demonstrate reduced acoustic contrasts in speech production, including smaller vowel space, reduced aspiration contrasts, and flatter tone contours (except for T1). While postlingually deafened adults showed deficits in vowel space and aspiration contrasts, their tone production remained largely intact except for T3. In contrast, prelingually deafened adults exhibited significantly greater deficits than postlingually deafened adults, particularly in tone production, suggesting that tone production relies heavily on early auditory experience. These findings highlight the importance of targeted speech rehabilitation for Mandarin-speaking CI users.

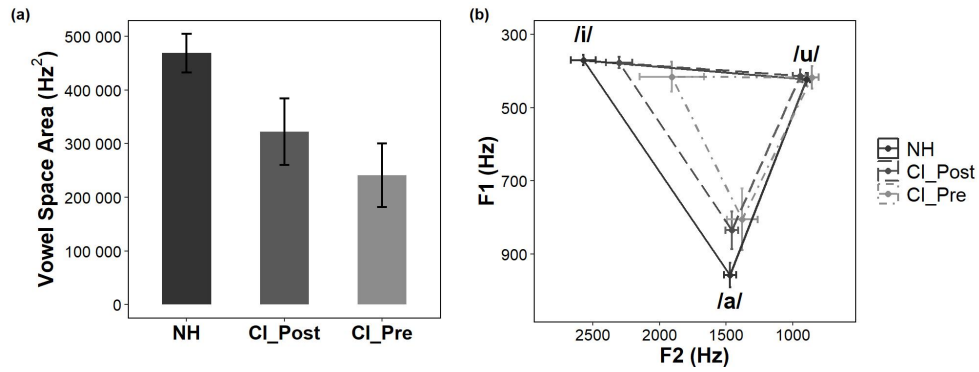


Fig. 1. (a) Vowel space area and (b) vowel space formed by /a, i, u/ in NH, postlingually deafened CI (CI_Post) and prelingually deafened CI (CI_Pre) groups.

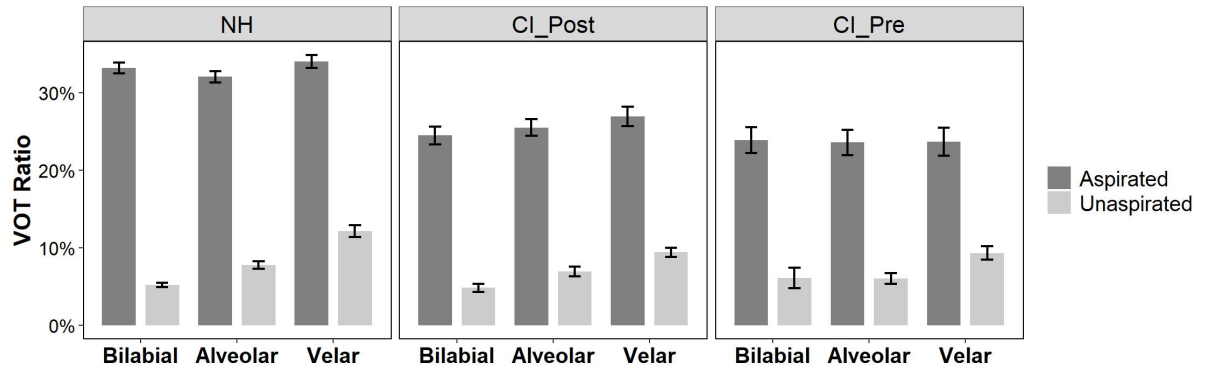


Fig. 2. VOT ratio (VOT/syllable duration) for stops across place and manner of articulation in NH adults and postlingually and prelingually deafened adults with CIs.

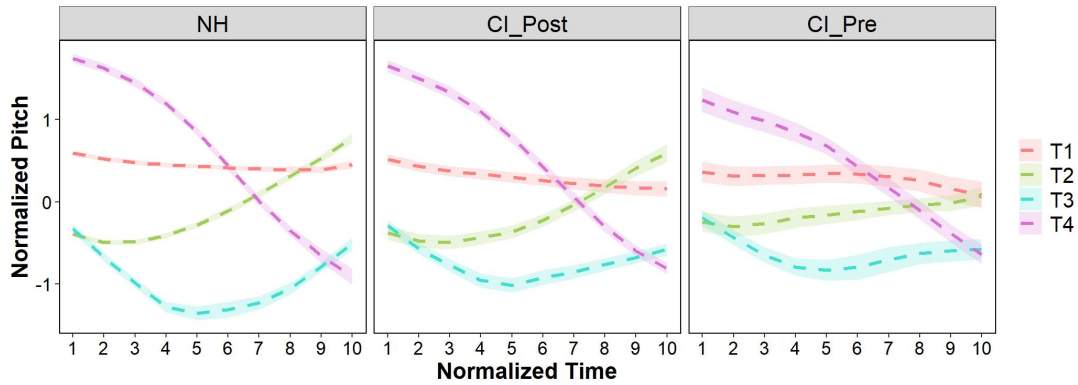


Fig. 3. Normalized lexical tone pitch contours in NH adults and postlingually and prelingually deafened adults with CIs.

References

- [1] Yang, J., Brown, E., Fox, R. A., & Xu, L. (2015). Acoustic properties of vowel production in prelingually deafened Mandarin-speaking children with cochlear implants. *The Journal of the Acoustical Society of America*, 138(5), 2791-2799.
- [2] Yue, J & Xia, X. (2019) Production of Mandarin stop consonants in prelingually deaf children with cochlear implants. *Proceeding of International Congress of Phonetic Sciences*, 3115-3119.
- [3] Tang, P., Yuen, I., Xu Rattanasone, N., Gao, L., & Demuth, K. (2019). The acquisition of Mandarin tonal processes by children with cochlear implants. *Journal of Speech, Language, and Hearing Research*, 62(5), 1309-1325.