

Acoustic and articulatory Correlates of lexical-stress in Mandarin accented English

Boram Kim

The Graduate Center, CUNY, Haskins Laboratories

There is ample evidence that second language (L2) English learners have difficulty with both phonological (Archibald, 1997; Backman, 1979; Broselow, 1988; Broselow, Hurtig, & Ringen, 1987; Grosser, 1993; Guion, 2005; Wenk, 1985; Willems, 1982) as well as phonetic aspects of English prosody and intonation (Adams & Munro, 1978; Barlow, 1998; Flege & Bohn, 1989; Flege & Hillenbrand, 1984; Fokes & Bond, 1989; Graham & Post, 2018; Grosser, 1993; Mennen, 2004; Ueyama, 2000). Few studies, however, have investigated the articulatory kinematics of non-native English in relation to prosodic factors. Therefore, we aim to study the articulatory correlate of the lexical stress condition in the English vowels produced by Mandarin learners of English. In American English, both tense-lax contrast and lexical stress are realized in spectral as well as temporal domains. Tense vowels are articulated in more extreme outer locations of the vocal tract than lax vowels, whereas lax vowels are articulated closer to the center of the vocal tract. Tense vowels also feature longer vowel durations than do lax vowels (Ladefoged, 2005; Ladefoged & Maddieson, 1996). English vowels associated with lexically-prominent (i.e. stressed) syllable features enhanced spectral and temporal information relative to the vowels that belong to lexically not prominent syllables (Cambier-Langeveld & Turk, 1999; Cole et al., 2010; Kochanski et al., 2005; Sluijter & Van Heuven, 1996). According to the Perceptual Assimilation Model (PAM), Mandarin speakers would merge English tense-lax vowel pair into a single category, resulting in assimilation in the spectral domain. Moreover, previous studies showed L2 Mandarin speakers' production of spectral cues lags considerably behind their mastery of the temporal cues (Chen, 2006; Jiang, 2008; Lin & Wang, 2001). Thus, we hypothesize that the Mandarin speaker retains the tense-lax contrast that are modulated by lexical stress condition in a temporal domain.

To test this hypothesis, the data was drawn from a Mandarin Accented English-Electromagnetic Articulography Corpus (Ji et al., 2014). It contains time-synchronous acoustic and articulatory-kinematic data, collected from native English speakers and Mandarin learners of English. The target vowels with and without lexical-prominence were selected from the subset of the corpus. Acoustic (spectral and temporal information) and articulatory (horizontal and vertical tongue tip and tongue body location) data of the target vowels were analyzed. The analysis relied upon the linear-mixed effect model and pairwise comparison for posthoc analysis. The model was built including Group (L1 vs L2) and Vowels as predicting factors with random intercept by the speaker. The results revealed that L1 speakers used both temporal and spectral cues to distinguish the tense-lax pair, regardless of stress conditions. The tense vowels were longer than the lax vowel in both stress conditions ($p < .01$). Two vowels were separated more clearly with a smaller overlap in the stressed condition than in the unstressed condition in articulatory and acoustic domains. On the other hand, L2 speakers used only temporal cues distinctively for the tense-lax pairs in both stress conditions ($p < .01$). The spectral cues of the tense and lax vowels were similar to each other showing a large overlap. In particular, the TT gestures (Fig. 1) of /i/ and /ɪ/ were more overlapped in the stressed condition (70%) than in the unstressed condition (61%). We describe additional details that we found from acoustic and articulatory results of other vowel categories.

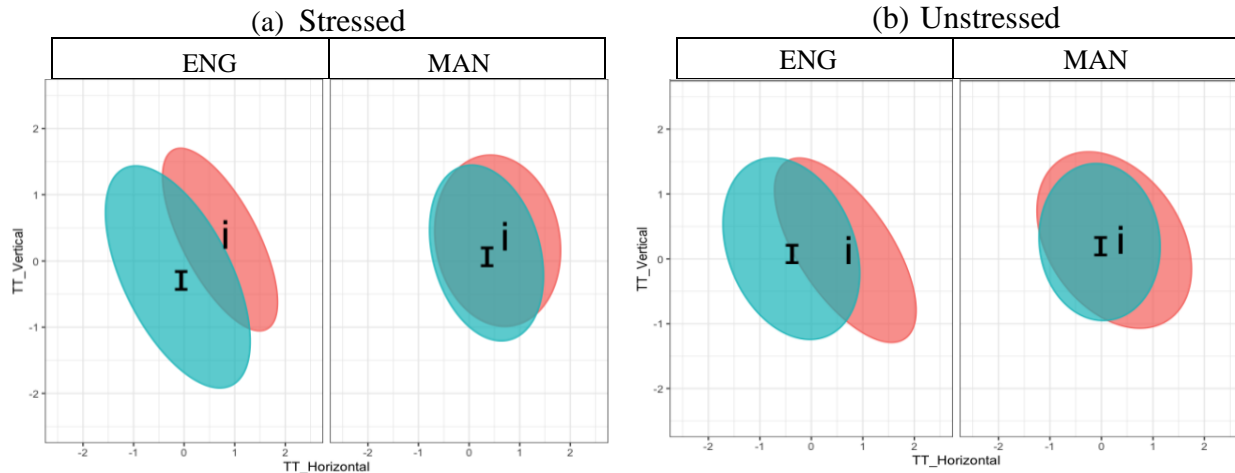


Figure 1. TT gesture of /i/ in red and /ɪ/ in green modulated by lexical stress.

- Adams, C. (1979). *English speech rhythm and the foreign learner*. Walter de Gruyter.
- Adams, C., & Munro, R. R. (1978). In search of the acoustic correlates of stress: Fundamental frequency, amplitude, and duration in the connected utterance of some native and non-native speakers of English. *Phonetica*, 35(3), 125–156.
- Andrews, G. C. (1985). *English Stress rules in Adult Second Language Acquisition*.
- Archibald, J. (1997). The acquisition of second language phrasal stress: A pilot study. *Language Acquisition and Language Disorders*, 16, 263–290.
- Backman, N. (1979). Intonation errors in second-language pronunciation of eight Spanish-speaking adults learning English. *Interlanguage Studies Bulletin*, 239–265.
- Barlow, J. S. (1998). *Intonation and Second Language Acquisition: A study of the acquisition of English intonation by speakers of other languages* [PhD Thesis]. University of Hull.
- Broselow, E. (1988). Prosodic phonology and the acquisition of a second language. In *Linguistic theory in second language acquisition* (pp. 295–308). Springer.
- Broselow, E., Hurtig, R. R., & Ringen, C. (1987). The perception of second language prosody. *Interlanguage Phonology: The Acquisition of a Second Language Sound System*, 350–361.
- Cambier-Langeveld, T., & Turk, A. E. (1999). A cross-linguistic study of accentual lengthening: Dutch vs. English. *Journal of Phonetics*, 27(3), 255–280.
- Chen, Y. (2006). Production of Tense-Lax Contrast by Mandarin Speakers of English. *Folia Phoniatica et Logopaedica*, 58(4), 240–249. <https://doi.org/10.1159/000093181>
- Cole, J., Mo, Y., & Hasegawa-Johnson, M. (2010). Signal-based and expectation-based factors in the perception of prosodic prominence. *Laboratory Phonology*, 1(2), 425–452. <https://doi.org/10.1515/labphon.2010.022>
- Flège, J. E., & Bohn, O.-S. (1989). An instrumental study of vowel reduction and stress placement in Spanish-accented English. *Studies in Second Language Acquisition*, 11(1), 35–62.
- Flège, J. E., & Hillenbrand, J. (1984). Limits on phonetic accuracy in foreign language speech production. *The Journal of the Acoustical Society of America*, 76(3), 708–721.
- Fokes, J., & Bond, Z. S. (1989). The vowels of stressed and unstressed syllables in nonnative English. *Language Learning*, 39(3), 341–373.
- Graham, C., & Post, B. (2018). Second language acquisition of intonation: Peak alignment in American English. *Journal of Phonetics*, 66, 1–14.
- Grosser, W. (1993). Aspects of intonation L2 acquisition. *Current Issues in European Second Language Acquisition Research*, 378, 81.
- Guion, S. G. (2005). Knowledge of English word stress patterns in early and late Korean-English bilinguals. *Studies in Second Language Acquisition*, 27(4), 503–533.
- Ji, A., Berry, J., & Johnson, M. T. (2014). *The Electromagnetic Articulography Mandarin Accented English (EMA-MAE) corpus of acoustic and 3D articulatory kinematic data*. 7719–7723.
- Jiang, H. (2008). *Effect of L2 phonetic learning on L1 vowels*. Dept. of Linguistics-Simon Fraser University.
- Kochanski, G., Grabe, E., Coleman, J., & Rosner, B. (2005). Loudness predicts prominence: Fundamental frequency lends little. *The Journal of the Acoustical Society of America*, 118(2), 1038–1054. <https://doi.org/10.1121/1.1923349>
- Ladefoged, P. (2005). *Vowels and Consonants*.
- Ladefoged, P., & Maddieson, I. (1996). *The sounds of the world's languages* (Vol. 1012). Blackwell Oxford.
- Lin, T., & Wang, L. (2001). *Yuyinxue Jiaocheng (A course in phonetics)*. Daxue Chubanshe (Peking University Press).
- Mennen, I. (2004). Bi-directional interference in the intonation of Dutch speakers of Greek. *Journal of Phonetics*, 32(4), 543–563.
- Sluijter, A. M., & Van Heuven, V. J. (1996). Spectral balance as an acoustic correlate of linguistic stress. *The Journal of the Acoustical Society of America*, 100(4), 2471–2485.
- Ueyama, M. (2000). *Prosodic transfer: An acoustic study of L2 English vs. L2 Japanese*, PhD diss, University of California. [PhD dissertation]. University of California, Los Angeles.
- Wenk, B. J. (1985). Speech rhythms in second language acquisition. *Language and Speech*, 28(2), 157–175.
- Wennerstrom, A. (1998). Intonation as cohesion in academic discourse: A study of Chinese speakers of English. *Studies in Second Language Acquisition*, 20(1), 1–25.
- Willems, N. (1982). *English intonation from a Dutch point of view: An experimental-Phonetic investigation of English intonation produced by Dutch native speakers*. author.