Can speech rate transfer between languages? Evidence from Japanese and Mandarin Chinese

Zhiqiang Zhu, Peggy Pik Ki Mok

The Chinese University of Hong Kong

zhiqiangzhu@link.cuhk.edu.hk, peggymok@cuhk.edu.hk

Abstract

Whether speech rate can transfer between languages with distinctive speech rates is an understudied issue. Impressionistically, Japanese is faster than Mandarin Chinese. We investigated the speech rate of native Japanese and Mandarin speakers, advanced L2 learners and simultaneous bilinguals respectively. Nine native Beijing Mandarin speakers, five native Japanese speakers, thirteen advanced L1 Japanese learners of Mandarin and eleven Japanese-Mandarin simultaneous bilinguals participated in a passage reading task and a spontaneous speech task. The comparison between Japanese and Mandarin by native Mandarin speakers and native Japanese speakers confirmed that the speech rate of native Japanese was faster than that of Mandarin. Comparison between the speech rate of Japanese and Mandarin by advanced Japanese learners and simultaneous bilinguals showed that both groups produced Japanese constantly faster than their Mandarin. Both advanced Japanese learners and simultaneous bilinguals produced Japanese similarly as native Japanese speakers did. However, the Mandarin speech rate by advanced Japanese learners was significantly slower than that of native Mandarin speakers, while the Mandarin speech rate between simultaneous bilinguals and native Mandarin speakers remained non-significant. The findings challenge previous proposals that speech rate transfer could happen at a language level. Moreover, simultaneous bilinguals showed an advantage over advanced L2 learners in speech rate mastery.

Index Terms: speech rate, prosody acquisition, Japanese and Mandarin, simultaneous bilingual

1. Introduction

In L2 speech prosody acquisition, speech rate is one of the most important measures of oral fluency as well as a very strong cue of perceived fluency [1,2]. For nonnative speakers, more fluent speakers are perceived as more proficient [3]. Many factors are influencing the learner's speech rate in a foreign language, including linguistic factors like context and genre [4] as well as non-linguistic factors like gender [5], age [6], working memory [7], and the nature of the task [8,9]. One of the interesting factors that this study is particularly concerned about is the nature of the learner's L1.

Past studies have shown that the difference in speech rate between native and non-native languages may depend on the nature of L1, and there is an interaction between the speech rate of languages [10, 11]. There is a strong relationship between L1 and L2 temporal fluency production for language learners. Speakers with a faster speech rate in their L1 will likely speak faster in their L2, or vice versa [12,13]. To investigate the fluency of the nonnative learners, both L1 and L2 should be analyzed temporally [14]. To investigate these claims, this study examined the speech rate interactions between Japanese and Mandarin of several groups of speakers.

Japanese often gives the impression of having a fast speech rate. To our knowledge, no direct comparison between the speech rates of Mandarin and Japanese has been done in the literature. However, the average speech rates of Japanese and Mandarin have been separately reported. Table 1 lists the average speech rate of the two languages.

Table 1 *Average speech rates of Mandarin Chinese and Japanese in previous literature.*

Language	Speech rate	Task	Literature source
Mandarin Chinese	284 syllables/min (4.73 syllables/s)	Speech	Wu (1980) [15]
	301 syllables/min (5.01 syllables/s)	Reading	Eady (1982) [16]
Japanese	6.584 syllable/s	Reading	Nishio et al (2006) [17]
	8.01 morae/s for Speech, 7.11 morae/s for Reading		Maekawa (2003) [18]

According to the speech rates data in Table 1, it is very obvious that the speech rate in Japanese is faster than that in Mandarin. The comparison of speech rates between Japanese and Mandarin could offer an ideal example to investigate speech rate interactions between languages. First, the syllable structures between Japanese and Mandarin are very similar, with the "CV" and "CVN" patterns being the dominant syllable structure, and both languages do not have consonant clusters [19,20,21]. Second, Mandarin is a tone language while Japanese is not, the implementation of tones into syllables may take more time. Third, Japanese and Mandarin belong to different rhythmic groups. Japanese is classified as mora-timed, while Mandarin is classified as syllable-timed [22]. The mora-timed Japanese is reported to have an even higher proportion of CV syllables than syllable-timed languages [23]. Moreover, vowel reduction processes are commonly found in Japanese [24,25], therefore, we hypothesized that the inherent syllable duration of Japanese would be shorter than that of Mandarin, i.e., the speech rate in Japanese would be faster than in Mandarin. The comparison of speech rates between Japanese and Mandarin would help to see the effects of language typological differences on speech rates.

Another focus of this study is the comparison of speech rates between early language learners (simultaneous bilingual, SB speakers) and late language learners (advanced Japanese, AJ speakers). Many past studies have shown that L2 learners tend to speak at a slower speech rate compared to native speakers [26]. However, very few studies have been done on the speech rate by simultaneous bilingual speakers. Simultaneous

bilinguals are bilingual speakers whose two languages were present from an early age, and they are reported to have a good mastery of the phonological systems of both languages [27]. The comparison of speech rates between the SB and the AJ groups could shed light on how early and late language learners differ in terms of speech rates between languages. In this study, speech rate transfer happens if a) the SB speakers or the AJ speakers transfer their slower speech rate of Mandarin into Japanese, i.e., they produced Japanese significantly slower than that of native Japanese speakers, or b) the SB speakers or the AJ speakers transfer their faster speech rate of Japanese into Mandarin, i.e., they produced Mandarin significantly faster than native Mandarin speakers did. Based on the previous findings of the L1-L2 interaction, we predicted that speech rate transfer could happen between Japanese and Mandarin.

2. Method

2.1. Participants

This study consists of four groups: 9 native Beijing Mandarin speakers (NM speakers), 5 native Japanese speakers (NJ speakers), 13 advanced L1 Japanese learners of Mandarin (AJ speakers) and 7 Japanese-Mandarin simultaneous bilinguals (SB speakers). Details of the participants are listed in Table 2.

Table 2: *Information of participants*

Group of speakers	Details
Advanced L1 Japanese speakers (AJ speakers)	13 participants (3 males, mean age=32.5, SD=7.19), > 1-year immersion in Beijing and with HSK-6 level.
Japanese-Mandarin simultaneous bilingual speakers (SB speakers)	11 participants (7 males, mean age=22.6, SD=3.17). Four of them were born in China, seven were born in Japan. All of them were exposed to both Japanese and Mandarin from an early age with their mothers being native Mandarin speakers. All with HSK-6 level.
Native Beijing Mandarin speakers (NM speakers)	9 participants (1 male, mean age=21, SD=2.06). All of them were born and raised in Beijing.
Native Japanese speakers (NJ speakers)	5 participants (1 male, mean age=29.4, SD=2.49). All of them were born and raised in Japan, with very limited knowledge of Mandarin.

It is notable that, for the AJ speakers, they were classified as "advanced" by two main criteria: they must have over one-year immersion in Beijing and they have passed the HSK-6 test, which is the highest level for Mandarin learners. The SB learners are early bilinguals of both Japanese and Mandarin, because at least one of the SB speakers' parents was a native Mandarin speaker. The SB learners were exposed to both Japanese and Mandarin from an early age. However, the SB speakers may have different language dominance, because four of them were born in China, and seven of them were born and raised mainly in Japan with their Mandarin being a heritage language. Although the SB speakers and the AJ speakers have the same degree of standard Mandarin proficiency test (all the SB speakers with HSK-6 level as well), we hypothesized that the SB speakers should be more proficient in Mandarin than the AJ speakers, or even likely to achieve the same proficiency as the NM speakers. First, regardless of language dominance, the SB speakers' age of Mandarin acquisition was far earlier than that of the AJ speakers. Second, the frequency of using

Mandarin was much higher for the SB speakers than the AJ speakers, because simultaneous bilingual's daily conservation with their parents consists of much Mandarin.

2.2. Tasks and Materials

Previous studies reported that L2 learners performed differently in different production tasks, they tended to speak faster in reading tasks than in spontaneous speech tasks [8,9]. This study thus investigated the speech rates under both passage reading and spontaneous speech settings.

For the passage reading task, the materials were the North Wind and Sun story of both Japanese and Mandarin Chinese versions. The Japanese version of North Wind and Sun consists of 226 syllables (or 254 morae) [28], while the Mandarin version consists of 166 syllables [29]. The participants were instructed to read the passage at a normal speech rate without any pause. Three repetitions were collected for each passage. The spontaneous speech task consisted of two questions, for each question, there were two versions in Japanese and Mandarin Chinese respectively. The first question asked the participants to do a self-introduction, while the second question concerned how and why they learn Mandarin or other foreign languages. For each question, the participants were asked to give a two-minute talk using Japanese and Mandarin, they were allowed to prepare for their talk within 30 seconds.

2.3. Recording procedure

The recording sessions took place at the Linguistic Laboratory of Beijing Language and Culture University. The participants were seated on a comfortable chair, the materials were shown in the PPT slides on the laptop screen in front of the participants. During the experiment, the participants were first presented with the passage reading task, followed by the spontaneous speech task. For the NJ and the NM groups, only materials using their native language were presented to them. For the SB and the AJ groups, both Japanese and Mandarin materials were presented to them. The production from the participants was recorded by a solid-state recorder with a 44.1kHz/16-bit sampling rate.

2.4. Acoustic measurements and data analysis

For all recordings, we manually segmented the production into separate utterances, because there were pauses longer than 1 second between sentences in their production. For each repetition of each task, the speech rate was measured by dividing the total number of syllables by the total duration of all the utterances. For Japanese materials, this study also measured speech rate using mora as the measuring unit, because Japanese is a mora-timed language, the duration of mora should be more stable than syllable in Japanese. The measurements of mora would provide a more precise reference for the comparisons of Japanese speech rate among different groups. In addition, mora measurements were a common practice for Japanese in the previous studies [18], and measuring mora would allow the results of this study to be compared with those of the previous literature.

Speech rates were modeled in linear mixed effect (LME) models for each set of data. The LME models were built in R [30] using the lme4 package [31]. The models included Group, Task and the interaction between Group and Task as fixed effects, and Subject and Utterance as random intercepts separately. The model terms were included in a step-wise manner, and the effects of the terms were achieved by model

comparison.

For the SB and AJ groups, another set of models was constructed to count for the language difference of speed rate within each group, which included Language, Task and the two-way interaction between Language and Task as fixed effects, and Subject and Utterance as random intercept separately.

3. Results

3.1. Speech rates of Japanese and Mandarin by native speakers

Figure 1 shows the speech rates of native Japanese and Mandarin by the NJ and NM groups respectively. Model comparison showed that there was a main effect of Group ($\chi^2(1) = 8.031$, $p < .01$) , a main effect of Task ($\chi^2(1) = 5.964$, $p < .05$) and a significant two-way interaction between Group and Task ($\chi^2(1) = 4.764$, $p < .05$). Post-hoc pairwise comparisons for Task showed that for the reading task, the speech rate of the NJ group was marginally significantly higher than the NM group ($t(22.1) = 2.053$, $p = .052$). For the speech task, the speech rate of the NJ group was significantly higher than the NM group ($t(29.9) = 3.736$, $p < .001$). Post-hoc pairwise comparisons for Group showed that for the NJ group, the difference between the two tasks was non-significant ($t(58.1) = -0.220$, $p > .05$). For the NM group, the speech rate of the reading task was significantly higher than the speech task ($t(58.1) = 3.370$, $p < .01$). The results confirmed that the speech rate of Japanese is faster than that of Mandarin in both the reading task and spontaneous speech task, which corroborate the previous literature about the speech rates of Japanese and Mandarin.
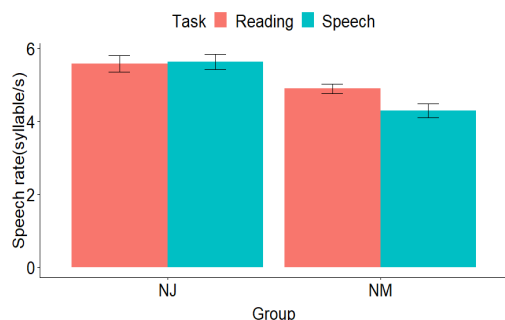

Figure 1: *Speech rates of Japanese and Mandarin by the NJ and NM groups respectively.*

3.2. Speech rates of Japanese and Mandarin by the AJ and the SB speakers

Figure 2a shows the speech rates of Japanese and Mandarin by the AJ speakers. Model comparison showed that there was a main effect of Language ($\chi^2(1) = 167.547$, $p < .001$), but no main effect of Task ($\chi^2(1) = 1.532$, $p > .05$) and no significant two-way interaction between Language and Task was found ($\chi^2(1) = 1.535$, $p > .05$). Post-hoc pairwise comparisons for Language showed that for the reading task, the speech rate of Japanese was significantly higher than that of Mandarin ($t(115) = 15.908$, $p < .001$). For the speech task, the speech rate of Japanese was significantly higher than that of Mandarin as well ($t(116) = 11.166$, $p < .001$). Post-hoc pairwise comparisons for Task showed that for Japanese, the speech rate of the reading task was significantly higher than that of the speech task ($t(115) = 2.885$, $p < .01$). For Mandarin, the difference between the two tasks was non-significant ($t(116) = 1.048$, $p > .05$). The results suggested that AJ speakers produced Japanese constantly faster

than Mandarin in both the reading task and speech task. Figure 2b shows the speech rates of Japanese and Mandarin by the SB speakers. Model comparison showed that there was a main effect of Language ($\chi^2(1) = 63.642$, $p < .001$), but no main effect of Task ($\chi^2(1) = 3.583$, $p > .05$) and no significant two-way interaction between Language and Task was found ($\chi^2(1) = 0.046$, $p > .05$). Post-hoc pairwise comparisons for Language showed that for the reading task, the speech rate of Japanese was significantly higher than that of Mandarin ($t(100) = 7.140$, $p < .001$). For the speech task, the speech rate of Japanese was significantly higher than that of Mandarin as well ($t(101) = 5.934$, $p < .001$). Post-hoc pairwise comparisons for Language showed that for Japanese, the difference between the two tasks was not significant ($t(101) = 1.535$ $p > .05$). For Mandarin, the difference between the two tasks was not significant as well ($t(100) = 1.891$, $p > .05$). The results suggested that, similar to the AJ speakers, the SB speakers produced Japanese constantly faster than Mandarin in both the reading task and spontaneous speech task as well.
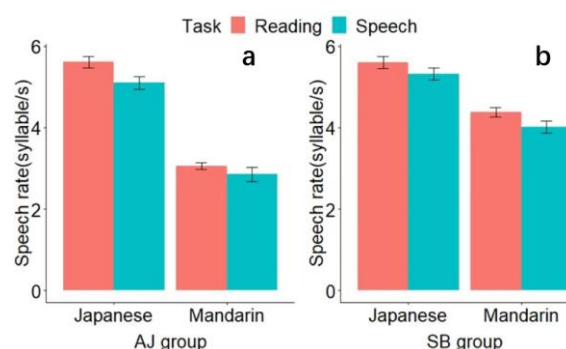

Figure 2: *Speech rates of Japanese and Mandarin by the AJ group (a) and by the SB group (b).*

3.3. Speech rate comparisons between native speakers, the AJ and the SB speakers

Figure 3a shows the speech rate (syllable/s) of Japanese by the NJ, SB and AJ groups. Model comparison found that there was a main effect of Task ($\chi^2(1) = 7.036$, $p < .001$), but no main effect of Group ($\chi^2(2) = 0.603$, $p > .05$) and no significant two-way interaction between Group and Task ($\chi^2(2) = 2.602$, $p > .05$) was found. Post-hoc pairwise comparisons for Task showed that there was no significant difference between each group pair in both tasks ($p > .05$). Post-hoc pairwise comparisons for Group showed that for the AJ group, the speech rate of the reading task was significantly higher than of the speech task ($t(117) = 2.743$, $p < .01$), but there was no significant difference between the two tasks for the NJ group ($t(117) = -0.176$, $p > .05$) and the SB group ($t(117) = 1.506$, $p > .05$). Figure 3b shows the speech rate (mora/s) of Japanese by the NJ, SB and AJ groups. Model comparison showed that there was no main effect of Group ($\chi^2(2) = 0.226$, $p > .05$) and no main effect of Task ($\chi^2(1) = 1.968$, $p > .05$), the two-way interaction between Group and Task yielded non-significance as well ($\chi^2(2) = 1.106$, $p > .05$). The results suggested that, regardless of using syllable or mora as the measuring unit, both the AJ and SB groups produced Japanese similarly as native Japanese speakers did, showing that their speech rates of Japanese were not affected by their slower speech rate in Mandarin.

Figure 3c shows the speech rate of Mandarin by the NM, SB and AJ groups. Model comparison showed that there was a main effect of Group ($\chi^2(2) = 43.739$, $p < .001$) and a main

effect of Task ($\chi^2(1) = 13.823$, $p < .001$), but no significant two-way interaction between Group and Task was found ($\chi^2(2) = 3.138$, $p > .05$). Post-hoc pairwise comparisons for Task showed that for the reading task, the speech rate of the AJ group was significantly slower than that of the NM group ($t(53.9) = -8.39$, $p < .001$) and the SB group ($t(54.0) = -6.370$, $p < .001$), but there was no significance between the NM and SB groups ($t(53.0) = 2.303$, $p > .05$). Similar pattern was found for the speech task as well, the speech rate of the AJ group was significantly slower than that of the NM group ($t(80.0) = -5.830$, $p < .001$) and the SB group ($t(80.4) = -4.955$, $p < .001$), but there was no significance between the NM group and the SB group ($t(76.5) = 1.118$, $p > .05$). Post-hoc pairwise comparisons for Group showed that the speech rate of the reading task was significantly higher than that of the speech task for the NM group ($t(130) = 3.420$, $p < .001$) and the SB group ($t(130) = 2.266$, $p < .05$), but there was no significant difference between the two tasks for the AJ group ($t(132) = 1.221$, $p > .05$). The results showed that the speech rate of Mandarin by the AJ speakers was significantly slower than that of the NM speakers in both tasks, while the speech rate of Mandarin between the SB speakers and the NM speakers remained non-significant.
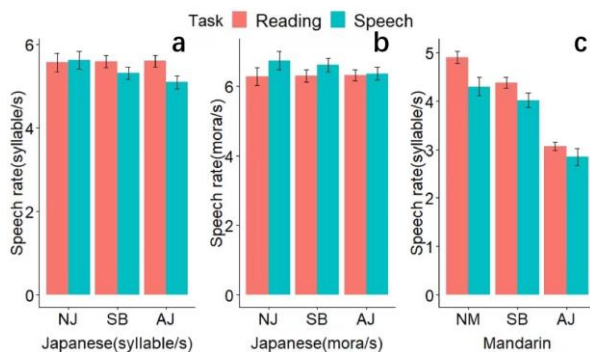

Figure 3: (a) *Speech rates of Japanese (syllable/s) by the NJ, SB and AJ groups, (b) Speech rates of Japanese (mora/s) by the NJ, SB and AJ groups, (c) Speech rates of Mandarin by the NM, SB and AJ groups.*

4. Discussion

By examining the speech rates between Japanese and Mandarin by native speakers, this study confirms that the speech rate of Japanese is faster than that of Mandarin in both reading task and speech task, contradicting with previous studies that different languages share similar speech rates in spontaneous speech [32]. The difference in speech rate is likely due to the inherent syllable duration difference between Mandarin and Japanese. As we hypothesized, the inherent syllable duration difference might be due to the typological difference between Japanese and Mandarin. First, Mandarin is a tone language, the realization of tones on syllables requires more time, resulting in a longer intrinsic duration for Mandarin syllables. Second, in the mora-timed Japanese, CV structure enjoys an even higher proportion and vowel reductions are commonly found [24,25], rendering the syllable duration of Japanese shorter than the syllable-timed Mandarin. However, the detailed effects of language typological differences on speech rate still await further investigation.

Given the findings of the speech rate difference between Japanese and Mandarin, it is theoretically interesting to investigate whether language learners would transfer their faster speech rate of Japanese to Mandarin, or have the backward transfer from Mandarin to Japanese. Contrary to the previous findings [12,13], the present study suggests that speech rate transfer does not happen between languages. By comparing the speech rates between Japanese and Mandarin by the AJ speakers and the SB speakers respectively, this study found that both late bilinguals and early bilinguals produced Japanese constantly faster than their Mandarin in both reading and speech tasks. Also, we found that the SB group serves as the ideal group to answer our main research question. The speech rate transfer was less likely to happen between a faster-speaking language and a slower-speaking language. Unlike the AJ group who produced Mandarin slower than the NM group, the SB speakers produced both Japanese and Mandarin similarly as the respective native speakers, suggesting that the speech rates of the SB group were not influenced by language proficiency. However, the SB group still clearly separated the two languages, as they employed different speech rates to produce their Japanese and Mandarin.

The comparisons between the AJ speakers and the SB speakers suggested that early bilinguals (SB) had an advantage over late bilinguals (AJ) in speech rate mastery. The AJ speakers failed to produce Mandarin as fast as the NM speakers and the SB speakers did, because the AJ speakers were L2 learners. Although the AJ speakers were very advanced and with the highest Mandarin proficiency level (HSK-6 level), their Mandarin still seemed less fluent compared to the SB and NM speakers. The AJ speakers might have some common problems of L2 learners, for example, not knowing how to deal with the fine details of Mandarin pronunciation (e.g., neutral tone, vowel reduction) and excessively speaking each syllable in its fullness, etc. [33]. Also, the advantage of the SB speakers corroborates the previous studies that early language experience can provide a significant boost to speakers' production of that language in comparison to L2 learners with no prior experience [34]. This study suggested the production boost by early language learners was evident in speech rate as well.

In addition, contrary to the claims of previous studies that participants especially L2 learners spoke faster in reading tasks than in speech tasks [8,9], we found that this was not necessarily true. The results yielded many non-significant comparisons of speech rate between the reading task and speech task by both native speakers and learners.

In conclusion, the present study confirmed that the speech rate of Japanese is faster than that of Mandarin. The study investigated whether speech rate transfer could happen between Japanese and Mandarin for advanced L1 Japanese learners and simultaneous bilinguals. The results showed little evidence of speech rate transfer. In addition, by comparing the speech rates of Japanese and Mandarin of these two groups, the study suggested that early language learners had an overall advantage over late language in terms of prosody acquisition of speech rates. Early language experience could facilitate language learners with greater oral fluency.

This study has three main implications for future research. First, more tasks are needed to confirm whether tasks would have an effect on speech rate. Second, more participants should be recruited for both Japanese-dominant simultaneous bilinguals and Mandarin-dominant simultaneous bilinguals to investigate the effect of language dominance. Third, this study only examined the speech rate of L1 Japanese learners. Efforts should be made to include L1 Mandarin learners of L2 Japanese to see whether the speech rate interactions between Mandarin and Japanese would happen from L1 Mandarin or not.

5. References

[1] H. R. Bosker, A. F. Pinget, H. Quené, T. Sanders, and N. H. de Jong, "What makes speech sound fluent? The contributions of pauses, speed and repairs," Lang. Test., vol. 30, no. 2, pp. 159–175, 2013.

[2] J. C. Mora, "Age effects on oral fluency development," Age rate foreign Lang. Learn., vol. 19, pp. 65–88, 2006.

[3] L. W. Fillmore, "10 - Individual Differences in Second Language Acquisition," in Individual Differences in Language Ability and Language Behavior, Eds. Academic Press, 1979, pp. 203–228.

[4] S. Tauroza and D. Allison, "Speech Rates in British English," Appl. Linguist., vol. 11, no. 1, pp. 90–105, 1990.

[5] S. P. Whiteside, "Temporal-based acoustic-phonetic patterns in read speech: some evidence for speaker sex differences," J. Int. Phon. Assoc., vol. 26, no. 1, pp. 23–40, 1996.

[6] L. A. Ramig, "Effects of physiological aging on speaking and reading rates," J. Commun. Disord., vol. 16, no. 3, pp. 217–226, 1983.

[7] R. Towell and J. M. Dewaele, "The role of psycholinguistic factors in the development of fluency amongst advanced learners of French," Focus French as a Foreign Lang. Multidiscip. Approaches, no. December 2018, pp. 210–239.

[8] T. Gráf, "Review of Götz (2013): Fluency in Native and Nonnative English Speech," Int. J. Learn. Corpus Res., vol. 1, no. 1, pp. 178–181, Apr. 2015.

[9] R. Ellis, "Planning and task-based research: Theory and research," Plan. task-performance a Second Lang., vol. 1, pp. 3–36, 2005.

[10] T. M. Derwing, M. J. Munro, R. I. Thomson, and M. J. Rossiter, "The relationship between L1 fluency and L2 fluency development," Stud. Second Lang. Acquis., vol. 31, no. 4, pp. 533–557.

[11] J. Yuan, M. Liberman, and C. Cieri, "INTERSPEECH 2006 Towards an Integrated Understanding of Speaking Rate in Conversation," 2006.

[12] O. V. Maletina and W. Baker-smemoe, "Understanding L1-L2 Fluency Relationship Across Different Languages and Different Proficiency Levels," 2014.

[13] T. Gráf, L. Jiránková, and A. Kvítková, "On the relation between L1 and L2 speech rate," 2019, pp. 19–41.

[14] D. Coulson, "Cognitive Bases of Second Language Fluency," System, vol. 39, no. 1, pp. 115–116, Mar. 2011.

[15] Y. Chen and M. P. Robb, "A study of speaking rate in Mandarin speakers of Anterican English," Asia Pacific Journal of Speech, Language and Hearing, vol. 9, no. 3, pp. 173–188, Jan. 2013.

[16] S. J. Eady, "Differences in the F0 patterns of speech: Tone language versus stress language," Lang. Speech, vol. 25, no. 1, pp. 29–42, 1982.

[17] M. Nishio and S. Niimi, "Comparison of Speaking Rate, Articulation Rate and Alternating Motion Rate in Dysarthric Speakers," Folia Phoniatr. Logop., vol. 58, no. 2, pp. 114–131, Feb. 2006.

[18] K. Maekawa, "Corpus of Spontaneous Japanese: design, annotation and XML representation," In: ISCA & IEEE Workshop on Spontaneous Speech Processing and Recognition. 2003.

[19] S. Duanmu, The phonology of standard Chinese. OUP Oxford, 2007.

[20] Y.-H. Lin, The Sounds of Chinese with Audio CD, vol. 1. Cambridge University Press, 2007.

[21] T. J. Vance, An introduction to Japanese phonology. SUNY Press, 1997.

[22] P. Mok, "On the syllable-timing of Cantonese and Beijing Mandarin," Chinese J. Phonetics, vol. 2, pp. 148–154, 2009.

[23] S. Liu and K. Takeda, "Mora-timed, stress-timed, and syllable-timed rhythm classes: Clues in English speech production by bilingual speakers," Acta Linguist. Acad., vol. 68, no. 3, pp. 350–369, 2021.

[24] N. Ogasawara, Processing of speech variability: Vowel reduction in Japanese. The University of Arizona, 2007.

[25] J. D. Whang, "Effects of predictability on vowel reduction," J. Acoust. Soc. Am., vol. 135, no. 4, p. 2293, 2014.

[26] R. Hincks, "Presenting in English or Swedish: Differences in speaking rate," Proc. FONETIK 2008, pp. 21–24, 2008.

[27] V. Yip and S. Matthews, The bilingual child: Early development and language contact. Cambridge University Press, 2007.

[28] H. Okada, "Japanese," J. Int. Phon. Assoc., vol. 21, no. 2, pp. 94–96, 1991.

[29] W. S. Lee and E. Zee, "Standard Chinese (Beijing)," J. Int. Phon. Assoc., vol. 33, no. 1, pp. 109–112, 2003.

[30] R. C. Team and others, "R: A language and environment for statistical computing," 2013.

[31] D. Bates, M. Mächler, B. Bolker, and S. Walker, "Fitting linear mixed-effects models using lme4," arXiv Prepr. arXiv1406.5823, 2014.

[32] T. Arai and S. Greenberg, "The temporal properties of spoken Japanese are similar to those of English.," 1997.

[33] C. B. Chang and Y. Yao, "Production of neutral tone in Mandarin by heritage, native and second language speakers," Proc. Int. Conf. Phonetic Siences 2019, pp. 2291–2295, 2019.

[34] S. A. Montrul, "Incomplete Acquisition in Bilingualism: Re-examining the Age Factor," vol. 39, Sep. 2008.