Missing /y/: Vowel perception in bilinguals whose languages differ in whether the high front rounded vowel is phonemic

Journal
Proceedings of the Annual Meeting of the Cognitive Science Society, 46(0)

Authors
Pan, Lei
Styles, Suzy J.

Publication Date
2024

Peer reviewed

Missing /y/: Vowel perception in bilinguals whose languages differ in whether the high front rounded vowel is phonemic

Lei Pan (panl0006@e.ntu.edu.sg)
Centre for Research in Child Development, National Institute of Education, Singapore
Psychology, School of Social Sciences, Nanyang Technological University, Singapore

Suzy J Styles (suzy.styles@ntu.edu.sg)
Psychology, School of Social Sciences, Nanyang Technological University, Singapore
Centre for Research and Development in Learning, Nanyang Technological University, Singapore

Abstract

Previous studies have demonstrated that bilinguals have discrete representations for speech sounds that are phonemic in both of their languages. In a lexical identification task for Singapore Mandarin words 椅(/i2/ 'chair') and 鱼(/y2/ 'fish'), we find steepness of the identification functions differs among bilinguals with different linguistic experience, with steeper slopes for early English-Mandarin bilinguals (for whom the /y/ vowel is phonemic) and shallower slopes for early English-Malay bilinguals (for whom /y/ is not phonemic, but is largely discriminable in the forced choice task). With nuanced language background information, this finding suggests that exposure to both /i/ and /y/ in early development shapes phonemic perception. Model comparisons demonstrate that continuous measures of early exposure are more powerful than simple categorical groupings of bilingual 'type'. Continuous measures of bilingual exposure are therefore highlighted as useful tools in the investigation of phoneme perception.

Keywords: phoneme identification; bilingual balance; early language exposure; individual differences

Introduction

Phonemic processing is known to differ across a bilingual speaker's languages. One previous study (Pan, Ke, & Styles, 2022) investigated perception of words differing in their initial stop consonants, along a /b/-/p/ acoustic spectrum – a phonemic contrast in both English and Mandarin. They found that the timing and amount of early language exposure influences how tightly a person's perception switches from perceiving one word to perceiving another as they hear tokens drawn from across an acoustic continuum, but their linguistic background does not influence the location of the perceptual switch between words in a pair.

Singapore has a multilingual environment with English, Mandarin, Malay, Tamil as official languages. Across the dominant ethnic groups in Singapore, around 30% of households use English as the majority language (Wu, O'Brien, Styles, & Chen, 2020), alongside Mandarin and Malay, which are also strongly represented in the community. Singapore has rich multilingualism in diverse language varieties, leading to asymmetries in the phoneme inventories of the inhabitants of Singapore. According to phoneme prevalence estimates (Moran & McCloy, 2019; Styles & Gawne, 2017), the high front unrounded vowel /i/ is prevalent in almost all languages, while the front rounded vowel /y/ is relatively uncommon. /i/ is phonemic in all of Singapore's official languages, while /y/ is only phonemic in Mandarin Chinese, as in Figure 1. Previous literature suggests that in Outer Circle varieties of Mandarin influenced by Southern Min dialects, the high front vowels are acoustically different from their canonical production in Beijing Mandarin (Duanmu, 2007). However, previous research has demonstrated that /i/ and /y/ are acoustically distinct in the Singapore variety of Mandarin (Pan, Moisik, & Styles, 2023). What remains unclear is how the phoneme is perceived by bilinguals growing up in this multilingual context – all of whom will have had passive acoustic exposure to the speech sounds in the linguistic environment, but for only some of whom, the speech sounds are phonemic.

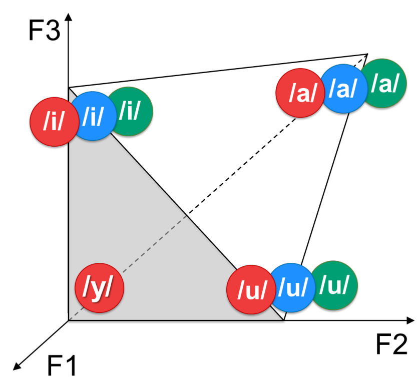

Figure 1: Schematic vowel inventories of peripheral vowels /i/, /a/, /u/ and /y/ in Mandarin (red), English (blue) and Malay (green).

Phoneme perception of both native languages and foreign languages can be shaped by early linguistic experience (Kuhl, 2004; Sebastian-Galles & Santolin, 2020), including perception for lost languages of childhood, such as Korean for early adoptees (Choi, Broersma, & Cutler, 2017), and Singaporeans who heard Hokkien spoken during their early childhood (Singh & Seet, 2019). In these forgotten language studies, early language exposure was associated with perceptual abilities in adulthood that are not shared with monolinguals, even though in both studies, participants reported no proficiency in the lost languages under investigation.

In the current study of vowel perception in bilinguals with different language backgrounds, participants have strongly represented /y/ and perhaps weakly represented /y/. In the

In L. K. Samuelson, S. L. Frank, M. Toneva, A. Mackey, & E. Hazeltine (Eds.), *Proceedings of the 46th Annual Conference of the Cognitive Science Society.*

current study, a wide range of people who consider themselves bilingual were recruited, as is representative of the local language context. Research questions can be raised as to whether the amount of Mandarin exposure makes a difference on bilinguals' ability to perceive vowels, and how much exposure is sufficient for vowel perception in bilingual.

Methods

Vowel perception in a large sample of early parallel English-Mandarin and English-Malay bilinguals in Singapore was investigated in a phoneme identification task using real Mandarin words that differ in their vowel formants across a synthesized vowel continuum. Prior to collecting data, the study and analysis plan was preregistered. To determine a well powered sample size, we used the effect size from a previously published study investigating consonant perception in English-Mandarin bilingual adults, which was implemented using the same method (Pan et al., 2022). The study was approved by the Institutional Review Board of the host institution (IRB-2019-01-034). Informed consent was obtained from all participants. Experimental procedures were in accordance with the relevant guidelines and regulations.

Hypothesis

Previous research suggests that ***bilingual balance*** is a predictor of gradient sensitivity in identifying phoneme contrasts that are phonemic in both of a bilingual's languages, for example, the /b/-/p/ VOT continuum in English and Mandarin (i.e., "beach" and "peach"; "鼻" and "皮"). In the current study, we investigate speech sounds which have asymmetrical representations across languages: For bilinguals of English and Mandarin, both /i/ and /y/ are phonemic in one language, while only /i/ is phonemic in the other. For bilinguals of English and Malay, only /i/ is phonemic in both languages. In this way we are able to control for the feature of 'being bilingual' while investigating the asymmetrical phonemic relationship across groups.

In our preregistered analysis, we predicted that English-Mandarin bilinguals would show a shallower decision gradient than English-Malay bilinguals when matching acoustic targets to pictures representing the two target words differing in whether their high front vowel is rounded. To compute the required sample size for the between-subject comparison, we conducted a power analysis for the hypothesis using G*power 3.1.9.4 (Faul, Erdfelder, Buchner, & Lang, 2009). In order to achieve a power of 0.8 to detect a median effect size (d) of 0.5, at an alpha level of 0.05, in an independent samples t-test (one-tailed), a total sample size of 102 (51 in each group) would be required. The preregistered prediction was tested in a between-subjects design with bilingualism as a categorical predictor. However, due to the prevalence of multilingualism in Singapore (Singapore Census of Population, 2020), bilinguals in each group may have exposure to the other language, either through passive exposure in a multilingual context, or through active early childhood exposure. We therefore follow the preregistered analysis with an exploratory analysis in which the level of experience with Mandarin was a continuous predicter of variance. Model comparisons are used to determine whether categorical grouping or continuous grouping of language is a more powerful predicter of perceptual differences.

Stimuli

Prototypes of /i2/ "chair" and /y2/ "fish" were selected from an open-access corpus of Singapore Mandarin speech elicited using picture prompts, and recorded in an acoustically treated room (Pan & Styles, 2022). Stimuli were selected which best represented typical acoustic values for /i/ and /y/ from a single bilingual speaker of Singapore English and Singapore Mandarin, resulting in selection of a 21-year-old female speaker.

Following the paradigm of acoustic measurements (Lisker & Abramson, 1964), we created a 16-step vowel continuum from prototypical /i/ to prototypical /y/, by synthesizing intermediate steps between two tokens of natural speech (edited for duration, pitch and intensity), using the Tandem-STRAIGHT approach (Kawahara et al., 2008). Amplitude adjustment and noise reduction for the words were applied to all tokens during synthesis. Each stimulus word were 270 ms, with 186.5 Hz pitch and intensity of 83 dB. 250 ms of silence was added to the start and end of each token.

Procedure

An adaptation of the open access task known as the CROWN Game (Ke, Pan, Le, & Styles, 2021) was created for the study. Participants were invited to take part in the CROWN Game online using OpenSesame OSWeb experiment builder 3.3.10 (Mathôt, Schreij, & Theeuwes, 2012), via a JATOS protocol. All participants took part in a headphone screening task (Woods, Siegel, Traer, & McDermott, 2017) lasting approximately 5 minutes, and an experimental session lasting approximately 15 minutes on the same day. After screening, participants were asked to fill in demographics and a Language Fingerprint survey that includes questions for each language on self-reported proficiency, age of acquisition (AoA), and estimated exposure rates during childhood.

In the task, participants are asked if each speech token was "椅" /i2 / 'chair' or "鱼" /y2/ 'fish'. The task storyline asks participants to help a monkey play a game in which the monkey should "pick the 'chair' card" or "pick the 'fish' card", appearing at either side of the screen (Figure 2). Participants heard a speech token drawn randomly from the 16-step vowel continuum, and they were asked to press 'C' or 'M' to select the left or right image, respectively. After the keypress, a pop sound played and the character moved to the selected image as a form of response feedback.

The task included two practice blocks in which participants heard only tokens of /i/ and /y/ drawn from the prototypical ends of the vowel continuum (eight practice trials and four bell sounds as an attention check in each block). The practice blocks included feedback on accuracy. Each test block contained one presentation of each of the 16 tokens in the vowel continuum and one bell sound, repeated for a total of ten blocks, with no feedback on accuracy. The position of the visual stimuli was fixed throughout the experimental blocks.

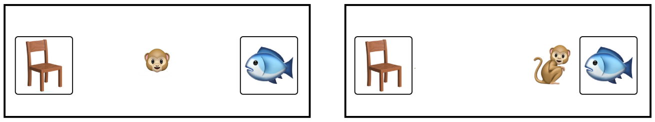

Figure 2: Example screens from the /y/ CROWN Game. Left: example of stimuli /i/ and /y/ presented on screen. Right: response feedback following a /y/ choice.

Measurements

Linear regression models were conducted to test the effects of language experience and bilingual balance on vowel perception in bilinguals with different language backgrounds. The following variables were computed for data analysis.

Early language exposure To quantify language exposure during early childhood, values from the language fingerprint were used to compute a Composite Language Input Profile for each language of interest: English, Mandarin Chinese, and Malay, along with Other Chinese varieties and Other Malayo-Polynesian varieties using a general formula (Woon, 2018), illustrated for English:CLIP-English = Caregiver 1 (% speaking English × % care time) + Caregiver 2 (% speaking English × % care time) + ...

Years of exposure Age of acquisition was used to compute Years of Exposure (YoE) in each language of interest by subtracting age of acquisition from age of the participant at the time of test.

Threshold and slope Individual responses were measured as the proportion of /y/ choices allowing a psychometric function to be fitted by using the quickpsy function in R (Linares & López-Moliner, 2016). The fitted psychometric curve is defined in part by the 50% crossover point and the slope of the curve at midpoint. The perceptual threshold is therefore the point on the vowel continuum at which an individual switches from making majority /i/ decisions to making majority /y/ decisions. The slope represents how abrupt the transition is from perception of /i/ to perception of /y/. Threshold and slope are automatically computed in the process of the fitting the psychometric function.

Participants

When enrolling in the study, participants self-identified as bilinguals of English and Mandarin or English and Malay. According to the preregistered sample size, 51 English-Mandarin bilinguals (age: M = 22.6 year, SD = 2.3, age range: 18-31 year; 30 females) and 51 English-Malay bilinguals (age: M = 23.9 year, SD = 4.4, age range: 18-39 year; 39 females) were recruited. All participants reported growing up and currently living in Singapore. Two additional participants in the English-Malay bilingual group were removed with replacement for failing to pass the headphone screening. No participants were excluded on the basis of their specific language backgrounds.

Results

Language exposure pattern

Early language input patterns of each participant are illustrated schematically in Figure 3. Both groups reported early exposure to English alongside Mandarin or Malay. Participants from both groups self-rated proficiency in the domains of ‘understanding when people speak’ (U) and ‘speaking to others’ (S) on a confidence scale from 0 “I don’t understand/speak this language” to 100 “native-level”. Participants in the English-Malay group reported strong language skills in English and Malay, with limited skills in Mandarin (English. U: Median = 100 (70–100), S: Median = 100 (58–100); Malay. U: Median = 90 (70–100); S: Median = 90 (45–100); Mandarin. U: Median = 5 (0–80), S: Median = 1 (1–60)). Participants in the English-Mandarin group reported strong language skills in English and Mandarin with limited language skills in Malay (English. U: Median = 100 (53–100), S: Median = 100 (47–100); Mandarin. U: Median = 80 (29–100), S: Median = 69.5 (15–100); Malay (U: Median = 0 (0–21); S: Median = 0 (0–10)).

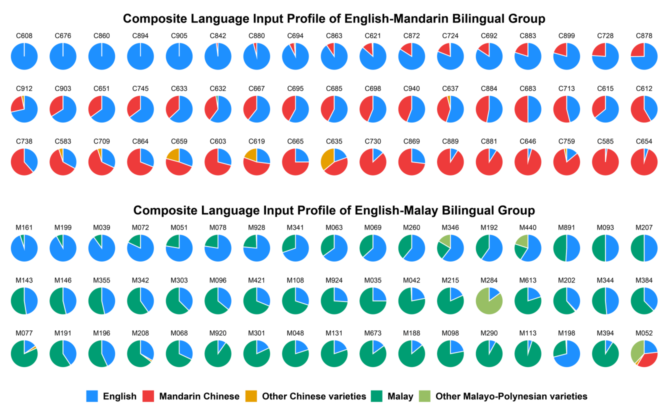

Figure 3: Composite Language Input Profile for each participant separated by language group. Upper: English-Mandarin bilinguals (n = 51) ordered by bilingual balance. Bottom: English-Malay bilinguals (n = 51) ordered by bilingual balance.

Figure 4 shows the results of a check for multicollinearity among the six language background variables, where multiple relationships are evident. Positive relationships are evident among the paired measures for each of the non-English languages (CLIP & YoE), according to which, more years of exposure is related to a larger proportion of childhood exposure. Negative relationships were observed between measures for Mandarin and measures for Malay (i.e., the more/earlier Mandarin the less/later Malay and vice versa). No significant relationship was observed between the YoE for English, and the proportion of exposure in either of the other languages (YoE-En vs CLIP-Ch: $r = -0.11$, $p = 0.269$;

YoE-EN vs CLIP-Ml: $r = 0.03$, $p = 0.735$), suggesting that the timing of early exposure to English does not increase the overall proportion of English heard, nor decrease the proportion of non-English languages.

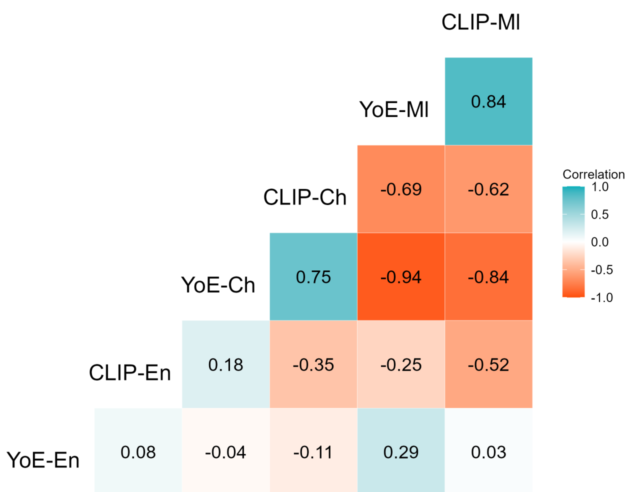

Figure 4: Pearson correlation matrix for the language background variables.

The extensive multicollinearity among language background variables makes this kind of data unsuitable for analysis in linear models without dimensional reduction. In line with previous studies of complex multilingual populations (Ke, Pan, O'Brien, & Styles, 2021; Pan et al., 2022), Principal Component Analysis (PCA) was conducted for the exploratory analysis.

Behavioural response and curve fitting

In line with the preregistered analysis plan, psychometric functions for identification /y/ was fitted for each participant. Figure 5 shows the psychometric functions for all participants, with the participant with the median slope value of each group highlighted. The typical threshold was close to step 8 on the /i/-/y/ vowel continuum for both groups (English Mandarin: Mean = 7.9, SD = 1.1; English-Malay: Mean = 8.1, SD = 1.3). The median slope for the English-Mandarin group was 1.453 (Range: 0.514–3.786). and for the English-Malay group, 1.181 (Range: 0.304–3.785).

Threshold and slope

Perceptual thresholds in the high front vowel identification task performed by bilinguals with two language backgrounds are normally distributed, and slope values are distributed in a loglinear scale as shown in Figure 6. To determine whether the thresholds and log-slopes of the two bilingual groups were significantly different, independent samples t-tests were conducted.

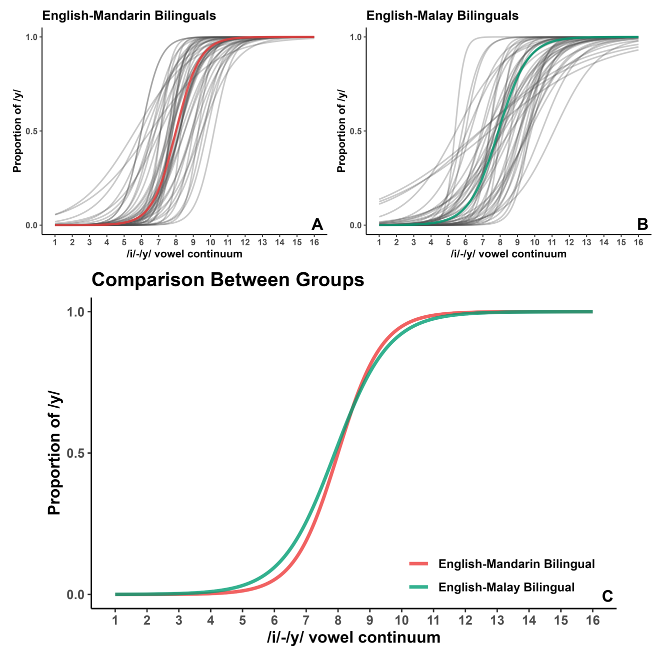

Figure 5: Psychometric curves in the high front vowel identification task. Two groups shown separately, with median slope-participant highlighted. A: English-Mandarin bilinguals (n = 51); B: English-Malay bilinguals (n = 51) ; C: Medians for each group shown together for comparison.

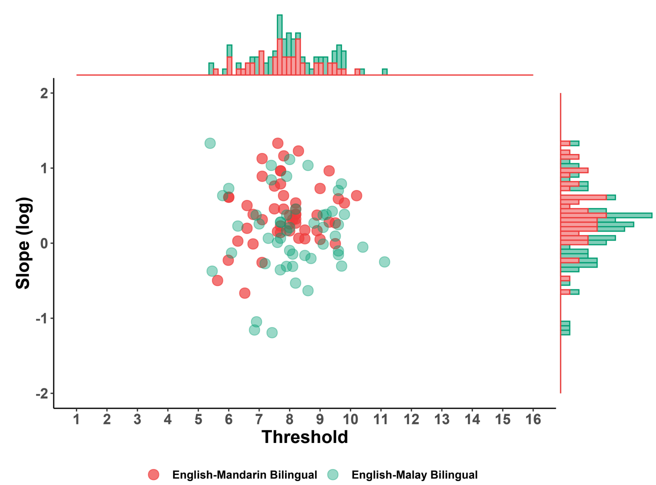

Figure 6: Scatter plot of thresholds and log-slope values from the fitted psychometric functions, with groups shown separately (N=102).

No significant effect of group was observed on threshold ($t(100) = -1.02$, $p = 0.3112$, 95% CI: −0.70–0.22). In line with our preregistered prediction, a significant effect of group was observed for slope ($t(100) = 2.89$, $p = 0.0047$, 95% CI: 0.09–0.47). English-Mandarin bilinguals (M = 0.404, SD = 0.414) showed a significantly steeper slope in identifying the high front vowel contrast in Mandarin, as compared to English-Malay bilinguals (M = 0.127, SD = 0.546).

In line with the notably multilingual context of Singapore, 20% of participants who self-identified as bilingual reported experience with *more than two languages* in early childhood, including English-Mandarin bilinguals reporting childhood exposure to other Chinese varieties (Hokkien, Cantonese, Teochew, Hakka) and Malay. Some Malay-English bilinguals reporting childhood exposure to other Malayo-Polynesian languages (Bahasa Indonesia, Javanese), but also to Chinese varieties in which /y/ is phonemic (Mandarin; Hakka). Indeed, a small number of Malay bilinguals who achieved Mandarin-like steepness in the slopes in their vowel perception also had bilingual balance scores closer to the Mandarin bilingual group. As these participants do not self-identify as bilinguals of Chinese, this finding is consistent with the growing literature on perceptual advantages for forgotten languages of early childhood (Choi et al., 2017; Singh & Seet, 2019).

Exploratory analysis

Contrary to our expectations at the time of preregistration, some participants in each self-identified language group also reported early childhood exposure to the other non-English languages. To extend the study in a (non-pre-registered) exploratory analysis, we investigated whether the amount of early exposure to a language with high front rounded vowel as a phonemic category has *graded impacts* on vowel perception patterns across speakers who identify as bilinguals of different languages, with a particular focus on slope, as this factor had shown sensitivity to the linguistic differences at the group level.

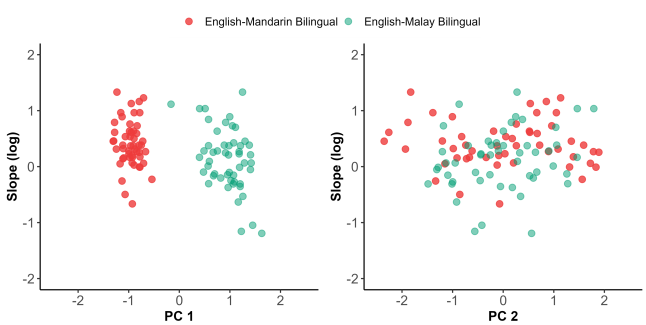

Figure 7: Scatter plot of individual slope values with components derived from a PCA of language background variables. LEFT: PC 1, 'timing and amount of exposure to Mandarin versus Malay'; RIGHT: PC 2, 'timing and amount of exposure to English' (N=102).

A Principal Component Analysis was conducted to reduce the multicollinearity among the six language background variables. Initial eigenvalues of the first two components accounted for 56.98% and 23.15% of the total variance, resulting in two Principal Components (PCs) considered significant sources of bilingual variance. PC 1. YoE-Ch, YoE-Ml, CLIP-Ch, and CLIP-Ml had large component-loadings on PC 1, such that an individual with a low factor score on PC 1 had more early Mandarin input, less early Malay input, and acquired Mandarin earlier than an individual with a low score on this dimension. PC 2. YoE-En, CLIP-En and CLIP-Ch had large component loadings on PC 2, such that an individual with a high PC 2 factor score had less early Mandarin input, more early English input, and acquired English earlier than an individual with a low score on this dimension. Figure 7 shows the relationships between each component and the log slope values. In the left panel, it is clear that PC 1 effectively captures the categorical structure of participants' self-identification as different kinds of bilinguals, but the continuous scale may have more explanatory power than the simple binary variable.

In the exploratory analysis, we conducted a Linear Regression Model on the individual slope for each bilingual, with PC 1 and PC 2 as predictors. Results showed that relative experience of Mandarin vs Malay (PC 1) significantly predicted a bilingual's slope value in perceiving the Mandarin high front vowels (SE = 0.05, $t = -3.78$, $p = 0.0003$), with steeper slopes for bilinguals who acquired Mandarin earlier and had more early Mandarin input. Early experience of English relative to the non-English languages (PC 2) did not significantly predict slope (SE = 0.05, $t = 0.81$, $p = 0.4187$). Model comparisons conducted using the anova function in R reveal that inclusion of the two bilingual factors result in a significantly better model fit than analysis with only the language grouping factor ($F(99,1) = 6.09$, $p = 0.0153$).

Discussion

The primary focus of the study was to investigate how patterns of early childhood language exposure may impact performance of bilinguals in perceiving a high front vowel contrast that is phonemic in one of their languages but not in the other, with another group of bilinguals as a 'control'. Mandarin, English and Malay all have the high front *unrounded* vowel /i/ as a category their vowel inventories, while only Mandarin has the high front *rounded* vowel /y/ as a category, resulting asymmetrical vowel inventories for bilinguals with different exposure to Mandarin. While many studies compare the perception of bilinguals to monolingual 'control' participants, few studies investigate perception in groups of participants for whom bilingualism is held constant while the specific languages of bilingualism are compared. While all bilinguals were able to identify which acoustic targets were which at the ends of the vowel continuum, details of an individual's experience with Mandarin are shown to influence high front vowel perception. This finding is aligned with speech production data collected in the same communities suggesting that bilinguals' patterns of early exposure may influence the acoustic realization of the high front vowel contrast, with larger differentiation between /i/ and /y/ for speakers with more early exposure to Mandarin Chinese (Pan et al., 2023).

Analysis from the mixed bilingual sample provides clear evidence that the two bilingual groups show different perceptual gradients across the /i/-/y/ continuum – both when analysed as a 'flat' grouping variable, and when analysed in a more nuanced model of early bilingualism using continuous measures of exposure. Bilinguals with more and earlier exposure to both /i/ and /y/ in Mandarin develop a steeper perceptual gradient than bilinguals who did not hear /y/ frequently in a linguistically contrastive context. Importantly, the model with two continuous language factors based on early childhood exposure better describes the variance in the data than the model with one 'flat' grouping variable, indicating that details of an individual's early language exposure have value to experimentalists.

Rather than splitting bilinguals into different groups only based on the type of language they report using currently, we demonstrate that continuous scales of bilingual exposure (in terms of timing and amount of early linguistic experience) are more sensitive for capturing variance in the perception of bilinguals with diverse language backgrounds.

Conclusion

In our study of high front vowel perception in Singaporean bilinguals with different language backgrounds, bilinguals who were exposed to more/earlier Mandarin exhibited steeper identification functions than those who were exposed to limited or no Mandarin in early childhood. In line with phoneme perception of bilabial stop *consonant* contrasts occurring in both of bilingual's languages, the current study demonstrates bilingual balance also influences the perception of high front rounded *vowels* that are contrastive in only one language. By treating exposure in multiple languages as continuous gradients, rather than using exposure to categorize people into groups, continuous models of bilingual balance show stronger effects of early linguistic experience, making them powerful tools for investigation of bilingual perception.

References

Choi, J., Broersma, M., & Cutler, A. (2017). Early phonology revealed by international adoptees' birth language retention. *Proceedings of the National Academy of Sciences*, *114*(28), 7307–7312.

Duanmu, S. (2007). *The phonology of standard chinese*. OUP Oxford.

Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2009). Statistical power analyses using g* power 3.1: Tests for correlation and regression analyses. *Behavior research methods*, *41*(4), 1149–1160.

Kawahara, H., Morise, M., Takahashi, T., Nisimura, R., Irino, T., & Banno, H. (2008). Tandem-straight: A temporally stable power spectral representation for periodic signals and applications to interference-free spectrum, f0, and aperiodicity estimation. In *2008 ieee international conference on acoustics, speech and signal processing* (pp. 3933–3936).

Ke, H., Pan, L., Le, T. A., & Styles, S. J. (2021). *The CROWN Game: An open access phoneme identification task.* OSF. doi: 10.17605/OSF.IO/F3B4C

Ke, H., Pan, L., O'Brien, B. A., & Styles, S. J. (2021). Is Categorical Perception for Phonemes Adult-Like by 6 Years of Age? Phoneme Identity and Reaction Time in the Flower Crown Task for Multilingual Children in Singapore.

Kuhl, P. K. (2004). Early language acquisition: cracking the speech code. *Nature reviews neuroscience*, *5*(11), 831–843.

Linares, D., & López-Moliner, J. (2016). quickpsy: An r package to fit psychometric functions for multiple groups. *The R Journal, 2016, vol. 8, num. 1, p. 122-131*.

Lisker, L., & Abramson, A. S. (1964). A cross-language study of voicing in initial stops: Acoustical measurements. *Word*, *20*(3), 384–422.

Mathôt, S., Schreij, D., & Theeuwes, J. (2012). Opensesame: An open-source, graphical experiment builder for the social sciences. *Behavior research methods*, *44*, 314–324.

Moran, S., & McCloy, D. (2019). Phoible 2.0. *Jena: Max Planck Institute for the Science of Human History*.

Pan, L., Ke, H., & Styles, S. J. (2022). Early linguistic experience shapes bilingual adults' hearing for phonemes in both languages. *Scientific Reports*, *12*(1), 4703.

Pan, L., Moisik, S. R., & Styles, S. J. (2023). Being a round/y: An acoustic description of high front vowels in singapore mandarin elicited by speakers with different bilingual balance in mandarin and english.

Pan, L., & Styles, S. J. (2022). *Green Grass Park Picture Description Corpus - Singapore Mandarin Adults.* DR-NTU (Data). doi: 10.21979/N9/OPSN64

Sebastian-Galles, N., & Santolin, C. (2020). Bilingual acquisition: The early steps. *Annual Review of Developmental Psychology*, *2*, 47–68.

Singapore Census of Population. (2020). *Statistical release 1: Demographic characteristics, education, language and religion.*

Singh, L., & Seet, S. K. (2019). The impact of foreign language caregiving on native language acquisition. *Journal of Experimental Child Psychology*, *185*, 51–70.

Styles, S. J., & Gawne, L. (2017). When does maluma/takete fail? two key failures and a meta-analysis suggest that phonology and phonotactics matter. *i-Perception*, *8*(4), 2041669517724807.

Woods, K. J., Siegel, M. H., Traer, J., & McDermott, J. H. (2017). Headphone screening to facilitate web-based auditory experiments. *Attention, Perception, & Psychophysics*, *79*, 2064–2072.

Woon, F. T. (2018). *Linguistic sound symbolism and reading development: Sound-shape matching and predictors of reading in multilingual singapore* .

Wu, C.-Y., O'Brien, B. A., Styles, S. J., & Chen, S.-H. A. (2020). The impact of bilingualism on skills development and education. *Transforming Teaching and Learning in Higher Education: A Chronicle of Research and Development in a Singaporean Context*, 47–69.