Individual variation in epenthetic vowel production by Brazilian Portuguese-Japanese bilinguals

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1. Abstract

Brazilian Portuguese (BP) and Japanese have phonological repair strategies that involve vowel epenthesis in illicit consonant clusters, but whereas BP inserts /i/, Japanese inserts /ɯ/ as a default. For example, a loanword like 'TikTok' is typically produced as /ti.ki.tɔ.ki/ in BP and as /tik.kɯ.tok.kɯ/in Japanese. Here, we ask whether balanced BP-Japanese bilinguals apply their language-specific repair strategies separately, or whether one language's strategy 'spills over' into the other, and if such spillover occurs, which individual factors predict its likelihood.

Twenty-two BP-Japanese bilinguals participated in a production task in which they were presented with stimuli containing illicit consonant clusters, e.g., /agbo/, and produced these forms within a BP or Japanese carrier sentence. A model predicting the likelihood of epenthesis type revealed that speakers mostly applied language-specific strategies separately, i.e., /i/-epenthesis in the BP sentences and /ɯ/-epenthesis in the Japanese sentences. However, in some cases, we observed 'spillover', e.g., /i/-epenthesis in Japanese or /ɯ/-epenthesis in BP. Individual variation in language dominance, aggregate immersion, and phonolexical perception acuity predicted the likelihood of such spillover. These findings contribute new production data to a growing body of literature on individual variation in bilinguals' language-specific phonotactics.

Keywords: Japanese, Brazilian Portuguese, epenthesis, individual variation, production

2. Background

2.1 Phonological repair strategies

When we speak, we often adapt the sounds of words from other languages to make those sounds compatible with the phonology of our own language(s). An example of such a phonological repair strategy is vowel epenthesis, which involves the insertion of a vowel to avoid illicit consonant clusters or codas. Vowel epenthesis has been widely documented in the production of foreign (loan)words by speakers of Brazilian Portuguese (John & Cardoso, 2017), Japanese (Mattingley et al., 2019), Korean (K. Kim & Kochetov, 2011), and Shona (Uffmann, 2007), amongst others. For example, the English word 'laptop' /læp.tɑp/ is typically produced as /lɛ.pi.tɔ.pi/ in Brazilian Portuguese (henceforth: BP) and as /ɾap.pɯ.top.pɯ/ in Japanese. This example shows not only segmental adaptations (e.g., /æ/ → /ɛ/ or /l/ → /ɾ/), but also suprasegmental adaptations, as /pt/ clusters and word-final /p/ codas (which are phonotactic violations in both BP and Japanese) are repaired by means of an epenthetic vowel.

Vowel epenthesis not only occurs in production, but also in perception. Perhaps one of the most striking findings from epenthetic vowel perception studies is that listeners can perceive an 'illusory' epenthetic vowel (Dupoux et al., 2011; Guevara-Rukoz, Lin, et al., 2017; Parlato-Oliveira et al., 2010). In other words, listeners sometimes perceive a vowel even when that vowel is not there. In one of the earliest studies on illusory vowel perception, Dupoux et al. (1999) showed that Japanese-L1 listeners reported hearing an /u/[1]vowel in consonant clusters in nonwords like /ebzo/ more than 70% of the time, whereas French-L1 listeners only reported hearing a vowel 10% of the time. Since /bz/ clusters are phonotactic violations in Japanese, Japanese participants in Dupoux et al. (1999) may have perceptually

[1] Some authors use the IPA rounded back vowel symbol <u> instead of, or alongside, the unrounded back vowel <ɯ> to describe the default epenthetic vowel in Japanese. We here use the <ɯ> symbol to describe this vowel, cf. Mattingley et al. (2019), but use <u> when referencing authors that use this symbol.

repaired /bz/, leading them to perceive /ebuzo/. French participants may have been less inclined to hear an illusory vowel because French allows complex syllable structures (Dupoux et al., 1999, p. 1569). These findings suggest that cross-linguistic speech perception is influenced not only by the interactions between first language (L1) and second language (L2) sounds, as has been described in theoretical models like the Perceptual Assimilation Model (Best, 1995) or the revised Speech Learning Model (Flege & Bohn, 2021), but that the structural constraints on those sounds, i.e., phonotactics, also play a role.

Studies since Dupoux et al. (1999) have demonstrated that not only L1 phonotactics, but also L2 phonotactics can affect speech perception. In an experiment by Alcorn (2018), BP monolinguals showed low perceptual sensitivity in detecting the absence or presence of an /i/-vowel in VC.CV-VCiCV pairs (e.g., /egma/-/egima/), potentially because L1 phonotactics triggered the perception of an epenthetic /i/. However, BP-L1 adult L2 learners of English had higher sensitivity and performed at a level somewhere between the levels of BP monolinguals and an English monolingual control group. Similarly, Cabrelli et al. (2019) report that BP-L1 adult L2 learners of English could accurately indicate the absence of an epenthetic vowel in VC.CV stimuli in 84% of trials in an identification task conducted in BP. This contrasts with BP monolinguals in an analogous task (Dupoux et al., 2011), who only accurately identified the absence of a vowel in 34% of similar stimuli. Cabrelli et al. (2019) take these findings to demonstrate that L2 phonotactic knowledge acquired in adulthood can influence L1 phonotactic perception. In a broader light, these findings suggest that bilinguals can go through “L2-L1 phonotactic restructuring” (Alcorn, 2018, p. 35), and that they can resort to phonotactic knowledge from two languages in “parallel activation” (Cabrelli et al., 2019, p. 65).

2.2. Vowel epenthesis in bilinguals

Assuming that bilinguals can indeed activate phonotactic knowledge from two

languages, a question that follows is what such activation would look like. Furthermore, what determines whether a bilingual resorts to the phonotactics of either language, or perhaps to both?

A tentative answer to this question comes from Parlato-Oliveira et al. (2010), who examined epenthetic vowel perception by first-generation Japanese immigrants (who moved to Brazil in adulthood), second-generation immigrants, simultaneous Japanese-BP bilinguals, and BP-L1 adult L2 learners of Japanese. These four groups, who represent a spectrum of degrees of bilingualism (ranging from high to low exposure, proficiency, and use of Japanese relative to BP) and a monolingual BP and Japanese group, took part in a perception task in which they were asked to indicate the presence and type of vowel in consonant clusters that are illicit in BP and Japanese, e.g., /bd/ in a stimulus like /abda/. On average, 'no vowel' response rates were between 20% and 36%, indicating that participants more often than not perceived the presence of an illusory epenthetic vowel, in line with BP and Japanese phonotactics, cf. Dupoux et al. (1999); Guevara-Rukoz, Lin, et al. (2017). When looking at *which* vowel listeners perceived, an interesting pattern emerged: Japanese monolinguals and first-generation immigrants mainly indicated hearing /u/, whereas second-generation immigrants, simultaneous bilinguals, and BP monolinguals mainly indicated hearing /i/. Similar vowel-specific patterns emerged in a categorization and sequence recall task, which served as a more implicit way to measure phonological perception (Parlato-Oliveira et al., 2010, p. 3742). Here, Japanese monolinguals were found to have difficulty distinguishing between no-vowel and /u/ words (e.g., /ebzo/-/ebuzo/), whereas BP monolinguals had difficulty distinguishing between no-vowel and /i/ words, (e.g., /ebzo/-/ebizo/). The bilingual groups patterned similarly with the BP monolinguals.

When revisiting the question of what parallel activation of phonotactic knowledge in bilinguals could look like, the findings from Parlato-Oliveira et al. (2010) reveal that

bilinguals can, and do, resort to both their languages' phonological repair strategies. In Japanese, the default epenthetic vowel is the high-back vowel /ɯ/ (Mattingley et al., 2019), whereas in BP, it is the high-front vowel /i/ (John & Cardoso, 2017). The BP-Japanese bilinguals in Parlato-Oliveira et al. (2010) perceived both these vowels, albeit to different degrees. For instance, first-generation immigrants—who were exposed to Japanese from birth and only later to Portuguese in adulthood—patterned with monolingual Japanese speakers and predominantly perceived /u/. By contrast, second-generation immigrants and simultaneous bilinguals—who were exposed to Japanese in the home environment but to Portuguese in society from an early age—patterned more with monolingual BP speakers and mostly perceived /i/. Although Parlato-Oliveira et al. (2010) predominantly report between-group results, they do report that *within* the group of adult learners, age of first exposure (henceforth: 'age of acquisition or 'AoA') correlated with the difference score between /i/ and /u/-epenthesis, such that learners who acquired Japanese earlier had relatively more /u/-epenthesis than /i/-epenthesis, similar to Japanese monolinguals. These findings suggest that bilinguals show within-group individual variation in terms of language-specific vowel epenthesis, and that this variation is influenced by factors like age of acquisition, at least in perception. As we will review below, some studies have simultaneously examined epenthetic vowel perception and production, but their findings underscore the need to look beyond perception alone, as production does not appear to fully mirror perception.

For instance, in Shin and Iverson (2010), who investigated epenthetic vowel perception and production in Korean-L1 L2-learners of English, individual variation in the degree of epenthetic vowel production did not correlate with individual variation in epenthetic vowel perception, suggesting that phonotactic constraints are "realized and repaired by L2 speakers differently in speech production and perception" (p. 1825). In the study by Cabrelli et al. (2019), BP-English bilinguals who did not have much vowel epenthesis in their

perception did in fact produce epenthetic vowels in both languages. Similarly, S. Y. Kim and Han (2024), who investigated epenthetic vowel perception and production by Korean-L1 L2-learners of English at prelexical levels (by means of an AX discrimination and pseudoword read-aloud task) and at lexical levels (by means of a lexical decision and picture-naming task), found no significant perception-production associations, either within or across processing levels. Finally, a study by De Leeuw et al. (2021) with Spanish-English sequential bilinguals on perception and production of /sC/ onsets (a phonotactic violation in Spanish that is repaired with a *prothetic* /e/, i.e., /sC/→/esC/), found no correlation between discrimination accuracy of stimuli with or without prothesis (i.e., /espi/-/spi/) and production accuracy of English /sC/-words.

Of interest to the present study, De Leeuw et al. (2021) found that bilinguals with higher exposure to English and a greater grammatical knowledge of English, as measured by a C-test (Klein-Braley, 1985), were better than those with less exposure and lower grammatical knowledge in producing English-like /sC/ target stimuli. This suggests that similar to how L2 age of acquisition explains within-group individual variation in language-specific phonological repair strategies in perception (Parlato-Oliveira et al., 2010), factors like L2 exposure and L2 grammatical proficiency may determine individual variation in bilinguals' activation of language-specific phonological repair strategies in production. Further evidence for sources of individual variation in production comes from a study with two groups of BP-English sequential bilinguals living in the US and Brazil (Alcorn, 2018), for which measures of participants' English language history, use, and proficiency were obtained using the *Bilingual Language Profile* questionnaire (Birdsong et al., 2012). In that study, higher English proficiency correlated with lower epenthesis rates in L2 English, and longer history, more use, and higher proficiency in L2 English correlated with lower epenthesis rates in L1 Portuguese.

These findings point to the additional roles of L2 experience in determining individual variation in bilingual speakers' epenthetic vowel production.

In the present study, we aim to further unpack the nature and sources of individual variation in bilingual speakers' epenthetic vowel production in both their languages. To this end, we examined bilingual production data from balanced BP-Japanese bilinguals in Japan. We ask whether these bilinguals apply language-specific phonological repair strategies in each language separately, such that they /i/-epenthesize when speaking Portuguese and /ɯ/-epenthesize when speaking Japanese, or whether they exhibit signs of what we will henceforth call 'spillover', which is the use of one language-specific strategy in another language. If such spillover occurs, a question that follows is which individual factors predict it. We formulate our research questions as follows:

RQ1: Do BP-Japanese bilinguals use language-specific phonological repair strategies in each language separately, or is there 'spillover'?

RQ2: What are the individual factors that predict the degree of such spillover?

3. The present study

3.1 BP-Japanese bilinguals in Japan

Japan is home to a Brazilian community of over 200,000 individuals[2] who, to various degrees, are bilingual in Portuguese and Japanese. Many (though not all) of these individuals are Brazilians of Japanese descent who arrived in Japan from the 1990s, at a time when Japan was experiencing rapid economic growth and introduced working visas that favored foreign nationals with Japanese heritage.

The linguistic profiles of the individuals in Japan's Brazilian community are diverse. They are shaped by different degrees of exposure to and use of Portuguese and Japanese in the home environment and in society, and are often influenced by changes in the linguistic environment over one's lifetime due to relocation to and from Brazil and Japan. Indeed, the bilinguals that we present in this study show a large degree of variation in terms of linguistic-experiential factors such as age of acquisition and the languages spoken by their caretakers during childhood, and in terms of self-reported attributes such as the frequency of switching languages in a conversation; whether they talk to themselves in Portuguese, Japanese or both; and which culture they associate with most (Supplemental Material 2).

While we are careful not to assign a uniform label to this diverse group of individuals with distinct linguistic profiles, the participants in this study could be best described as balanced BP-Japanese bilinguals. As we will describe in more detail in section 4.1, they have comparable measures across both languages in terms of language dominance (reflecting self-reported language proficiency and hours using each language in various social settings), aggregate immersion (reflecting age of acquisition and years of use), as well as measures of phonolexical perception and lexical access. Yet naturally, even within these measures we observe individual differences, and it is this individual variation that we factor in to

[2] Based on data from the Japan Immigration Services Agency https://www.moj.go.jp/isa/publications/press/13_00047.html .

investigate the extent to which language-specific vowel epenthesis spills over from one language into another.

3.2 Vowel epenthesis in BP and Japanese

In BP, most obstruent-obstruent and obstruent-nasal clusters are illicit, and the only obstruent permitted in word-final syllable codas is /s/ (Cabrelli et al., 2019, p. 56; Guevara-Rukoz, Lin, et al., 2017, p. 569). Illicit consonant clusters and codas are typically repaired by means of an epenthetic /i/, such that a loanword like *TikTok* is rendered as /ti.ki.tɔ.ki/[3]. In Japanese, the maximum syllable structure is CV(C), and the coda consonant can only be a nasal or the first part of a geminate consonant (Hasegawa, 2018, pp. 135-153). Like BP, violations of this syllable structure are repaired by means of an epenthetic vowel, such that *TikTok* would be rendered as /tik.kɯ.tok.kɯ/.

Whilst the mechanisms of vowel epenthesis in BP and Japanese appear similar, one striking difference is the quality of the epenthetic vowel. In BP, the default epenthetic vowel is almost always an /i/-like vowel (Guevara-Rukoz, Parlato-Oliveira, et al., 2017), although studies with nonwords report occasional epenthesis with /u/ or /a/-like vowels (John & Cardoso, 2017). In Japanese, the quality of the epenthetic vowel is context-dependent: it is /ɯ/ in most environments, but /i/ following a palatal affricate /tɕ/ or /dʑ/, and /o/ following an alveolar stop /t/ or /d/. However, recent production data from L1 speakers suggest that the traditional tripartite system of vowel epenthesis for nativized loanwords may be shifting to one where /ɯ/ is the default vowel in all environments, although this is subject to substantial individual variation (Mattingley et al., 2019). In the present study, we used /a$C_1C_2V_2$/ stimuli for which we would expect an epenthetic /i/ in BP, and an epenthetic /ɯ/ in Japanese.

3.3 Factors that may predict phonotactic spillover

In the context of the present study, we assume that the default phonological repair

[3] In many BP varieties and also in Japanese, /ti/ is often palatalized.

strategy is /i/-epenthesis in BP and /ɯ/-epenthesis in Japanese. Yet, as we reviewed in section 2.2., previous studies have shown that bilinguals may deviate from such language-specific strategies as a result of spillover from phonotactics from another language, and that the likelihood of such spillover may be predicted by factors like L2 age of acquisition (Parlato-Oliveira et al., 2010), or L2 exposure/use and proficiency (Alcorn, 2018; De Leeuw et al., 2021). In the present study, we examine balanced bilinguals' epenthetic vowel production in both their languages, and focus on four factors that we deemed to be relevant to predict within-group individual variation: language dominance ratio, language immersion, phonolexical perception, and lexical access.

The first two individual factors (language dominance ratio and aggregate immersion) were calculated[4] by the *Language History Questionnaire 3* (*LHQ3*), a survey tool to assess the language background of speakers of more than one language (Li et al., 2020).

Language dominance is a measure that is "closely related to multiple factors including participants' proficiency and daily usage of each language" (Li et al., 2020, p. 941). In our analyses, we used the language dominance *ratio*, which is described as the most suitable language dominance measure for between-subject analyses (Li et al., 2020, p. 941). It is obtained by dividing the dominance in $language_i$ by the dominance in $language_j$, where $language_j$ is typically the native language. In our analyses, we used language dominance ratio of Japanese against Portuguese. We did this because—despite the fact many participants acquired both languages from birth or from an early age, making it difficult to determine 'the' native language—most participants acquired Portuguese before Japanese[5].

Aggregate immersion is an "overall aggregated scoring function of immersion for each language that the participant knows, based on her Age, Age of Acquisition (AoA), and Years

[4] See the LHQ3 documentation for the exact calculation https://lhq-blclab.org/static/docs/aggregate-scores.html
[5] We also ran analyses where we used language dominance ratio and other measures of BP relative to Japanese. As expected, this alternative analysis (Supplemental Material 3) revealed similar findings as the analyses that we report here, but in the reverse direction.

of Use of the language" (Li et al., 2020, p. 940). Although previous studies investigated the effect of L2 age of acquisition (AoA) to predict individual differences in phonotactic spillover in bilinguals (Parlato-Oliveira et al., 2010), we considered aggregate immersion to be a more suitable measure than AoA. This is because aggregate immersion accounts for scenarios in which an individual acquired a language at a certain age but then stopped using it for some time. Such scenarios are in fact exactly exemplified by some participants in our study who temporarily relocated from Japan to Brazil, leading to a significant decrease in exposure to Japanese, and who returned to Japan at a later age. (These are the individuals in Supplemental Material 2 for whom the number of years spent in Japan does not correspond with the difference between current age and age of acquisition of Japanese). Language immersion for these individuals "should be different from (less immersive than) that of a participant who started to learn a language at the same age but has remained an active user of the language" (Li et al., 2020, p. 941). Therefore, in the context of the present study, the measure of aggregate immersion was considered a more representative indicator of age-related linguistic experiential factors than AoA. Following our choice to use dominance ratio of Japanese relative to BP, we also used aggregate immersion in Japanese (as opposed to aggregate immersion in BP) in our analyses.

Finally, we examined the effects of phonolexical perception and lexical access. Here, 'phonolexical perception' refers to the perceptual encoding of phonemes into lexical representations, a process that is also known as "phonolexical encoding" (Llompart, 2021, p. 2) or "phonolexical processing" (Pelzl et al., 2021, p. 3). 'Lexical access' refers to the "ability with which a speaker can retrieve lexical items from the lexicon" (Martínez Vera et al., 2023, p. 4). We operationalized phonolexical perception by means of a gating task, and lexical access by means of the *MINT Sprint* multilingual image-naming task (Garcia & Gollan, 2022). We included phonolexical perception and lexical access as possible predictors of

individual variation as they may capture elements of bilingual proficiency and dominance that a questionnaire like the *LHQ3* (which relies on self-reported values) cannot capture. Although the study by S. Y. Kim and Han (2024) investigated the link between phonolexical perception and epenthetic vowel production in Korean-L1 English-L2 speakers by means of an English-L2 lexical decision task (which could tap into similar phonolexical processes as a gating task), no link was found between phonolexical perception and epenthetic vowel production. To the best of our knowledge, there are no studies that have investigated the link between lexical access and variation in phonological repair strategies in bilinguals.

In light of the literature reviewed above and our research questions, we hypothesize the following:

H1: We predict some degree of phonotactic spillover in BP-Japanese bilinguals, such that speakers sometimes /i/-epenthesize in Japanese, and /ɯ/-epenthesize in BP.

H2: We predict that language dominance ratio, language immersion, phonolexical perception, and lexical access all affect the likelihood of phonotactic spillover. For instance, a higher value for all four scores in Japanese (relative to BP) is expected to result in more spillover of Japanese-typical strategies (ɯ-epenthesis) into BP.

4. Methodology

4.1 Speakers

The study was approved by the ethics committee of the National Institute for Japanese Language and Linguistics. Participants provided written consent prior to participation. They were recruited via word-of-mouth and were paid JPY 2,500 for their participation. All were residing in Japan at the time of the experiment and were bilingual in BP and Japanese, and most reported knowledge of a third language like English or Spanish, which they acquired as part of Brazilian or Japanese school curricula (we discuss potential implications of L3 exposure in section 6.1). In the following, we present production data from 22 participants[6] (15 female).

Table 1 shows an overview of these participants. Detailed participant information can be found in Supplemental Material 2.

	Mean	*SD*	Min	Max
Age	33.50	12.30	20.00	60.00
Age of first exposure to BP (spoken)	1.27	2.41	0.00	7.00
Age of first exposure to Japanese (spoken)	5.73	5.34	0.00	16.00
Aggregate immersion BP	0.70	0.18	0.41	1.00
Aggregate immersion Japanese	0.61	0.18	0.22	1.00
Language dominance BP	0.52	0.14	0.14	0.89
Language dominance Japanese	0.59	0.16	0.38	1.17
Language dominance ratio Japanese:BP	1.31	0.90	0.63	5.00
Language dominance ratio BP:Japanese	0.95	0.33	0.20	1.58
Phonolexical perception BP	0.72	0.09	0.47	0.86
Phonolexical perception Japanese	0.76	0.12	0.41	0.97
Lexical access BP	0.70	0.17	0.13	0.88
Lexical access Japanese	0.58	0.12	0.32	0.80

Table 1: Overview of the 22 participants

[6] Fourteen additional participants were excluded from the present analysis because they were either relatively late acquirers of their second language (beyond age 16; 8 participants); had learned European Portuguese (1 participant); had resided in an English-speaking country during childhood (1 participant); and because of incomplete or missing data for one or more of the tasks (6 participants).

4.2 Experiment overview

The experiment was carried out online on *Gorilla.sc* (Anwyl-Irvine et al., 2020). The experiment can be accessed via the *Gorilla.sc* Open Materials (Supplemental Material 4). Headphone checks (Woods et al., 2017) prior to the experiment ensured that the raters were using headphones and were in a quiet environment. Written instructions for each task were accompanied by audio tracks of a native BP speaker and a native Japanese speaker (neither speaker had knowledge of the other language) who read out the instructions.

Participants completed three tasks, each once in Portuguese and once in Japanese, in the following order: a phonolexical perception task, the MINT Sprint image-naming task, and a syllable concatenation production task. At the end of the experiment, participants filled out an adapted version[7] of the *LHQ3* (Li et al., 2020). The questions were presented bilingually in Japanese and Portuguese and participants could reply to the questionnaire in either language. Participants averaged 30-40 minutes to finish the experiment.

Table 2 shows an overview of the experiment's tasks. Participants switched between languages for each task before moving onto the next task. An abridged version of the *Musical Ear Test* (Wallentin et al., 2010)[8] served as a buffer task to avoid consecutive production tasks in two different languages. The 'Randomiser' in *Gorilla.sc* resulted in balanced groups of participants starting either with BP or Japanese (we discuss possible implications of switching between languages within the experiment in section 6.3).

[7] The adaptation involved the removal of some questions that were unnecessary for calculating aggregate immersion or dominance.

[8] The abridged MET also served to measure musicality scores and to investigate how this related to individual performance in each of the tasks. For brevity, we do not discuss the musicality scores here, but it suffices to say that it predicted some degree of individual variation.

Description	Language	Duration (minutes)
Phonolexical perception	A	4
Phonolexical perception	B	4
MINT Sprint	A	3
Short Musical Ear Test: Rhythm	B	2
MINT Sprint	B	3
Production	A	4
Short Musical Ear Test: Melody	B	2
Production	B	4
Production: Mixed	AB	4
Questionnaire and debriefing	AB	5

Table 2: Experiment overview. A = language that was first displayed (either BP or Japanese) and B = language that was displayed after. AB indicates that both languages were displayed.

4.3 Control tasks

Before the syllable concatenation production task (section 4.4), participants completed two 'control tasks' that we briefly describe here.

4.3.1 Gating task (phonolexical perception)

The purpose of this task was to measure phonolexical perceptual acuity in both languages. It consisted of a gating task in which participants heard a snippet from the first syllable of a disyllabic word and needed to indicate which word they thought it belonged to. The target words were minimal pairs that contrasted in pitch/stress accent, e.g., [ka˩˥mi] – [ka.mi˩˥] 'paper' – 'god' in Japanese and [ˈdu.vi.dɐ] – [du.ˈvi.dɐ] 'doubt' (noun) – 'he/she doubts' (verb) in BP, and (near)-minimal pairs that contrasted in vowel nasalization, e.g., [˩˥kɐ̃ɲ.dʑi] – [˩˥ka.dʑi] 'organizer'–'house chores' in Japanese and [ˈlĩ.du] – [ˈli.du] 'pretty' – 'have read' in BP. These words were produced by a native BP speaker and a native Japanese speaker (neither speaker had knowledge of the other language). Participants completed 49 trials in each language. A phonolexical perception score was obtained from the proportion of correct responses. To account for any individual variation that may be due to inherent task ease or difficulty and to operationalize relative phonolexical perception in one language to the other, we used the ratio of perception score in Japanese against perception score in BP in our

analyses.

4.3.2 MINT Sprint (lexical access)

The purpose of this task was to measure lexical access in both languages with the MINT Sprint paradigm (Garcia & Gollan, 2022). Participants were shown a grid of 80 images and had to name as many as they could within 3 minutes. A lexical access score was obtained from the number of correctly named images. Similar to phonolexical perception, we used the ratio of lexical access score in Japanese against the score in BP in our analyses.

4.4 Production task

The production task was a multisyllable concatenation task (Wayland et al., 2006) to elicit production of epenthetic vowels in illicit consonant clusters. Participants were instructed that they would be listening to foreign words cut up in two, and that they had to 'repair' these words by producing them in full in a carrier sentence in BP (*eu falo __ uma vez*) or Japanese (*watashi wa __ to iimasu*), meaning 'I say __'.

4.4.1 Stimuli

Stimuli were based on a list of items reported in Guevara-Rukoz et al. (2017) and had a disyllabic /a$C_1C_2V_2$/ structure, with V_2 vowels from the set {a, o} and the C_1C_2 cluster from the set {gb, bd, gn, bn}, resulting in eight unique stimuli for which we would expect /i/-epenthesis in BP and /ɯ/-epenthesis in Japanese. We did not include coronal consonants as these may yield palatalization-induced epenthesis in BP (Azevedo, R.Q. et al., 2017), nor did we include voiceless consonants as these result in high vowel devoicing in Japanese, cf. Mattingley et al. (2019).

Stimuli were voice-recorded by a Dutch-English bilingual male speaker, who voiced and released coda stops, at a sampling rate of 44,1 kHz in a sound-attenuated booth. Stimuli were subsequently spliced in two in *Praat* (Boersma & Weenink, 2019), resulting for instance in /ag/ and /ba/. These monosyllabic stimuli were converted to 70dB using the "scale

intensity" command in *Praat* before being loaded as .mp3 files in *Gorilla.sc*.

4.4.2 Procedure

Monosyllabic stimuli were aurally and orthographically presented in roman capital letters[9] with a 500 ms interval, i.e. <AG> + 500 ms <BA>. After this, the BP or Japanese carrier sentence was orthographically displayed on the screen (with a blank space in the place of the target word), and participants were instructed to say out loud the repaired word within the carrier sentence. Participants started with a practice round with four trials of practice stimuli (/a/ + 500 ms /pa/) and (/a/+ 500 ms /ti/)[10]. In this practice round, participants heard a native speaker of BP or Japanese produce the repaired word (/apa/, /ati/) within the carrier sentence after their own production.

After the practice round, participants completed 8 trials in language A (see Table 2). They then completed the melody component of the Musical Ear Test in language B, after which they completed 8 trials in language B. Finally, they completed 16 trials in a mixed-language block (8 trials for each language). Stimuli presentation was fully randomized within each block.

4.4.3 Annotation procedure

Recordings were analyzed and annotated in *Praat*. The *Montreal Forced Aligner* (McAuliffe et al., 2017) and a script adapted to recognize nonwords (Chodroff, 2018) was used to automatically annotate the recordings. Annotations were then checked manually by the first author and corrected where necessary for the target words.

Intersyllabic voiced intervals longer than 40 ms and for which there was a clear waveform were annotated as vowels. Following Shaw and Davidson (2011); Shin and

[9] We included an orthographic representation with the aural stimuli to ensure that participants would not delete coda consonants, which sometimes happens in Japanese loanword adaptation of aural-only stimuli (Shoji & Shoji, 2014). We discuss the potential implications of orthographic stimuli in section 6.1.

[10] We did not include VC + CV items in the practice stimuli to avoid that the audio feedback would influence epenthesis patterns in the main block.

Iverson, (2014), voiced intervals shorter than 40 ms were labeled as ‘null’ as these may be *phonetic* epenthetic vowels, which result from gestural mistiming between consonant production, and not *phonological* epenthetic vowels. (We discuss the implications of applying this 40 ms threshold in section 6.1). An example of a token without epenthesis and a token with epenthesis is shown in Figure 1. (The interested reader can listen to these and other examples in Supplemental Material 1 – d_audio_example).

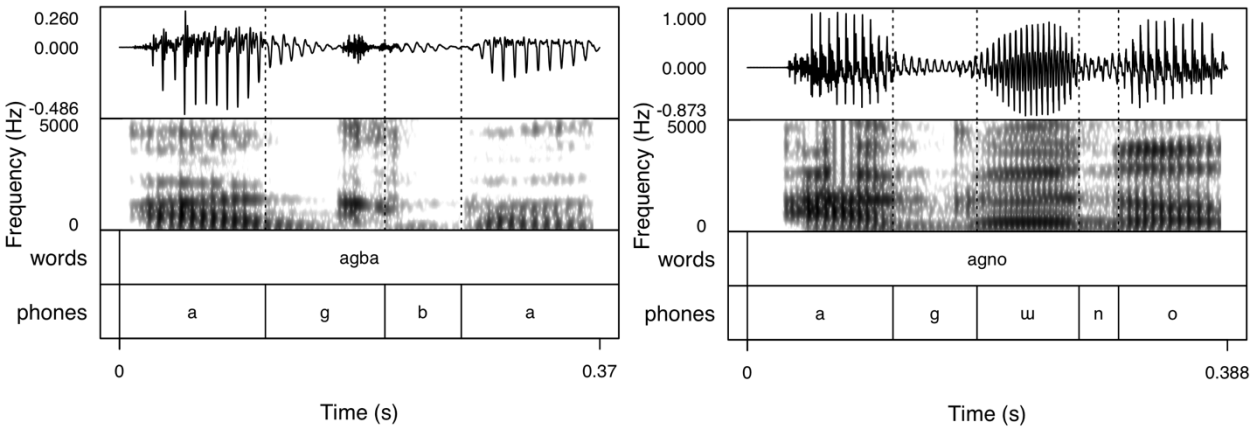

Figure 1: Spectrograms, generated with praatpicture *(Puggaard-Rode, 2024), showing an example of a token labeled without epenthesis (left) and a token labeled with epenthesis (right).*

Vowel quality of epenthetic vowels was determined based on auditory impressions and available spectral information. Twenty-six tokens were labeled as ‘missing’ and discarded from analysis because they contained noise, or because participants mispronounced a word (e.g., /agna/ instead of target /agba/) or appeared to apply different repair strategies such as deletion, (e.g., /abo/ instead of /abdo/). Sometimes participants produced other epenthetic vowels than /i/ or /ɯ/, namely /a/, /e/, /i̞/, /ɯ̟/, /u/, /o/. Since their occurrence was relatively low (23 tokens) we grouped these under ‘other’ and excluded them from analyses. A phonetician who was not involved in the project annotated the presence and type of epenthetic vowels in a random sample of 41 stimuli, and labeled 39 of the stimuli in correspondence with the original labels by the first author (Supplemental Material 1 –

d_sample_check_by_phonetician).

Although an extensive acoustic analysis was beyond the scope of this study, Figure 2 presents a vowel plot of epenthetic /i/ and /ɯ/ per carrier sentence language for illustration purposes. Overall, it shows the fronted position of /i/ and the back position of the /ɯ/.

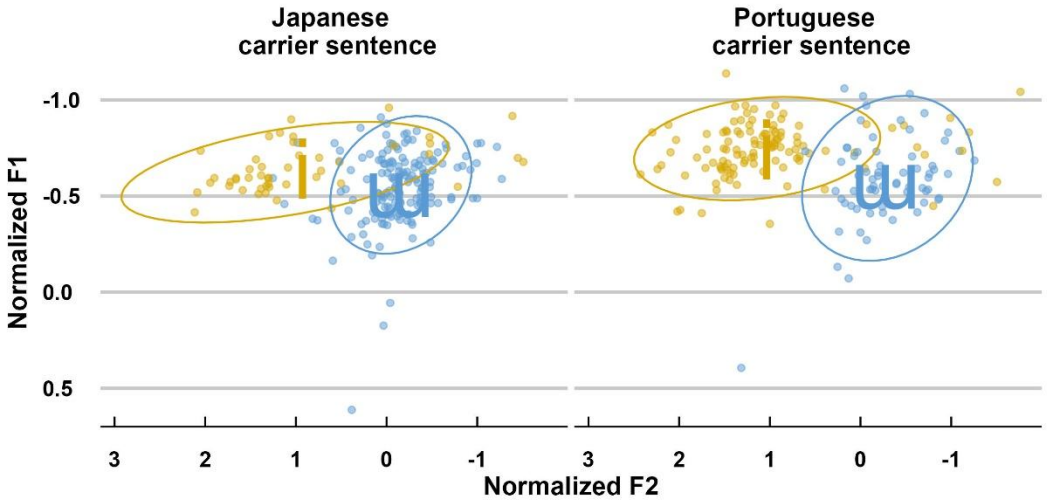

Figure 2: Lobanov-normalized F1-F2 plot for vowels labeled as /i/ (light dots) and /ɯ/(dark dots) per carrier sentence language.

4.5 Statistical procedures

We a ran a Bayesian multinomial model in the *brms* package (Bürkner, 2018) to predict the likelihood of /i/, /ɯ/, or null-epenthesis. The model structure was motivated by our research questions and contained fixed effects for carrier sentence *Language* (BP, Japanese; sum-contrast coded), *Vowel* (/i/, /ɯ/, null; sum-contrast coded), and the four continuous variables of interest: *Dominance ratio* (Dominance ratio Japanese:BP); *Immersion* (Immersion in Japanese); *Phonolexical perception* (Gating score Japanese:BP), and *Lexical Access* (MINT score Japanese:BP). All continuous factors were centered and scaled. The model contained two-way interactions between *Language* and each of the continuous variables. The random-effects structure consisted of a by-subject random slope for *Language* and a random intercept for *Item*. In our analyses, we grouped together the trials from the single-language and mixed blocks, as an exploratory model revealed that the distribution of

/i/-epenthesis, /ɯ/-epenthesis, and null-epenthesis was similar across blocks (Supplemental Material 1 – code_epenthesis_analysis).

We used weakly informative priors with prior specification in *brms* set as (0,1) for 'Intercept', (0,1) for 'b', (0, 0.1) for 'sd' priors and LKJ(2) for correlation priors, and ran four sampling chains with each 3000 iterations and 1500 warm-up iterations. We conducted model diagnostics by observing Rhat values (ensuring these were close to 1) and by inspecting posterior draws using the *brms* pp_check() function, cf. Veríssimo (2025, p. 26). Multicollinearity between continuous variables was checked with the *performance* package (Lüdecke et al., 2021) and revealed low levels of correlation (all Variance Inflation Factors < 3).

To investigate the nature of interactions, planned comparisons were carried out in the *marginaleffects* package (Arel-Bundock et al., 2024). In the following, we report findings for which the 95% Credible Intervals (CrIs) of the effect estimates provided by the posterior distribution did not contain zero, and for 95% CrIs that did contain zero but that had a relatively high maximum probability of direction (pd). We take such findings to be 'suggestions' of an effect (Nicenboim et al., 2018). For planned comparisons, we report findings that did not contain zero in the 95% highest posterior density (HPD) as calculated by the *marginaleffects* package.

5. Results

5.1 Descriptive statistics

Figure 3 shows the distribution of epenthesis types in the BP, Japanese, and mixed blocks out of a total of 678 observations. Within these observations, there were 406 counts of vowel epenthesis, i.e., 59.88% of the time. In terms of vowel quality, /ɯ/ was most common (224 observations; 55.17% of all epenthetic vowels), followed by /i/ (159 observations; 39.16% of all epenthetic vowels), and 'other' vowels (23; 5.66%). As shown in Figure 3, /i/-epenthesis predominantly occurred in the BP block (with only Portuguese carrier sentences) and to a lesser extent in the Japanese block (with only Japanese carrier sentences). By contrast, /ɯ/-epenthesis predominantly occurred in the Japanese block, and to a lesser extent in the BP block. In the mixed block, in which there was an even number of trials with BP and Japanese carrier sentences, /i/-epenthesis occurred relatively often in trials with BP sentences, and /ɯ/-epenthesis relatively often in trials with Japanese sentences. As mentioned in section 4.5, we henceforth analyze the results grouped together for the single-language and mixed blocks.

Figure 3 also suggests that some phonotactic spillover occurred, as evidenced by the occurrence of language-atypical /i/-epenthesis in Japanese sentences and language-atypical /ɯ/-epenthesis in Portuguese sentences. Zooming in more closely on these language-atypical epenthesis types, we found that thirteen out of 22 participants at least once produced a nonword with a Japanese-typical /ɯ/ in Portuguese instead of the default /i/. In contrast, five participants at least once produced a nonword with a Portuguese-typical /i/ in Japanese instead of the default /ɯ/. We discuss this asymmetry in more detail in section 6.3.

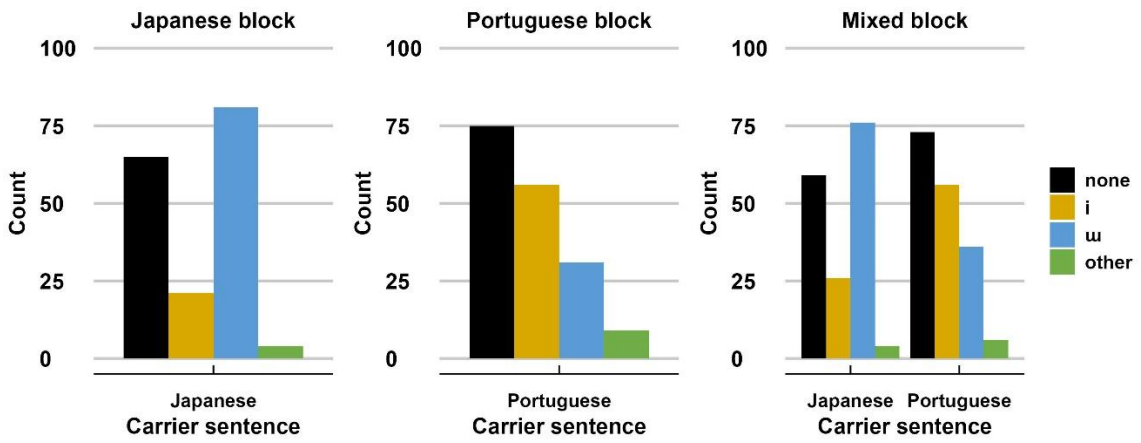

Figure 3: Bar charts showing the distribution of epenthesis type per block and per trial language.

5.3 Model results

The complete posterior distributions and multiple comparison tables are in Supplemental Material 3. The posterior distribution suggested effects of *Language*, *Dominance ratio*, *Immersion*, *Phonolexical perception*, and *Lexical access*. It also revealed *Language:Dominance ratio* and *Language:Phonolexical perception* interactions, suggesting that these effects differed per trial language. To examine these effects, we report estimates for each vowel, and for interaction effects, estimates for each vowel by trial language. We reiterate here that we only report estimates and planned comparisons for which zero was not included in the 95% CrI or HPD.

5.3.1 Comparisons between and within language

Planned comparisons between trial languages suggested that there was more /i/-epenthesis in trials with a Portuguese carrier sentence than in trials with a Japanese sentence, $b = 0.21$ (0.16, 0.26). The comparisons further revealed that there was more /ɯ/-epenthesis in Japanese trials than in Portuguese trials, $b = 0.26$ (0.20, 0.32). The comparisons suggested no difference in null-epenthesis between trial language.

Comparisons between vowels within each trial language suggested that among Japanese trials there was more /ɯ/-epenthesis, *b* = 0.45 (0.32, 0.57), and null-epenthesis, *b* = 0.43 (0.32, 0.54), than /i/-epenthesis. Among Portuguese trials, there was more null-epenthesis than /i/-epenthesis, *b* = 0.34 (0.13, 0.54), and more null-epenthesis than /ɯ/-epenthesis *b* = 0.43 (0.28, 0.54) . The predicted probability per carrier sentence language and vowel type is shown in Figure 4.

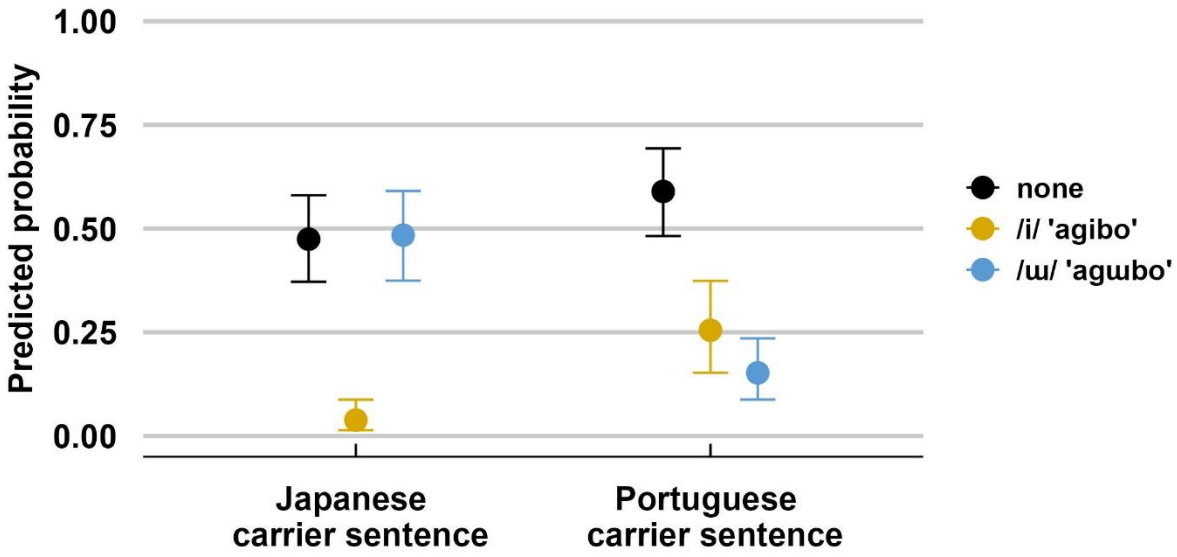

Figure 4: Predicted probability (95% Highest Posterior Density) per carrier sentence and vowel type.

5.3.2 Interaction Language:Dominance ratio

Estimates for the effect of *Dominance* (Japanese relative to Portuguese) per trial language suggested that higher dominance in Japanese decreased /i/-epenthesis, *b* = -0.23 (-0.37, -0.11), and increased /ɯ/-epenthesis in Japanese trials, *b* = 0.24 (0.09, 0.39). There was no suggestion that dominance affected /i/ or /ɯ/-epenthesis in Portuguese trials, or that it affected null-epenthesis in either language.

5.3.3 Effect of immersion

In absence of a *Language:Immersion interaction*, the estimates for the effect of *Immersion* (in Japanese) suggested that overall, greater immersion in Japanese decreased /i/-epenthesis, *b* = -0.05 (-0.09, 0.00), and increased /ɯ/-epenthesis, *b* = 0.07 (0.02, 0.12). There was no suggestion that immersion affected null-epenthesis.

5.3.4 Interaction Language:Phonolexical perception

Estimates for the effect of *Phonolexical perception* (Japanese relative to Portuguese) per trial language suggested that higher phonolexical perception acuity in Japanese decreased /i/-epenthesis, *b* = -0.14 (-0.23, -0.07), and increased /ɯ/-epenthesis, *b* = 0.08 (0.03, 0.13) in Portuguese trials. There was no suggestion that phonolexical perception affected /i/ or /ɯ/-epenthesis in Japanese trials, or that it affected null-epenthesis in either language.

5.3.4 Effect of lexical access

In absence of a *Language:Lexical access* interaction, the estimates for the effect of *Lexical access* (Japanese relative to Portuguese) suggested that overall, greater lexical access in Japanese decreased /ɯ/-epenthesis, *b* = -0.16 (-0.30, 0.03). There was no suggestion that lexical access affected /i/-epenthesis or null-epenthesis.

An overview of the model's predicted probability per vowel and trial language against each of the continuous variables is shown in Figure 5.

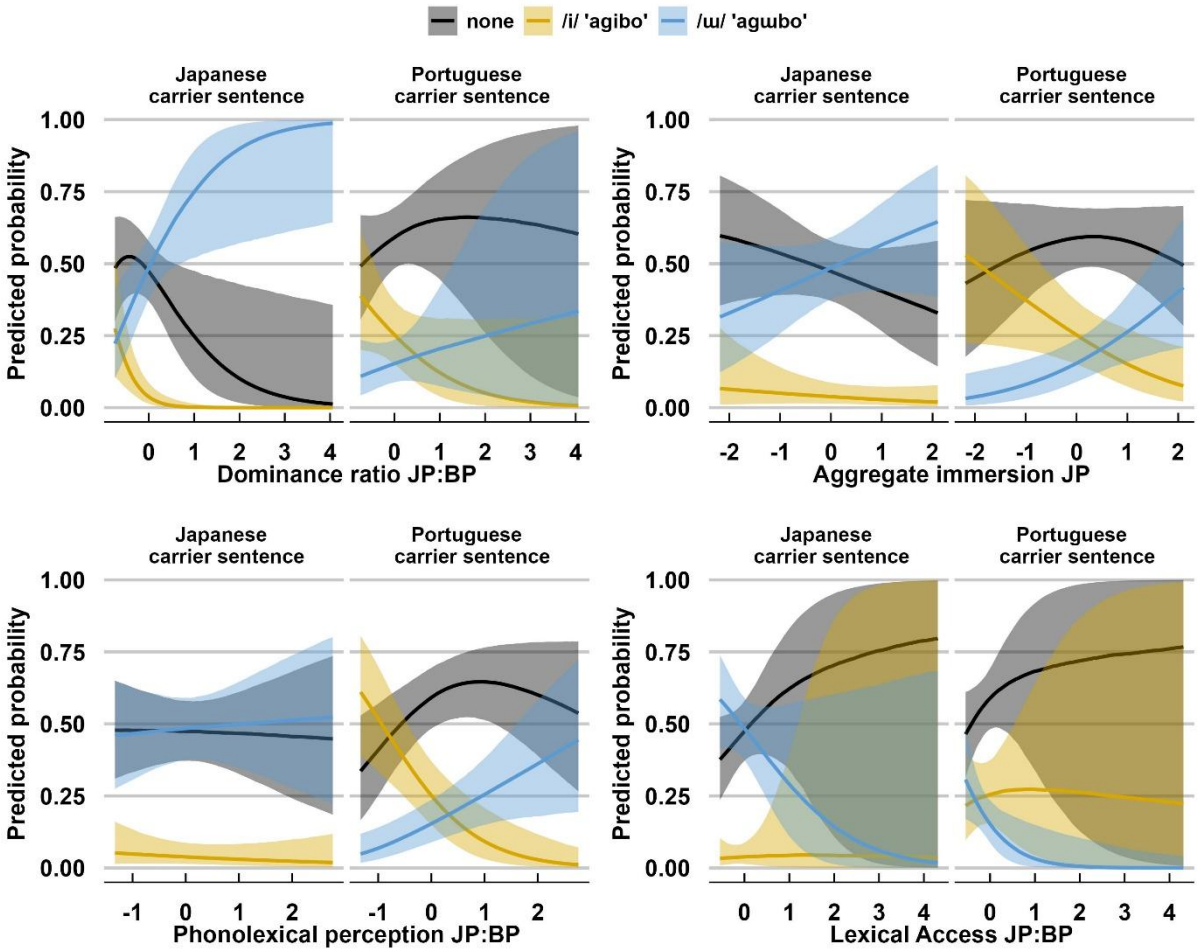

Figure 5: Predicted probability per vowel, trial language, and each of the four continuous variables. Shaded ribbons represent 95% Credible Intervals.

6. Discussion

6.1 Occurrence and distribution of vowel epenthesis

In Research Question 1, we asked whether BP-Japanese bilinguals use language-specific phonological repair strategies in both their languages separately, such that they would /i/-epenthesize when producing words with illicit consonant clusters in a Portuguese carrier sentence and /ɯ/-epenthesize in a Japanese sentence, or if there they would demonstrate signs of what we call 'spillover', in which one language-specific strategy is used in the other. Based on our production data and the posterior distribution provided by the model, we found between-language differences in terms of epenthetic vowel quality. There was more /i/-epenthesis in Portuguese carrier sentences than in Japanese carrier sentences, and more /ɯ/-epenthesis in Japanese sentences than in Portuguese sentences. This suggests that the speakers, to some extent, used language-specific phonological repair strategies in each language separately.

Before we continue to discuss the occurrence and distribution of /i/-epenthesis and /ɯ/-epenthesis, we must note that in about 40% of all productions, we recorded no vowel epenthesis at all ('null-epenthesis'). The proportion of epenthetic vowel production in our study (59.88%) appears to be relatively low in comparison to production data with Japanese-L1 speakers that revealed "epenthetic vowels between two consonants in 100% of the experimental tokens where they were expected" (Mattingley et al., 2019, p. 8), as well as production data with BP-L1 speakers, where epenthesis occurred between 64% and 88% of the time in word-medial illicit consonant clusters (John & Cardoso, 2017).

We offer three reasons that may account for this discrepancy. The first is task-specificity. In Mattingley et al. (2019), target stimuli like <agba> were presented only orthographically, and participants were instructed to read the target words out as if they were Japanese words. This may have "maximized the use of Japanese phonology" (p. 7), resulting

in vowel epenthesis in target stimuli. Similarly, John and Cardoso (2017) found that epenthetic vowel production of English nonwords was most frequent in a read-aloud task (88%), but least frequent in a repetition task (64%). In our syllable concatenation task, stimuli were aurally and orthographically presented (e.g., <AG> + 500 ms + <BO>), and participants were asked to reproduce the word in full in a carrier sentence. This reproduction of an auditory-orthographic stimulus may have made participants rely less on L1 phonotactics than they would in a read-aloud task (John & Cardoso, 2017, p. 179), and instead more on the auditory signal, which would lower the likelihood of phonotactically-induced vowel epenthesis.

A second explanation for the relatively high frequency of null-epenthesis relates to our acoustic threshold for determining the presence of an epenthetic vowel. We labeled voiced intervals shorter than 40 ms as 'null', guided by the notion that such intervals may be phonetic, and not phonological, epenthetic vowels. The appropriateness of such a threshold has been questioned, based on empirical evidence that shows that phonological epenthetic vowels can in fact be shorter than 40 ms, as discussed in S. Y. Kim & Han (2024, pp. 294-295)[11]. In our data, 76 tokens (56 of which were labeled as /ɯ/ and 9 of which were labeled as /i/) did contain auditory and acoustic evidence of an epenthetic vowel, but were labeled as 'null' because they were shorter than 40 ms. Had we labeled these tokens as an epenthetic vowel, the total frequency of vowel epenthesis would have been 71.09% instead of the currently reported 59.88%. Although our cut-off point of 40 ms may thus have resulted in a slight undercount of epenthetic vowels, we believe that with this threshold, we could at least maximize the probability that the vowels that we identified were likely phonological epenthetic vowels (Davidson, 2006; K. Kim & Kochetov, 2011, p. 526).

[11] A reviewer suggested another way to identify phonetic epenthetic vowels in our data: by looking for an epenthetic /a/. This is because transitional vocoids typically mirror the following vowel (Davidson, 2010), which in our nonwords was always /a/. We did find 11 tokens with an epenthetic /a/, but these were not included in our main analyses, as they were labeled under 'other' vowels.

A final, third reason that could explain the relatively high frequency of null-epenthesis is that most participants reported some knowledge of English (Supplemental Material 2), which most had acquired in school as part of the Brazilian and Japanese school curricula. If exposure to English indeed affected epenthetic vowel production, English phonotactics would have competed with BP and Japanese phonotactics, leading to higher degrees of null-epenthesis, cf. Alcorn, (2018); Cabrelli et al. (2019); John & Cardoso (2017). Additionally, in line with the "Similarity Convergence Hypothesis" (Brown-Bousfield & Chang, 2023), BP might be additionally more susceptible than Japanese to L3 English influence given its relative typological proximity to English (the fact that our model suggested that for BP trials, null-epenthesis was in fact more likely than /i/-epenthesis or /ɯ/-epenthesis, would support this notion). It is also possible that our mixed aural-orthographic stimuli presentation (with roman capital letters) cumulatively enhanced any influence that English may have had on epenthesis patterns, cf. Mattingley et al. (2019, pp. 27-29); Vendelin & Peperkamp (2006), thus further increasing the likelihood of null-epenthesis.

Yet on the whole, more often than not did we observe that participants repaired illicit consonant clusters by producing a vowel that was absent from the auditory stimulus. This suggests that they adapted the nonwords to align with their languages' phonotactics. The distribution of the type of epenthetic vowel (Figure 3) further confirmed expected language-specific repair strategies: /i/-epenthesis was prevalent when the nonwords were spoken in Portuguese sentences, and /ɯ/-epenthesis was prevalent when they' were spoken in Japanese sentences. However, there were also signs of phonotactic spillover, given that some /i/-epenthesis occurred in Japanese sentences, as did /ɯ/-epenthesis in Portuguese sentences. In Research Question 2, we asked which individual factors (dominance, immersion, phonolexical perception, and lexical access) could account for such spillover.

6.2 Factors that predicted phonotactic spillover

Our model suggested that both language dominance and aggregate immersion explained phonotactic spillover. For instance, language dominance in Japanese decreased /i/-epenthesis (A BP-typical strategy) in Japanese trials. A similar role was found for immersion: participants who were more immersed in Japanese had more Japanese-typical /ɯ/-epenthesis and less BP-typical /i/-epenthesis, regardless of trial language. Our results with regard to language dominance, a measure representing daily exposure and self-reported proficiency, resemble the production data by De Leeuw et al. (2021), who found that self-reported percentage of English daily use by Spanish-L1 speakers was associated with more L2 English-like production of /sC/ clusters without a prothetic vowel (i.e., patterning more with English than with Spanish phonotactics). Similarly, our findings regarding language immersion mirror the perception data by Parlato-Oliveira et al. (2010), who found that an earlier age of acquisition (AoA) of L2 Japanese correlated with a higher proportion of Japanese-typical perceptual /u/-epenthesis in BP-L1 adult listeners. Although we deemed aggregate immersion to be a more suitable measure than AoA given our participant's dynamic linguistic profiles, we note here that a control model that additionally included a *Language:Japanese AoA* interaction similarly suggested that an earlier AoA of Japanese was associated with more Japanese-typical /ɯ/-epenthesis in Japanese sentences (Supplemental Material 1 – code_epenthesis_analysis). In that same model, greater immersion in Japanese led to more Japanese-typical /ɯ/-epenthesis in Portuguese sentences. AoA therefore also appears to be a factor that explains some degree of phonotactic spillover in balanced BP-Japanese bilinguals, in a similar way as does aggregate immersion.

In sum, our findings suggest that a higher dominance and greater immersion in one language increase the likelihood of activation of that language's specific phonological repair

strategy (vowel epenthesis, here). In some cases, this activation is strong enough to override the parallel activation of another language's repair strategy. In a larger light, these findings support studies and models that attribute a (combined) role to age-related and exposure-related factors to determine how much competition there is between two linguistic systems (MacWhinney, 2018) and to what extent entrenchment has taken place (Steinkrauss & Schmid, 2017).

As to the effect of two other factors—phonolexical perception accuracy and lexical access—we found that these too explained spillover, albeit less clearly so than did language dominance and aggregate immersion. Higher phonolexical perception in Japanese (relative to Portuguese) decreased /i/-epenthesis and increased /ɯ/-epenthesis in Portuguese sentences, suggesting that individual differences in phonolexical perception acuity (as measured by a gating task) accounted for spillover from Japanese phonotactics. The role of lexical access in our data is more difficult to interpret. Counterintuitively, our model suggested that individuals with a larger lexical access in Japanese relative to Portuguese had in fact less Japanese-typical /ɯ/-epenthesis overall. An investigation of our alternative model (in which we investigated the role of lexical access in BP relative to Japanese, see Supplemental Material 3), suggested that higher lexical access in BP increased null-epenthesis, and (counterintuitively) decreased BP-typical /i/-epenthesis in Japanese trials.

Although we included phonolexical perception and lexical access to investigate the role of direct measures of language dominance and proficiency —as opposed to questionnaire-based measures captured by the *LHQ3*— our findings suggest that only phonolexical perception plays a role in determining some degree of spillover of language-specific vowel epenthesis. One interpretation of this finding may be that our production task was inherently phonological in nature and may therefore be more related to bottom-up phonolexical encoding than to top-down lexical access. Although it cannot be excluded that

the use of nonwords induces some sort of lexical processing (or the formation thereof), we argue that our task with nonwords (which do not have any meaning associated with them) most likely involved prelexical processing (S. Y. Kim & Han, 2024, p. 296), for which measures of phonolexical perception would be relevant.

6.3 Final considerations

We conclude with some considerations regarding the interpretability of our findings. The first consideration regards the language mode that our participants may have operated in. Although we attempted to induce a language-specific mode in each task by providing written and spoken instructions in each language separately, and by having participants produce the words in a Portuguese or Japanese carrier sentence, it may be that the switching between languages during the experiment induced the participants' bilingual mode, which could have led to more phonotactic spillover than if the experiment were conducted in two separate single-language sessions. In particular, it is possible that recency effects (Castle et al., 2025) affected results in the production task. Although we found no differences in the distribution of epenthetic vowels between the single-language and mixed-language blocks, it could be that the production in some trials was affected by the language of the previous trial. However, the overall observation that participants applied BP and Japanese phonotactics separately, despite the potential challenge of having to switch languages regularly (in some cases trial-by-trial), highlights their flexibility in switching between languages. This is indeed representative of their daily language use: most participants indicated that they switch between languages within the same conversation on a daily basis (Supplemental Material 2). Future studies could investigate the effect of language switching skills on task performance (De Bruin & Xu, 2023; Mas-Herrero et al., 2021) in the context of bilinguals' phonological repair strategies.

A second consideration concerns the direction of the phonotactic spillover. Our data suggest that there was more spillover from Japanese phonotactics (/ɯ/-epenthesis) into

Portuguese than vice-versa. As observed in Figure 3, the proportion of language-atypical epenthetic vowels was higher in the Portuguese block than in the Japanese block. This was confirmed by our model, which suggested that whereas there was a difference between language-typical /ɯ/-epenthesis and language-atypical /i/-epenthesis in Japanese sentences, there was in fact no difference between language-typical /i/-epenthesis and language-atypical /ɯ/-epenthesis in Portuguese sentences. Individual patterns also appear to support this notion: only five participants ever produced an atypical epenthetic vowel in Japanese (/i/), whereas thirteen did so in Portuguese (/ɯ/). We offer two possible explanations for this asymmetry: first, as suggested by a reviewer, if many of the vowels that we labeled as phonological epenthetic vowels were phonetic epenthetic vowels after all, their quality could have been influenced not just by the following /a/ or /o/ within the target word (Davidson, 2010), but potentially also by the /u/ that surrounded the target words in the Portuguese carrier sentence ('*eu fal*/u/ ___/ /u/*ma vez*'), hence increasing the likelihood of /ɯ/ epenthesis. A second—and in our view, more plausible explanation—is that because all participants were residing in Japan at the time of the experiment, more "passive linguistic experience" (Wigdorowitz et al., 2023) with Japanese could have enhanced the activation of Japanese-specific /ɯ/-epenthesis across the board. Indeed, ambient language may further determine phonotactic spillover in bilinguals beyond the factors that we have investigated here. This has been suggested by Alcorn, 2018 (p. 60), who found that BP-English bilinguals in the US produced fewer epenthetic vowels in English than did proficiency-matched BP-English bilinguals residing in Brazil. To further investigate how ambient language influences the direction of phonotactic spillover, we could replicate our study with BP-Japanese bilinguals residing in Brazil.

Our third and final consideration regards the nature of the vowel epenthesis that we observed. Although we attempted to disentangle phonetic from phonological epenthesis by applying a 40 ms threshold, we did not consider whether participants had metalinguistic

knowledge of phonological epenthesis and were explicitly producing or not-producing epenthetic vowels in the experiment. We did conduct a general debriefing where participants could share their thoughts on the experiment and their bilingualism, but none mentioned (dis)similarities between BP and Japanese phonology (Supplemental Material 1 - d_debriefing). It thus remains unclear whether participants' epenthetic vowel production was the result of a 'choice' motivated by explicit knowledge of BP or Japanese phonology, or whether it resulted from unconscious activation of phonotactic knowledge from either language. In future studies, an experimental design that includes both 'implicit' and 'explicit' tasks, cf. De Leeuw et al. (2021, p. 611); Parlato-Oliveira et al. (2010), as well as a more systematic debriefing, cf. Cabrelli & Pichan (2021, p. 156), could elucidate this further. Future studies could also probe whether and how balanced BP-Japanese bilinguals activate language-specific vowel epenthesis in real-word environments, such as L3 English.

7. Conclusion

In this study, we investigated the nature and sources of individual variation in epenthetic vowel production by BP-Japanese balanced bilinguals. Results from a syllable concatenation task revealed that participants often produced an epenthetic vowel that was absent from the original auditory stimulus, suggesting that they phonologically 'repaired' the stimulus to align it with BP and Japanese phonotactics. Participants generally applied language-typical repair strategies, exhibiting /i/-epenthesis in BP trials and /ɯ/-epenthesis in Japanese trials, but some individuals appeared to exhibit 'phonotactic spillover', in which one language's repair strategy was used when speaking the other language. Analyses suggested that the sources of this variation in phonological repair strategies were individual differences in language dominance, aggregate immersion, and phonolexical perception acuity. Overall, this paper adds new production data to a growing body of literature on the nature and sources

of individual variation in bilinguals' language-specific phonotactics.

Data availability statement

The following materials are available on https://osf.io/ts8n9/?view_only=31ab8ee4219d4609bcecc1004d34bb6c:

1. Data and code, including audiovisual examples
2. Participant details
3. Full model output including alternative model output
4. Gorilla.sc tasks

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CRediT statement

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Competing interests

The authors declare none.

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