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Effects of word frequency and familiarity on perceptual epenthesis*

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Lu, Yihui and Jae Yung Song. 2024. Effects of word frequency and familiarity on perceptual epenthesis. *Linguistic Research* 41(Special Edition): 75-107. This study aimed to examine the effects of word frequency and familiarity on second-language (L2) learners' perceptual vowel epenthesis in words that violate the phonotactics of their native language. To this end, we conducted two lexical decision tests on 55 participants, comprised of native English controls (n = 19), and native speakers of Korean (n = 18) and Chinese (n = 18) learning English as an L2. During the two tests, one of which focused on the onset and the other on the coda, the participants listened to each word and indicated whether it was a real English word or not. The stimuli consisted of base items (e.g., *please*, *week*), which varied in frequency, and test (e.g., *p[ʊ̆]lease*, *week[ɨ]*) and control (*p[ɪ]lease*, *week[a]*) items, which were created by inserting an extra vowel to the base items. It is well known that high-frequency words are more likely to be accepted as real words than low-frequency words. If L2 learners have difficulty distinguishing between stimuli with vowel epenthesis (e.g., *p[ʊ̆]lease*) and those without (e.g., *please*), they should accept high-frequency words with vowel epenthesis (e.g., *p[ʊ̆]lease*) as real words more often than low-frequency words with vowel epenthesis (e.g., *p[ʊ̆]lier*). This was confirmed in the onset position, but not in the coda position. The word familiarity results were in line with the frequency results. These findings add to the body of literature by demonstrating the role of word frequency/familiarity in L2 learners' perceptual epenthesis. **(Chung-Ang University)**

Keywords perceptual epenthesis, phonotactics, frequency, familiarity, L2 English

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1. Introduction

When listeners are exposed to a word containing sound sequences that are not permitted in their native language (L1), they may perceptually repair it with an inserted vowel to conform to the phonotactic patterns of their L1 (Polivanov 1969). For instance, when Japanese listeners are exposed to consonant sequences that are not allowed in their native phonology, such as *ebzo*, they mistakenly perceive an epenthetic [u] between the consonants. As a result, they are unable to differentiate between stimuli that have the vowel *(ebuzo)* and those that do not *(ebzo)* (Dupoux et al. 1999). This phenomenon is known as perceptual epenthesis.

Perceptual epenthesis suggests that the phonotactic patterns of listeners' L1 can influence their perception of second-language (L2) sounds (Dupoux et al. 1999; Weber and Cutler 2006). In particular, listeners may perceive an illusory vowel to break up illegal consonant clusters, even when there is no vocalic unit present in the acoustics of the speech stream. Every language has phonotactic constraints, which place restrictions on the number and type of phonemes allowed in the particular position of a syllable. These constraints are developed early in life. By around nine months, infants show sensitivity to their L1 syllable patterns, but not to the syllable patterns of other languages, suggesting that they have acquired the phonotactic patterns of their L1 (Jusczyk et al. 1993).

Due to the early-acquired language-specific phonotactic constraints, L2 learners may perceive or produce non-native illegal sound sequences with a variety of adjustments, including consonant deletion, vowel insertion, and consonant mutation. These adjustments are often referred to as phonotactic repair (Darcy and Thomas 2019). Perceptual epenthesis, which is a type of phonotactic repair, has been demonstrated in various L1 groups, including the native speakers of Japanese (Dehaene-Lambertz et al. 2000; Dupouxet al. 2001), Korean (Kabak and Idsardi 2003, 2007; de Jong and Park 2012), and Mandarin Chinese (Durvasula et al. 2018). In Mandrin Chinese, the onset position and the coda position can only contain a singleton consonant (See Figure 1). Moreover, in the coda position, only one of the two consonants, the nasals /n/ and /ŋ/, is allowed (Ma et al. 2015). Likewise, only singleton onsets and codas are allowed in Korean, and the consonants that can appear in the coda position are limited to /p/, /t/, /k/, /m/, /n/, /ŋ/, and /l/ (Kang 2003). In contrast, in English, the maximum number of consonants that can occur in the onset position is three, and four in the coda position (Yavas 2020). Therefore, when perceiving English words, one common strategy employed by Korean and Chinese speakers to deal with the discrepancies between L1 and L2 phonotactics is to perceptually insert a vowel. This can occur both in the onset (CvCV) and coda (CVCv) positions. For example, Korean speakers might perceive the English word *food* as [ˈfudɨ] and also encode it lexically as a disyllabic word /ˈfudɨ/, at least in the early stages of exposure. More intriguingly, when an English word is borrowed into Korean, a vowel can be variably added after a word-final stop (e.g., week /ˈwikɨ/), even though the word-final stop (/k/) is legal in the coda position in Korean (For a thorough discussion of the possible factors affecting vowel insertion, see Kang 2003).

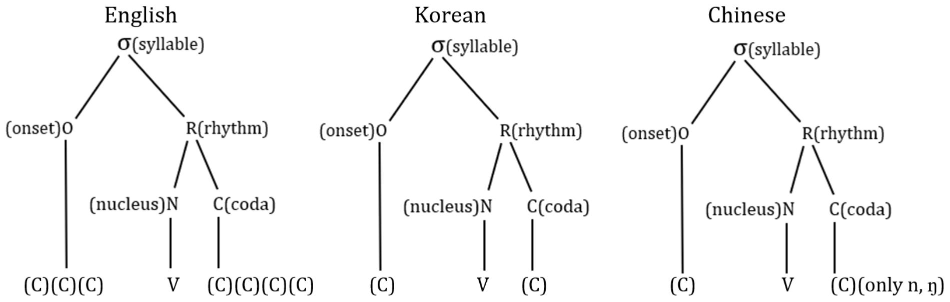

Figure 1. The differences in syllable structure between English, Korean, and Chinese

A number of factors are known to affect perceptual epenthesis (For relevant discussion, also see de Jong and Park 2012). For example, in order to examine the possible role of L2 learner's experience with the target language, Abrahamsson (2003) looked at the prevalence of epenthesis after postvocalic consonants in the speech of Chinese learners of Swedish over a two-year period. The study, which expanded upon the findings of Sato (1984), Osburne (1996), and Hansen (2001), found that consonant deletion was more common in the early stages of the acquisition process, while epenthesis was more common during the middle of the two-year period. In a study on Japanese learners of French, Detey and Nespoulous (2008) demonstrated that the audiovisual and visual conditions triggered more epenthesis than the auditory condition, suggesting a possible influence of orthography on perceptual epenthesis.

Furthermore, Gibson (2012) showed that the effects of perceptual epenthesis diminished when Spanish-speaking learners of English saw written forms of English words. This could be because the English orthography makes it obvious that consonant clusters do not contain vowels (Darcy and Thomas 2019).

Regarding the effects of word frequency and familiarity on perceptual epenthesis, previous research has produced inconsistent, if not weak, results. For example, Davidson (2006) examined whether the frequency of clusters influenced the production of non-native consonant cluster. To this end, frequency was computed over type and token, and mono- and multi-morphemic lexical items. However, none of these frequency counts were significantly correlated to the production accuracy. Tajima, Erickson, and Nagao (2000) examined factors affecting the production of intrusive (epenthetic) vowels in English words by native Japanese speakers, who often insert vowels between consonants or after word-final consonants. They found that there was a moderate tendency for high-familiarity words to exhibit fewer instances of epenthesis compared to low-familiarity words. Also, the rate of occurrence of epenthetic vowels was not significantly affected by how often an English word appeared as a loanword in Japanese. In contrast, speaking rate, as well as the phonological properties of the adjacent consonants, significantly affected the production of vowel epenthesis. Their follow-up study reaffirmed these initial findings, demonstrating a slight but statistically significant negative correlation between word familiarity and the rate of occurrence of epenthetic vowels (Tajima, Erickson, and Nagao 2002).

In the domain of speech perception, Darcy and Thomas (2019) investigated whether L1 phonotactic constraints influenced L2 lexical representations, focusing on Korean learners of English. L2 learners often perceive target words with modifications and therefore, the modified representations of the words (also known as repaired lexical representation) are likely to be stored in their mental lexical, at least in the early stages of learning (Matthews and Brown 2004). As a result, if their repaired representation of a word matches a non-word and is subsequently activated, it could lead to an incorrect identification of the non-word as a real word. For example, Korean tend to perceptually repair illicit word-initial obstruent-liquid clusters common in English (e.g., *blue*) by inserting an epenthetic vowel similar to [ʊ̆], thus perceiving *blue* as *b[ʊ̆]lue* (Kabak 2003; Kabak and Idsardi 2007). As a result of perceptual epenthesis during word learning, it is possible that Korean learners of English store English words with spurious vowels in their mental lexicon. If so, Korean speakers would more frequently accept non-words containing epenthetic vowels as real English words (e.g., *b[ʊ̆]lue* for *blue*) compared to native English listeners, who typically store unmodified or repair-free lexical representations of words. The results of Darcy and Thomas (2019) supported this hypothesis, revealing high error rates on test non-words (e.g., *b[ʊ̆]lue*) among Korean participants, suggesting that their lexical representations for L2 words can be activated by non-words conforming to their L1 phonotactic grammar. In contrast, Korean participants showed low error rates for control non-words (e.g., *b[ɪ]lue*), suggesting that their lexical representations for L2 words were activated only by non-words with the [ʊ̆] vowel epenthesis, not by non-words containing any additional vowel.

In addition, Darcy and Thomas (2019) asked the participants to rate on a scale of 1-3 how familiar they were with the base words (e.g., *blue*), which were used to create the test and control items. This was done to ensure that the participants were familiar with the base words. As expected, both native controls and Korean speakers rated all of the base words as highly familiar. Thus, highly familiar words were susceptible to perceptual epenthesis, which has important implications for the current study.

Our literature review suggests that there are gaps in our understanding of the factors affecting perceptual epenthesis. In particular, there has been little research done on the effects of word frequency and familiarity on vowel epenthesis, and the majority of the existing literature focuses on speech production. Thus, the primary goal of this study was to provide a systematic analysis of the role of word frequency and familiarity in perceptual epenthesis. Specifically, we investigated whether and how the rate of perceptual epenthesis varies as a function of word frequency and familiarity for native-speakers of Korean and Chinese learning English as a second language. By employing both an objective measure of L2 words, frequency (how often a word appears in a speech corpus), and a subjective measure of L2 words, familiarity rating (the degree to which an individual is familiar with a word), the current study seeks to provide a more thorough understanding of the factors affecting perceptual epenthesis. In addition, it extends the existing discussion of perceptual repairs of words with onset clusters (Darcy and Thomas 2019) to include codas.

2. Methods

2.1 Participants

We collected data from a total of 55 participants: 19 were native speakers of English who served as controls, 18 were native speakers of Korean learning English as a second language, and 18 were native speakers of Mandarin Chinese learning English as a second language. Native speakers of English were recruited from United States using Amazon's Mechanical Turk (http://www.mturk.com/). Native speakers of Korean and Chinese were primarily recruited through campus advertisements at a university located in Seoul, Korea, although some of them were recruited through personal contacts and social media. Table 1 provides basic background information of the participants.

After completing the experiment, participants were asked to fill out a questionnaire about their language backgrounds. The following is a breakdown of the native controls based on the dialect they use: There were 8 individuals speaking the New England dialect, 6 speaking the West dialect, 3 speaking the South dialect, and 2 speaking the North dialect (for these categories, see Ohio State University, 2016). While three of the participants said they had some experience learning a second language (see Table 1), none of them had any knowledge of Korean or Chinese.

Table 1. Participant background information

	English speakers	Korean speakers	Chinese speakers
Gender (male/female)	11/8	4/14	6/12
Mean age (SD)	43.8 (10.6)	23.6 (6.0)	26 (5.1)
Other languages	Spanish (2) Greek (1)	Chinese (1) Japanese (1)	Korean (9) Spanish (2) Japanese (1)
Education background	High school (2) Technical college (3) Undergraduate (13) MA/PhD (1)	High school (3) Undergraduate (12) MA/PhD (3)	High school (1) Undergraduate (7) MA/PhD (10)

The L2 learners self-reported their proficiency level of English by choosing one of the six provided levels: 1 = Beginner, 2 = Elementary, 3 = Intermediate, 4 = Upper intermediate, 5 = Advanced, 6 = Fluent. On average, Korean speakers rated themselves 4.3, and Chinese speakers rated themselves 3.2. Furthermore, 7 of our Korean speakers and 2 of our Chinese speakers reported they had resided in an English-speaking country. The mean duration of residence in an English-speaking country was 6.78 months for Korean speakers (range: 0-4 years) and 0.78 months for Chinese speakers (range: 0-1 years). Finally, all of our participants reported having normal vision and hearing.

2.2 Stimuli

The lexical decision task consisted of two tests: Test 1 and Test 2. Each test included base, test, and control items. To examine possible effects of word frequency on perceptual epenthesis, the base items were divided into high- and low-frequency categories (For a complete list of stimuli, see Appendix). High-frequency words were defined as having 60 or more occurrences per million words, while low-frequency words were defined as having fewer than 15 occurrences per million words, in accordance with Miller et al. (2020). Frequency statistics were taken from COCA (the Corpus of Contemporary American English): https://www.english-corpora.org//coca/.

In Test 1, the base items consisted of 20 real English words containing onset clusters that began with a bilabial stop (b, p) followed by a liquid (l, r) (e.g., *please* [pliz]). The test items consisted of 20 non-words, which were created by inserting the vowel /ʊ/ between the first two consonants of each base word (e.g., *please* [pʊliz]). When a word begins with an illicit consonant cluster, Korean speakers often perceptually repair it with the high back unrounded vowel [ɯ]; this vowel was commonly substituted with the English [ʊ] in earlier research (Kabak 2003; Darcy and Thomas 2019). Chinese speakers often insert the vowel /u/ between onset clusters (Chen 2008). In the present study, we used /ʊ/ to study both Korean and Chinese speakers. The control items included 20 non-words, which were created by inserting the vowel /ɪ/ between the first two consonants of each base word (e.g., *please* [pɪliz]). This insertion does not represents a common epenthesis pattern found among Korean and Chinese speakers. Since Korean and Chinese speakers do not typically use /ɪ/ to perceptually repair illicit consonant clusters, it was expected that control words would be easily identified as non-words. All of the non-words in Test 1 received the primary stress on the second syllable.

In Test 2, the base items consisted of 20 real English words with singleton codas (t, d, k, g) (e.g., *week* [wik]). The test items comprised 20 non-words, which were created by appending a vowel close to [ɨ] to these codas (e.g., *week* [wikɨ]). In English loanwords borrowed into Korean, the epenthetic vowel typically added after alveolar and velar coda consonants has been described as high central [ɨ] (Kim and Kochetov 2011). Chinese typically inserts [ə] after stop consonants (Chen 2008; Chang 2011). To accommodate both Korean and Chinese speakers, we adopted an intermediate articulation between [ɨ] and [ə], but somewhat closer to [ɨ]. The control items consisted of 20 non-words with the appended vowel [ɑ], a vowel not typically inserted by these speakers to repair illicit codas. All of the non-words in Test 2 received the primary stress on the first syllable.

The stimuli were recorded in a recording booth by a native speaker of English, who was a faculty member of the English Language and Literature at a Korean university. Despite his limited knowledge of the Korean language, he was somewhat familiar with the epenthetic vowels prevalent in English loanwords adopted by Korean. We believe that his familiarity with the Korean language helped him produce more natural sounding non-words with extra vowels.

2.3 Procedure

The experiment was conducted entirely online through a specially created website. The website was built utilizing HTML5, CSS3, and JavaScript for web programming. The online experiment required participants to use a personal computer and a mouse in a quiet environment. After giving consent, the participants were directed to a page containing detailed instructions and a sample question to familiarize them with the task. The experiment consisted of three parts: The lexical decision task (Test 1, Test 2), word familiarity questionnaire, and a survey regarding the participants' language background. The order of Test 1 and Test 2 was randomized. Within each test, the order of the stimuli was also randomized.

In both Test 1 and Test 2, participants listened to words one at a time and indicated whether the word they heard was a real English word or not by pressing one of two options marked "Yes" or "No". Participants were instructed to respond "Yes" only if they believed the word to be a real word based on standard American English pronunciation. They were also informed that some non-words can sound similar to real words. In addition, they were instructed to make their selection immediately upon hearing the word. The task was conducted without a time constraint, yet reaction times were recorded. Each stimulus was presented once without repetition.

Following the lexical decision task, a word familiarity survey was conducted to examine how familiar each participant was with the words used in the lexical decision task. This survey included only the real English words (i.e., base items) used in Test 1 and Test 2, and participants were asked to indicate how familiar they were with each word on a scale of 1 to 5 (Table 2). The scale was adopted from Connell (2017). Unlike Test 1 and Test 2, where the words were presented in an audio format, the words in the survey were presented in a written format.

The entire experiment took approximately 1 hour to complete. Upon completion of the experiment, participants received compensation for their participation. All of the study procedures were approved by the university's IRB.

Table 2. Word familiarity ratings and corresponding descriptions

Rating	Rating Description
1	I have never seen/heard this word.
2	I have occasionally seen/heard this word, but I don't know what it means.
3	I have occasionally seen/heard this word and I know what it means in context, but I could not provide a definition for it.
4	I have frequently seen/heard this word and I know what it means in context, but I could not provide a definition for it.
5	I have frequently seen/heard this word, I know what it means, and I can provide a definition for it.

2.4 Scoring of data

In total, 6600 trials (55 participants × 2 tests × 60 words) were analyzed. Since all of the base items were real words (e.g., *please*), "Yes (I think it is a real word)" responses were counted as correct, while “No (I do not think it is a real word)” responses were counted as incorrect. On the other hand, for the made-up test and control items (e.g., *p[ʊ]lease*, *p[ɪ]lease,*), “No (I do not think it is a real word)” responses were counted as correct and “Yes (I think it is a real word)” responses were counted as incorrect. The accuracy was the proportion of correct responses.

RTs (in seconds) were measured from the onset of the word. RT data were checked for outliers prior to the statistical analyses. Following Darcy and Thomas (2019), outliers were defined as being more than 2.5 standard deviations from the mean RT for each group across all conditions, or less than 250 milliseconds. Data from one native speaker of Chinese was completely discarded from the RT analysis, because approximately 50% of her tokens (62 out of 120) were found to be outliers. Along with her 120 tokens, 258 tokens in total (3.91% of the data) were eliminated from the RT analysis.

2.5 Statistical analyses

Statistical analyses were carried out in R 4.2.3 (R core Team 2023) using mixed-effects regression models. The effects of word frequency and familiarity were examined in two separate models. In one model, word frequency (low vs. high), speaker group (English vs. Korean vs. Chinese), and condition (base vs. control vs. test) were included as fixed effects, and participants and word items were included as random intercepts. The factors in the other model were the same, but word familiarity was included in place of word frequency. All categorical variables (word frequency, group, condition) were sum coded, and the word familiarity ratings were transformed to z-scores. The dependent measures were accuracy (either correct or incorrect) and RT. We used the *glmer* and *lmer* functions from the *lme4* package (Bates, Mächler, Bolker, and Walker 2015) for accuracy and RT, respectively. In addition, the *car* package (Fox and Weisberg 2019) was utilized to conduct the type III ANOVA tests to determine the significance of the main effects and their interactions. Note that we have two predictors with more than two levels: speaker group (English vs. Korean vs. Chinese) and condition (base vs. control vs. test). We conducted post-hoc pairwise comparisons for significant main effects of these predictors and interactions using the *emmeans* function of the *emmeans* package (Lenth 2021). To improve the readability of the results from a large number of pairwise comparisons, we will only report *p*-values for the significant comparisons in the Results section (coming next). All reported *p*-values were Bonferroni corrected for multiple comparisons.

2.6 Prediction

Extensive research has demonstrated that high-frequency words are privileged over low-frequency words in speech perception (Todd, Pierrehumbert, and Hay 2019). In lexical decision, high-frequency words are more frequently accepted as real words (Luce and Pisoni 1998) and elicit faster responses (Forster and Chambers 1973) than low frequency words. In light of these findings, we predicted that, in the base condition, high-frequency words (e.g., *please*) would be more frequently accepted as real words and elicit faster responses than low frequency words (e.g., *plier*) across all three speaker groups. In the test condition, it was predicted that L2 learners would accept high-frequency words with vowel epenthesis (e.g., *p[ʊ̆]lease*) as real words more often than low-frequency words with vowel epenthesis (e.g., *p[ʊ̆]lier*). That is, the accuracy of lexical decision of test words would decrease with increasing word frequency/familiarity. This would suggest that L2 learners indeed have difficulty distinguishing between stimuli with vowel epenthesis (e.g., *p[ʊ̆]lease*) and those without (e.g., *please*).

The above prediction postulates that L2 learners' representations of English words are likely to be different from those of native English speakers. However, given the experimental studies demonstrating diminished effects of perceptual epenthesis in the presence of written word forms (Gibson 2012), it seems reasonable to think about the potential long-term effects of exposure to written forms on the development of more native-like word representations. Although words may initially be represented with an epenthetic vowel, the initial representations can be further revised or redefined for words we encounter frequently. For words with low frequency or familiarity – those with no or little exposure – L2 learners are likely to perceive them with epenthesis, in accordance with their L1 phonotactic patterns, and store these perceived repaired representations in their mental lexicon. This may lead learners to mistakenly accept non-words (e.g., *p[ʊ̆]lier*) as real words. On the other hand, for words with high frequency or familiarity, substantial exposure could enable L2 learners to perceive them in a native-like manner, devoid of epenthesis, thereby storing repair-free representations. This may lead L2 learners to accurately reject non-words (e.g., *p[ʊ̆]lease*) derived from high-frequency base words. If exposure to written forms indeed facilitates the development of more native-like word representations, there is the possibility that the accuracy of lexical decision of test words may increase with increasing word frequency/familiarity.

3. Results

3.1 Lexical decision test 1 (onset)

3.1.1 Effects of word frequency

First we examined how word frequency, speaker group, and condition affected the accuracy and RT of lexical decisions made for words with onset consonant clusters. The statistical results from the mixed-effects regression analyses are presented in Table 3. As can be seen in the table, the effect of speaker group was significant on both accuracy and RT. Pairwise comparisons using R's *emmeans* function revealed that Chinese speakers were overall less accurate when compared to English ($p < 0.001$) and Korean speakers ($p < 0.05$) (see Figure 2). Unexpectedly, though, Korean speakers did not differ significantly from English speakers. When it comes to RT, English speakers tended to have shorter RT than Chinese ($p = 0.080$) and Korean ($p = 0.055$) speakers, although the differences did not reach statistical significance after Bonferroni correction was applied. The effect of condition was also significant on both accuracy and RT. As expected, the test condition was associated with lower accuracy compared to the base ($p < 0.001$) and control conditions ($p < 0.001$). The test condition also resulted in slower RTs than the base condition ($p < 0.001$), but not when compared to the control condition. The control condition had lower accuracy ($p < 0.001$) and slower RTs ($p < 0.001$) than the base condition. Also, there was a significant interaction between speaker group and condition on both accuracy and RT. The findings from paired comparisons indicated that, in contrast to English ($p < 0.001$) and Chinese ($p < 0.001$) speakers, Korean speakers did not exhibit any differences in accuracy between the base and control conditions. Moreover, unlike English ($p < 0.05$) and

Korean ($p < 0.05$) speakers, Chinese speakers showed no difference in RT between the base and test conditions.

The main effect of frequency was significant on RT but not on accuracy; overall, participants responded more quickly to high-frequency words (see Figure 3). However, there was a significant interaction of Condition × Frequency, which may account for the lack of a frequency effect on accuracy across different conditions. In the base condition, high-frequency words were more accurate than low-frequency words ($p < 0.001$); however, in the test condition, the relationship was revered ($p < 0.001$). In the control condition, there was no difference. Regarding RT, in the base condition, high-frequency words were responded more quickly than low-frequency words ($p < 0.001$); however, no difference was found in the other two conditions. To reiterate the most important finding, participants were more likely to make errors (i.e., accept words with vowel epenthesis as real English words) with more frequent words in the test condition. The results were observed across different speaker groups, as indicated by the lack of a significant Group × Condition × Frequency interaction.

Table 3. Statistical analyses of the effects of speaker group, condition, and word frequency on the accuracy and RT of lexical decisions made for words with onset consonant clusters. Significant results are shaded in grey

	Accuracy			RT		
	χ2	Df	*p*-value	χ2	Df	*p*-value
(Intercept)	57.69	1	< 0.001	457.79	1	< 0.001
Group	17.95	2	< 0.001	7.13	2	< 0.05
Condition	447.43	2	< 0.001	26.18	2	< 0.001
Frequency	0.07	1	0.797	10.13	1	< 0.01
Group × Condition	28.64	4	< 0.001	10.48	4	< 0.05
Group × Frequency	2.21	2	0.331	5.88	2	0.053
Condition × Frequency	116.10	2	< 0.001	19.76	2	< 0.001
Group × Condition × Frequency	6.94	4	0.139	1.48	4	0.831

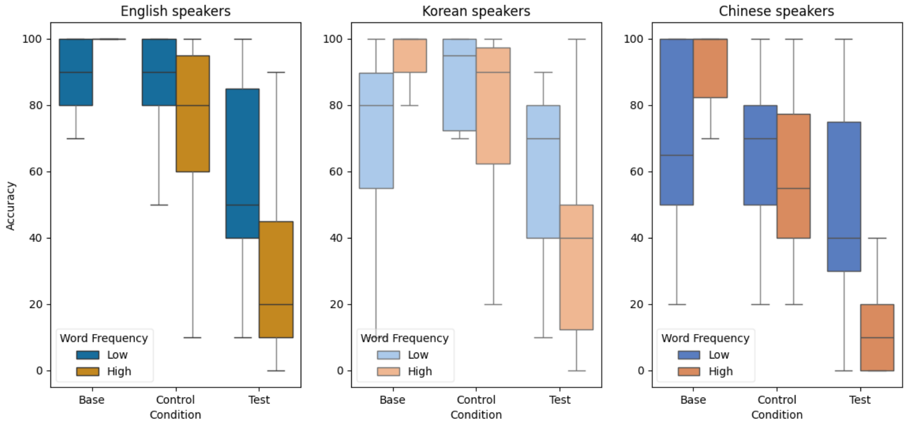

Figure 2. Boxplots of the accuracy of lexical decisions (onset). The line in the middle of the boxplot represents the median value

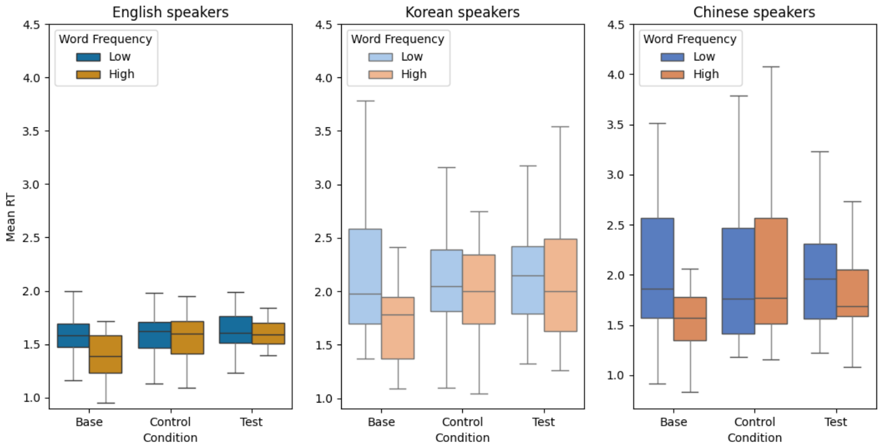

Figure 3. Boxplots of the speed of lexical decisions (onset). The line in the middle of the boxplot represents the median value

3.1.2 Effects of word familiarity

In the second analysis, we looked at how word familiarity, speaker group, and condition affected the lexical decisions of words with onset consonant clusters. But before presenting those results, we will first present the results from correlation analyses to determine whether word frequency and familiarity in our dataset are related. Although some studies have demonstrated a positive correlation between the two measures (Begg and Rowe 1972; Karlsen and Snodgrass 2004; Tanaka-Ishii and Terada 2011), some others also pointed out the discrepancies between the two (Gernsbacher 1984; Nusbaum, Pisoni, and Davis 1984; Connine, Mullennix, Shernoff, and Yelen 1990). In the current dataset, we found a positive relationship between word frequency and familiarity for all three speaker groups (see Figure 4): English speakers: $r(18) = 0.453$, $p < 0.05$; Korean speakers: $r(18) = 0.65$, $p < 0.01$; Chinese speakers: $r(18) = 0.823$, $p < 0.001$. As indicated by the correlation coefficients, the size of correlation was smaller for English speakers than for L2 speakers. This may be explained by the fact that English speakers generated a narrower range of ratings than L2 speakers. As shown in Figure 4, all of the words were actually rated either 4 or 5 by English speakers. Note in Figure 4 that the ratings were presented here on a scale of 1-5 to facilitate interpretation, although z-scores were used in the mixed-effects regression analyses.

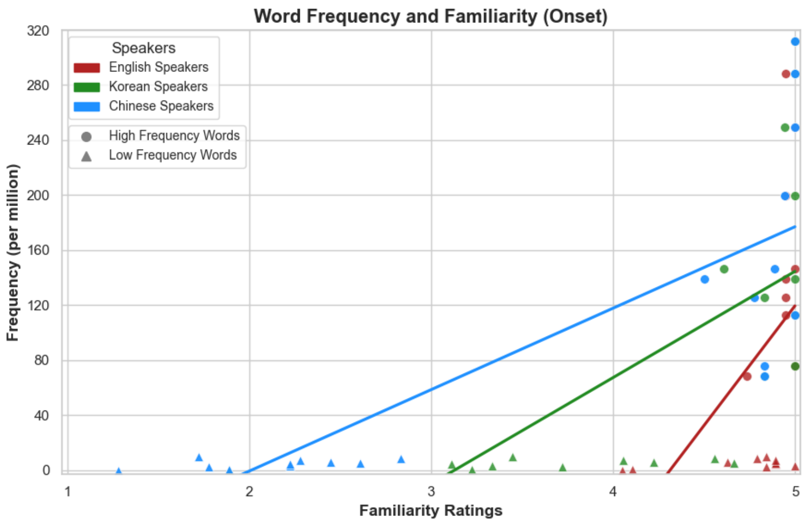

Figure 4. Correlations between word frequency and familiarity ratings

Not surprisingly, the results of the mixed-effects regression analyses for word familiarity and frequency showed a considerable amount of overlap. As shown in

Table 4, the effect of speaker group was significant, suggesting that Chinese speakers were generally less accurate than English ($p < 0.001$) and Korean speakers ($p < 0.05$). No difference was found between Korean and English speakers. English speakers tended to have shorter RTs than Chinese ($p = 0.079$) and Korean ($p = 0.057$) speakers. The effect of condition was also significant. The accuracy of the test condition was found to be lower when compared to the base ($p < 0.001$) and control ($p < 0.001$) conditions. The test condition also produced slower RTs when compared to the base condition ($p < 0.001$), but not to the control condition. The control condition resulted in slower RTs than the base condition ($p < 0.001$), although there was no difference in accuracy. Also, a significant interaction between speaker group and condition was found. Unlike English ($p < 0.001$) and Chinese ($p < 0.001$) speakers, Korean speakers did not exhibit any differences in accuracy between the base and control conditions. Furthermore, there was no difference in RT between the base and test conditions for Chinese speakers, in contrast to English ($p < 0.05$) and Korean ($p < 0.05$) speakers.

The effect of familiarity was significant on RT but not on accuracy; overall, participants responded faster to more familiar words. However, as indicated by a significant Condition × familiarity interaction on both accuracy and RT, the effect of familiarity was mediated by condition. In the base condition, more familiar words were more likely to be correctly identified as real English words ($p < 0.001$); on the other hand, in the test condition, participants were more likely to make errors (i.e., accept words with vowel epenthesis as real English words) with more familiar words ($p < 0.001$); in the control condition, there was no effect of familiarity on accuracy. In terms of RT, only the base condition showed a difference, with faster reactions to more familiar words ($p < 0.01$).

Table 4. Statistical analyses of the effects of speaker group, condition, and word familiarity on the accuracy and RT of lexical decisions made for words with onset consonant clusters. Significant results are shaded in grey

	Accuracy			RT		
	$\chi 2$	Df	*p*-value	$\chi 2$	Df	*p*-value
(Intercept)	58.83	1	< 0.001	451.39	1	< 0.001
Group	19.38	2	< 0.001	7.06	2	< 0.05

Condition	461.32	2	< 0.001	26.42	2	< 0.001
Familiarity	0.05	1	0.823	6.29	1	< 0.05
Group × Condition	30.42	4	< 0.001	10.40	4	< 0.05
Group × Familiarity	3.14	2	0.208	4.12	2	0.128
Condition × Familiarity	144.89	2	< 0.001	12.76	2	< 0.01
Group × Condition × Familiarity	8.71	4	0.069	4.33	4	0.363

In the next section we present the results from Test 2, which examined lexical decisions made for words with coda consonant clusters. Note that we present the effects of word frequency and familiarity in this order, following Test 1.

3.2 Lexical decision test 2 (coda)

3.2.1 Effects of word frequency

The main effects of speaker group and condition, as well as their interaction, were significant (see Table 5). Consistent to Test 1, Chinese speakers performed less accurately than English ($p < 0.001$) and Korean speakers ($p < 0.05$). There was no difference between Korean and English speakers. Compared to Chinese speakers, there was a tendency for English speakers to have shorter RTs, though not significantly ($p = 0.054$). As for the effect of condition, the test condition yielded less accurate responses than the base ($p < 0.001$) and control ($p < 0.001$) conditions. The test condition also resulted in slower RTs relative to the base condition ($p < 0.001$), but not relative to the control condition. In addition, the control condition had slower RTs ($p < 0.01$) than the base condition, although the difference in accuracy was not significant. A Group × Condition interaction was also significant on both accuracy and RT. The results of paired comparisons revealed that Chinese speakers were more accurate in the base condition than in the control condition ($p < 0.001$), unlike Korean and English speakers, who showed no difference in accuracy between the two conditions. Moreover, in contrast to Korean ($p < 0.01$) and Chinese speakers ($p < 0.05$), who had significantly slower RTs for the test condition compared to the base condition, English speakers showed no difference between the two conditions.

Although the main effect of frequency was not significant, there was a significant interaction of Condition × Frequency. In the base condition, high-frequency words resulted in higher accuracy ($p < 0.001$) and faster RTs ($p < 0.01$) than low-frequency words. In the test condition, despite a tendency for high-frequency words to have lower accuracy (Figure 5) and slower RTs (Figure 6) than low-frequency words, the differences turned out to be statistically insignificant. In the control condition, high-frequency words resulted in lower accuracy ($p < 0.01$), although no difference was found in terms of RT. However, the observed difference in accuracy between high and low-frequency words in the control condition appears to be modulated by speaker group, as evidenced by a significant Group × Condition × Frequency interaction. Specifically, the difference was significant only for Chinese speaker ($p < 0.001$) (see Figure 5).

Table 5. Statistical analyses of the effects of speaker group, condition, and word frequency on the accuracy and RT of lexical decisions made for words with coda consonant clusters. Significant results are shaded in grey

	Accuracy			RT		
	$\chi2$	Df	*p*-value	$\chi2$	Df	*p*-value
(Intercept)	120.71	1	< 0.001	693.13	1	< 0.001
Group	20.82	2	< 0.001	6.27	2	< 0.05
Condition	267.42	2	< 0.001	34.44	2	< 0.001
Frequency	0.68	1	0.411	1.71	1	0.192
Group × Condition	37.69	4	< 0.001	11.44	4	< 0.05
Group × Frequency	0.81	2	0.667	1.38	2	0.503
Condition × Frequency	98.48	2	< 0.001	26.29	2	< 0.001
Group × Condition × Frequency	10.41	4	< 0.05	4.95	4	0.292

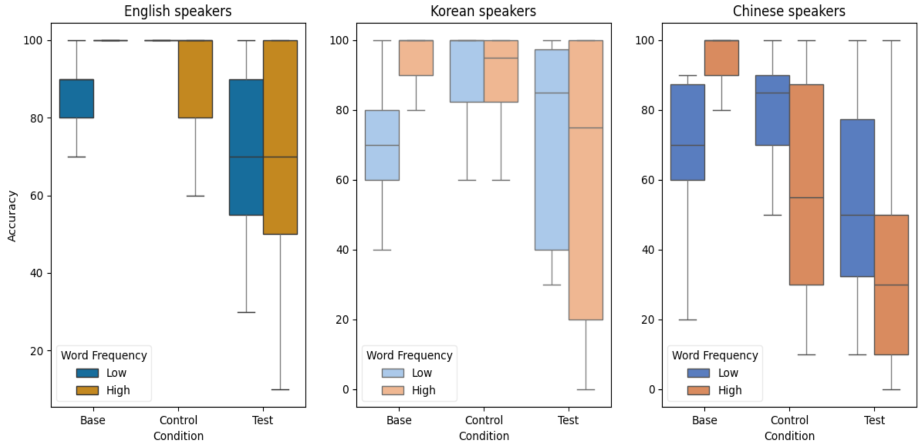

Figure 5. Boxplots of the accuracy of lexical decisions (coda). The line in the middle of the boxplot represents the median value

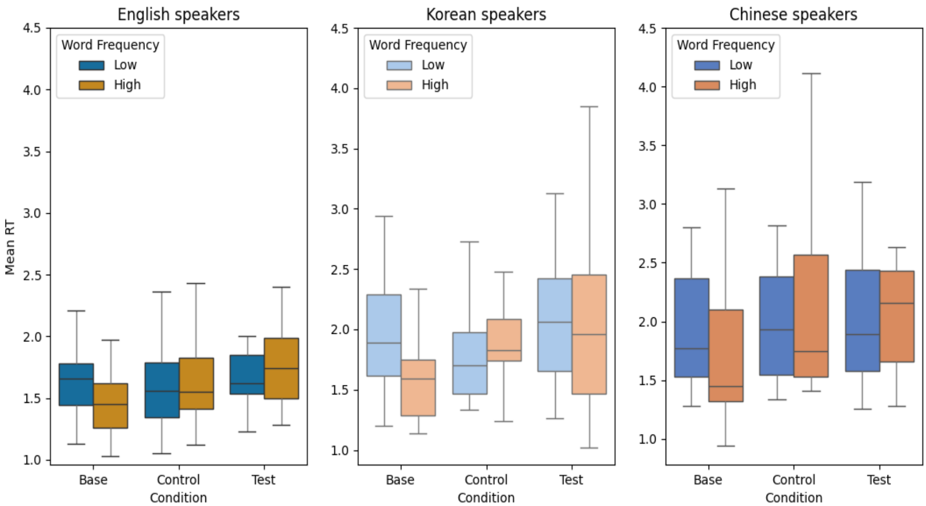

Figure 6. Boxplots of the speed of lexical decisions (coda). The line in the middle of the boxplot represents the median value

3.2.2 Effects of word familiarity

We will start this section by examining how word familiarity was related to frequency. Again, we found a positive relationship between the two measures for both L2 groups (see Figure 7): Korean speakers: $r(18) = 0.749$, $p < 0.001$; Chinese speakers: $r(18) = 0.841$, $p < 0.001$. The result for English speakers marginally missed significance: $r(18) = 0.436$, $p = 0.055$. The majority of English speakers' familiarity ratings were on the higher end, which may be the reason for the lack of correlation. Note in Figure 7 that the ratings were presented here on a scale of 1-5 to facilitate interpretation, although z-scores were used in the mixed-effects regression analyses.

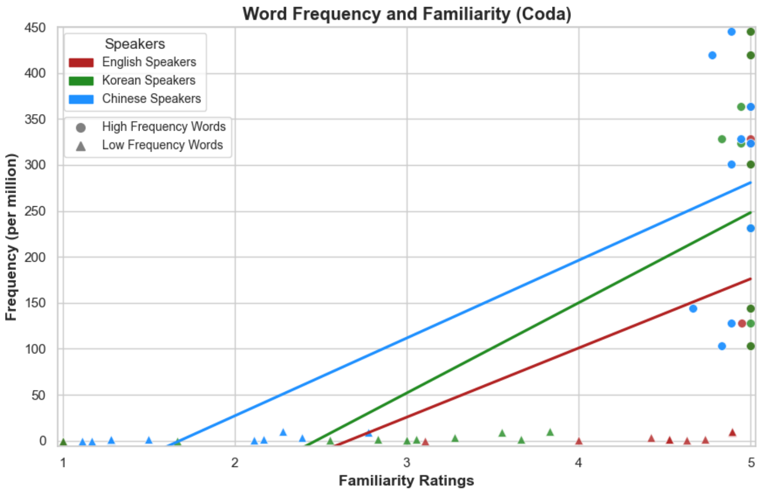

Figure 7. Correlations between word frequency and familiarity ratings

As in Test 1, we found that the word familiarity results are in line with the frequency results. The main effects of speaker group and condition, as well as their interaction, were significant (see Table 6). Since the results of pairwise comparisons aligned with those reported in the previous section, we will not repeat them here.

Familiarity had no significant main effect. However, the effect of familiarity was modulated by condition, as evidenced by a significant Condition × familiarity interaction on accuracy and RT. In the base condition, the likelihood of correctly identifying words as real English words increased with familiar words ($p < 0.001$). Also, only the base condition differed in terms of RT, with faster reactions to more familiar words ($p < 0.001$). In the control condition, familiarity had no effect on accuracy. Critically, in the test condition, participants were more likely to make errors (i.e., accept words with vowel epenthesis as real English words) with more familiar words ($p < 0.001$). The observed difference in accuracy between high and low familiarity words in the test condition was modulated by speaker group, as suggested by a significant Group × Condition × Frequency interaction. Specifically, the difference did not hold true for Korean speakers, but only for English ($p < 0.05$) and Chinese speaker ($p < 0.01$).

Table 6. Statistical analyses of the effects of speaker group, condition, and word familiarity on the accuracy and RT of lexical decisions made for words with onset consonant clusters. Significant results are shaded in grey

	Accuracy			RT		
	χ2	Df	*p*-value	χ2	Df	*p*-value
(Intercept)	119.60	1	< 0.001	686.27	1	< 0.001
Group	24.77	2	< 0.001	6.17	2	< 0.05
Condition	231.98	2	< 0.001	34.78	2	< 0.001
Familiarity	0.00	1	0.965	2.02	1	0.155
Group × Condition	35.23	4	< 0.001	11.50	4	< 0.05
Group × Familiarity	1.90	2	0.388	8.77	2	< 0.05
Condition × Familiarity	190.42	2	< 0.001	34.81	2	< 0.001
Group × Condition × Familiarity	10.12	4	< 0.05	5.63	4	0.228

Table 7 summarizes the main findings thus far from Test 1 and Test 2. Before going over the table, it is important to note two points. First, the table only presents the results of word frequency and familiarity, along with their interactions with other factors, as these are the primary interests of the current study. Second, the results of word frequency and familiarity are presented jointly using the slash symbol /, as there was no difference in the two factor's statistical significance, with only one exception; for RT analysis in Test 2, the Group × Frequency interaction was insignificant, whereas the Group × Familiarity interaction was significant. This is shown as ns/* in Table 7.

As can be seen in Table 7, the main effects of Frequency/Familiarity were not significant, suggesting that participants' accuracy and RT of lexical decision did not vary systematically with these factors. An exception to this finding was observed for RT in Test 1, where participants answered high-frequency/familiarity words with greater speed than low-frequency/familiarity words. Furthermore, the Group × Frequency/Familiarity interaction was not significant either, except for the RT measure in Test 2. Although there was no main effects of Frequency/Familiarity, there was a significant interaction of Condition × Frequency/Familiarity in both Test 1 and 2, suggesting that the effects of Frequency/Familiarity depended on the condition. In the base condition, high-frequency/familiarity words (e.g., *please*) were more accurate and responded more quickly than low-frequency/familiarity words (e.g., *plier*); however, in the test condition, participants were more likely to accept high-frequency/familiarity words with vowel epenthesis (e.g., *p[ʊ]lease*) as real English words, leading to low accuracies for these non-words. In contrast, low-frequency/familiarity words with vowel epenthesis (e.g., *p[ʊ]lier*) were less likely to be accepted as real English words, leading to higher accuracies for these non-words. No difference in RT was found between high- and low-frequency/familiarity words in the test condition. Also, the observed difference in accuracy between high- and low-frequency/familiarity words in the test condition turned out to be significant only in the onset position; in the coda position, the difference did not reach statistical significance. In fact, in the coda position, it was primarily Chinese speakers who showed the difference between high- and low-frequency/familiarity words in the test condition. The discrepancy is reflected in the significant Group × Condition × Frequency/Familiarity interaction on accuracy in Test 2. The overall picture that emerges from these results, despite some variability, is that high-frequency/familiarity words with vowel epenthesis are more likely to be accepted as real words compared to low-frequency/familiarity words with vowel epenthesis.

Table 7. Summary of the results from Test 1 and Test 2
ns = insignificant results, * = significant results

	Accuracy		RT	
	Test 1	Test 2	Test 1	Test 2
Frequency/Familiarity	ns	ns	*	ns
Group × Frequency/Familiarity	ns	ns	ns	ns/*

Condition × Frequency/Familiarity	*	*	*	*
Group × Condition × Frequency/Familiarity	ns	*	ns	ns

4. Discussion

The main purpose of this study was to investigate whether and how word frequency and familiarity influence L2 perceptual epenthesis, focusing on Korean and Chinese learners of English. The results from the current study showed a positive relationship between word frequency and familiarity ratings. Furthermore, the results overall indicated that L2 learners were more likely to accept non-words derived from high-frequency/familiarity words (e.g., *p[ʊ̆]lease*) as real words when they heard non-words with an extra vowel that followed their native phonotactic grammar.

It is well known that high-frequency words are more likely to be accepted as real words (Luce and Pisoni 1998) and elicit faster responses (Forster and Chambers 1973) than low-frequency words in lexical decision. These studies explain why, in the base condition, high-frequency words (e.g., *please*) were more frequently accepted as real words and elicited faster responses than low-frequency words (e.g., *plier*) across all three speaker groups. These studies also help explain why, in the test condition of Test 1, the L2 speakers were less accurate for high-frequency words; the error rates for high-frequency words increased because L2 speakers were more likely to accept high-frequency words with vowel epenthesis (e.g., *p[ʊ̆]lease*) as real words than low-frequency words with vowel epenthesis (e.g., *p[ʊ̆]lier*). Our results corroborate previous findings that L2 learners, whose L1 does not permit consonant clusters, have representations of English words that contain spurious vowels (Darcy and Thomas 2019), which makes it difficult for them to distinguish between stimuli that contain an additional vowel (e.g., *p[ʊ̆]lease*) and those do not (e.g., *please*) (Dupoux, Kakehi, Hirose, Pallier and Mehler 1999).

However, it is puzzling why native controls in the current study were less accurate with high-frequency words in the test condition in Test 1, just like L2 speakers. The finding contradicts earlier research and was certainly unexpected. For example, Darcy and Thomas (2019) demonstrated that native controls, unlike Korean speakers, showed high accuracy for both test (86%) and control (88.5%) words, which suggested that for native controls, a word like *p[ʊ̆]lease* is just as unacceptable as the word *p[ɪ]lease*.

Crucially, in their study, the base words that were used to create the test and control items were all highly familiar to the listeners.

Although we do not have a full understanding of why this discrepancy occurred, we would like to propose one possible explanation. Following the experiment, we played our test stimuli to several native speakers of English who were not part of the study and asked for their input, in an effort to better understand the findings. One common observation we received from them was that many of the non-word items sounded more like exaggerated English words than like non-words. This is due to the fact that English speakers often pronounce words with an extra vowel when enunciating or exaggerating the pronunciations of words (e.g., *Great!* comes out as *[gʊreɪt]*). In light of the observation, it is possible that the native controls in our experiment had a loose definition of what counts as a real English word, and thought our test items might be different (but possible) pronunciations of the base words, resulting in a lower accuracy for the test items. We made our best effort to inform them to only select "Yes" if they believed the word was real based on how it is pronounced in standard American English. Unfortunately, it was not possible for us to monitor the participants and give them proper feedback during the online experiment. Overall, our findings raise the possibility that instructions play an important role in lexical decision, and therefore further research in this area could be promising.

If our native controls indeed had a loose definition of what counts as a real English word, and believed our test items to be variants of the base words, it makes sense that they did this more often with high-frequency words than low-frequency words. Research has shown that non-words are much more likely to be misidentified as real words if they are orthographically similar to high-frequency words rather than to low-frequency words (O'connor and Forster 1981). Similarly, listeners might be more inclined to judge non-words as real words if they sound more like high-frequency words rather than low-frequency words. That is, not only high-frequency words (e.g., *break*) are frequently accepted as real words, but similar pronunciations (e.g., *b[ʊ]reak*) might also be more frequently accepted as real words. In contrast, not only low-frequency words (e.g., *plier*) are less frequently accepted as real words, but the pronunciations similar to the them (e.g., *p[ʊ]lier*) might also be less frequently accepted as real words.

It is important to note that Test 2 did not show any effects of word frequency on the perceptual epenthesis in the coda. In line with the findings of Test 1, there was a tendency for high-frequency words to have lower accuracy than low-frequency words in the test condition of Test 2. However, the differences turned out to be statistically insignificant. The lack of difference between high- (e.g., *week[ɨ]*) and low-frequency (e.g., *psig[ɨ]*) words might be due to the fact that the mean accuracy of lexical decision was higher overall for words with an epenthetic vowel in the coda position (e.g., *week[ɨ]*) than words with an epenthetic vowel in the onset position (e.g., *b[ʊ̆]reak*). This suggests that, for both native controls and L2 learners, words with an epenthetic vowel in the coda position are less acceptable as real words than words with an epenthetic vowel in the onset position.

In Korean, vowel epenthesis commonly occurs in order to repair illegal consonant clusters in the onset position. In contrast, vowel epenthesis in loanword adaptation can occur variably after a stop in the coda position and is affected by a number of factors, including tenseness of the pre-final vowel, and voicing and place of articulation of the final stop (Kang 2003). In particular, word-final stops in English are released more often following a tense vowel than following a lax vowel. Accordingly, vowel epenthesis in Korean loanwords can occur more often when the English word's pre-final vowel is tense (e.g., week → *위크*) as opposed to lax (e.g., quick → *퀵*) (Kang 2003). This might provide insights into why some words with an epenthetic vowel in the coda position were less acceptable to Korean speakers as real words than words with an epenthetic in the onset position. Unfortunately, tenseness of the pre-final vowel and other factors influencing vowel epenthesis were not controlled for when creating our stimuli for Test 2, and this remains as a limitation of the present study.

Overall, our data does not support the hypothesis that learners' exposure to or familiarity with written forms of English words would suppress perceptual epenthesis. One possibility is that our L2 learners are still in the early stages of their L2 learning and have not yet advanced to the point where exposure to written word forms can exert an effect. Although there is currently little evidence to believe that their representations of English words differ from those of native English speakers, increased exposure to written English word forms can help them acquire repair-free representations in the long term.

An alternate explanation for why exposure to written forms of English words did not reduce perceptual epenthesis is that high-frequency English words are also among the most common Korean loanwords. Because many high-frequency English words are likely to have Korean loanword equivalents, L2 learners may be exposed to the written forms of the loanwords (e.g., *브레이크*) just as frequently as the written forms of the corresponding English words (e.g., *break*). This could explain why frequent exposure to the orthography of English words failed to lead to a reduction of perceptual epenthesis. To address the possibility, we examined the actual frequency with which our high-frequency English words are used as loanwords in Korean using the corpus analysis tool of the Research Institute of Korean Studies at Korea University (Choe and Lee 2014). Then we examined whether the loanword frequency values were indeed positively correlated with perceptual epenthesis. However, the results from correlation analyses showed that a high loanword frequency did not necessarily lead to a decrease in accuracy of the test items: Test 1 ($r(8)$ = -0.296, p = 0.407) and Test 2 ($r(8)$ = -0.306, p = 0.390). Similarly, Darcy and Thomas (2019) found that of the words examined, 'cream', 'drive', and 'track'—each assigned a loanword score of 6—exhibited epenthesis error rates of 61%, 44%, and 39% respectively, while 'brought', which had a loanword score of 0, also triggered a high error epenthesis rate of 61%, suggesting that loanword status in stimuli does not appear to have clear effects. Relatedly, Tajima (2011) showed that the ability of Japanese students to accurately perceive the original English words was not hindered by their familiarity with Japanese loanwords.

A number of studies have looked at the role of speech perception in loanword adaptation. According to Daland, Oh, and Davidson (2019), vowel epenthesis during loanword adaptation can be driven by speech perception, since loanword adapters must first perceive the word forms. For example, when Korean adapters heard a consonant with a release burst or other frication noise, they exhibited poor discrimination for the presence/absence of a following vowel. This could explain why vowels are epenthesized after fricatives in loanword adaptation in the Korean language (Daland, Oh, and Davidson 2019).

Finally, in light of the research demonstrating a relationship between L2 learners' experience with the target language and a decrease in perceptual epenthesis (Abrahamsson 2003), one might wonder whether there is a connection between our L2 learners' English proficiency and their performance in the experiment. It is likely that Korean speakers in this study were more proficient in English than Chinese speakers, based on self-reported English levels and length of residence in an English-speaking country. The mean error rates for test items in Test 1 were as follows:

High-frequency words Chinese (87.78%) > high-frequency words Korean (62.78%) > low-frequency words Chinese (52.23%) > low-frequency words Korean (37.23%), and in Test 2: High-frequency words Chinese (64.44%) > low-frequency words Chinese (45.00%)> high-frequency words Korean (39.44%) > low-frequency words Korean (29.44%). These error rates not only confirm the finding that high-frequency words are more likely to cause L2 learners to accept nonwords as real words compared to low-frequency words, but they also suggest that non-word acceptance tends to decline with increasing English proficiency. However, these results, of course, must be interpreted with caution since our L2 learners' English proficiency was self-reported and assessed only on a scale of 1-5. Further research using more objective measures of English proficiency is needed in order to draw more concrete conclusions regarding the effects of L2 learners' proficiency on perceptual epenthesis. In addition, it would be ideal to include more participants from more diverse L1 backgrounds to see if similar results would still be found.

Another limitation of the present study involves the way the stimulus was presented. Because the stimuli in each test were presented in a completely randomized order, there were times when base items were presented next to related test or control items. A more careful presentation of the stimuli, such as breaking up the related three items into three blocks, would have been beneficial, as listening to these related items in succession may influence the listeners' lexical decision. Future research should take this point into account.

The findings from the current study suggest that word frequency/familiarity play an important role in explaining perceptual epenthesis in L2 learners. Specifically, Korean and Chinese speakers were more likely to accept non-words with vowel epenthesis (e.g., *p[ʊ̆]lease*) as real words if the words were derived from frequently occurring, highly familiar English words (e.g., *please*). Our results not only demonstrate the role of word frequency/familiarity in perceptual epenthesis, but also support earlier research suggesting that L2 learners may represent English words with extra vowels if their L1 does not allow consonant clusters. The repaired representations could in turn hinder their ability to distinguish between stimuli that have an extra vowel (e.g., *p[ʊ̆]lease*) and those do not (e.g., *please*), which could explain why L2 learners often accepted both types of stimuli as real words.

References

Abrahamsson, Niclas. 2003. Development and recoverability of L2 codas: A longitudinal study of Chinese-Swedish interphonology. *Studies in Second Language Acquisition* 25(3): 313-349.

Bates, Douglas, Martin Mächler, Ben Bolker, and Steve Walker. 2014. Fitting linear mixed-effects models using lme4. *arXiv preprint arXiv:1406.5823*.

Begg, Ian Rowe and Edward J. 1972. Continuous judgments of word frequency and familiarity. *Journal of Experimental Psychology* 95(1): 48-54.

Chang, Yu-cheng. 2011. On the epenthetic vowels in Mandarin accented English. *Online Proceedings of Glow in Asia Workshop for Young Scholars*, 31-43.

Choe, Jae-Woong and Do-Gil Lee. 2014. Trends 21 corpus: Public web resources and search tools. *Korean Cultural Studies* 64: 3-23.

Connell, Katrina S. 2017. *The use of segmental and suprasegmental information in lexical access: A first- and second-language Chinese investigation*. PhD Dissertation. University of Kansas.

Daland, Robert, Mira Oh, and Lisa Davidson. 2019. On the relation between speech perception and loanword adaptation: Cross-linguistic perception of Korean-illicit word-medial clusters. *Natural Language & Linguistic Theory* 37(3): 825-868.

Darcy, Isabelle and Trisha Thomas. 2019. When blue is a disyllabic word: Perceptual epenthesis in the mental lexicon of second language learners. *Bilingualism: Language and Cognition* 22(5): 1141-1159.

Davidson, Lisa. 2006. Phonology, phonetics, or frequency: Influences on the production of non-native sequences. *Journal of Phonetics* 34(1): 104-137.

Dehaene-Lambertz, Ghislaine, Emmanuel Dupoux, and Ariel Gout. 2000. Electrophysiological correlates of phonological processing: A cross-linguistic study. *Journal of Cognitive Neuroscience* 12(4): 635-647.

De Jong, Kenneth and Hanyong Park. 2012. Vowel epenthesis and segment identity in Korean learners of English. *Studies in Second Language Acquisition* 34(1): 127-155.

Detey, Sylvain and Jean-Luc Nespoulous. 2008. Can orthography influence second language syllabic segmentation?: Japanese epenthetic vowels and French consonantal clusters. *Lingua* 118(1): 66-81.

Dupoux, Emmanuel, Christophe Pallier, Kazuhiko Kakehi, and Jacques Mehler. 2001. New evidence for prelexical phonological processing in word recognition. *Language and Cognitive Processes* 16(5-6): 491-505.

Dupoux, Emmanuel, Erika Parlato, Sonia Frota, Yuki Hirose, and Sharon Peperkamp. 2011. Where do illusory vowels come from?. *Journal of Memory and Language* 64(3): 199-210.

Dupoux, Emmanuel, Kazuhiko Kakehi, Yuki Hirose, Christophe Pallier, and Jacques Mehler. 1999. Epenthetic vowels in Japanese: A perceptual illusion?. *Journal of Experimental Psychology: Human Perception and Performance* 25(6): 1568-1578.

Durvasula, Karthik, Ho-Hsin Huang, Sayako Uehara, Qian Luo, and Yen-Hwei Lin. 2018. Phonology modulates the illusory vowels in perceptual illusions: Evidence from Mandarin and English. *Laboratory Phonology* 9(1): 7.

Forster, Kenneth I. and Susan M. Chambers. 1973. Lexical access and naming time. *Journal of Verbal Learning and Verbal Behavior* 12(6): 627-635.

Fox, John and Sanford Weisberg. 2019. Using car functions in other functions. *CRAN R*.

Gernsbacher, Morton A. 1984. Resolving 20 years of inconsistent interactions between lexical familiarity and orthography, concreteness, and polysemy. *Journal of Experimental Psychology: General* 113(2): 256-281.

Gibson, Mark. 2012. Perception-based vowel insertion by native Spanish-speaking learners of English. *TIPA: Travaux Interdisciplinaires sur la Parole et le Langage* 28: 1-18.

Hansen, Jette G. 2001. Linguistic constraints on the acquisition of English syllable codas by native speakers of Mandarin Chinese. *Applied Linguistics* 22(3): 338-365.

Jusczyk, Peter W., Angela D. Friederici, Jeanine MI Wessels, V. Y. Svenkerud, and Anne M. Jusczyk. 1993. Infants' sensitivity to the sound patterns of native language words. *Journal of Memory and Language* 32(3): 402-420.

Kabak, Baris. 2003. *The perceptual processing of second language consonant clusters*. PhD Dissertation. University of Delaware.

Kabak, Bariş and William Idsardi. 2003. Syllabically conditioned perceptual epenthesis. *Annual Meeting of the Berkeley Linguistics Society* 29(1): 233-244.

Kabak, Bariş and William Idsardi. 2007. Perceptual distortions in the adaptation of English consonant clusters: Syllable structure or consonantal contact constraints?. *Language and Speech* 50(1): 23-52.

Kang, Yoonjung. 2003. Perceptual similarity in loanword adaptation: English postvocalic word-final stops in Korean. *Phonology* 20(2): 219-273.

Karlsen, Paul Johan and Joan Gay Snodgrass. 2004. The word-frequency paradox for recall/recognition occurs for pictures. *Psychological Research* 68: 271-276.

Kim, Kyumin and Alexei Kochetov. 2011. Phonology and phonetics of epenthetic vowels in loanwords: Experimental evidence from Korean. *Lingua* 121(3): 511-532.

Lenth, Russell. 2021. Emmeans: Estimated Marginal Means, Aka Least-Squares Means. *R package Version 1.6.1*.

Luce, Paul A. and David B. Pisoni. 1998. Recognizing spoken words: The neighborhood activation model. *Ear and Hearing* 19(1): 1-36.

Ma, Liang, Pascal Perrier, and Jianwu Dang. 2015. Strength of syllabic influences on articulation in Mandarin Chinese and French: Insights from a motor control approach. *Journal of Phonetics* 53: 101-124.

Matthews, John and Cynthia Brown. 2004. When intake exceeds input: Language specific perceptual illusions induced by L1 prosodic constraints. *International Journal of Bilingualism* 8(1): 5-27.

Miller, Krista A., Gary E. Raney, and Alexander P. Demos. 2020. Time to throw in the towel? No evidence for automatic conceptual metaphor access in idiom processing. *Journal of Psycholinguistic Research* 49: 885-913.

Nusbaum, Howard C., David B. Pisoni, and Christopher K. Davis. 1984. Sizing up the Hoosier mental lexicon. *Research on Spoken Language Processing Report* 10(3): 357-376.

O'Connor, Rodney E. and K. I. Forster. 1981. Criterion bias and search sequence bias in word recognition. *Memory & Cognition* 9: 78-92.

Osburne, Andrea G. 1996. Final cluster reduction in English L2 speech: A case study of a Vietnamese speaker. *Applied Linguistics* 17(2): 164-181.

Polivanov, Evgenij. 1969. La perception des sons d'une langue étrangère. *Change* 3: 111-114.

R Core Team. 2020. R: A language and environment for statistical computing. Vienna, Austria: *R Foundation for Statistical Computing*. https://www.r-project.org/.

Sato, Charlene J. 1984. Phonological processes in second language acquisition: Another look at interlanguage syllable structure. *Language Learning* 34(4): 43-58.

Tajima, Keiichi. 2011. Do native-language loanwords affect second-language speech perception?. *Proceedings of the International Congress of Phonetic Sciences (ICPhS),* 1938-1941.

Tajima, Keiichi, Donna Erickson, and Kyoko Nagao. 2000. Factors affecting native Japanese speakers' production of intrusive (epenthetic) vowels in English words. *Proceedings of the Sixth International Conference on Spoken Language Processing*: 558-561. Beijing.

Tajima, Keiichi, Donna Erickson, and Kyoko Nagao. 2002. Production of syllable structure in a second language: Factors affecting vowel epenthesis in Japanese-accented English. *IULC Working Papers* 2(2): 77-91.

Tanaka-Ishii, Kumiko and Hiroshi Terada. 2011. Word familiarity and frequency. *Studia Linguistica* 65(1): 96-116.

Todd, Simon, Janet B. Pierrehumbert, and Jennifer Hay. 2019. Word frequency effects in sound change as a consequence of perceptual asymmetries: An exemplar-based model. *Cognition* 185: 1-20.

Weber, Andrea and Anne Cutler. 2006. First-languagephonotactics in second-language listening. *The Journal of the Acoustical Society of America* 119(1): 597-607.

Yavas, Mehmet. 2020. *Applied English phonology*. Hoboken, NJ: John Wiley & Sons.

Appendix

A. Test 1 stimuli

Frequency Category	Base Word	Frequency (per million)
Low	plier	0.02
Low	prawn	0.28
Low	prank	2.49
Low	brisk	2.97
Low	bleak	4.42
Low	blur	4.86
Low	brow	5.61
Low	plage	6.92
Low	bronze	8.77
Low	brass	9.68
High	blog	68.17
High	plus	75.99
High	blue	112.69
High	price	125.85
High	press	139.32
High	break	146.70
High	plan	199.83
High	please	249.12
High	play	288.60
High	black	312.12

B. Test 2 stimuli

Frequency Category	Base Word	Frequency (per million)
Low	nark	0.02
Low	psig	0.07
Low	glade	0.56
Low	chug	1.07
Low	twig	1.31
Low	hunk	1.78
Low	snug	1.83
Low	jade	3.82
Low	halt	9.61
Low	jerk	9.95
High	bank	102.88
High	dark	128.32
High	sound	143.97
High	food	231.86
High	hand	301.15
High	thank	323.26
High	week	328.82
High	talk	363.31
High	kind	419.92
High	found	445.38

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