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The Impact of Learner and Acoustic Variables on Foreign Accentedness in L2 English Vowels*

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ABSTRACT

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Foreign accents are typically slow to change, although the perceived strength of foreign accent is affected by many learner factors (e.g., initial L2 age, age of arrival [AOA] and length of residence [LOR] in L2-speaking environments, amount of L1/L2 use). Furthermore, foreign-accented speech deviates from native acoustic norms across diverse acoustic measurements (e.g., frequencies of the first formant (F1), the second formant (F2), the third formant (F3), and vowel duration). While most research on the perceived strength of foreign accent focuses on either learner variables or acoustic properties, this study investigates the impact of both learner (initial L2 age, AOA, LOR, and full-time equivalent [FTE] years of L2 input) and acoustic variables (F1/F2/F3 distances and vowel duration differences from native acoustic norms) on foreign accentedness in L2 English vowels with L1-Korean-speaking adults living in the U.K. Four native speakers of Standard Southern British English (SSBE) and 28 Korean learners produced 12 *bVt* English words (e.g., *bit, bot*). Four different native SSBE listeners assessed the perceived strength of foreign accent on a 7-point Likert scale. The productions of native speakers and Korean learners were subjected to acoustic measurements. The effects of learner and acoustic variables on foreign accentedness were statistically estimated with ordinal mixed-effects regression models. The results from learner variables showed that only the effect of LOR was significant. The results from LOR and four acoustic measures as well as two-way interactions of LOR and each acoustic variable showed that all main effects and LOR were statistically significant; shorter F1, F2, F3 distances and longer vowel durations led to a significantly weaker foreign accentedness. The interaction between F2 distance and LOR and that between duration difference and LOR were also significant, indicating that the impact of F2 distance and duration difference grew stronger with increased LOR. The results suggest that adult L2 learners were perceived as foreign accented as their acoustic measures deviate from native acoustic norms and that adult L2 learners' foreign accentedness can be reduced as their LOR increases. The study further discusses the implications of the findings for L2 theories of phonological acquisition.

KEYWORDS

learner variables, acoustic variables, LOR, foreign accentedness, L2 vowels

1. Introduction

1.1 The Effect of L2 Learner Variables on L2 Foreign Accent

The L2 phonological acquisition literature has documented that the degree of foreign accent is affected by a wide range of learner factors such as initial L2 age/or age of L2 learning (AOL), age of arrival (AOA) and/or length of residence (LOR) at an L2-speaking country, amount of L1 or L2 use, language learning aptitude, motivation, attitudes, and identity (Idemaru et al. 2021, Major 2018, Piske et al. 2001)[1]. For instance, Piske et al. (2001) examined L1-Italian L2-English bilinguals' L2 foreign accent and found that AOL and amount of L1 use were the most influential factors on the degree of foreign accent. The authors also maintained that developing a native-like pronunciation of a target language would be the first ability that language learners lose.

Previous studies found that, as far as pronunciation is concerned, the earlier one learns a target language, the better it will be produced (Flege and Bohn 2021, Flege et al. 1995, Moyer 1999, Oyama 1976). The age effect has partially been attributed to a loss of neural plasticity, to some kind of neurofunctional reorganization during development (Lenneberg 1967, Neville et al. 1992), or to the degree of the interaction between a learner's L1 and L2 systems (Bialystok 1997, Flege 1987, 1995, Flege and Bohn 2021, Piske et al. 2001). However, several studies have also shown that adult L2 learners were able to speak an L2 without a noticeable foreign accent. For example, Bongaerts et al. (1997) reported that some Dutch learners of English, who had an extensive exposure to English at the age of around 18 years, received ratings comparable to those given to native English controls. This suggests that the age effect may be entangled with other learner variables such as the amount of L1 and/or L2 use and the amount of L2 experience.

The variable LOR, which indicates the amount of L2 experience, has produced conflicting results concerning its role in L2 foreign accent or L2 production. Flege (1988) investigated adult L1-Taiwanese L2-English learners' foreign accent ratings. The learners were divided into two groups depending on their LOR (1.1 years vs. 5.1 years), but their LOR did not affect foreign accent ratings. Based on the results, Flege contended that LOR did not influence L2 learners' foreign accent when they were not in early stage of L2 learning and began learning the L2 as adults. Meador et al. (2000) re-recorded (4 years later) 62 of 240 L1-Italian L2-English learners from earlier Flege et al.'s (1995) study. The Italian learners' AOA in Canada was 11 years, and their LOR was 35 years on average. Flege et al. (1995) and Meador et al. (2000) employed different scaling measures (continuous scaling vs. 9-point scaling) and different speech materials as well as different raters. Meador et al. found a very strong correlation between the two sets of ratings and maintained that four more years of L2 experience are unlikely to change the degree of foreign accent.

By contrast, in Flege and Fletcher's (1992) study, late L1-Spanish L2-English learners with different LORs in the U.S. (inexperienced group: 0.7 years vs. experienced group:14.3 years) produced English sentences and native English listeners rated the utterances for degree of foreign accent. Flege and Fletcher reported that the experienced group had significantly higher scores (i.e., less accented and more nativelike) than the inexperienced group. Kim and Silva (2003) also found a positive effect of LOR on Korean speakers' production of English vowels. Thirty Korean speakers with different LORs in the U.S. (LOR: less than 1 year, 1~5 years, 5~8 years) produced four English front vowels (/i/, /ɪ/, /e/, /ɛ/). The results indicated that, the longest LOR group's F2 values for English /i/ and /ɛ/ were significantly different from the other groups' F2 values. The same pattern was observed for the

[1] As noted by Piske et al. (2001), many studies on L2 foreign accent indexed 'age of L2 learning (AOL)' as 'age of arrival (AOA) at an L2-speaking country.'

duration of English /i/. Idemaru et al. (2021), who looked into L1-English L2-Japanese learners' acoustic sources of foreign accent at different age (early vs. late learners) and at four different instructional levels, noticed that the difference between early and late learners may result from the early learners' longer experience with Japanese rather than early exposure in itself, suggesting that learners' LOR could still be an important predictor of foreign accent. More recently, however, Flege and Bohn (2021, p. 7) maintained that "full-time equivalent [FTE] years of L2 input" may be a "better estimate of quantity of L2 input than LOR alone." FTE years of L2 input are computed by multiplying years of residence in an L2-speaking environment by the proportion of L2 use (i.e., self-reported percentages of L2 use).

As for the effect of L2 use on L2 foreign accent, Flege and Fletcher (1992) found that L1-Spanish L2-English learners' degree of foreign accent did not show a significant correlation with the learners' percentage daily use of English. However, Flege et al. (1999), who examined L1-Korean L2-English learners' pronunciation accuracy, reported that the patterns of L1/L2 use exhibited a significant effect on foreign accent. This was because the Korean learners who used English quite often but used Korean seldom demonstrated a meaningfully better pronunciation than those who used English seldom but used Korean relatively often. Flege et al. (1995) also found that L1-Italian L2-English learners' percentage use of L1 and L2 at home, work, and social settings accounted for 15% of the variance in the foreign accent ratings next to AOL. Piske et al. (2001) looked into English sentences produced by early and late Italian-English bilinguals. The bilinguals were matched for AOA but differed with respect to self-reported L1 use. When native English listeners assessed the bilinguals' productions for foreign accent, the results showed that the amount of L1 use as well as AOA exhibited significant effects on the perceived strength of foreign accent. Mora et al. (2015) investigated the production of Catalan vowels by adult Catalan and Spanish speakers who had begun using both Catalan and Spanish in early childhood but differed in the percentage of Catalan use. Early learners of Catalan who continued using Spanish were less successful in producing the Catalan vowels /ɛ/ and /e/ in spite of the fact that they had acquired their L2 at school age.

The literature reviewed so far on the effects of L2 learner variables on L2 foreign accent indicates that the degree of foreign accent appears to vary with the characteristics of L2 learners including AOA, LOR, and L1/L2 use. However, LOR among L2 learner variables deserves further investigation due to its mixed effects on the perceived strength of foreign accent. Moreover, given that FTE years of L2 input may be a "better estimate of quantity of L2 input than LOR alone" (Flege and Bohn 2021, p. 7), further exploration of both LOR and FTE years of L2 input is needed to shed light on how L2 learner characteristics influence L2 foreign accent.

1.2 The Effect of Acoustic Variables on L2 Foreign Accent

Besides L2 learner variables, acoustic properties of L2 production affect L2 foreign accent. Existing research on L2 phonological acquisition has shown that acoustic properties of foreign-accented speech deviate from native acoustic norms across diverse acoustic measurements such as vowel formant frequencies, formant movement, vowel duration, and word duration (Munro 1993, Porretta and Tucker 2012, Porretta et al. 2015). For example, Munro (1993) examined five native English listeners' foreign accent ratings of a subset of English vowels (e.g., front vowels in a *bVt* frame) produced by male L1-Arabic speakers. The results showed that F1 frequency (for vowels /ɪ/, /ɛ/, and /æ/), which provides information of tongue height, and movement in F2 (for /eɪ/), which gives information of tongue position, were the most important predictors of the accent ratings, but the significant predictors differed depending on vowels.

Porretta and Tucker (2012) investigated which acoustic measures are the most important predictors for foreign accent ratings among vowel formant frequencies, vowel duration, and word duration. Recordings and foreign

accent ratings of nine male L1-Chinese speakers and one male L1-English speaker were obtained from the Wildcat Corpus of native- and foreign-accented English (Van Engen et al. 2010). F1, F2, F3 frequencies and vowel and word durations were measured. The results showed that vowel duration, word duration, and the interaction between the two played a crucial role in predicting a foreign accent. Deviations of F1 frequencies from a native acoustic reference point also had a strong impact on predicting a foreign accent. Porretta et al. (2015) examined the influence of acoustic distances and lexical properties on L1-Chinese L2-English speakers' foreign accent ratings. Recordings of nine male L1-Chinese speakers and seven male L1-English speakers were obtained from the same Wildcat Corpus (Van Engen et al. 2010). The first recording of the word list (40 words) produced by each of the Chinese and English speakers was selected for acoustic measurements (F1, F2, F3 frequencies, vowel duration, and word duration). In an accent rating task, only one L1-English speaker's productions were included, and the other six L1-English speakers' productions were used as the native acoustic reference and thirty L1-English listeners served as judges. The results indicated that the distances of F1 and F2 and the distance of vowel-to-word ratio from the native acoustic reference had a great impact on foreign accent ratings with increased acoustic distances associated with increased foreign accent ratings.

Idemaru et al. (2021) investigated whether acoustic properties causing L1-English L2-Japanese learners' perceived foreign accents changed in early versus late learners as well as at four different instructional levels. The learners completed a delayed repetition task with six test sentences. For vowels, F1 and F2 frequencies were measured in five short vowels and two long vowels. Other consonant features (e.g., VOT) and prosodic features were also analyzed to assess a foreign accent. The results of native Japanese raters' foreign accent judgments showed that important acoustic properties predictive of the foreign accent varied not only with learners at different instructional levels but also between early and late learners. Specifically, prosodic features mainly influenced late learners' foreign accent (i.e., more heavily accented), but most vowel features affected early learners' foreign accent (i.e., less heavily accented). The authors further noticed that the difference between the early and late learners may result from the early learners' longer experience with Japanese rather than from their early exposure to Japanese itself, as discussed earlier.

Oganyan et al. (2021) examined correlations between segmental (VOT of stops, F1 and F2 frequencies of vowels) and prosodic (duration, pitch, intensity) dimensions and foreign accentedness using stimuli recorded by 30 native speakers of English, Spanish, Hindi, Mandarin and Korean (6 speakers for each language). Each speaker from the five languages produced 60 disyllabic trochaic English words. Twenty native English listeners assessed the strength of a foreign accent for each word. The results indicated that speakers' L1 played a significant role in predicting which acoustic properties were related to the foreign accentedness; VOT was the strongest segmental predictor of the foreign accent for Spanish and Hindi speakers, while duration was the strongest prosodic predictor for Mandarin and Korean speakers. F1 and F2 of vowels were also correlated with the foreign accent ratings for Korean speakers.

Native speakers of L1 seem to be sensitive to the acoustic divergencies between L1 and L2 productions and use the acoustic information stored in their memory when assessing foreign accentedness. Accordingly, foreign accentedness can be viewed as an outcome of nonnative productions deviating from native speakers' acoustic targets and we can examine the extent to which different acoustic measures influence foreign accentedness by computing the distance of L2 productions from native acoustic norms (Porretta et al. 2015).

1.3 The Present Study

As discussed earlier, LOR has yielded mixed results concerning its role in L2 foreign accent. Flege (1988) and

Piske et al. (2001) also contended that increases in LOR may not lead to an additional ameliorative effect on L2 pronunciation when L2 learners did not begin learning the L2 at an early age or after L2 learners have lived a certain period in an L2-speaking country (Oyama 1976). According to Nagle (2018) who examined comprehensibility and accentedness of English-speaking L2-Spanish learners over a yearlong period, the learners showed a quick improvement in comprehensibility but a steady improvement in foreign accentedness. Based on the results, Nagle maintained that L2 learners should be provided with supplementary targeted training in order to reduce foreign accentedness. Thus, it is worth investigating whether adult L2 learners' foreign accentedness could be reduced as their LOR in an L2-speaking country increases. Moreover, most previous studies used AOA in L2-speaking environments to index AOL (i.e., age of L2 learning or initial L2 age; Piske et al. 2001). However, AOL and AOA should be differentiated for late L2 learners in L2-speaking countries as they normally had prior exposure to L2 when they had been in their home country. Further, while earlier studies on L2 foreign accent have demonstrated that diverse learner variables affect L2 speech, more recent studies have focused on what acoustic properties of nonnative speech led to a perceived foreign accent. However, not many studies have examined which combination of learner and acoustic properties is most predictive of a perceived foreign accent.

The present study investigates the impact of learner and acoustic variables on L1-Korean L2-English learners' foreign accentedness of L2 vowels. Specifically, the present study explores diverse learner variables such as initial L2 age, AOA, LOR, FTE years of L2 input as well as diverse acoustic properties like F1, F2, F3 distances and vowel duration in order to shed further light on the impact of these intraspeaker variables on L2 foreign accentedness, asking the following research questions: (1) Which learner variable (or variables) is (or are) most predictive of L2 foreign accentedness; (2) Which acoustic property (or properties) is (or are) most predictive of L2 foreign accentedness as well as in conjunction with the most predictive learner variable(s)?

2. Experiment

2.1 Participants

Twenty-eight Korean-speaking learners of English living in or near London participated in the experiment. Most of the participants were undergraduate or graduate students, but some were working in London and its metropolitan area when the experiment was conducted. The participants had intensive exposure to British English, in particular Standard Southern British English (SSBE), for more than one and a half years at the time of the experiment.[2] All the participants reported that they were familiar with SSBE. The participants' background information is provided in Table 1.

Four native speakers of SSBE also participated in the production task. The four speakers (two male and two female) were from London and hence their speech typified SSBE speech. All of them were graduate students (mean age: 26 years) at University College London (UCL) in London. Another group of four native SSBE speakers served as raters (two male and two female). They were all graduate students (mean age: 25 years) who had either taken phonetics courses or majored in phonetics at UCL.

[2] The participants were mainly exposed to SSBE, even though they may also have been partly exposed to other varieties like American English through watching films or YouTube.

Table 1. Participants' Language Background (Standard Deviations are in Parentheses.)

Number of participants	Chronological age	Initial L2 age	AOA	LOR	English use	FTE	L2 listening	L2 speaking
28	25.6	9.75	19.7	4.6	3.3	2.56	4	3.9
(M:11, F: 17)	(3. 7)	(2. 7)	(5.7)	(3.1)	(1.0)	(1.77)	(0.9)	(0.9)

Note. M: male speakers, F: female speakers; Chronological age, in years: Initial L2 age = age of English learning, in years; AOA = age of arrival in the U.K., in years; LOR = length of residence in the U.K., in years; English use = self-reported percentage daily use of English (1 = 0–20%, 2 = 21–40%, 3 = 41–60%, 4 = 61–80%, 5 = 81–100%); FTE = FTE years of L2 input calculated by multiplying LOR by self-reported L2 use, in years; L2 listening/L2 speaking = self-reported L2 listening/L2 speaking proficiency (1 = beginning, 2 = lower-intermediate, 3 = intermediate, 4 = upper-intermediate, 5 = advanced)[3]

2.2 Materials

Twelve English words with the target SSBE vowels placed in a /b/__/t/ frame were selected for the production task: *beat* /i/, *bit* /ɪ/, *bait* /eɪ/, *bet* /ɛ/, *bat* /a/, *boot* /u/, *boat* /əʊ/, *bought* /ɔ/, *bot* /ɒ/, *but* /ʌ/, *Burt* /ɜ/, *Bart* /ɑ/. As for SSBE vowels, the vowel in *car* and *fur* is a nonrhotic vowel [ɜ] and the vowel in *Bart* is also a nonrhotic /ɑ/. Words such as *coat* and *gold* are realized with the vowel [əʊ] and words like *hot* and *pot* are produced with the low back rounded vowel [ɒ] in SSBE. The vowel in *bath* and *bat* is realized as [a] (Ladefoged 2006, Svartvik and Leech 2006, Wells 1982).

2.3 Procedure

Each target word was presented along with a high frequency English word which includes a corresponding target English vowel. This was to minimize potential errors that might occur due to the participants' unfamiliarity with the target word. For instance, *Burt* was presented with *word* and *bit* was presented with *sit* in parentheses (Iverson and Evans 2009).

The Korean-speaking and English-speaking participants were requested to produce the target stimuli in a sentence frame ('Say _____ again.') three times. The stimuli were displayed on a computer monitor. Before the production experiment, the participants were asked to go through each target word to make sure that they knew how to produce the stimuli. Their productions were recorded with a RODE-NT1A microphone and the Speech Filing System at a sampling rate of 44,100 Hz in a soundproof lab at UCL and were stored as wave files. A phonetically trained researcher extracted each word (e.g., *beat, boat*) from the files using Praat (Boersma and Weenink 2014), inspecting both the spectrograms and waveforms. For instance, the beginning of the word-initial stop /b/ was marked at the release burst, and the end of the word-final stop /t/ was marked after a short release burst following a silent gap.

The stimuli were presented on computers using Praat for the foreign accent ratings. The stimuli were arranged into two blocks of six words each and four SSBE raters wearing headphones were informed of which word they would be listening to for their evaluation of the perceived foreign accentedness. The raters assessed the strength of a foreign accent on a 7-point Likert scale in which "1" indicated "heavily accented" and "7" "nativelikeness" using a computer keyboard (Munro 1993).

[3] Unless the Korean participants provided the precise percentage of daily English use, we averaged their reported daily English use to compute FTE years of L2 input. Additionally, native speakers' raw (not the Bark-scale converted) acoustic data were presented in Lee and Cho (2020), Lee et al. (2022), and Lee et al. (2019).

2.4 Analyses

According to Porretta et al. (2015), F1, F2, F3 frequencies and vowel duration (and word duration) are the acoustic measurements that are most likely to contribute to foreign accent ratings. For each item produced by each speaker, four acoustic measures and one accentedness score were derived. The acoustic measures were F1 distance, F2 distance, F3 distance, and duration difference. Three formant values were first extracted in Hertz at the midpoint of each vowel token and converted to the Bark scale. Then, the Bark values were normalized as *z*-scores within each speaker in order to control individual differences in frequency ranges. Finally, formant distances were calculated as the Euclidean distance between formant values of Korean speakers' productions and the average formant values from the native speakers' productions of the corresponding vowel. A higher formant distance value represented a greater formant difference between the item and the native target. Vowel durations were measured in milliseconds and normalized as z-scores within each speaker. Duration differences were calculated by subtracting the native speakers' average duration of each vowel from the duration of the Korean speakers' vowel tokens. A positive value indicated that the Korean speaker produced the item with a longer vowel than the native speakers did. In addition, four accentedness scores on each token were used in the analysis (4 raters * 3 repetitions = 12 raw scores per item). A lower accentedness score represented that the item was perceived as being more accented. Average formant frequencies and vowel durations across each speaker group and target vowels are presented in Appendix.

Four native English speakers who participated in the production task were referred to as native acoustic reference/norms. The inter-rater reliability of the accent ratings was obtained using the cronbach.alpha() function in the *ltm* package (Rizopoulos 2022) in R version 4.2.1 (R Core Team 2023). The resulting Cronbach's alpha of 0.99 indicated that the ratings were highly consistent.

3. Results

The effects of learner and acoustic variables on the perceived strength of foreign accent were statistically estimated by building ordinal mixed-effects regression models (also known as cumulative linked models), which estimate the effects of predictors on an ordered categorical variable such as responses on a Likert scale. The models were fit using the clmm() function in the *ordinal* package (Christensen 2019) in R. In addition to fixed effects, each model included by-participant and by-item intercepts as random effects.

The first model examined the effects of four learner variables (Initial L2 age, AOA, LOR, and FTE) as fixed effects on the foreign accentedness scores, and the results are summarized in Table 2. Among the four learner variables, LOR was found to have the strongest effect on foreign accentedness. Higher LOR values were associated with significantly higher accentedness scores (i.e., less foreign accented), which indicates that learners who had lived in the U.K. for longer tended to produce the vowels with a weaker foreign accent.

Table 2. Estimated Effects of Four Learner Variables on Foreign Accentedness

	Estimate	*SE*	*z*	*p*	sig.
Initial L2 age	-0.071	0.048	-1.471	.141	
AOA	-0.028	0.032	-0.865	.387	
LOR	0.279	0.098	2.854	.004	**
FTE	-0.190	0.154	-1.231	.218	

Note. * $p < .05$, ** $p < .01$, *** $p < .001$

Since LOR was found to yield a significant effect on foreign accentedness, the second model was built on the effects of LOR and four acoustic measures (F1 distance, F2 distance, F3 distance, and duration difference) as well as two-way interactions of LOR and each acoustic variable. The result of this model is summarized in Table 3. Figure 1 shows the relations between each acoustic variable and foreign accentedness scores.

Table 3. Estimated Effects of Four Acoustic Variables and LOR on Foreign Accentedness

	Estimate	*SE*	*z*	*p*	sig.
F1 distance	-1.143	0.106	-10.768	.000	***
F2 distance	-0.484	0.081	-6.002	.000	***
F3 distance	-0.131	0.050	-2.611	.009	**
Duration difference	0.237	0.051	4.650	.000	***
LOR	0.757	0.126	6.023	.000	***
F1 distance:LOR	-0.158	0.115	-1.377	.168	
F2 distance:LOR	-0.228	0.069	-3.326	.001	***
F3 distance:LOR	-0.013	0.061	-0.219	.827	
Duration difference:LOR	0.194	0.059	3.309	.001	***

Note. * $p < .05$, ** $p < .01$, *** $p < .001$

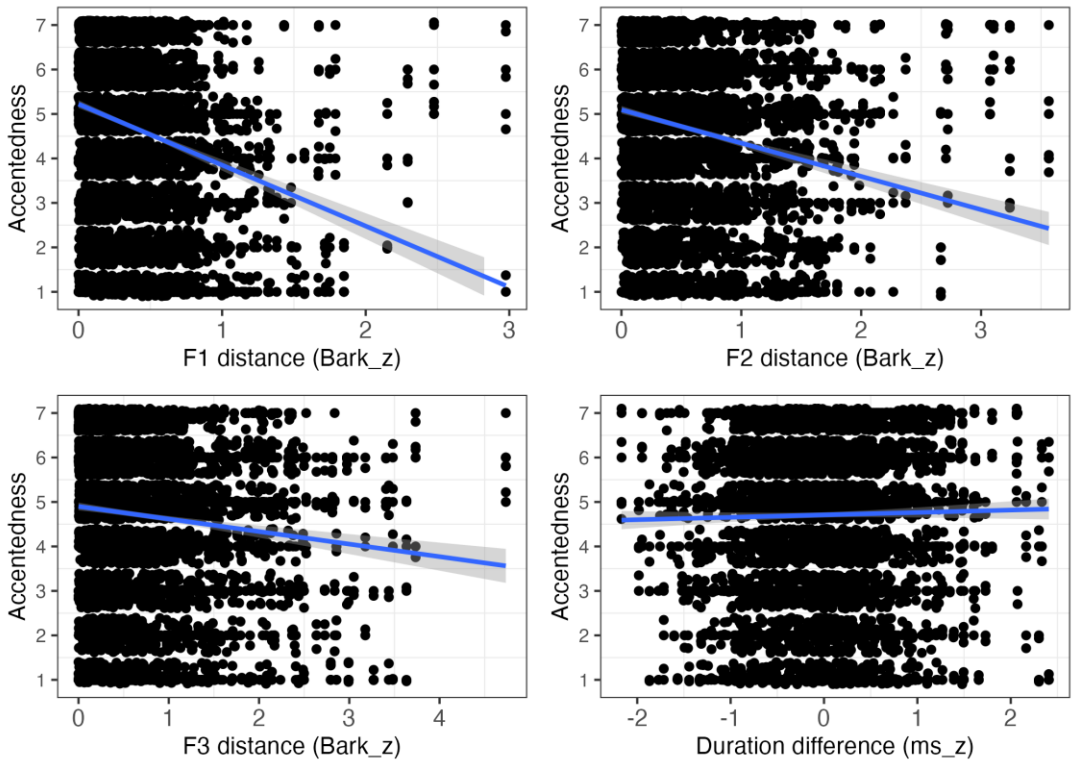

Figure 1. Relationship Between Each Acoustic Variable (F1 Distance, F2 Distance, F3 Distance, and Duration Difference) and Foreign Accentedness Scores.

The ordinal regression model indicated that all main factors, including the four acoustic variables and LOR had significant effects on foreign accentedness, such that greater F1, F2, F3 distances and shorter duration differences

led to significantly lower accentedness scores (i.e., more foreign accented). This pattern is also shown in the top and lower panels in Figure 1. In other words, a vowel was perceived as more accented when its F1, F2, F3 distances were farther from native acoustic norms and its duration was shorter than the native acoustic values. The model also showed a significant effect of LOR on foreign accentedness, similar to the result of the first model (Table 2), revealing that the combination of LOR and all the acoustic properties is most predictive of a perceived foreign accent. Importantly, the interaction between F2 distance and LOR and that between duration difference and LOR were significant, indicating that the effects of F2 distance and duration difference were more apparent in the participants with longer LORs than those with shorter LORs. Figure 2 visualizes these interaction effects, with the participants grouped into two LOR groups (Short vs. Long, split at the median; Short LOR mean = 1.9, Long LOR mean = 5.5).

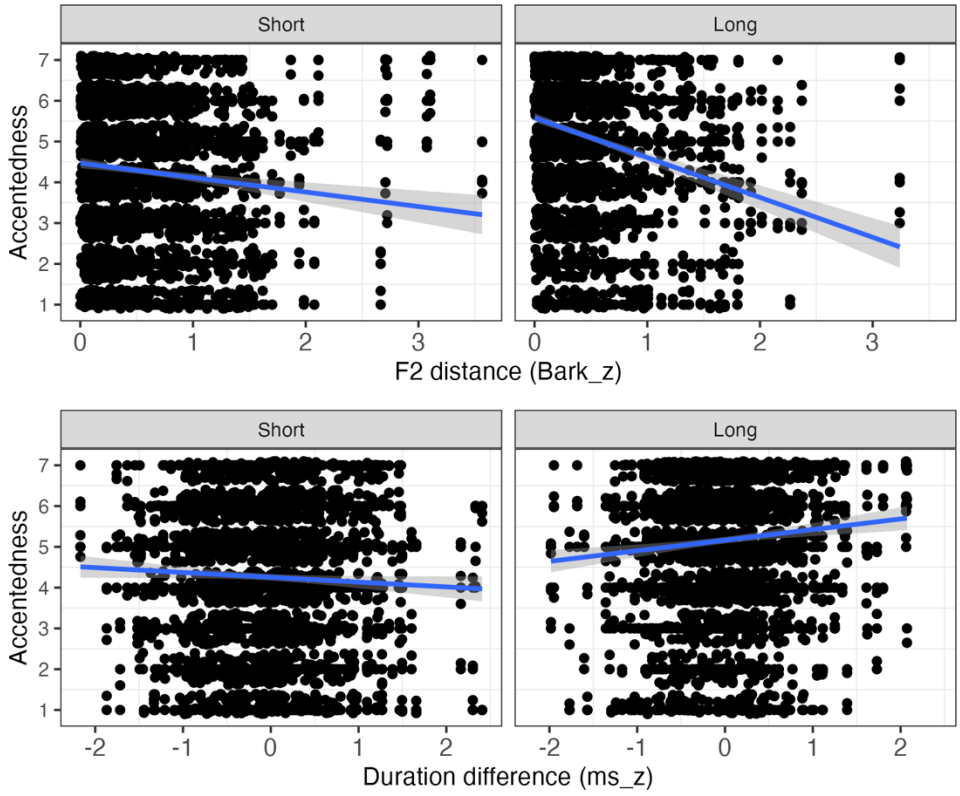

Figure 2. Interactions Between LOR (Short vs. Long) and Two Acoustic Variables (F2 Distance and Duration Difference) on Foreign Accentedness Scores.

4. General Discussion

The current study investigated how learner and acoustic variables affect foreign accentedness in L2 English vowels. Twenty-eight Korean-speaking adults living in London and its vicinity produced 12 English words presented in a *bVt* format (e.g., *bat, Burt, boot*). Four native speakers of SSBE also produced the same English words and another four native SSBE listeners assessed the perceived strength of foreign accent on a 7-point Likert scale. As for learner variables, the Korean learners' initial age of L2 learning, AOA and LOR in the U.K., and FTE

years of L2 input were considered (Flege and Bohn 2021, Piske et al. 2001). Concerning acoustic variables, F1, F2, F3 distances and vowel duration differences from native speaker norms were investigated. The effects of learner and acoustic variables on foreign accentedness were statistically estimated with ordinal mixed-effects regression models.

The first model, which examined the influence of four learner variables on foreign accentedness scores, showed that only LOR had a significant effect on foreign accentedness. This was because the learners who had lived in the U.K. for longer tended to produce the English vowels with a weaker foreign accent. The second model, which explored the influences of LOR and four acoustic measures as well as two-way interactions of LOR and each acoustic variable, revealed significant main effects for all factors: the four acoustic variables (F1 distance, F2 distance, F3 distance, and duration difference) and LOR. That is, a vowel was perceived as more foreign accented when its formant distances were farther from native acoustic references and its duration was shorter than native acoustic values. Notably, the significant interactions between F2 distance and LOR and between duration difference and LOR showed that the effects of F2 distance and duration difference were more evident among learners with longer LORs than those with shorter LORs.

First, the significant effect of LOR on foreign accentedness suggests that adult L2 learners were perceived as less foreign accented as their LOR in the U.K. increased. Although foreign accents are typically slow to change (Meador et al. 2000, Nagle 2018), the English vowels produced by the Korean learners in the current study seemed to have approximated at least several SSBE vowels, especially as the learners' LOR in the U.K. increased. However, the Korean learners' FTE years of L2 input did not have a significant effect on the learners' foreign accent ratings, which was not in line with the prediction of the Revised Speech Learning Model (SLM-r: Flege and Bohn 2021). This may partly be because the Korean learners' self-reported percentage of L2 use included their heavy use of written English rather than spoken English. That is, according to Flege and Bohn (2021: 14), learners' self-reported percentage of L2 use must be considered in the context in which they communicate verbally. It may also be due to their continued use of Korean during family or social events (refer to Table 1). Further, unless the Korean learners specified their daily English use in precise percentages, we averaged their reported daily English use to compute FTE years of L2 input (footnote 3). Hence, all these speculated reasons may have contributed to the nonsignificant effect of FTE years of L2 input on the Korean learners' foreign accent scores. This indicates that future study should focus the optimal amount of L2 input in L2 oral interactions when calculating the FTE years of L2 input. Alternatively, future study could explore whether the effect of FTE years of L2 input on foreign accents can be better attested when learners' L2 use is evaluated only in oral interactions, or in both oral and written interactions.

Secondly, among the diverse acoustic variables investigated, as the Korean learners' F1, F2, and F3 distances deviated further from native acoustic norms, they were perceived as highly foreign accented. Also, when the Korean learners' vowel durations were shorter than native acoustic values, they were perceived as having a heavy accent.[4] The results are in line with the findings of previous studies (Munro 1993, Porretta and Tucker 2012, Porretta et al. 2015), especially with respect to the impact of F1 and/or F2 frequencies, and/or vowel duration on foreign accent ratings. According to Witteman et al. (2013), deviations in vowel quality are an impetus in the

[4] An anonymous reviewer asked whether vowel duration was easier to acquire than spectral properties like F1 and F2 in the current study based on the premise that L2 learners often rely heavily on temporal cues when distinguishing L2 vowels, even when their L1 lacks a relevant spectral distinction (Bohn 1995). However, we found no special status for durational properties as F1, F2, and F3 distances as well as vowel duration differences all contributed to foreign accentedness ratings in the current study.

perception of foreign accent. This is because F1 frequency provides information of tongue height and F2 frequency information of tongue advancement and these acoustic measures are closely related to vowel categorization. Thus, variability along F1 and F2 ranges may potentially lead not only to miscategorization of vowels but also to the perception of foreign accentedness of vowels. As for F3, it is influenced by lip rounding as rounded vowels such as /o/ and /ɔ/ are associated with lower resonant formant frequencies, especially F3 frequency (Kent and Read 2002, Ladefoged 2006). Hence, when F3 is not lowered enough, it makes a vowel more heavily accented. Given that Korean has fewer rounded vowels than SSBE (e.g., /u/, /əʊ/, /ɔ/, /ɒ/), the Korean learners' production of some SSBE rounded vowels with higher F3 values than native ones may have been perceived as more foreign accented. Similarly, Arslan and Hansen (1997) showed that F2 and F3 frequencies are more important compared to other resonant frequencies in accent discrimination. That is, according to the authors, nonnative speakers often face challenges with the precise tongue movements, which indicates that F2 and F3 frequencies (i.e., the F2-F3 range) play a more significant role in accent discrimination. Concerning vowel duration differences in foreign accentedness ratings, the nonrhotic SSBE vowels /ɜ/ (e.g., *Burt*) and /ɑ/ (*Bart*) tend to be lengthened (Ladefoged 2006, Svartvik and Leech 2006, Wells 1982). Indeed, our data showed that the Korean learners produced these two vowels approximately 30-40 milliseconds shorter than the native norms on average, which is a noticeably larger difference compared to the other vowels (see Appendix). When the Korean learners did not produce these nonrhotic vowels with appropriate lengths, their productions were more likely to be perceived as more foreign accented.

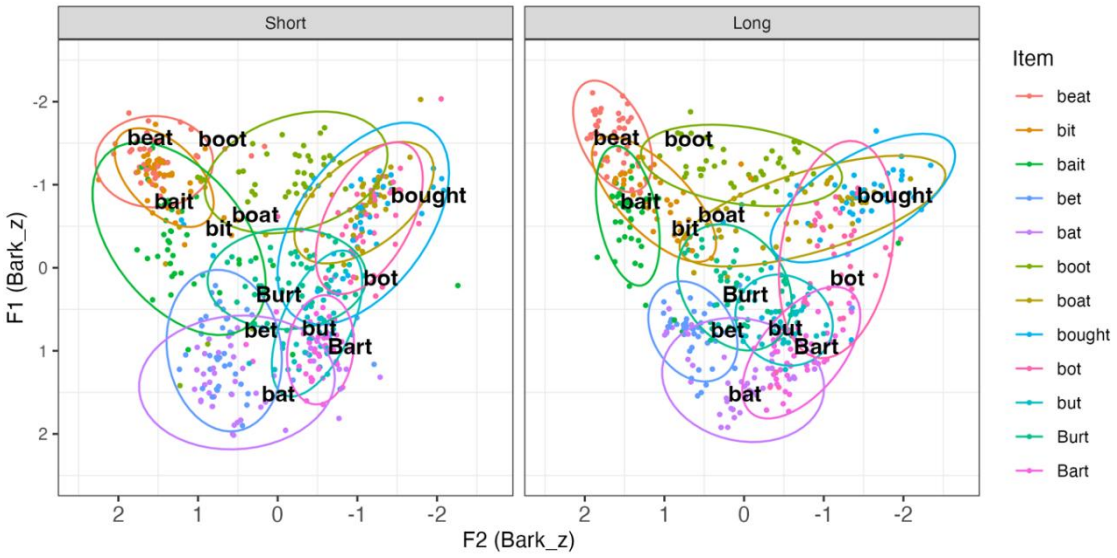

Figure 3. F1 and F2 Frequencies of Korean Learners' Vowel Productions Grouped by LOR (Short vs. Long). The Placement of Item Labels Indicates the Average F1 and F2 Frequencies from Native Speakers' Productions.

The interaction analyses, moreover, indicated that the effects of F2 distance and duration difference became more apparent as the learners' LOR increased, thus revealing the important role of LOR again in foreign accentedness ratings. Figure 3, illustrating the F1 and F2 frequencies of the vowels produced by speakers with short versus long LOR (split at the median), shows that those with long LOR tended to exhibit less overlap between vowel categories and their productions were more centered toward the native norms. For example, their

productions of *boot* /u/ and *boat* /əʊ/, which are much fronted in SSBE, had higher F2 frequencies compared to the short group, indicating more nativelike fronting. That is, learners with long LORs seemed to more closely approximate native speakers' vowel categories with respect to F2.

Native speakers have the ability to detect deviations from native acoustic norms as they store acoustic, phonetic, and phonological properties of native productions in memory and compare nonnative speech stimuli with the instances stored in memory, that is, exemplars (Pierrehumbert 2001). For instance, Flege (1984) examined native English listeners' ability to detect foreign accent of computer-edited stimuli (e.g., /t/, /u/, /tu/, *two little dogs*) produced by native speakers of English and French. Naïve as well as phonetically trained English listeners were able to accurately identify the speech produced by native speakers of French. Based on the results, Flege maintained that listeners establish highly refined phonetic category representations against which to assess their native speech sounds. As native English speakers are assumed to have good exemplars or a prototype of a vowel category stored in their phonetic representation, they make use of the stored exemplars of a vowel category when they judge foreign accentedness. Hence, vowel tokens that differ from good exemplars or a prototype along resonant frequency dimensions (F1, F2, and F3) and vowel duration seem to be judged as foreign accented. However, foreign accentedness ratings vary depending on the size or degree of differences between native speech and nonnative speech. Also, the acoustic properties raters consider when evaluating foreign accentedness could vary across vowel categories (Munro 1993, Oganyan et al. 2021). As our data (Figure 3) also suggests that the distribution of acoustic cues may vary across vowel categories, future studies could investigate whether the effects of these acoustic properties on perceived foreign accentedness also differ across vowels.

When an L2 learner has not established a target-appropriate new L2 phonetic category, the phonetic properties of the L2 sound and those of the L2's close L1 counterpart may be merged into "a composite L1-L2 category," which is more likely to lead to a foreign-accented L2 production (Flege and Bohn 2021, Piske et al. 2001: 212). ESL (English as a second language) learners like the participants in the current study need to make themselves understood to a diverse range of speakers in an environment where English is the primary language for communication. Although improved intelligibility has been assumed to be the most important goal of pronunciation instruction and intelligibility and accentedness are partially independent, foreign accents may still reduce intelligibility not only in nonnative–native speakers' interactions but also in nonnative–nonnative speakers' interactions. Foreign accents may lead to negative social evaluation and even discrimination (Derwing and Munro 2005, Munro 2003). Foreign-accented speech also increases processing time and incurs recognition errors (Chan and Hall 2019, Floccia et al. 2009, Munro and Derwing 1995) and shows a steady but no quick improvement (Nagle 2018). Hence, it seems to be necessary to pay close attention to reducing L2 foreign accents in addition to increasing intelligibility.

This study is among a few studies to examine how learner-related factors and acoustic properties jointly affect perceived foreign accentedness. Our findings show that the effects of acoustic cues on foreign accentedness are modulated by L2 experience, particularly LOR in an L2-speaking country. Increased exposure to an L2-speaking environment is associated with vowel productions that more closely approximate native exemplars, leading to reduced foreign accentedness. Thus, the results provide further support for the role of LOR in L2 acquisition, which has yielded mixed effects on the perceived strength of foreign accent, demonstrating that even adult L2 learners can be perceived as less foreign accented as their LOR in an L2 environment increases. This suggests that LOR may not be completely replaced by the FTE years of L2 input unless much compelling evidence for the concept emerges in L2 phonological acquisition studies. Moreover, by focusing on Korean learners of British English, especially SSBE, this study broadens the scope of L2 phonological research, which has predominantly examined the pronunciation of North American English (Cho et al. 2005, Flege et al. 2006, Kim and Silva 2003,

Yang 2021).

The current study has some limitations. First, as noted earlier, the study computed FTE years of L2 input based on the Korean learners' reported daily English use, which could have included both oral and written usage. Hence, future study should focus on the optimal amount of L2 input in L2 oral interactions as well as the authenticity of L2 input when calculating the FTE years of L2 input. Secondly, four native SSBE speakers' vowel productions were used as native acoustic norms and another four native SSBE listeners served as raters in the current study. For future studies, many native L2 speakers' productions should be used as native acoustic norms and many native L2 listeners should serve as raters to strengthen the findings of the current study about L2 foreign accent. Also, future studies should examine other L2 learner variables such as auditory precision, cognitive capacity, motivation, and learning aptitude in order to increase our understanding of the effects of these other learner variables on L2 foreign accentedness (Derwing and Munro 2013, Saito and Tierney 2025, Trofimovich et al. 2015).

5. Conclusion

Given that most previous studies on the perceived strength of foreign accentedness focused either on learner variables or on acoustic properties, this study examined how both learner (initial L2 age, AOA, LOR, and FTE years of L2 input) and acoustic variables (F1, F2, F3 distances, and vowel duration differences) affected L1-Korean-speaking adults' foreign accentedness of L2 SSBE vowels. The results from learner variables revealed that only the impact of LOR was significant. The results from LOR and four acoustic variables and two-way interactions of LOR and each acoustic variable indicated that all main effects and LOR were statistically significant; greater F1, F2, F3 distances and shorter vowel durations led to a significantly heavy foreign accent. The interactions between F2 distance and LOR and between duration difference and LOR were also significant, showing that the effects of F2 distance and duration difference were more evident in the learners with longer LORs than those with shorter LORs. The results suggest that adult L2 learners are perceived as more foreign accented as their acoustic measures deviate farther from native acoustic norms and that adult L2 learners' foreign accentedness can be reduced as their LOR increases. Therefore, the results overall indicate that the combination of LOR and all the acoustic properties is most predictive of a perceived foreign accent, reinforcing the notion that LOR is an important learner variable in studies of L2 foreign accent.

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Appendix: Mean Acoustic Measures of Each Vowel from Korean and SSBE Speakers

		Korean speakers (n = 28)				SSBE speakers (n = 4)			
Item		F1	F2	F3	Duration	F1	F2	F3	Duration
beat	/i/	3.6 (0.5)	14.4 (1.1)	16.1 (0.7)	177 (39)	3.4 (0.6)	14.4 (1.0)	16.2 (0.5)	178 (27)
bit	/ɪ/	4.3 (0.6)	13.7 (1.1)	15.6 (0.7)	131 (32)	4.9 (0.4)	12.6 (1.9)	15.3 (0.8)	151 (24)
bait	/eɪ/	4.9 (0.8)	13.6 (1.5)	15.3 (0.7)	215 (45)	4.4 (0.6)	13.8 (0.6)	15.7 (0.5)	222 (35)
bet	/ɛ/	6.7 (0.8)	12.2 (1.1)	14.8 (0.8)	154 (37)	6.5 (0.7)	11.5 (1.5)	14.9 (0.9)	161 (24)
bat	/a/	7.2 (0.8)	11.3 (1.5)	14.8 (0.7)	175 (44)	7.6 (0.9)	11.1 (0.4)	14.6 (0.5)	175 (25)
boot	/u/	4 (0.7)	10.6 (1.6)	14.9 (0.7)	179 (46)	3.4 (0.3)	12.5 (0.5)	14.6 (0.6)	192 (31)
boat	/əʊ/	4.6 (0.6)	8.8 (1.8)	15 (0.9)	205 (51)	4.6 (0.3)	11.7 (0.9)	14.6 (0.6)	199 (42)
bought	/ɔ/	4.7 (0.9)	8.1 (1.5)	15.3 (0.6)	213 (47)	4.3 (0.5)	7.2 (0.8)	15.1 (0.4)	238 (29)
bot	/ɒ/	5.1 (0.9)	8.2 (1.0)	15.2 (0.6)	161 (42)	5.7 (0.5)	8.4 (0.6)	15.1 (0.6)	158 (29)
but	/ʌ/	6.3 (0.8)	9.7 (0.8)	15.1 (0.7)	155 (38)	6.5 (0.8)	10.1 (0.8)	15 (0.5)	156 (32)
Burt	/ɜ/	5.7 (0.7)	10.7 (1.1)	14 (1.2)	227 (43)	6 (0.7)	11.1 (0.6)	15.1 (0.6)	266 (32)
Bart	/ɑ/	6.8 (0.6)	9.5 (0.8)	14.5 (1.2)	241 (46)	6.9 (1.0)	9.3 (0.7)	14.8 (1.6)	272 (25)

Note. Formant frequencies in Bark and durations in milliseconds; Standard deviations are given in parentheses.

Examples in: English
Applicable Languages: English
Applicable Level: Intermediate, High-intermediate and Advanced level

