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Estimating Korean EFL listeners' perception of English vowels with reference to cross-language labelling

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Lee, Shinsook and Dong-Jin Shin. 2015. Estimating Korean EFL listeners' perception of English vowels with reference to cross-language labelling. *Studies in Phonetics, Phonology and Morphology*. 21.2. 297-321. This paper explores whether Korean EFL listeners' perception of English vowels and their English vowel category development can be estimated from cross-language labelling between English and Korean. The paper also investigates whether cross-language labelling makes different predictions for General American English (GAE) vowels and British English (Received Pronunciation, RP) vowels, given that vowel category variation exists between the two accents. Thirty-six university students in Seoul completed cross-language labelling and English vowel identification. Fit indices were calculated based on cross-language labelling for both GAE and RP vowels in order to answer the questions posed. Specifically, the paper tested the assumption of the Speech Learning Model (SLM) that L2 category development is closely related to the perceived phonetic distance between L1 and L2 sounds by calculating fit indices. The results reveal that the fit indices computed had limitations in accounting for the identification accuracy of L2 vowels. The fit indices also made similar predictions for GAE and RP vowels, but there were accent and vowel category variations between GAE and RP. Thus, the overall results suggest that L2 vowel perception or L2 vowel category learning depends on factors such as L2 learners' target language accent and their overall interlanguage phonological system, as well as the perceived phonetic distance between an L2 sound and its closest L1 counterpart. **(Korea University and Hankuk University of Foreign Studies)**

Keywords: English vowel perception, cross-language labelling, category learning, SLM, accent and category variation

1. Introduction

There has been a considerable body of research on Korean EFL learners' perception of English vowels, but most research has been limited to American English vowels without looking at British English vowels (Yang 1996, 2000, Tsukada et al. 2005, Yun 2005, Hwang and Lee 2012, Hong 2013). American English, especially General American English (GAE), is different from British English, in particular, Received Pronunciation (RP) in terms of vowel inventories, in addition to other pronunciation differences like allophonic variation, stress, and intonation. For instance, GAE uses a low front vowel /æ/ in words like *bat* and *bad* while RP uses /a/ for the same

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words. GAE employs a low back unrounded vowel /ɑ/ whereas RP has a low back rounded vowel /ɒ/ in words such as *hot* and *spot*. GAE also contains a mid-central *r*-coloring vowel /ɝ/ but RP deletes /r/ in coda position with a concomitant lengthening of a preceding vowel. Accordingly, words like *sir* and *bird* are realized differently between GAE and RP. In addition, GAE has a mid back vowel /oʊ/ in words like *low* and *goat* but RP has /əʊ/ in these words (Ladefoged 2006, Celce-Murcia et al. 2010).

Thus, it is of great interest to examine how Korean EFL listeners perceive RP vowels as well as GAE vowels because the same words such as *bat, hot, sir*, and *goat* are realized with different vowels depending on accents. More specifically, how do Korean EFL listeners identify vowels typical of RP given that they have not had much exposure to RP? Also, do Korean EFL listeners show similar perceptual patterns for other vowels which do not demonstrate accent differences between GAE and RP? Moreover, the Speech Learning Model (SLM) proposed by Flege (1995) and the Perceptual Assimilation Model-L2 (PAM-L2) proposed by Best and Tyler (2007) predict that sounds in L2 which are perceptually analogous to those in L1 pose a great perceptual challenge to L2 listeners. That is, the models predict that L2 vowels with close matching vowels in L1 tend to be equated with or assimilated into those L1 vowels, causing a perceptual challenge to L2 listeners. For example, English distinguishes between the high front tense vowel /i/ and its lax counterpart /ɪ/ whereas Korean has only /i/ which is more analogous to English tense /i/ than lax /ɪ/ (Yang 1996, Flege et al. 1997). PAM-L2 predicts that both English /i/ and /ɪ/ will be mapped onto Korean /i/, causing perceptual problems to Korean ESL/EFL listeners. Similar predictions are made by SLM as English /i/ and /ɪ/ tend to be equated with Korean /i/. Consequently, it is of significance to investigate the relationship between English-Korean vowel category labelling and Korean EFL listeners' English vowel perception.

More specifically, the present paper addresses the following questions on Korean EFL listeners' English vowel perception: 1) Will cross-language vowel labelling between English and Korean be a good indicator for estimating Korean EFL listeners' identification of English vowels?; 2) Can cross-language vowel labelling make a better prediction of Korean EFL listeners' identification of RP vowels than their identification of GAE vowels? This is because the listeners generally have had little exposure to RP and thus they are more likely to depend on L1 vowel categories when perceiving less familiar L2 vowels; 3) Will the cross-language labelling data predict vowel identification with a similar degree of accuracy for all vowels or will the data make a better prediction of certain vowels relative to other vowels? In order to answer the research questions, the paper conducted a cross-language vowel labelling task and an English vowel identification task on Korean EFL listeners for both GAE and RP vowels.

2. Previous studies on cross-language category labelling

Research on a second language has shown that L2 learners' categorization of the sounds in an L2 is different from that of native speakers of the L2 and this often leads to incorrect perception or production of the L2 sounds. For instance, L2 learners' categorization of L2 sounds may be based on phonetic/acoustic cues different from those used by L1 speakers partly due to the interference from the L2 learners' L1 (Flege et al. 1997, McAlister et al. 2002, Iverson et al. 2003). Moreover, the ability to form a target-like sound category has been assumed to be inversely related to the beginning age of L2 learning (Flege 1995, Ioup 2008) and to be affected by a perceived phonetic distance between an L2 sound and any existing sound categories in L1 (Flege 1991, 1995, Best 1995, Best and Tyler 2007). Specifically, Flege (1995) contended that L2 learners are more likely to form a new sound category for an L2 sound if they start to learn the L2 early in life. Flege (1987) also reported that experienced English speakers of French were able to produce French /y/ target-appropriately but neither they nor inexperienced English speakers of French produced French /u/ in a native-like way. This was because French /y/ is a new sound category while French /u/ is similar to its English counterpart, thus causing more perceptual and production difficulty to English speakers of French.

As for the perceived phonetic distance between the sounds in L1 and those in L2, it has often been assessed by cross-language category labelling between an L1 and an L2 using orthography classification techniques. In particular, Guion et al. (2000) examined Japanese listeners' identification of Japanese (/b, ɯ, t, d, s, ɾ, h/) and English consonants (/b, v, w, ɵ, s, t, r, l/) in terms of a Japanese consonant category, along with goodness ratings to that Japanese category. They also conducted a category discrimination test in which the discrimination of English-Japanese pairs (/t/-/t/, /b/-b/, /r/-/ɾ/, /l/-/ɾ/, and /ɵ/-/s/) in addition to the discrimination of Japanese-Japanese and English-English pairs was assessed. The Japanese listeners differed with respect to their English experience: high-experience group, mid-experience group, and low-experience group. Guion et al. then compared the results from category labelling data with the results from the category discrimination test in terms of 'a fit index'. They calculated the fit index for a particular English consonant in terms of the proportion of Japanese labeling for the English consonant multiplied by the mean goodness-of-fit of that Japanese labelling. For example, Guion et al. obtained the fit index for English /s/ stimuli by multiplying the proportion of responses receiving Japanese /s/ labelling (0.87) by the goodness rating of that Japanese labelling (4.5), which resulted in a fit index of 3.9 for English /s/ to Japanese /s/. When English consonants were identified in terms of two Japanese consonants as in English /l/ (Japanese /ɾ/ and /ɯɾ/) and /ɵ/ (Japanese /s/ and /ɸ/), both Japanese labellings were considered when computing a fit index. Guion et al. further classified English consonants, whose fit indices fell within 1.0

standard deviation of the average fit index computed for the Japanese consonants, as good exemplars of a Japanese category. By contrast, English consonants, whose fit indices were more than 2.0 standard deviations below the average fit index gained for the Japanese consonants, were classified as poor instances of a Japanese category[1].

Importantly, when the English consonant was regarded as a poor exemplar of the Japanese consonant category it was contrasted with, Japanese listeners, especially those with more English experience were assumed to discriminate the English consonant well. This was because Guion et al. (2000) contended that L2 listeners with more English experience should demonstrate evidence of learning, which can be manifested in terms of establishing new L2 sound categories. According to Guion et al. (2000), Japanese listeners with high English experience showed a good discrimination ability only for the English-Japanese /r/-/ɾ/ pair compared to those with less English experience, even though the three English-Japanese contrasts (i.e., /r/-/ɾ/, /l/-/ɾ/, and /ɵ/-/s/) all contain poor-fitting English consonants (i.e., /r/, /l/, and /ɵ/). However, the two English-Japanese contrasts (/t/-/t/ and /b/-/b/) with good-fitting English consonants (i.e., /t/ and /b/) demonstrated very low discrimination ability regardless of the Japanese listeners' English experience. Thus, the overall results indicated that the fit index computed for the perceptual distance between L1 and L2 sounds was able to predict the discrimination of some English-Japanese sound contrasts rather well while it was not for some other English-Japanese contrasts.

Concerning vowel categories, Flege (1991) examined cross-language vowel labelling between American English and Spanish using Spanish orthography. Sixty native Spanish listeners labelled the vowels in multiple productions of English words *beat* (/i/), *bit* (/ɪ/), *bet* (/ɛ/), and *bat* (/æ/) using one of the vowel letters (<a>, <e>, <i>, <o>, <u>) employed to spell Spanish vowel phonemes or using the 'none' label if the Spanish listeners were not able to find a Spanish-matching vowel. The Spanish listeners were different in terms of their English-learning experience: Spanish monolinguals, Spanish listeners with a limited experience with English (inexperienced group, 0.6 years of stay in the US), and Spanish listeners with more experience with English (experienced group, 6.6 years of stay in the US). According to Flege (1991), experienced Spanish listeners' use of the 'none' label was more frequent than that of inexperienced Spanish listeners. Also, inexperienced Spanish listeners used the 'none' label more frequently than Spanish monolinguals, indicating that listeners' different English-learning experience had an impact on cross-language vowel labelling. Cebrian (2006) investigated the effect of English-learning experience on English vowel categorization by native Catalan listeners with varying English-learning experience and reported that there was no effect of English-learning experience on vowel categorization.

[1] The average fit index gained for the Japanese consonants in Japanese-Japanese category labelling was 4.5 (s.d. = 1.1) (Guion et al. 2000: 2716).

Several studies examined how Korean L2 listeners perceptually assimilate English consonants or vowels into Korean consonants or vowels using an orthography classification method. For instance, Schmidt (1996) looked into Korean L2 listeners' perceptual assimilation patterns of English consonants into Korean consonants by using Korean orthography and the listeners' category goodness ratings. Park and de Jong (2008) provided a quantitative model to predict Korean EFL listeners' accuracy in English obstruent identification based on bidirectional cross-language labelling between English and Korean (i.e., English-to-Korean and Korean-to-English labelling). Park and de Jong reported that the accuracy of some English obstruents, especially the accuracy of stop consonants, was able to be predicted on the basis of L1 (i.e., Korean) consonant categories when weighted by the listeners' L2-to-L1 goodness ratings. Importantly, they found that there was an overall negative correlation between high accuracy results in consonant identification and the mean goodness-of-fit to the Korean consonants. This result corroborated the claims made by SLM and PAM-L2 that L2 learners are more likely to establish new sound categories for the sounds in L2 when the L2 sounds are dissimilar to existing L1 sound categories.

Tsukada et al. (2005) examined Korean ESL listeners' Korean vowel categorization patterns for English vowels and English vowel discrimination using vowel pairs /i/-/ɪ/, /eɪ/-/ɛ/, /æ/-/ɛ/, /ɑ/-/ʌ/, and /i/-/ɑ/. According to Tsukada et al., the Korean listeners' responses to the vowels in question demonstrated partial overlapping patterns or one-to-multiple mapping patterns in the L2-to-L1 categorization task. Also, the Korean listeners' discrimination scores of these English vowel pairs were overall low except the score of the English vowel pair /i/-/ɑ/ which functioned as a control in the discrimination task. Thus, Tsukada et al. were able to predict which English vowel pairs were challenging for the Korean listeners on the basis of the cross-language vowel labelling task; English vowels which showed partial overlapping or one-to-multiple mapping like /ɛ/ and /ʌ/ scored very low in the vowel discrimination test (e.g., /ɛ/-/æ/ and /ɑ/-/ʌ/).

The previous studies that were cited above showed that L2-to-L1 category labelling was at least partially successful in predicting which sound categories in L2 would pose more perceptual problems to L2 listeners compared to other L2 sound categories. Nonetheless, most studies were mainly concerned with either English consonants or American English vowels but not with British English vowels. Moreover, except some studies such as the study by Park and de Jong (2008), most L2 research investigated the relationship between cross-language labelling and L2 sound discrimination (Guion et al. 2000) but not the relationship between cross-language labelling and L2 sound identification. Further, most previous studies examined the influence of English accents on English vowel perception by native speakers of American English or British English but not by L2 listeners (Evans and Iverson 2004, 2007, Clopper et al. 2005, Labov et

al. 2006). Accordingly, the present study aims to answer the research questions posed in Section 1 by conducting a cross-language labelling task and an English vowel identification task on Korean EFL listeners.

3. Experiment

3.1 Participants

Thirty six university students from a private university in Seoul participated in the experiments as partial fulfillment of course credits. The participants' ages ranged from 19 to 30 years (mean age=22.5) and they were all English language education majors (including double majors). The participants could be considered high or upper-high level learners of English because their IBT-TOEFL scores ranged from 85-115 with the mean score of 104. The participants also completed a language background questionnaire which assessed their familiarity with several varieties of English. The participants reported that they were mostly exposed to GAE since they began to learn English. By contrast, their experience with RP was very limited to sporadic encounters through media and thus they were not familiar with RP.

3.2 Stimuli

One female speaker of American English from Ohio produced test words in GAE accent while another female speaker of British English from London in RP accent. Test words used in the experiments consisted of 14 /b/-/V/-/t/ words: *beat* /i/, *bit* /ɪ/, *bait* /eɪ/, *bet* /ɛ/, *bat* /æ-a/, *Burt* /ɝ-ɜ/, *Bart* /ɑr-ɑ/, *but* /ʌ/, *bot* /ɑ-ɒ/, *bought* /ɔ/, *boat* /oʊ-əʊ/, *boot* /u/, *bite* /aɪ/, and *bout* /aʊ/ (Iverson and Evans 2007)[2]. The speakers produced the stimulus words in a carrier sentence of "Say _____ again" at a sound-controlled laboratory at University College London located in London. The recordings produced by the speakers were inspected by 4 native English speakers with phonetic training, 2 for GAE accent and 2 for RP accent. In addition, a phonetic trainer examined all the recordings. The recording was done with 16-bit 44,100 samples per second with Speech Filing System (SFS) and a RODE-NT1A microphone.

[2] *Burt* and *Bart* in RP have a lengthened vowel due to post-vocalic /r/ deletion but vowel lengthening is not marked in the paper (Ladefoged 2006). Also, when two vowels are presented for the same word, the first vowel denotes a GAE vowel and the second an RP vowel. Additionally, in order to minimize the influence of word-familiarity on the participants' responses, each stimulus word was presented with a word with the same vowel quality as the stimulus word but with high-frequency, as in Iverson and Evans (2007). For instance, the word *bot* was presented with the word *hot*, which was given in parentheses.

3.3 Procedure

The participants completed two tasks in a sound-attenuated room at a university in Seoul, first a vowel identification task and then a vowel labelling task. For the vowel identification task, the participants wore headphones and *bVt* words were played at random 4 times, and thus there were 112 trials in total (14 words × 2 speakers × 4 repetitions). For each trial, the participants were requested to click the word they heard from the 14 words presented on the computer monitor and then to click the 'OK' button. They were allowed to replay the stimulus words up to 2 times. The identification test consisted of two blocks, one block of 56 trials of GAE accent and the other block of RP accent. For counterbalancing, half the participants completed the block of GAE first while the other half the block of RP first. Before the task, the participants finished 28 trials for practice and they were able to take a break after the first block.

The stimuli used in the identification task were also employed in the vowel labelling task. In the vowel labelling task, however, there were 56 trials (14 words × 2 speakers × 2 repetitions). The participants were asked to listen to *bVt* words played at random and to click the Korean vowel they thought most similar to the English vowel in the stimulus item from the 14 Korean vowels displayed on the computer monitor (Table 1). They also rated the goodness-of-fit of the Korean vowel labeling to the English vowel in the stimulus word on a 7 point scale where '1' indicates 'very different' and '7' denotes 'very similar'. Korean vowels were presented in Korean orthography and the participants finished 14 trials for practice before the main test. Similar to the vowel identification task, the participants were allowed to replay the stimuli up to 2 times. Both vowel identification and vowel labelling tasks were conducted using Praat.

4. Results and discussion

4.1 Vowel labelling task

Table 1 presents the percentages of Korean vowel labeling chosen for each GAE vowel with its mean goodness rating. The percentages denote the frequency with which Korean vowel categories were selected to classify the GAE vowel stimuli.

Table 1. Matrix for GAE vowels labeled in terms of Korean vowels and their mean goodness ratings (in parentheses). Boldfaced values mark modal responses.

Korean vowels	English vowels													
	/i/	/ɪ/	/eɪ/	/ɛ/	/æ/	/ʌ/	/ɚ/	/ɑr/	/ɑ/	/ɔ/	/oʊ/	/u/	/aɪ/	/aʊ/
/i/	**100**	**94**	3									3	4	
이	(5.7)	(5.3)	(3.0)									(1.5)	(2.7)	
/e/			**69**	39	29									
에			(2.5)	(5.8)	(5.7)									
/ɛ/		6	21	**61**	**69**								4	
애		(5.0)	(3.5)	(5.3)	(5.4)								(2.0)	
/ʌ/						**97**	**93**	17	**59**	**70**				
어						(5.6)	(4.4)	(4.8)	(4.6)	(4.1)				
/ɨ/												1		
으												(5.0)		
/a/						3		**83**	34	4			**90**	**74**
아						(6.0)		(4.3)	(4.5)	(5.0)			(2.5)	(2.3)
/o/							7		4	21	**94**			
오							(2.4)		(3.3)	(3.1)	(3.3)			
/u/											4	**94**		10
우											(3.0)	(5.5)		(2.7)
/jɛ/			4		1									
얘			(1.3)		(7.0)									
/wa/									3	3			1	13
와									(3.0)	(4.5)			(3.0)	(3.4)
/jʌ/														
여														
/jo/										1				
요										(2.0)				
/ju/											1	1		3
유											(2.0)	(3.0)		(1.0)
/wɛ/			3		1									
왜			(2.5)		(3.0)									

Note: Labels totaling less than 1% are not given in the table.

The data in Table 1 show that many GAE vowels were matched onto a single Korean vowel category. For instance, English vowels /i/ and /ɪ/ were almost always labelled as Korean /i/ while English /ʌ/ and /ɝ/ as Korean /ʌ/. Interestingly, English /i/ was heard as Korean /i/ in 100% of instances. Similarly, English /oʊ/ and /u/ were mostly mapped onto Korean /o/ and /u/, respectively. On the other hand, some English vowels were connected to two or more Korean vowel categories. For example, English /ɛ/ was mostly labelled as Korean /ɛ/ and /e/ and the same pattern was obtained for English /æ/, which means that the participants heard some English vowels as intermediate between two Korean vowel categories. More specifically, English /æ/ was heard as Korean /ɛ/ 69% of the time and as Korean /e/ 29% of the time. English /ɑ/ was also heard as Korean /ʌ/ 59% of the time and as Korean /a/ 34% of the time, which was rather unexpected, given that English /ɑ/ was assumed to be more similar to Korean /a/ rather than Korean /ʌ/. English /ɔ/ was mostly heard in terms of two Korean vowels; Korean /ʌ/ (70%) and Korean /o/ (21%). The English diphthong /aʊ/ was mapped onto Korean /u/ and /wa/ in addition to its predominant mapping onto Korean /a/ (74%).

The mean percentage of Korean labeling and the goodness-of-fit data were combined into a single metric called a fit index by multiplying the two numbers, as in Guion et al. (2000). Nine out of 14 English vowels were consistently labelled with one Korean vowel (around ≥ 74%) and hence the modal response was considered for these vowels. For the 5 English vowels that were mostly identified in terms of 2 Korean vowels (/eɪ/, /ɛ/, /æ/, /ɑ/, /ɔ/), both Korean labellings were considered as in Guion et al. (2000). For example, the fit index for English /i/ stimuli was calculated by multiplying the proportion of the modal responses (1.0) by the mean goodness rating of that response labeling (5.7), which resulted in a fit index of 5.7. For English /ɔ/ stimuli with two Korean vowel categories of /ʌ/ '어' and /o/ '오', two fit indices were computed. The proportion of /ʌ/ labelling (0.70) was multiplied by the mean goodness rating for the /ʌ/ classification (4.1), giving a fit index of 2.9 while the proportion of /o/ labeling (0.21) was multiplied by the goodness rating for the /o/ response (3.1), resulting in a fit index of 0.7.

As can be seen in Table 2, the fit indices ranged from a low value of 0.7 (the fit of English /eɪ/ to Korean /ɛ/ and that of English /ɔ/ to Korean /o/) to a high value of 5.7 (the fit of English /i/ to Korean /i/) for GAE vowels. As in Guion et al. (2000), the English vowel categories with high fit indices will be considered as 'good' instances of a Korean vowel category whereas those with low fit indices will be regarded as 'foreign' or as deviant instances of a Korean vowel category.

More specifically, the 14 GAE vowels were divided into subclasses on the basis of the fit indices with the total mean fit index as a subgrouping criterion. The mean fit index calculated for the 14 vowels was 3.0. The English vowels whose fit index was over 4.0 were categorized as 'good' instances of a Korean vowel category. This means that English vowels /i/, /ɪ/, /ʌ/, /ɝ/, and

/u/ were good fitting vowels. English vowels whose fit index ranged from 2.0 to 4.0 were assumed to be 'fair' instances of a Korean vowel. For example, English /ɛ/ was regarded as having a fair fit index to Korean /e/ '에' (2.3) and /ɛ/ '애' (3.2). Finally, English vowels with a fit index below 2.0 were considered to be 'poor' instances of a Korean vowel category. English /ɔ/ was considered to have a poor fit index to Korean /o/ '오' (0.7) as well as a fair fit index to Korean /ʌ/ '어' (2.9) (Guion et al. 2000). Fit indices were calculated to provide overall fit of each English vowel to a Korean vowel category.

Table 2. Fit indices calculated for GAE vowels in terms of Korean vowels. Labellings that were more than 20% are included.

English vowel	Most common labelling(s)	Proportion of labelling(s)	Goodness ratings	Fix index	
/i/	/i/ 이	1.0	5.7	5.7	good /i/
/ɪ/	/i/ 이	0.94	5.3	5.0	good /i/
/eɪ/	/e/ 에	0.69	2.5	1.7	poor /e/
	/ɛ/ 애	0.21	3.5	0.7	poor /ɛ/
/ɛ/	/e/ 에	0.39	5.8	2.3	fair /e/
	/ɛ/ 애	0.61	5.3	3.2	fair /ɛ/
/æ/	/e/ 에	0.29	5.7	1.7	poor /e/
	/ɛ/ 애	0.69	5.4	3.7	fair /ɛ/
/ʌ/	/ʌ/ 어	0.97	5.6	5.4	good /ʌ/
/ɝ/	/ʌ/ 어	0.93	4.4	4.1	good /ʌ/
/ɑr/	/a/ 아	0.83	4.3	3.6	fair /a/
/ɑ/	/ʌ/ 어	0.59	4.6	2.7	fair /ʌ/
	/a/ 아	0.34	4.5	1.5	poor /a/
/ɔ/	/ʌ/ 어	0.70	4.1	2.9	fair /ʌ/
	/o/ 오	0.21	3.1	0.7	poor /o/
/oʊ/	/o/ 오	0.94	3.3	3.1	fair /o/
/u/	/u/ 우	0.94	5.5	5.2	good /u/
/aɪ/	/a/ 아	0.90	2.5	2.3	fair /a/
/aʊ/	/a/ 아	0.74	2.3	1.7	poor /a/

Now, let us consider RP vowels. Table 3 presents the labelling results for the RP vowels.

Table 3. Matrix for RP vowels labeled in terms of Korean vowels and their mean goodness ratings (in parentheses). Boldfaced values mark modal responses.

Korean vowels	English vowels													
	/i/	/ɪ/	/eɪ/	/ɛ/	/a/	/ʌ/	/ɜ/	/ɑ/	/ɒ/	/ɔ/	/əʊ/	/u/	/aɪ/	/aʊ/
/i/	**100**	**97**										4		
ㅇㅣ	(5.7)	(5.3)										(3.5)		
/e/		3	**66**	26	10								1	
ㅇㅔ		(5.0)	(2.7)	(5.5)	(5.0)								(2.0)	
/ɛ/			30	**70**	30								6	
ㅇㅐ			(3.2)	(5.6)	(4.7)								(4.0)	
/ʌ/				1	17	**99**	**100**	**67**	27	3	17			1
ㅇㅓ				(5.0)	(4.3)	(5.6)	(4.7)	(4.1)	(4.1)	(5.5)	(3.3)			(4.0)
/i/											1	3		
ㅇㅡ											(2.0)	(5.0)		
/a/				3	**41**	1		31	1				**91**	**74**
ㅇㅏ				(5.0)	(5.0)	(4.0)		(4.1)	(3.0)				(2.7)	(2.6)
/o/									**70**	**93**	**70**			
ㅇㅗ									(4.4)	(4.4)	(2.9)			
/u/										3	4	**93**		9
ㅇㅜ										(3.0)	(2.3)	(5.3)		(1.7)
/jɛ/			3											
ㅇㅒ			(4.5)											
/wa/								1					1	14
ㅇㅘ								(4.0)					(5.0)	(3.1)
/wʌ/											1			
ㅇㅝ											(4.0)			
/jo/									1	1	4			
ㅇㅛ									(2.0)	(3.0)	(2.3)			
/ju/											1			1
ㅇㅠ											(2.0)			(1.0)
/wɛ/			1		1									
ㅇㅞ			(2.0)		(4.0)									

Note: Labels totaling less than 1% are not given in the table.

Similar to GAE vowels, both English /i/ and /ɪ/ were connected to Korean /i/. English /ʌ/ and /u/ were also labelled as Korean /ʌ/ and /u/, respectively. One of the main interests of the present paper was to find out whether vowels typical of RP showed labelling patterns different from those of GAE. RP /a/ was classified in terms of 5 Korean vowel categories: /a/ (41%), /ɛ/ (30%), /ʌ/ (17%), /e/ (10%), and /wɛ/ (1%). This labelling pattern was very different from GAE /æ/, which was mostly mapped onto Korean /ɛ/ followed by /e/. The *r*-coloring GAE vowel /ɑr/ was mostly connected to Korean /a/ (83%) followed by Korean /ʌ/ (17%) but its RP counterpart /ɑ/ showed the opposite pattern (/ʌ/ 67% and /a/ 31%). By contrast, RP /ɜ/ was labelled as Korean /ʌ/, similar to its GAE counterpart /ɝ/. RP /ɒ/ was mostly mapped onto Korean /o/ (70%) followed by Korean /ʌ/ (27%), which was also different from its GAE counterpart /ɑ/. RP /əʊ/ was mainly labelled as Korean /o/ but it was also connected to other Korean vowels like /ʌ/ (17%) whereas GAE /oʊ/ was predominantly mapped onto Korean /o/ (94%). In addition, RP /ɔ/ was mostly connected to Korean /o/, which was also different from its GAE counterpart. Thus, the labelling results for RP vowels indicate that vowels typical of RP showed different labelling patterns from those of GAE except /ɜ/. However, diphthongs /aɪ/ and /aʊ/ did not show much difference between GAE and RP.

Similar to GAE vowels, fit indices were computed for RP vowels and the results are presented in Table 4.

Table 4. Fit indices calculated for RP vowels in terms of Korean vowels. Labellings that were more than 20% are included.

English vowel	Most common labelling(s)	Proportion of labelling(s)	Goodness ratings	Fix index	
/i/	/i/ 이	1.0	5.7	5.7	good /i/
/ɪ/	/i/ 이	0.97	5.3	5.1	good /i/
/eɪ/	/e/ 에	0.66	2.7	1.8	poor /e/
	/ɛ/ 애	0.30	3.2	1.0	poor /ɛ/
/ɛ/	/e/ 에	0.26	5.5	1.4	poor /e/
	/ɛ/ 애	0.70	5.6	3.9	fair /ɛ/
/a/	/ɛ/ 애	0.30	4.7	1.4	poor /ɛ/
	/a/ 아	0.41	5.0	2.1	fair /a/
/ʌ/	/ʌ/ 어	0.99	5.6	5.5	good /ʌ/
/ɜ/	/ʌ/ 어	1.0	4.7	4.7	good /ʌ/
/ɑ/	/ʌ/ 어	0.67	4.1	2.7	fair /ʌ/
	/a/ 아	0.31	4.1	1,3	poor /a/
/ɒ/	/ʌ/ 어	0.27	4.1	1.1	poor /ʌ/
	/o/ 오	0.70	4.4	3.1	fair /o/
/ɔ/	/o/ 오	0.93	4.4	4.1	good /o/
/əʊ/	/o/ 오	0.70	2.9	2.0	fair /o/

/u/	/u/ 우	0.93	5.3	4.9	good /u/
/aɪ/	/a/ 아	0.91	2.7	2.5	fair /a/
/aʊ/	/a/ 아	0.74	2.6	1.9	poor /a/

As for the RP vowels, the mean fit index computed was 3.0, similar to that of the GAE vowels. Accordingly, RP vowels with a fit index above 4.0 were categorized as good instances of a Korean vowel while those below 2.0 were classified as poor examples of a Korean vowel. For instance, RP vowels /i/, /ɪ/, /ʌ/, /ɜ/, /ɔ/, and /u/ were considered to be good fitting vowels. On the other hand, the RP vowel /ɒ/ was considered not only to be a fair instance of Korean /o/ '오' (3.1) but also to be a poor example of Korean /ʌ/ '어' (1.1). In Section 4.3 the fit indices computed for GAE and RP vowels will be discussed in terms of the relationship between cross-language vowel labelling and L2 vowel identification (Guion et al. 2000).

4.2 Vowel identification task

The proportions of English vowels selected for each GAE vowel stimulus are presented in Table 5.

Table 5. Mean percentage of GAE vowel identification. Boldfaced values mark modal identification responses.

English vowels	English vowels													
	/i/	/ɪ/	/eɪ/	/ɛ/	/æ/	/ʌ/	/ɝ/	/ɑr/	/ɑ/	/ɔ/	/oʊ/	/u/	/aɪ/	/aʊ/
/i/	**86**	11	1											
/ɪ/	13	**88**	3											
/eɪ/			**94**											
/ɛ/	1	1		**51**	32									
/æ/				48	**68**									
/ʌ/				1		**89**		1	24	12				
/ɝ/						1	**89**	17	1	1				
/ɑr/							2	**79**	9					
/ɑ/						3			20	10	1			
/ɔ/						4	1	1	**27**	**55**	15			12
/oʊ/			2			3	8		9	13	**78**			
/u/												**97**		
/aɪ/								1	1				**97**	
/aʊ/									9	9	5	1		**88**

Note: Identifications totaling less than 1% are not given in the table.

The participants correctly identified several GAE vowels such as /i/, /ɪ/, /eɪ/, /ʌ/, /ɝ/, /u/, /aɪ/, and /aʊ/ at a rate of more than 85%. For instance, the accuracy rate for English /u/ and /aɪ/ was 97%. By contrast, the participants had much difficulty in identifying English /ɑ/ as its mean accuracy rate was only 20%. This was because it was mainly confused with English /ɔ/ (27%) and /ʌ/ (24%) in addition to some other vowels. The low mean rate of English /ɑ/ could partly be due to the low frequency of the word *bot* and the merging of /ɑ/ and /ɔ/ in GAE (Clopper and Pisoni 2006, Labov et al. 2006). The rate for English /ɛ/ was 51% because it was mostly misidentified as English /æ/ (48%). English /æ/ was also misidentified as English /ɛ/ in 32% of instances, hence showing bidirectional errors. This may partly be due to the merging of Korean /e/ and /ɛ/ (Yang 1996). The mean accuracy for English /ɔ/ was also relatively low (55%) since it was confused with other vowels like /oʊ/ (13%), /ʌ/ (12%), and /ɑ/ (10%). English /o / was correctly identified in 78% of instances and it was mainly confused with /ɔ/ (15%). As for the two *r*-coloring vowels, /ɝ/ (89%) was better identified than /ɑr/ (79%).

The general patterns of vowel identification indicate that the participants had most difficulty with English /ɑ/ followed by /ɛ/, /ɔ/, and /æ/ in that order. However, they did not have much difficulty with English /i/, /ɪ/, /ʌ/, /ɝ/, /u/, or diphthongs. The results were somewhat unexpected given that most previous studies reported that Korean EFL learners tended to have perceptual problems for English /ɪ/ and /ʌ/ in addition to /ɛ/, /æ/, and /ɔ/, but not for /ɑ/ (Yun 2005, Hwang and Lee 2012, Hong 2013). The results will further be discussed later.

Now, let us move onto RP vowels. The results for RP vowel identification are presented in Table 6.

Table 6. Mean percentage of RP vowel identification. Boldfaced values mark modal identification responses.

English vowels	English vowels													
	/i/	/ɪ/	/eɪ/	/ɛ/	/a/	/ʌ/	/ɜ/	/ɑ/	/ɒ/	/ɔ/	/əʊ/	/u/	/aɪ/	/aʊ/
/i/	**71**	17	1									1		
/ɪ/	28	**81**		1									1	
/eɪ/			**96**										8	
/ɛ/	1	1		**59**	11	1								
/a/			2	37	**35**	1								
/ʌ/				3	18	**71**	31	14	4			1		
/ɜ/					3	6	**44**	24	1		13			
/ɑ/					17	4	3	12			1			
/ɒ/					14	8	6	6	28	10	3			
/ɔ/					1	4	6	**34**	19	23	17		1	9
/əʊ/			1		1	2	5	3	**42**	**56**	**53**		1	1
/u/										3	2	**97**		
/aɪ/													**88**	
/aʊ/						2	3	7	6	8	11	1	1	**90**

Note: Identifications totaling less than 1% are not given in the table.

As can be seen from the data in Table 6, rather different identification patterns were obtained for RP vowels. The participants correctly identified some RP vowels such as /eɪ/, /u/, and diphthongs at a rate of more than 87%, similar to GAE vowels. By contrast, the rate for RP /i/ was 71%, which was relatively low compared to its GAE counterpart (86%) due to its confusion with /ɪ/. RP /ɪ/ was accurately identified at a rate of 81% and it was mostly confused with /i/, thus showing errors in both directions. As for RP /ɛ/ and /a/, the mean accuracy for /ɛ/ was 59% and it was mainly misidentified with /a/ (37%) while /a/ was confused with many other vowels (/ʌ/, /ɑ/, /ɒ/) including /ɛ/ (11%), hence showing low mean accuracy (35%). Interestingly, the rates for the two *r*-less vowels /ɜ/ and /ɑ/ were quite low (44% and 12%, respectively). /ɜ/ was mostly misidentified with /ʌ/ (31%) while /ɑ/ with many other vowels such as /ɔ/ (34%), /ɜ/ (24%), and /ʌ/ (14%). The accuracy rates for RP /ɒ/ (28%) and /ɔ/ (23%) were also very low. This was because both of them were mainly confused with RP /əʊ/ (42% and 56%, respectively) as well as with each other. RP /əʊ/ was correctly identified in 53% of the time due to its confusion with other vowels like /ɔ/ (17%) and /ɜ/ (13%). The rate for RP /ʌ/ (71%) was also relatively low compared to its GAE counterpart.

The overall identification patterns of RP vowels show that the participants had much difficulty in identifying vowels typical of RP such as /ɑ/, /ɒ/, /a/, /ɜ/, and /əʊ/, thus suggesting that the participants' little exposure to RP influenced their identification of RP vowels. The participants also showed difficulty in identifying vowels like /ɔ/ and /ɛ/, which were assumed to pose much perceptual difficulty to Korean EFL learners (Hwang and Lee 2012, Hong 2013).

Statistical analyses indicated that the difference in mean rates between GAE and RP was significant ($t(35)=8.736$, $p<.001$), as shown in Figure 1. Thus, the results of the identification test show that overall the participants had more difficulty with RP vowels than with GAE vowels.

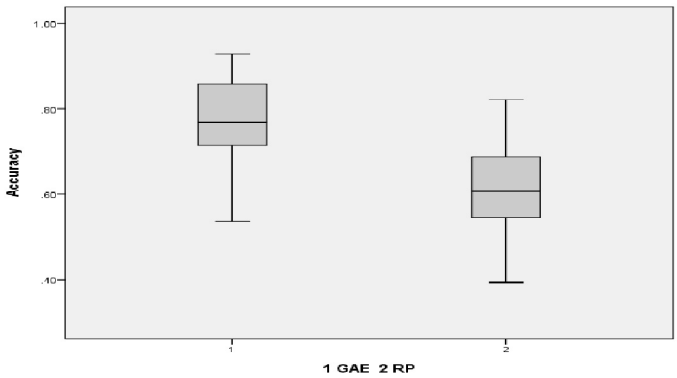

Figure 1. Mean rates (%) of identification accuracy by accent

4.3 Cross-language vowel labelling and L2 vowel identification

This section examines the relationship between the data from cross-language vowel labelling and those from L2 vowel identification in order to test some predictions of SLM (Flege 1995), given that SLM focuses on advanced L2 learners' L2 sound learning and the participants in the present study were advanced L2 (EFL) learners. Specifically, as mentioned earlier, SLM claims that the perceived phonetic distance between an L2 sound and its closest L1 counterpart plays a decisive role in category formation for the sounds in an L2. That is, if an L2 sound and its closest L1 sound are perceptually very similar, then new category formation for the L2 sound is much less likely than for an L2 sound which is perceptually distant from its matching L1 sound. The prediction of category formation for GAE vowels based on fit indices derived from cross-language vowel labelling is presented in Table 7.

Table 7. Predictions of SLM for GAE vowels based on fit indices derived from cross-language vowel labelling

English vowel	Fit index	Prediction: Category learning	Identification accuracy (%)
/i/	good /i/	Unlikely	86
/ɪ/	good /i/	Unlikely	88
/eɪ/	poor /e/ or /ɛ/	More likely	94
/ɛ/	fair /e/ or /ɛ/	Maybe	51
/æ/	poor /e/ or fair /ɛ/	Likely	68
/ʌ/	good /ʌ/	Unlikely	89
/ɝ/	good /ʌ/	Unlikely	89
/ɑr/	fair /a/	Maybe	79
/ɑ/	fair /ʌ/ or poor /a/	Likely	20
/ɔ/	fair /ʌ/ or poor /o/	Likely	55
/oʊ/	fair /o/	Maybe	78
/u/	good /u/	Unlikely	97
/aɪ/	fair /a/	Maybe	97
/aʊ/	poor /a/	More likely	88

As shown in Table 7, both English /i/ and /ɪ/ were perceived as good exemplars of Korean /i/. English /ʌ/ and /ɝ/ were also perceived as equivalent to Korean /ʌ/. Similarly, English /u/ was equated with Korean /u/. All these cases were predicted to cause perceptual difficulty to the participants as these English vowels were judged to be perceptually close to their matching Korean vowels. Contrary to prediction, the participants' identification accuracy for those vowels was relatively high. By contrast, English /eɪ/ and /aʊ/ were perceived as poor exemplars of their corresponding Korean vowels and their mean rates were rather high,

supporting the SLM's prediction for category learning. As for English /ɑr/, /oʊ/, /aɪ/ and /ɛ/, they were neither perceptually very close to their corresponding Korean vowel categories nor very distant from them, in which case category development was a possibility. The Korean participants performed very well on /aɪ/ but moderately on /ɑr/ and /oʊ/. However, their identification accuracy for /ɛ/ was relatively low. The results suggest that the SLM's prediction was partly supported. English /æ/, /ɑ/, and /ɔ/ were all perceived at least partly distant from the closest Korean vowel categories, in which case category leaning was assumed to be more likely. Contrary to prediction, the mean accuracy for /ɑ/ was the lowest and the rates for /ɔ/ and /æ/ were rather low, which again does not support the SLM's prediction for category learning.

The prediction of category formation for RP vowels on the basis of fit indices is shown in Table 8.

Table 8. Predictions of SLM for RP vowels based on fit indices derived from cross-language vowel labelling

English vowel	Fit index	Prediction: Category learning	Identification accuracy (%)
/i/	good /i/	Unlikely	71
/ɪ/	good /i/	Unlikely	81
/eɪ/	poor /e/ or /ɛ/	More likely	96
/ɛ/	poor /e/ or fair /ɛ/	Likely	59
/a/	poor /ɛ/ or fair /a/	Likely	35
/ʌ/	good /ʌ/	Unlikely	71
/ɜ/	good /ʌ/	Unlikely	44
/ɑ/	fair /ʌ/ or poor /a/	Likely	12
/ɒ/	poor /ʌ/ or fair /o/	Likely	28
/ɔ/	good /o/	Unlikely	23
/əʊ/	fair /o/	Maybe	53
/u/	good /u/	Unlikely	97
/aɪ/	fair /a/	Maybe	88
/aʊ/	poor /a/	More likely	90

Similar to GAE, both RP /i/ and /ɪ/ were equated with Korean /i/ and English /ʌ/ and /ɜ/ were also perceived as good exemplars of Korean /ʌ/. English /u/ and /ɔ/ were perceived as equivalent to Korean /u/ and /o/, respectively. As mentioned earlier, SLM predicts that these cases cause perceptual difficulty to L2 listeners. The prediction was born out for some of these vowels but not for other vowels. For instance, the Korean participants had much difficulty in identifying RP vowels like /ɔ/ and /ɜ/ but they did not have difficulty with /u/. The rates for /i/ and /ʌ/ were 71% while the rate for /ɪ/ was 81%. As for the three vowels /eɪ/, /əʊ/, and /aʊ/, whose fit indices

were relatively low, the Korean participants performed well on /eɪ/ and /aʊ/ but not on /əʊ/, showing that the SLM's prediction was partly supported. The vowels /ɛ/, /a/, /ɑ/, and /ɒ/ were all perceived as either poor or fair exemplars of their closest Korean vowel categories, in which case the participants' identification of the vowels was expected to be relatively good. However, the accuracy rates for these vowels were very low (/a/, /ɑ/, /ɒ/) or relatively low (/ɛ/), which again does not support the SLM's prediction about category learning. Interestingly, the vowels /ɑ/, /ɒ/, /a/, /ɜ/, and /əʊ/, for which the participants' mean accuracy was very or relatively low, are all typical vowels of RP and this seems to suggest that the Korean participants' little exposure to RP may have played a crucial role in the identification of the RP vowels. Finally, the fit index for /aɪ/ was fair and the participants performed rather well on this vowel.

The results from GAE and RP vowels seem to suggest that the SLM's prediction for category development based on the perceived phonetic distance or similarity between the sound categories in an L1 and those in an L2 should be modified, as noted in Guion et al. (2000). Namely, other factors such as L2 learners' experience with target language accent, overall interlanguage phonological system, and acoustic properties of L2 vowels should also be considered in accounting for L2 learners' L2 category development, which will further be discussed in the following section.

5. General discussion and implications

The paper investigated whether cross-language vowel labelling between English and Korean can estimate Korean EFL listeners' identification of English vowels and their English vowel category learning. The paper also examined whether cross-language vowel labelling can make a better prediction of Korean EFL listeners' identification of RP vowels than their identification of GAE vowels, given that the Korean listeners have had little exposure to RP. Further, the study explored whether the cross-language labelling data can make a prediction for vowel category variation between the two accents. In particular, the paper computed fit indices for both GAE and RP vowels based on cross-language vowel labelling in an attempt to answer the questions addressed.

The results from the vowel category labelling test indicated that several GAE and RP vowels like /i/, /ɪ/, /ʌ/, /u/, /ɝ/-/ɜ/, and /aɪ/ tended to be identified in terms of a single Korean vowel category. By contrast, both GAE and RP vowels such as /eɪ/, /ɛ/, /æ/-/a/, /ɑ/-/ɒ/, /ɑr/-/ɑ/, and GAE /ɔ/ and RP /əʊ/ showed one-to-two or one-to-many category labelling, although there were some variations as to the mapping Korean vowels. Specifically, variations in the mapping Korean vowels between GAE and RP were most obvious for the vowels which show differences between the two accents such as /æ/-/a/, /ɑ/-/ɒ/, and /o/-/əʊ/.

The results of GAE vowel identification revealed that the Korean EFL

listeners had most difficulty in identifying English /ɑ/ followed by /ɛ/, /ɔ/, and /æ/ in that order. However, they did not have much difficulty in identifying several vowels such as /i/, /ɪ/, /ʌ/, /ɝ/, /u/, and diphthongs. As for the results of RP vowel identification, the Korean listeners had much difficulty with the characteristic RP vowels like /a/, /ɒ/, /ɑ/, /ɜ/, and /əʊ/, which can partly be ascribable to the Korean listeners' little exposure to RP, although they also had perceptual difficulty with /ɔ/ and /ɛ/. Additionally, the Korean listeners' overall mean rates for GAE vowels such as /i/, /ɪ/, and /ʌ/ were higher than those of the corresponding RP vowels. This may be attributed to speaker variation or some subtle differences in the acoustic cues between the two accents, which deserves further research.

As for the relationship between cross-language vowel labelling and English vowel identification, it was shown that some GAE vowels like /i/, /ʌ/, and /u/, whose fit indices were high and thus considered as good exemplars of their corresponding Korean vowel categories, showed high mean accuracy rates. This contradicts the basic assumption of SLM that the perceptual phonetic distance between L1 and L2 sound categories is inversely related to L2 category perception; the smaller the perceived phonetic deviation between L1 and L2 sounds, the lower the mean accuracy of L2 sounds. Some poor- or fair-fitting English vowels such as /ɑ/, /ɔ/, and /ɛ/ showed low mean accuracy contrary to the prediction again, whereas the prediction was born out for poor-fitting English vowels /e/ and /a/. As for RP vowels, good-fitting vowels like /ɔ/ and /ɜ/ showed low mean accuracy while the rate for /u/ was very high in spite of the fact that /u/ was also a good-fitting vowel. Further, poor- or fair-fitting RP vowels /a/, /ɑ/, and /ɒ/ showed low mean accuracy rates, contrary to the prediction. /əʊ/ and /ɛ/ also demonstrated relatively low rates.

Therefore, the overall results indicated that the SLM's assumption about the relationship between perceived phonetic gap between L1 and L2 sounds and L2 category learning was born out only for some GAE and RP vowels but not for other vowels. Namely, the fit indices computed on the basis of cross-language category labelling had limitations in accounting for the identification accuracy of L2 vowels. Also, the fit indices seemed to make similar predictions for GAE and RP vowels.

Given that both L1 and L2 sound categories coexist in L2 learners' phonological system (Flege 1995), not only the perceptual closeness between the sounds in an L1 and those in an L2 but also "comparative relationships within the interlanguage phonological system" (Best and Tyler 2007: 30) seem to play a role in accounting for the overall relationship between cross-language labelling and L2 sound identification. For example, both GAE /ɑ/ and /ɔ/ were perceived as fair examples of Korean /ʌ/ in addition to Korean /a/ and /o/, respectively. Likewise, RP /ɑ/ and /ɒ/ were equated with the same Korean vowel category /ʌ/, along with Korean /a/ and /o/, respectively. Accordingly, the extent to which L2 sounds are perceptually similar to L1 sounds and also the degree of closeness to one another within the same

phonological space seem to matter.

Besides, as mentioned earlier, the mean accuracy rates for characteristic RP vowels such as /a/, /ɒ/, /ɑ/, /ɜ/, and /əʊ/ were low or relatively low, which seems to indicate that the Korean EFL listeners' little exposure to RP was partly responsible for the listeners' low mean accuracy of the vowels. Namely, the Korean EFL listeners may not have identified these characteristic RP vowels accurately in the vowel identification test because the vowels were realized in the different phonological space than the listeners had expected for the corresponding GAE vowels. For example, the *r*-coloring vs. *r*-less vowels /ɑr-ɑ/ (*Bart*) and /ɝ-ɜ/ (*Burt*) were mainly differentiated from each other in terms of F_3 and duration as the GAE vowels were produced with lower F_3 values and shorter duration than their RP counterparts (2347 vs. 3165 (F_3), 195ms vs. 275ms for /ɑr-ɑ/; 2015 vs. 3072 (F_3), 174ms vs. 261ms for /ɝ-ɜ/). Similarly, /æ/ (*bat*) was noticeably different from its RP counterpart /a/ in terms of F_2 (1970 vs. 1614), which indicates that /æ/ was produced in the more front region of the oral cavity than /a/. GAE /ɑ/ (*bot*) was also different from its RP counterpart /ɒ/ with respect to F_1 (886 vs. 673) and F_2 (1290 vs. 1084). Accordingly, the Korean EFL listeners may have had difficulty in perceiving the primary acoustic/phonetic cues of these RP vowels due to their little exposure to the vowels.

However, the Korean listeners also had difficulty with GAE /ɑ/ (*bot*) in addition to RP /ɒ/. As for why the Korean listeners showed low mean rate even for GAE /ɑ/, it could partly be due to the merging between /ɑ/ and /ɔ/ in GAE (Clopper and Pisoni 2006, Labov et al. 2006), even though the two vowels were produced differently by the native speaker of GAE who recorded the vowels. It could also be ascribable to the low frequency of the word *bot* which contains the vowel /ɑ/. Further, the Korean listeners had difficulty with /ɔ/, especially produced in RP accent. By contrast, the Korean listeners performed very well on several Korean-similar English vowels such as GAE /i/, /ɪ/, /ʌ/, and /u/ and also RP /u/. The Korean listeners may have established separate vowel categories at least for these vowels, suggesting category learning of these vowels, given that their overall English proficiency was very high (mean IBT-TOEFL score = 104).

To conclude, the SLM's prediction of category learning for the sounds in an L2 should be modified to include factors such as L2 learners' amount of exposure to the target language accent and L2 learners' overall interlanguage phonological system, in addition to the perceived phonetic distance between an L2 sound and its closest L1 counterpart. Also, L2 listeners' overall target language proficiency and acoustic/phonetic properties of the target language vowels seem to figure in accounting for L2 category learning.

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