Predicting Second-language Vowel Perception Based on Acoustic Similarities

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Over the past few decades, various models have been developed to explain how the native language (L1) phonological system affects second-language (L2) perception and production. The Second Language Linguistic Perception model (L2LP) [1] proposes that acoustics can successfully predict L2 sound learning. L2LP claims that any acoustic variation in native and target vowel production can influence speech perception [2]. L2LP further suggests that listener's initial perception of L2 vowels should closely match the acoustic properties of vowels as they are produced in the listener's L1 [1]. L2LP proposes that L2 categorisation patterns and discrimination difficulties can be predicted through a detailed comparison of the acoustic similarity between the sounds of the L1 and L2.

Some studies have reported that results of cross-language discriminant analyses (LDAs) trained on the acoustic properties of native vowels and tested on those of non-native vowels follow trends seen in listeners' perceptual assimilation patterns [3]. The present study provides new evidence with respect to assessing the effectiveness of LDAs for predicting non-native perceptual assimilation patterns. The eleven Standard Southern British English (SSBE) monophthongs are categorized into the nine Azerbaijani (AZ) vowel categories based on their acoustic properties. Subsequently, the cross-language categorization patterns are compared to AZ listeners' perceptual assimilation of SSBE vowels as previously reported in [4]. The AZ data used in the present study consists vowel productions by 23 female subjects aged 20-35 years old. The SSBE stimuli consisted of the productions of SSBE vowels by two female native speakers. The SSBE data is the same as stimuli used in the perceptual assimilation test in [4].

Figure 1 shows the F1 × F2 vowel space of AZ and SSBE based on means across speakers. It can be seen in Figure 1 that the vowel systems of the two languages are very different. The SSBE vowel space is more dispersed compared to that of AZ. Visual inspection suggests that there are AZ and SSBE vowels that are very similar based on F1 × F2 characteristics. For instance, AZ /y/ and /ɑ/ seem to be very close to SSBE /u/ and /ɑ/, respectively.

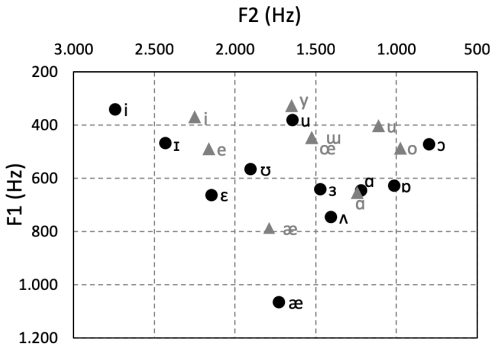

Fig 1. F1 × F2 average values (Hz) for AZ and SSBE vowels based on production of female speakers. Black dots show the SSBE vowels and gray rectangles show AZ vowels.

We first conducted separate LDAs for each language using the F1, F2 (in Bark) tokens. A cross-language LDA was conducted to establish the spectral similarity of SSBE and AZ vowels. The tokens of the SSBE corpus served as the test corpus and were classified with respect to AZ vowel centers of gravity established in the training model. In this way, the LDA classification results (percentage classifications) show how well SSBE vowels fall with respect to the centers of gravity of the AZ corpus tokens. The SSBE vowel category which receives the highest classification percentage for a given AZ vowel indicates that this SSBE vowel is the non-native vowel

acoustically closest to the AZ vowel category. Table 1 shows the LDA results for SSBE vowels classified in terms of AZ vowel categories.

Table 1. Average probability scores of predicted group membership for SSBE tokens tested on a AZ model. The AZ vowel category with the highest predicted probability appears in bold and those probabilities below 0.20 appear in grey.

SSBE vowels	AZ vowels								
	æ	ɑ	e	i	ɯ	o	œ	u	y
æ	**1.00**	-	-	-	-	-	-	-	-
ɑ	-	**0.83**	-	-	-	0.16	-	0.01	-
ɪ	-	-	**1.00**	-	-	-	-	-	-
i	-	-	**1.00**	-	-	-	-	-	-
ɔ	-	-	-	-	-	**0.92**	-	0.08	-
ɒ	-	**0.61**	-	-	-	0.38	-	0.01	-
ɛ	0.28	-	**0.72**	-	-	0.00	-	-	-
ɜ	**0.49**	0.27	-	-	0.02	0.14	0.05	0.03	-
ʊ	-	-	**0.73**	-	0.09	-	0.17	-	-
ʌ	0.47	**0.53**	-	-	-	-	-	-	-
u	-	-	0.01	-	0.26	-	0.16	0.01	**0.55**

Based on the results shown in Table 1, SSBE /æ/, /ɑ/ /ɪ/, /i/ and /ɔ/ are each acoustically similar to one AZ vowelÍ with probability scores over 80%. However, other SSBE vowels were acoustically similar to a more than one AZ vowel over different ranges of probability scores. There are cases of similarity overlap where some SSBE vowels are acoustically similar to one AZ category. For instance, /ɪ/ and /i/ vowels both were strongly acoustically similar to AZ /e/. Similarly, SSBE /ʊ/ and /ɛ/ also had the highest probability scores to be categorized as AZ /e/. The most probable categorization of vowels in the three-way contrast of /ɑ-ɒ-ʌ/ is the AZ /ɑ/ category. To quantify predictions of L2 vowel discrimination difficulty, following [5], we calculated *"cross-language assimilation overlap"* scores. This method gives a score of overlap between each member of L2 contrast and L1 vowels (Table 2).

Table 2. Acoustic overlap scores for AZ listeners.

SSBE contrasts	Overlap	SSBE contrasts	Overlap
/i-ɪ/	100	/ɑ-ɔ/	17
/ʊ-u/	26	/i-ɛ/	72
/ɑ-ʌ/	53	/ɔ-ɒ/	39
/æ-ɛ/	28	/æ-ʌ/	47

The categorization patterns based on LDA were largely in line with the previously found perceptual assimilation patterns [4]. However, our findings show that the LDA cross-language classifications solely based on F1-F2 information of vowels could not accurately predict perceptual assimilation patterns involving all vowels contrasts. Future studies may consider inclusion of other factors like vowel duration, F0, F3 and formant trajectories in the LDAs for more accurate comparisons with perceptual assimilations.

References

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