Probabilistic accessibility of words and vowel phonetic details of L1 and L2 speakers

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Previous studies [1, 2] showed that vowel formants are more drastically contrasted in low-frequency words with many neighborhood words (probabilistically hard words, henceforth), compared to frequent words with few neighborhood words (easy words). This effect is broadly explained by the communicative function of improving intelligibility of words with perceptual difficulty [3], and word-specifically shaped exemplar-based phonetic representations via lifetime experiences with probabilistic accessibility of words [4]. However, the spectral expansion in hard words may be accompanied by temporal reduction [2, 5], arguably because a hard word's high density also possibly means frequent articulatory activation of its segmental sequences through the use of many phonologically similar words. We re-examined these hypotheses (i.e., spectral expansion and temporal reduction of vowels in hard words) with L1 and L2 speakers in utterance-final position where articulatory declension was expected. We also tested if the effects interacted with the presence or absence of the speaker's communicative attention driven to the target word.

6 native speakers of American English and 6 high-proficiency Korean learners of English participated in a speech production experiment. Our lexical set in Table 1 was taken from [2], in which 6 different vowel categories /i, ɪ, æ, ɑ, o, u/ were repeatedly measured across 15 easy and 15 hard monosyllabic words. Each participant was recorded in two experimental blocks, differing in the level of speaker attention to the target word. In the 'unattended' block, participants read naturally the sentence "I _____ say the word, [TARGET].", filling in the blank with an adverb of frequency of their choice that best-matched their own usage frequency (among *seldom*, *sometimes*, *usually*, or *often*). By doing so, we intended to draw attention to the word's frequency, eliciting a narrow focus on the adverb and relatively reduced articulatory attention to the target word. Following the unattended block, the 'attended' block was conducted. The target appeared in a different carrier sentence, "This is the word, [TARGET].", drawing attention to the target word itself. Lexical items were randomly presented for each speaker, with 4 repetitions per block. Thus, a total of 2,880 tokens (30 words × 2 attentions × 4 repetitions × 12 participants) were obtained.

As shown in Fig. 1, while the native group showed clear separation of spectral distributions across vowel categories, the L2 group showed subsequent overlaps between /i/ and /ɪ/, and between back vowels, both of which are typically found in Korean L2-ers' speech. Importantly, the native group showed an 26.8% increase in the hexagonal area created by each of the six vowels' mean x- (F2) and y- (F1) values (both z-scored) on the reversed coordinate plane, when the vowel was contained in a hard word (3.12 z^2), compared to an easy word (2.46 z^2). In line with previous studies [1, 2, 5], back vowels induced less clear expansion than front vowels, particularly for /o/ and /ɑ/, possibly due to restrictions for retracting the tongue root. On the other hand, the L2 group barely exhibited such a trend, with a 1.5% increase from easy words (2.67 $z^{2)}$ to hard words (2.71 z^2) while their vowels were somewhat generally fronted in hard words. Manipulation of speaker attention, however, did not add any significant effect on the spectral pattern.

As for the effects on relative vowel length (vowel length divided by word length) shown in Fig. 2, the native group had a significant main effect of lexical difficulty (p<.05) in a conservative linear mixed effects analysis (with by-participant random intercept and slopes for difficulty and attention, and by-item intercept and slope for group), indicating that vowels were shorter in hard words than in easy words. Vowel length also varied as a function of speaker attention. Vowels were generally longer in the attended condition (p<.001), and the difficulty effect was greater in magnitude in the attended condition (p<.001). The L2 group, however, showed none of these effects.

Our results suggest that native speakers fine-tune the vowel form in word memory in accordance with probabilistic accessibility of words in line with [1, 2, 5], even utterance-finally. Further, vowel shortening of high-density hard words may also be part of the phonetic feature that is enhanced in

contextually-driven hyperarticulation [3]. The lack of both types of effects in our L2 data highlights high-proficiency L2-ers' insensitivity to communicative cooperation suited for word accessibility and/or weaker low-level connections among phonologically similar words; alternatively, it may sheerly arise from sparse phonological links extractable from relatively small-sized lexicon, all of which are related to experience-based phonological shaping in interaction with lexical use [4].

Table 1. Lexical stimuli

Vowel	/i/	/ɪ/	/æ/	/ɑ/	/o/	/u/
EASY word	*peace teeth*	*give ship thing*	*gas Jack path*	*job shop wash watch*	*both vote*	*food*
HARD word	*bead weed*	*hick kin kit*	*hack hash pat*	*cod cot knob wad*	*goat moat*	*hoop*

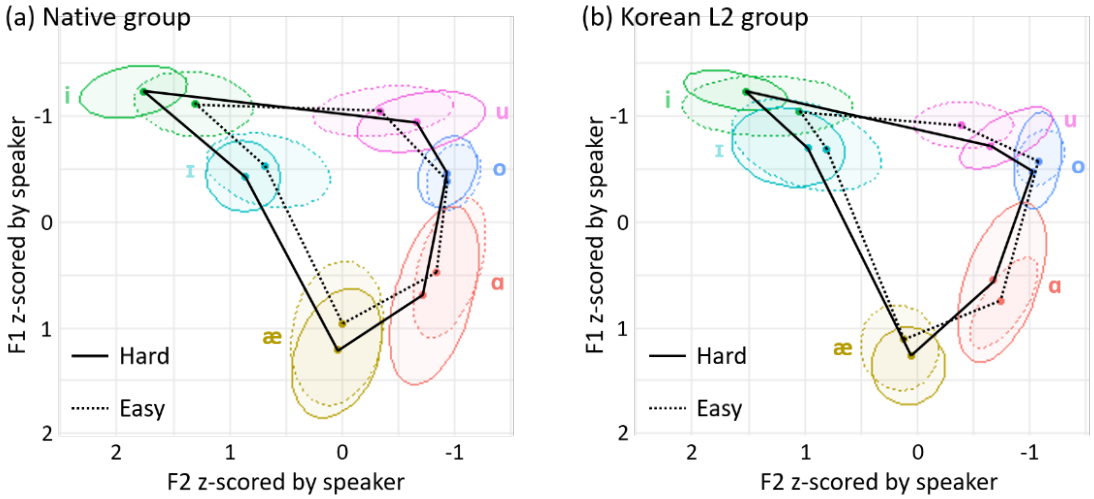
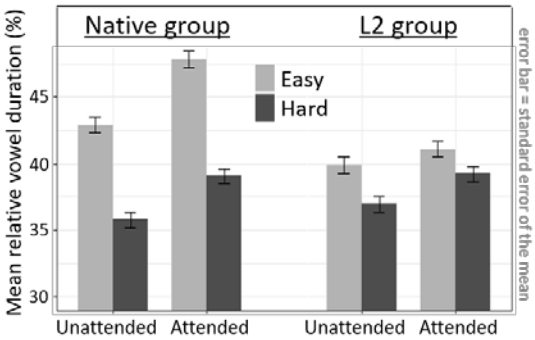


Fig. 1. Vowel plots conditioned by lexical difficulty: The ovals in six different colors were created using the stat_ellipse function (with level = 0.5) in the ggplot2 package in R to delimit the central distribution of each vowel category.



	Native group		L2 group	
	estimate	*p*-value	estimate	*p*-value
(Intercept)	0.554	<.001	0.566	<.001
Difficulty = hard	**-0.069**	**.036**	-0.018	.305
Attention = attended	**0.041**	**<.001**	0.017	.129
Difficulty : Attention	**-0.074**	**.001**	0.01	.104
Onset = voiceless obstruent	-0.107	<.001	-0.087	<.001
Onset = sonorant	-0.105	<.001	-0.097	<.001
Coda = voiceless obstruent	-0.127	.002	-0.141	<.001
Coda = sonorant	-0.016	.045	-0.205	<.001

Fig. 2. Results for vowel length: Relative vowel duration (vowel/word, in %) is predicted by difficulty, attention, and their interaction for each group in the bar-plot and in the lmer model. The model was fit separately to each group with random effects structure best supported by the data.

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