2008

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Original Publication Citation

Baker, W, & Trofimovich, P. (2008). Lexical and segmental influences on child and adult learners' production of second language vowels. COPAL, 1, 3-15.

Concordia Working Papers in Applied Linguistics

Concordia Working Papers in Applied Linguistics, 1, 2008

Lexical and Segmental Influences on Child and Adult Learners' Production of Second Language Vowels

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Abstract

This study examined how two segmental or sound-related factors (cross-language perceptual similarity, syllabic context) as well as two lexical or word-related factors (word frequency, subjective word familiarity) influenced the production of eight English vowels by 40 Korean children and adults exposed to English in the U.S. for an average of 1 and 7 years. Results of two experiments revealed that lexical factors affected adults' second language (L2) production more than children's and depended (at least for adults) on amount of L2 experience. Lexical influences on L2 production were obtained when segmental influences were particularly strong (for dissimilar L2 vowels or vowels in "difficult" syllabic contexts) and when learners lacked extensive experience with the L2 (within 1 year of L2 experience). These findings suggested that learners' experience with the L2 lexicon (becoming familiar with more words, perhaps through frequent exposure to them) may help learners overcome native language constraints on L2 phonological learning. These findings are relevant to conceptualizations of phonological development and have implications for L2 acquisition by children and adults.

What factors influence child and adult learners' production of second language sound segments (or "sounds" for short)? Previous research has identified at least two. The first factor, *cross-language similarity*, refers to how perceptually similar sounds are in the learner's native (L1) and second (L2) language. That is, the degree of perceived dissimilarity (or similarity) between L1 and L2 sounds determines how L2 sounds are perceived and produced (Guion, Flege, Akahane-Yamada, & Pruitt, 2000). For example, Japanese learners may produce the English /ɹ/ more accurately than the English /l/ (Flege, Takagi, & Mann, 1995) because they are more likely to perceptually differentiate the English /ɹ/, but not /l/, from the Japanese /ɾ/ (Aoyama, Flege, Guion, Akahane-Yamada, & Yamada, 2004). By contrast, Japanese learners may also produce the English /t/ more accurately than the English /θ/ because they are more likely to perceptually equate the English /t/, but not /θ/, with the similar Japanese /t/ (Guion et al., 2000). L2 production thus depends on the perceived distance between L1 and L2 sounds. These findings indicate that, depending on the particular relationship between individual L1 and L2 sounds, cross-language similarity can either help or hinder L2 production (MacKay, Flege, Piske, & Schirru, 2001; Flege, Schirru, & MacKay, 2003).

The second factor that influences L2 production is related to the phonetic, syllabic, phonotactic, or prosodic *context* in which L2 sounds occur (e.g., Anderson-Hsieh, Johnson, & Koehler, 1992; Strange, Akahane-Yamada, Kubo, Trent, et al., 1998). That is, learners may have more difficulty producing an L2 sound when it occurs in the context of certain sounds or in certain word- or phrase-stress conditions (Strange et al., 1998). It is known, for example, that English approximants (e.g., /ɹ/ and /l/) differ in phonetic realization in word-initial and word-final position (Dalston, 1975) and, perhaps because of this, Japanese adults differ in the ability to produce English /ɹ/-/l/ distinctions as a function of word position (Bradlow, Pisoni, Akahane-Yamada, & Tohkura, 1997). Both factors—perceived cross-language similarity and phonetic context—may be thought of as segmental or "sound-related" factors.

In addition to these sound-related factors, *lexical factors* may also influence the production of L2 sounds. Because learning sounds is inextricably linked to learning words, at least in L1 development (Ferguson & Farwell, 1975; Beckman & Edwards, 2000), factors that index the various properties of a language user's lexicon—for example, word

frequency (Marslen-Wilson, 1973), word concreteness and imageability (Kolers, 1963), word familiarity (Macken & Barton, 1980), age of word acquisition (Walley & Metsala, 1992), word cognate status (Preston & Lambert, 1969), or lexical-neighborhood density (Vitevitch & Luce, 1999) – may also determine how L2 sounds are produced. Unlike sound-related factors, whose influence on L2 perception and production has been relatively well attested (see Strange, 1995, for review), the role of these lexical or "word-related" factors, and their importance in relation to sound-related factors in determining L2 production, have not merited sufficient attention in L2 speech research. The present study was conducted to address this issue.

ROLE OF LEXICAL FACTORS IN L1 LEARNING

That learning the lexicon has direct consequences upon phonological development has been well documented (Ferguson & Farwell, 1975; Beckman & Edwards, 2000; see Broe & Pierrehumbert, 2000, for review). In essence, phonological generalizations, typical of a native speaker's knowledge of language, emerge as a result of lexical development, representing the process of learning phonological regularities of language from the ambient linguistic input.

Supporting this view of language development and use are the results of investigations with monolingual speakers that demonstrate that both children and adults—at all levels of linguistic processing, from lower-level perceptual processes to higher-level processes of phonological encoding, word recognition, and production—are sensitive to the relative frequency of phonological regularities in the lexicon. For example, studies that have examined listeners' metalinguistic ratings of wordlikeness (listeners' judgments of the similarity of non-words to genuine words) indicate that wordlikeness ratings are determined by the frequency of allowable sound sequences observed in the lexicon (Hay, Pierrehumbert, & Beckman, 2000). In a related study, Vitevitch, Luce, Charles-Luce, and Kemmerer (1997) demonstrated that the linguistic processing involved in a word-repetition task was similarly modulated by the frequency with which syllabic sequences occurred in English. In their analyses of both repetition accuracy and repetition latency, Vitevitch et al. determined that the words containing low-frequency syllables were repeated more inaccurately and slowly than those composed of high-frequency syllables (see Dell, Reed, Adams, & Meyer, 2000; Treiman, Kessler, Knewasser, Tincoff, & Bowman, 2000).

Other investigations have suggested that lexical frequency and familiarity effects are likewise salient throughout language development. Leonard and Ritterman (1972) reported that normally developing children articulated the phoneme /s/ less accurately when it occurred in low- than in high-frequency initial consonant clusters. Both extending and replicating this finding, Beckman and Edwards (2000), who asked English children to repeat non-words varying in their sound-sequence frequency, reported more accurate repetitions of high- than low-frequency non-word sequences.

Taken together, these findings demonstrate that children and adults are sensitive to lexical factors in their L1 (Broe & Pierrehumbert, 2000). Apparently, children and adults—when acquiring and using their L1—learn something about sounds from (mere) experience with words. In fact, in L1 development, children appear to first learn words as whole phonological units and only later to "decompose" them into individual sounds (Menn, 1981; see Werker & Tees, 1999, for review).

ROLE OF LEXICAL FACTORS IN L2 LEARNING

Are lexical factors as important in L2 leaning as they appear to be in L1 development? Do children and adults also learn something about L2 *sounds* from experience with L2 *words*? Relatively few studies have addressed such questions, and, to our knowledge, none have done so by comparing children and adults learning an L2. For example, one study examined adult Japanese speakers' perception of the English /ɹ/-/l/ contrast (Flege, Takagi, & Mann, 1996). In that study, the speakers tended to correctly identify the /ɹ/ and /l/ tokens when they occurred in words that were more familiar to the speakers than their minimal pairs. It was easier for speakers to identify English /ɹ/ in *room* when it was paired with *loom* than English /ɹ/ in *rip* when it was paired with *lip*. Notably, *room* is much higher in frequency (and therefore more familiar to listeners) than *loom*, whereas the opposite is true for *rip* and *lip*.

More (albeit indirect) evidence for the importance of lexical factors in L2 speech learning comes from studies of word identification. In one study, Bradlow and Pisoni (1999; Meador, Flege, & MacKay, 2000) asked adult L2 learners to identify "easy" and "difficult" words spoken by a single or multiple speakers. Easy words were high-frequency words with few similar-sounding lexical neighbors (e.g., *work, long, both*) whereas hard words were low-frequency words with many lexical neighbors (e.g., *hoot*,

mace, *moan*). L2 learners appeared less likely to accurately identify hard words than easy ones even when word familiarity was controlled, indicating that such lexical factors as word frequency and neighborhood density (factors that defined the perceptual difficulty of spoken words) effectively modulated learners' L2 perceptual accuracy.

Other research, however, has yielded conflicting results with respect to the influence of lexical factors on L2 sound learning. One study, for example, examined adult Spanish speakers' production of the word-initial English /t/ in words that differed by age of acquisition, cognate status, imageability, frequency of occurrence, and word familiarity (Flege, Frieda, Walley, & Randazza, 1998). None of these lexical factors appeared to influence the speakers' productions, suggesting that "sound-sized units of speech" (Flege et al., 1998; p. 177) may be more salient to adult learners, at least in certain L2-acquisition contexts, than word-sized units.

THE CURRENT STUDY

Although suggestive, these findings indicate that it is not yet possible to draw firm conclusions as to whether, or to what extent, learners' experience with particular lexical items influences their production and perception of phonetic segments making up those items. Similarly unanswered is the question as to what extent such an influence, if obtained, differs for child and adult L2 learners and whether the degree of such an influence changes with an increasing amount of L2 experience. In other words, more research is needed to determine how *both* lexical and segmental factors influence L2 learning and to extend investigations of these factors from adults to children and to learners differing in amount of L2 experience.

The present study was thus undertaken to answer two related questions: (1) How do lexical and segmental factors influence L2 learning by children and adults? and (2) Does this influence differ depending on children's and adults' amount of experience with L2 sounds and words? Two experiments were conducted. Experiment 1 examined how two segmental (cross-language similarity, syllabic context) and two lexical (word frequency, word familiarity) factors influenced native Korean child and adult learners' production of eight English vowels in 24 words after a relatively short exposure to English. Experiment 2 examined how these same factors influenced child and adults learners' production of the same vowels after a longer exposure to English.

EXPERIMENT 1

Experiment 1 examined the production of English vowels by Korean adults and children who had lived only briefly (about 1 year) in the U.S. The aim was to determine if the learners' production accuracy was consistent, or whether it varied across the two lexical and two segmental factors examined in this study: (a) the perceived similarity between English and Korean vowels, (b) the context in which vowels occur, (c) word frequency and/or (d) word familiarity.

Method

Participants. The participants were 10 native Korean children (designated KC-1, where "1" indicates about 1 year of U.S. residence) who had arrived in the U.S. at an average age of 8 (6.0-9.6 years) and had resided there for a mean of 1 year (0.4-1.7 years), and 10 native Korean adults (KA-1) who had arrived in the U.S. at an average age of 22 (19.6-25.1 years) and had resided there for about 7 months (0.1-1.8 years). The children and adults were asked to rate their English-speaking ability on a 10-point scale (1 = *I don't speak any English*, 10 = *I am a native English speaker*) and to estimate the amount of Korean spoken daily. (See Table 1 for a summary of pertinent information about the participants.) The two groups of Korean children and adults differed only in their chronological age, $t(18) = 23.63$, $p < .001$, and in their age of arrival in the U.S., $t(18) = 25.36$, $p < .001$. Ten age-matched native English adults (EA) and 10 children (EC) also participated for comparison purposes.

Table 1. Characteristics of Participants in Experiments 1 and 2

Group	CA[a]	AOA[b]	RES[c]	K. Use[d]	E. Rating[e]
KA-1 (n = 10)	22.8 (1.6)	22.2 (1.4)	0.6 (0.5)	56%	5.0 (1.5)
KC-1 (n = 10)	8.8 (1.1)	7.8 (1.3)	1.0 (0.5)	68%	4.4 (2.5)
KA-7 (n = 10)	28.0 (7.0)	21.6 (5.3)	6.9 (3.3)	61%	6.7 (1.8)
KC-7 (n = 10)	16.1 (4.0)	9.0 (2.3)	7.1 (3.6)	48%	7.4 (1.6)
EA (n = 10)	20.7 (1.4)				10.0 (0.0)
EC (n = 10)	8.6 (0.5)				9.4 (0.5)

Note. [a]Chronological age, in years. [b]Age of arrival in the U.S., in years. [c]Length of U.S. residence, in years. [d]Percent of daily Korean use. [e]English self-rating on a scale from 1 to 10. Standard deviations appear in parentheses.

Materials. The vowels used in this and the following experiment included eight English vowels (/i/, /ɪ/, /u/, /ʊ/, /ɑ/, /ʌ/, /æ/, and /ɛ/) in 24 monosyllabic words (Table 2). The words were chosen because they represented concrete objects suitable for a picture-naming task (described in detail below). The vowels were chosen because, in earlier studies, they were shown to be difficult for Korean learners of English to perceive and produce (Flege, Bohn, & Jang, 1997).

Table 2. English Words Used in Experiments 1 and 2

	English vowel							
Context[a]	/i/	/ɪ/	/ɛ/	/æ/	/u/	/ʊ/	/ʌ/	/ɑ/
Vs	beat	bit	pet	bat	boot	book	bud	pot
Vd	bead	big	bed	bad	booed	good	bug	pod
H	heat	hid	head	hat	hoop	hood	hut	hot

Note. [a]Syllabic context: voiceless-final (Vs, $n = 7$), voiced-final (Vd, $n = 9$), or /h/-initial (H, $n = 8$).

The words were spoken by a female native English speaker (age: 31) who produced three repetitions of each word as written on individual cue cards randomly presented one at a time. In this and the following experiment, the speaker (and the participants) were recorded using a unidimensional head-mounted microphone (Shure SM10A) and DAT tape recorder (Sony TCD-D8). The speaker's last rendition of each word was excised from the speech stream and normalized for peak intensity and perceived loudness.

Procedure. The participants were tested individually in a quiet room. A picture-naming task was used to elicit the English words; the audio stimuli were presented using presentation software (Smith, 1997) running on a PC computer. The meaning of each word was depicted in a simple line drawing. The drawings were presented to the participants three times in randomized sets. As the first set of pictures was presented, the participants heard the name of the picture over loudspeakers as spoken by the native English speaker and repeated the word. As the second and third sets were presented, the participants were asked to remember the name of the picture and to say it upon seeing the picture. The participants were thus not merely shadowing (imitating) the female speaker but were attempting to phonologically encode the perceived word. If the participants were unable to recall the name of the picture, they heard the

speaker's model again and then repeated the word. Most participants were able to say the name of the picture without a prompt in the third (and final) set.

The recorded spontaneous productions of the 960 English words (40 participants × 24 words) were digitized at 16 kHz, excised from the speech stream, and normalized for peak intensity and perceived loudness for inclusion in a listening test. Ten native English listeners (trained in phonetics) participated in the listening test. All listeners were students in a linguistics program and had experience with non-native English speech. With no explicit instructions as to the intended vowel or word, the listeners heard each word played one at a time over computer loudspeakers and chose, by clicking the appropriate button on the computer screen, one of the 15 vowels of American English presented in IPA symbols. The dependent variable was the number of listeners (maximum = 10) who identified the vowel in each of the 24 words spoken by each participant as intended (e.g., transcribed the vowel in *bit* as /ɪ/).

Data Analysis. The production scores obtained for the two child groups (KC-1, EC) and the two adult groups (KA-1, EA), calculated by averaging the scores for words in each set (see below), were examined in separate two-way repeated-measures analyses of variance (ANOVAs) because the Korean adults and children differed along dimensions in addition to age of arrival in the U.S. (e.g., years of English education in Korea, amount of native-speaker input in the U.S.). In each ANOVA, native language (Korean vs. English) served as a between-subjects factor. Perceived cross-language similarity, syllabic context, word frequency, and word familiarity (see below) served as within-subjects factors. For all ANOVAs, alpha was set at .05. Bonferroni tests (t-tests with α adjusted for number of pairwise comparisons) were used to explore significant main effects and interactions.

The 24 English words were divided into several word sets depending on the lexical or segmental factors examined. The participants' production scores for words in each set were then compared to determine if production accuracy varied across the four factors. Two sets of words were examined to evaluate *perceived cross-language similarity* (hereafter, similarity). One set of words contained the English vowels (/i/, /ɪ/, /u/, and /ɑ/) that were judged by Korean children and adults in an earlier study (Trofimovich, Baker, & Mack, 2001) to be relatively similar to Korean vowels (/i/, /i/, /u/, and /a/, respectively). The other set contained the English

vowels (/ʌ/, /ʊ/, /æ/, and /ɛ/) that were judged to be relatively dissimilar to the closest Korean vowel (/ʌ/, /u/, /e/, and /ɛ/, respectively). In that earlier study, Korean adults and children identified each similar vowel with a single Korean vowel on average 79% and 66% of the time, respectively, and each dissimilar vowel with a single Korean vowel 59% and 41% of the time.

Cross-language similarity most likely influences L2 sound learning differently in early than in late stages of L2 learning (Trofimovich et al., 2001). In early stages of L2 learning, learners are likely to produce L2 sounds that are similar to L1 sounds more accurately than those that are relatively dissimilar to the closest L1 sound. With more L2 experience, however, dissimilar sounds are ultimately produced more accurately than the similar ones because, by hypothesis, perceived cross-language dissimilarity promotes phonetic-category formation (e.g., Flege, 1995). As already mentioned, the Koreans had lived in the U.S. for only about 1 year, and so might be regarded as relatively inexperienced in English. It was predicted therefore that the participants would produce English vowels judged to be relatively similar to Korean vowels more accurately than English vowels judged to be relatively dissimilar to the closest Korean vowel (Baker, Trofimovich, Flege, Mack, & Halter, 2008).

For analyses by *syllabic context* (hereafter, context), the words were divided into three sets, containing either voiced-final (Vd, $n = 9$), voiceless-final (Vs, $n = 7$), or /h/-initial (H, $n = 8$) words (Table 2). (The word sets differed in other ways as well; e.g., the /h/-initial words ended in /t/, /d/, and /p/.) Whereas the voiceless glottal fricative /h/ exerts little influence on the acoustic properties of the following English vowel (Olive, Greenwood, & Coleman, 1993), word-final stops systematically influence English vowels. That is, English vowels are shorter before voiceless than voiced stops (House & Fairbanks, 1953), at least in stressed, prepausal positions (Mack, 1982). Predictions based on cross-language similarity may refer not only to segments, but also to "segments-in-contexts". By extension, then, L2 sounds should be produced more accurately by inexperienced L2 learners if sounds occur in a familiar than an unfamiliar context. If so, then the participants should produce English vowels more accurately before voiceless word-final stops and after a word-initial /h/ (which exist in Korean) than before voiced word-final stops (which do not).

For analyses by *text frequency* (Kucera & Francis, 1967), the words were divided into two sets, with one set containing 12 words (*pot, beat, heat, hat, bad, head, bit, hot, big, bed, book, good*) of relatively high frequency (mean:

211; range: 28-807) and the other 12 words (*bud, pod, hut, pet, bat, bug, hid, bug, bead, boot, booed, hood, hoop*) of relatively low frequency (mean: 7; range: 1-18). Of course corpus-based frequency estimates may not closely reflect the frequency with which children and adults experience L2 words. Nevertheless, it seems reasonable to assume that if word frequency influences L2 production, then the participants should produce English vowels more accurately in high- than in low-frequency words.

For analyses by *word familiarity*, the words were divided into two sets, based on the Korean participants' rating of the 24 words on a 7-point scale (1 = *I don't know the word*, 4 = *I have heard the word but am not sure what it means*, 7 = *I know the word*). The rating was administered at the end of the testing session. Following the practice of Bradlow and Pisoni (1999), these ratings will be referred to as "subjective word familiarity" ratings. One set thus contained 12 relatively familiar words (*pot, beat, heat, hat, bad, head, bit, hot, big, bed, book, good*) and the other set contained 12 relatively unfamiliar words (*bead, hoop, hid, bug, bud, hut, booed, pod, boot, hood, pet, bat*). For the children, mean ratings for the familiar and unfamiliar sets were 6.3 (5.7-7.0) and 4.5 (1.7-6.2), respectively; for the adults, they were 6.9 (6.1-7.0) and 5.3 (2.7-7.0), respectively. If familiarity influences L2 production, then the participants should produce English vowels more accurately in familiar than unfamiliar words. The independent variables investigated in this study are summarized in Table 3.

Table 3. Independent Variables Investigated in this Study

Variable	Levels
Similarity	Similar, dissimilar
Syllabic context	Voiced-final (Vd), voiceless-final (Vs), /h/-initial (H)
Text frequency	High, low
Word familiarity	Familiar, unfamiliar

Results

Effect of Segmental and Lexical Factors: Similarity. The EC group received higher mean-accuracy scores than the KC-1 group did, both for similar (99% vs. 75%) and dissimilar vowels (93% vs. 67%). The ANOVA examining these scores yielded significant main effects of language, $F(1,18) = 23.0$, $p < .001$, and similarity, $F(1,18) = 14.1$, $p < .001$, but no significant language × similarity interaction. The KC-1 group produced vowels significantly less accurately than the EC group; neither group's scores differed as a function of similarity.

The EA group received higher scores than the KA-1 group for similar

(96% vs. 63%) and dissimilar vowels (94% vs. 51%). The ANOVA comparing these scores yielded significant main effects of language, $F(1,18) = 428.4$, $p < .001$, and similarity, $F(1,18) = 13.1$, $p < .01$, and a significant language × similarity interaction, $F(1,18) = 7.7$, $p < .025$. The KA-1 group produced vowels less accurately than the EA group. In addition, the KA-1 group, but not the EA group, produced similar vowels more accurately than dissimilar vowels ($p < .01$).

Effect of Segmental and Lexical Factors*: *Context. The EC group scored higher than the KC-1 group for vowels in the voiced (96% vs. 71%) and voiceless (96% vs. 71%) contexts. The ANOVA examining these scores yielded a significant main effect of language, $F(1, 18) = 23.0$, $p < .001$, but no significant main effect of context and no significant language × context interaction. The KC-1 group produced vowels significantly less accurately than the EC group; neither group's scores differed as a function of context.

The EA group scored higher than the KA-1 group for vowels that occurred in the voiced (86% vs. 58%) and voiceless (86% vs. 57%) contexts. The ANOVA comparing these scores again yielded only a significant main effect of language, $F(1, 18) = 8.66$, $p < .01$, but no significant main effect of context and no significant language × context interaction. The KA-1 group produced vowels less accurately than the EA group; neither group's accuracy differed as a function of context.

***Effect of Segmental and Lexical Factors*: *Frequency and familiarity*.** The EC group scored higher than the KC-1 group, both for vowels in high- (98% vs. 73%) and low- (94% vs. 69%) frequency words and vowels in more (97% vs. 72%) and less (95% vs. 70%) familiar words. The EA group scored higher than the KA-1 group, for vowels in high- (96% vs. 58%) and low- (94% vs. 56%) frequency words and vowels in more (95% vs. 56%) and less (95% vs. 59%) familiar words. ANOVAs examining these scores yielded a significant effect of language in the analysis by frequency, $F(1,18) = 466.68$, $p < .001$, and by familiarity, $F(1,18) = 429.45$, $p < .001$, but no significant main effects of frequency or familiarity and no significant interactions with the language factor.

Interaction Between Segmental and Lexical Factors

Previous analyses compared the production of vowels that differed along several dimensions, which may have been confounded. For example, vowels that varied in perceived similarity between English and Korean or

vowels in different syllabic contexts may not have been equally represented in word sets divided by word frequency or familiarity. Therefore, in an attempt to reduce the effect of possible confounds, the word sets were subdivided further. Words containing similar and dissimilar vowels were subdivided according to frequency (yielding 4 sets of 6 words) and familiarity (yielding 4 additional sets). Similarly, words classified by syllabic contexts were subdivided according to frequency (yielding 6 sets of 4 words) and familiarity (yielding 6 additional sets). This resulted in 4 combinations of segmental and lexical factors: (1) frequency × similarity, (2) frequency × context, (3) familiarity × similarity, (4) familiarity × context. Table 4 displays mean characteristics of the resulting words. (The words making up each combination of lexical and segmental factors appear in the Appendix.) The production scores for each participant group were submitted to two-way repeated-measures ANOVAs in which similarity, context, frequency, and familiarity served as within-subjects factors.

Table 4. Mean Word Frequency and Subjective Word Familiarity for Word Sets Used in Analyses of Interactions

	Similarity		Syllabic Context		
	Similar	Dissimilar	Vd	Vs	H
High frequency[a]	131	292	359	98	177
Low frequency[a]	4	10	4	13	7
More familiar[b]					
KC-1	6.5	6.2	6.3	6.8	6.3
KA-1	6.8	7.0	7.0	6.9	6.8
Less familiar[b]					
KC-1	3.9	5.0	3.4	5.3	4.4
KA-1	4.3	5.5	3.8	4.6	5.5

Note. [a]Text frequency, occurrences per million.
[b]Mean word familiarity rating, 1-7.

These analyses revealed that cross-language similarity and syllabic context affected the production of vowels by the Korean adults (KA-1), but not children (KC-1), yielding 2 significant interactions for the KA-1 group: frequency × similarity, $F(1, 9) = 27.6$, $p < .001$, familiarity × similarity, $F(1, 9) = 28.1$, $p < .001$. These interactions suggested, as shown in Figure 1, that the effects of similarity and context on the adults' production accuracy were confined to low-frequency and less familiar words. The KA-1 group's production thus differed as a function of similarity only in low-frequency (similar: 70%; dissimilar: 43%) and less

familiar (similar: 77%; dissimilar: 41%) words ($p < .01$). The KA-1 group's production also differed as a function of context only in low-frequency (Vd: 74%; H: 40%) and less familiar (Vd: 74%; H: 41%) words ($p < .01$).

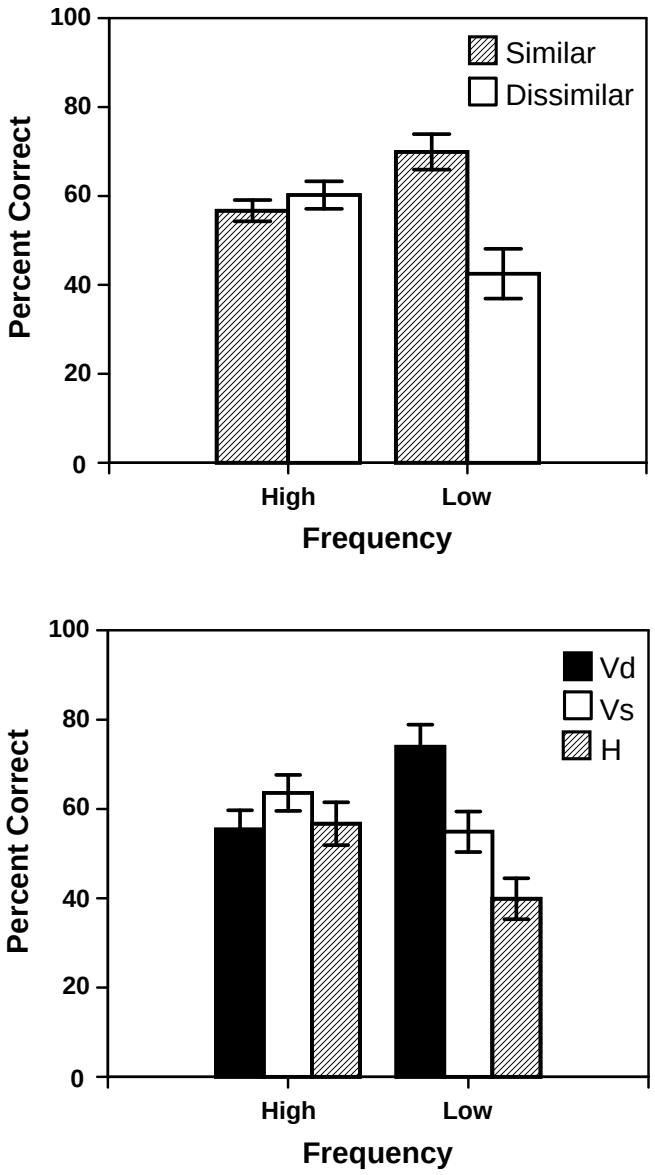

Figure 1. Inexperienced Korean adults' (KA-1) production of English vowels in high- and low-frequency words by similarity (top) and context (bottom). Brackets enclose ± 2 SE. The production of English vowels in more and less familiar words by similarity and context followed the same pattern and is not depicted graphically.

Discussion

This experiment revealed that lexical and segmental factors affected how the Korean adults—but not the Korean children nor the native English children and adults—produced English vowels. The Korean adults showed effects of cross-language similarity and syllabic context. That is, they produced similar vowels more accurately than dissimilar vowels, and vowels in some contexts more accurately than in others. The Korean adults also showed frequency and familiarity effects. That is, whenever English vowels occurred in low-frequency and less familiar words, but not high-frequency and more familiar words, the adults obtained higher production scores for similar than dissimilar vowels, and higher scores for vowels in the Vd than in the H context. Put differently, when vowels occurred in high-frequency and more familiar words, the adults were able to "overcome" the effects of cross-language similarity and context (i.e., L1-based factors affecting L2 production).

Taken together, these findings are in accord with results of prior research demonstrating (segmental) effects of cross-language similarity and syllabic context on L2 production by inexperienced adult learners (Strange et al., 1998; Aoyama et al., 2004). These findings also extend earlier studies that report lexical effects in adult learners' processing of L2 speech (Flege et al., 1996; Bradlow & Pisoni, 1999) and suggest that, as L2 learning progresses and knowledge of the L2 lexicon increases, the effect of developing lexical knowledge on segmental production may be more evident for adults than for children, at least within the first year of L2 experience.

The results of Experiment 1 raised the following question: Does more extensive experience with L2 sounds and words (i.e., experience beyond 1 year) affect children's and adults' L2 production accuracy? That is, do lexical and segmental factors influence how children and adults who are exposed to an L2 for a longer period of time produce L2 sounds? It is likely that, with longer L2 exposure (and thus more extensive experience with L2 sounds and words), children will again show no effects of lexical and segmental factors while adults will demonstrate reduced effects of these factors. A second experiment was conducted to test this hypothesis.

EXPERIMENT 2

Experiment 2 examined the production of English vowels by Korean adults and children who had lived in the U.S. for about 7 years. The

assumption was that the participants examined here had spoken and heard English more often than the Korean participants in Experiment 1 (Flege & Liu, 2001). Thus, the aim was to determine if these relatively experienced Korean speakers of English would produce English vowels consistently or whether, with an extended length of residence in the U.S. (7 years), they would still show the influence of the two segmental and two lexical factors examined in this study: (a) similarity, (b) context, (c) frequency, and/or (d) familiarity (see Table 3).

Method

Participants. The participants were 10 native Korean child learners (designated KC-7, where "7" indicates about 7 years of U.S. residence) who had arrived in the U.S. at an average age of 9 (6.7-13.4 years) and had resided there for a mean of 7 years (4.4-15.7 years), and 10 native Korean adult learners (KA-7) who had arrived in the U.S. at an average age of 22 (14.6-30.6 years) and had resided there for a mean of 7 years (5.0-15.1 years). As in Experiment 1, the participants were asked to estimate their English-speaking ability and the amount of Korean spoken daily (Table 1). The two groups of Korean child and adult learners differed only in their chronological age, $t(18) = 4.89$, $p < .001$, and in their age of arrival in the U.S., $t(18) = 6.88$, $p < .001$. The same 20 age-matched native English adults (EA) and children (EC) who participated in Experiment 1 were used for comparison purposes in this experiment as well.

Materials and Procedure. This experiment used the same materials and procedures as described earlier for Experiment 1. As in Experiment 1, the data for the Korean adults and children were examined separately because the adults and children differed along dimensions in addition to age of arrival in the U.S. (e.g., amount of native-speaker input in the U.S.).

Results

Effect of Segmental and Lexical Factors: Similarity. The EC group scored higher than the KC-7 group, both for similar (99% vs. 89%) and dissimilar (93% vs. 84%) vowels. The ANOVA examining these scores yielded significant main effects of language, $F(1,18) = 8.0$, $p < .025$, and similarity, $F(1,18) = 10.5$, $p < .01$, but no significant language × similarity interaction. The EC group produced similar vowels more accurately than the KC-7 group; neither group's scores differed as a function of similarity.

The EA group received higher scores than the KA-7 group, for both similar (96% vs. 73%) and dissimilar (94% vs. 69%) vowels. The ANOVA comparing these scores yielded a significant main effect of language, $F(1,18) = 89.7$, $p < .001$, but no significant main effect of similarity and no language × similarity interaction. The KA-7 group produced vowels less accurately than the EA group; neither group's scores differed as a function of similarity.

Effect of Segmental and Lexical Factors: Context. The EC group scored higher than the KC-7 group, at least for vowels in some contexts: Vd (97% vs. 91%), Vs (97% vs. 83%), H (95% vs. 83%). The ANOVA examining these scores yielded significant main effects of language, $F(1,18) = 8.6$, $p < .01$, and context, $F(2,36) = 7.2$, $p < .01$, and a significant language × context interaction, $F(2,36) = 4.2$, $p < .025$. The KC-7 and EC groups' scores differed significantly only for vowels in the Vs context ($p < .01$). The KC-7 group produced vowels more accurately in the Vd than in the Vs and the H contexts ($p < .01$).

The EA group scored higher than the KA-7 group for vowels in the Vd (95% vs. 78%), Vs (93% vs. 64%), and H (95% vs. 67%) contexts. The ANOVA examining these scores yielded significant main effects of language, $F(1,18) = 94.0$, $p < .001$, and context, $F(2,36) = 9.1$, $p < .001$, and a significant language × context interaction, $F(2,36) = 6.3$, $p < .01$. The KA-7 group produced vowels less accurately than the EA group in all contexts ($p < .001$). The KA-7 group's production was more accurate in the Vd than in the Vs and the H contexts ($p < .01$).

Effect of Segmental and Lexical Factors: Frequency. The ANOVA comparing the EC and KC-7 groups' scores for vowels in high- (98% vs. 87%) and low- (94% vs. 85%) frequency words yielded a significant main effect of language, $F(1,18) = 8.5$, $p < .01$, but no main effect of frequency and no language × frequency interaction. The KC-7 group produced vowels less accurately than the EC group; neither group's scores differed as a function of frequency.

The ANOVA comparing the EA and KA-7 groups' scores for vowels in high- (96% vs. 74%) and low- (94% vs. 68%) frequency words yielded a significant main effect of language, $F(1,18) = 88.9$, $p < .001$, but no significant main effect of frequency and no language × frequency interaction. The KA-7 group produced vowels less accurately than the EA group; neither group's scores differed as a function of frequency. (No analyses by familiarity were performed because the participants rated all

words as familiar.)

Interaction Between Segmental and Lexical Factors

Analyses of interactions between lexical and segmental factors were performed as in Experiment 1. These analyses revealed that syllabic context affected the production of vowels by the Korean adults (KA-7), but not children (KC-7), yielding a significant frequency × context interaction for the KA-7 group, $F(2,18) = 9.9$, $p < .001$. This interaction suggested, as shown in Figure 2, that the effect of context on the adults' production accuracy was confined to low-frequency words. That is, the KA-7 group's scores were higher for vowels in the Vd than in the other two contexts ($p < .01$) when these vowels occurred in low-frequency words (Vd: 78%; Vs: 64%; H: 67%). This was the same pattern of results obtained for less experienced Korean adults in Experiment 1 (depicted in Figure 1).

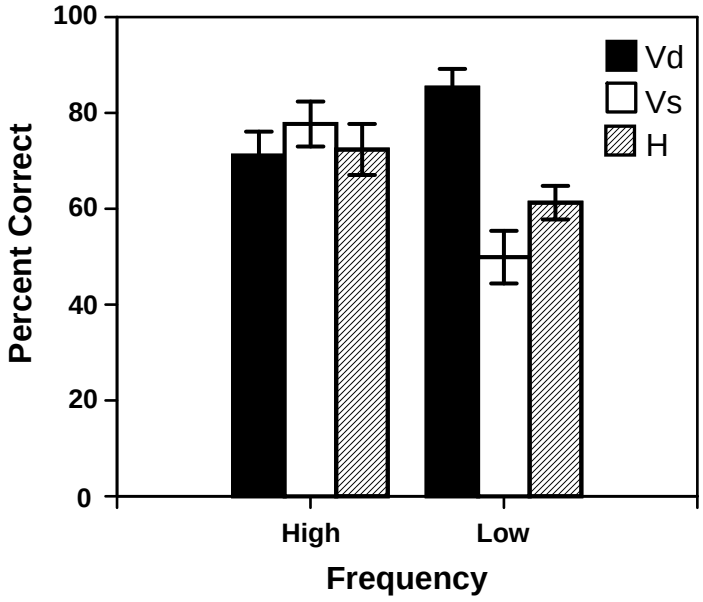

Figure 2. Experienced Korean adults' (KA-7) production of English vowels in high- and low-frequency words by syllabic context (Vd = voiced-final, Vs = voiceless-final, H = /h/-initial). Brackets enclose ± 2 SE.

Discussion

Results of this experiment revealed that only one factor affected how the Korean adults and Korean children produced English vowels. Korean adults and children who had resided in the U.S. for about 7 years showed

context effects, producing vowels more accurately in one lexical set (Vd) than in the other two. It is uncertain why this finding was obtained. Perhaps hearing English vowels in words ending in /d/ (which does not terminate Korean words) called special attention to the vowels (cf. Hazan & Simpson, 1998), or perhaps vowel lengthening before English /d/ highlighted differences between English and Korean vowels (Flege, Munro, & Skelton, 1992). The important finding of this experiment was that the adults were able to overcome this effect of lexical set (roughly equivalent to phonetic context) when they produced vowels in high-frequency words. Thus, additional experience with L2 words seemed to influence how adults produced L2 vowels.

Comparisons across the two experiments revealed significantly more accurate production by children and adults who had resided in the U.S. 7 vs. 1 year (children: $t(18) = 2.5$, $p < .025$; adults: $t(18) = 4.6$, $p < .0001$). The more experienced participants showed less variation in production accuracy across syllabic context, similarity, lexical frequency, and familiarity than did the relatively inexperienced participants. One possible interpretation of these findings is that more generalized, abstract representations are developed for L2 sound segments during the course of L2 learning (Flege, 1995; Walley & Flege, 1999). By hypothesis, such representations allow L2 learners to perceive and produce L2 sounds accurately regardless of the context (whether segmental or lexical) in which L2 sounds occur.

GENERAL DISCUSSION

Situated within a broad theoretical framework which postulates that knowledge of the phonological structure of language (and, for that matter, knowledge of any linguistic structure) emerges as a "by-product" of a learner's experience with language (e.g., Beckman & Edwards, 2000), the present study investigated whether child and adult L2 learners' experience with particular lexical items influences their production of phonetic segments making up those same lexical items. In particular, this study was conducted to answer two related questions: (1) How do lexical and segmental factors influence L2 learning by children and adults? and (2) Does this influence differ depending on children's and adults' amount of L2 experience? This study examined how two segmental factors (cross-language similarity, syllabic context) as well as two lexical factors (word frequency, subjective word familiarity) influenced L2 production by

children and adults exposed to the L2 for an average of 1 and 7 years. The results of this study indicated that lexical and segmental influences on L2 production differed for children and adults and depended (at least for adults) on amount of L2 experience. These findings are relevant to conceptualizations of phonological development and have implications for L2 acquisition by children and adults. These will be discussed in turn.

The results of this study fit well within the theoretical framework of L1 phonological development described earlier (Beckman & Edwards, 2000) and extend previous research on lexical influences on speech processing to L2 learning. In particular, the results of this study suggested that L2 learners—much like child and adult L1 speakers—are sensitive to the structure of the L2 lexicon, as indexed within the present study by word frequency and subjective word familiarity (Bradlow & Pisoni, 1999; Munson, 2001). This finding is important because it suggests that L2 learners are sensitive to phonological regularities at two levels of abstraction. They are sensitive to sound-level regularities in variation of individual L2 segments, making phonological generalizations across specific phonetic, syllabic, phonotactic, or prosodic contexts (e.g., Strange et al., 1998). Our findings also indicated that L2 learners (adults, in particular) are also sensitive to higher-order word-level regularities within L2 lexicon, making phonological generalizations both within and across L2 lexical items. This claim is in accord with a recent conceptualization of L1 phonological development and use (Pierrehumbert, 2003) which views phonology as emerging from "generalizations over the word-forms in the lexicon, which are in turn generalizations over speech" (p. 178). If phonological development is indeed a product of learning at different levels of generalization and from a number of sources, as this conceptualization suggests, then L2 phonological acquisition is no exception to this observation.

At first glance, it may seem that the performance of the child L2 learners in this study provides one exception to the claim that lexical factors play an important role in L2 phonological development. Indeed, the effect of lexical factors on child L2 production was non-significant. This finding might be due, at least in part, to the use of a relatively insensitive measure of vowel production accuracy. That is, lexical influences on child L2 production may have been detected had a more sensitive measure of production been obtained (Flege et al., 1998) or had different tasks been used (Munson, 2001), especially those more appropriate for children.

Another, and perhaps more plausible, reason for this finding might be

related to differences in children's and adults' L2 experience. That is, lexical factors may have influenced the Korean children's vowel production to a lesser degree than the adults' because the children had received more native-speaker input (e.g., while attending U.S. schools) and/or had progressed further in their learning of the English sound system than the Korean adults had (Jia & Aaronson, 2003), even within the first year of L2 experience. In effect, due to differences in input quantity and quality, children may have surpassed adults in their word learning, which in turn resulted in diminished effects of lexical frequency and/or familiarity (Scarborough, Cortese, & Scarborough, 1977). A comparison of Korean children's and adults' production of English vowels at 1 year of U.S. residence suggested that children indeed outperformed adults, $t(18) = 2.54$, $p < .025$. If this explanation is valid, then a hypothesis to be explored in further research is this: As L2 learning progresses, L2 segmental production should show progressively less influence of lexical and segmental factors, with children progressing through learning faster than adults. Of course, in order to explore such a hypothesis, researchers will need to use measures of children's and adults' lexical knowledge and to evaluate their L2 proficiency more objectively (i.e., not through self-reports). In any case, the Korean children examined here, but not the Korean adults, seemed to produce English vowels consistently, that is, in a way that showed relatively little influence of lexical and segmental factors. In this sense, they resembled the native English children and adults.

The findings of this study indicated that adult L2 learning of phonology can be characterized by an interaction between lexical and segmental factors. In particular, adult L2 production was influenced by segmental factors (cross-language similarity, syllabic context) as well as by lexical factors (word frequency and familiarity), especially when segmental influences were particularly strong (i.e., for dissimilar L2 vowels or vowels in relatively "difficult" syllabic contexts) and when learners lacked extensive experience with the L2 (i.e., within 1 year of L2 experience). These findings are important for L2 speech research. They suggest that adults' word knowledge (indexed here by learners' subjective word familiarity) and their accruing experience with the L2 lexicon (indexed here by word frequency) may help them overcome L1-based constraints on L2 segmental learning. They also indicate that the role of adults' word knowledge and of their experience with the lexicon may diminish as L2 learning progresses, perhaps as a consequence of creating more generalized, abstract representations for L2 segments (Flege, 1995; MacKay et al., 2001).

IMPLICATIONS AND CONCLUSIONS

These findings have several specific implications for L2 speech research. First, they extend earlier studies that reported lexical effects in adult learners' processing of L2 speech (Flege et al., 1996; Bradlow & Pisoni, 1999) but suggest that lexical effects on L2 production accuracy may be more detectable for some aspects of L2 phonology than for others. For example, Flege et al. (1998) did not obtain effects of lexical variables (age of acquisition, imageability, cognate status, word familiarity and frequency) on adult L2 learners' production of English stops, a finding that held true even for those L2 learners whose amount of L2 experience was most comparable to that used in this study (1 year of U.S. residence). In future research, it is thus important to examine those variables (e.g., context of acquisition, particular segments studied, type and token frequency of segments in the lexicon, etc.) that affect learners' sensitivity to L2 segments at the lexical level. Second, these findings demonstrate the need to systematically control such lexical variables as word frequency, subjective word familiarity, or lexical neighborhood density in L2 speech research (Flege et al., 1996; Bradlow & Pisoni, 1999). In other words, measuring L2 perception and production accuracy using materials that vary in lexical frequency may lead to over- or under-estimating learners' L2 perception and production abilities.

Further, these findings suggest that L2 speech training practitioners and researchers may capitalize on such lexical factors as word frequency or word familiarity in designing and conducting L2 speech training. If learners are able to accurately perceive and produce certain (and often quite difficult) L2 segments in high-frequency and more-familiar words but fail to do so in low-frequency and less-familiar words, then it is perhaps important to expose learners, in the context of L2 speech training, to instances of such L2 segments in low-frequency and less-familiar words (cf. Bradlow et al., 1997). Finally, these findings emphasize an important relationship between L2 phonological learning and vocabulary acquisition. It is likely that a rich vocabulary may be necessary not only for the development of L2 reading skills (Hsueh-Chao & Nation, 2000) and the acquisition of L2 syntax (Bates & Goodman, 1997) but also for learning to accurately perceive and produce an L2.

In summary, the present study revealed a complex relationship between several factors involved in L2 learning and provided evidence that this relationship may differ in child and adult L2 learning. This

finding underscored the importance of considering both lexical and segmental factors in the development of models of child and adult L2 phonological learning.

ACKNOWLEDGEMENTS

This research was partially supported by a NIH Grant 501 DC02892-05; CFDA#93.173. The authors extend their sincerest gratitude to James E. Flege and Molly Mack for their support and invaluable advice throughout this research project and to Randall Halter and two anonymous reviewers for their comments on an earlier draft of this paper.

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APPENDIX

ENGLISH WORDS USED IN ANALYSES OF INTERACTIONS BETWEEN LEXICAL AND SEGMENTAL FACTORS

	Similarity		Syllabic Context		
	Similar	Dissimilar	Vd	Vs	H
High frequency	pot, beat heat, bit hot, big	hat, bed bad, book head, good	bad, bed big, good	pot, bit beat, book	hot, hat head, heat
Low frequency	bead, hid booed, pod hoop, boot	bug, hood bud, pet hut, bat	pod, bead booed, bud	bat, pet boot	hid, hoop hood, hut
More familiar					
KC-1	heat, hid boot, hot pot, big	head, bad hat, bug book, pet	bad, bed big, good	pot, pet book	hot, hat head, hid
KA-1	hid, hot bit, beat heat, big	pet, bad hat, bed book, good	bad, bed big, good	pet, bit beat, book	hot, hat hid, heat
Less familiar					
KC-1	bead, beat bit, booed hoop, pod	bad, bed bud, good hood, hut	pod, bead booed, bud	bat, bit beat, boot	heat, hoop hood, hut
KA-1	booed, pod hoop, bead pot, boot	bud, hut hood, bat bug, head	pod, bead booed, bud	pot, bat boot	head, hoop hood, hut