The Effect of Perceived Phonetic Similarity on Non-Native Sound Learning by Children and Adults

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1. Introduction

It is axiomatic that most children, unlike adults, learn to speak and understand a second language (L2) in a native-like manner[1] (Munro, Flege, & MacKay, 1996). One of the most salient factors influencing the outcome of child and adult L2 learning is the effect of the learner's native language (L1) on the ability to learn L2 consonants and vowels (or "sounds" for short). Adult L2 learners' speech perception and production are often influenced by their native language. By contrast, as studies using a retrospective developmental design have indicated, individuals who began learning their L2 as children usually approximate the phonetic system of the L1 more closely than individuals who began learning their L2 as adults (Flege, MacKay, & Meador, 1999; Mack & Trofimovich, 2001; Mack, in press). However, few studies have directly compared adult and child L2 learners, as was done in the present study.

According to Flege's Speech Learning Model (SLM), an important source of child-adult differences observed in L2 speech learning is the interaction between the L1 and L2 phonetic systems at the time of first exposure to an L2 (Flege, 1995; 1999). This tenet of the SLM rests on two claims. The first presupposes that accurate L2 perception and production, indicative of developing long-term representations (categories) for L2 sounds, are attainable if the L2 learner perceives the phonetic differences that exist between L1 and L2 sounds or if L2 sounds are not strongly perceptually identified with L1 sounds (Flege, 1995; Best & Strange, 1992). The second claim states that, as the sound categories making up the L1 phonetic system slowly develop through childhood and into adolescence (Ohde, Haley, & McMahon, 1996; Sharma, Kraus,

1. The terms "native" and "monolingual" are often used interchangeably in the literature, although Mack (1997, in press) makes a clear distinction between these terms. However, in the interest of brevity and convenience, "native" is here treated as synonymous with "monolingual."

McGee, & Nicol, 1997), they become more powerful "attractors" of L2 sounds. Adult L2 learners may therefore be more likely than child L2 learners to judge L2 sounds as members of L1 sound categories, and may thus be less likely to create categories for L2 sounds. In other words, the ability to create L2 categories diminishes as the learner's age of first exposure to the L2 increases.

An important step in evaluating the SLM's claim that children's L1 sound categories may be less powerful attractors of L2 sounds than those of adults lies in determining whether children are less likely than adults to judge L2 sounds as members of L1 sound categories and whether this tendency is associated with measurable benefits in L2 speech learning. For example, inexperienced adult Korean learners of English typically identify tokens of English /ʊ/ as instances of Korean /ɯ/ (Trofimovich & Baker, 2000). If children's L1 sound categories are less powerful attractors of L2 sounds than those of adults, as the SLM proposes, then child L2 learners should be less likely to identify English /ʊ/ as an instance of Korean /ɯ/ than adults who have received a similar amount and type of L2 input. If this is the case, child L2 learners should also be more likely to establish a native-like category for this English vowel and therefore be more successful than adults in perceiving and producing it (only if production is predicated on perception, as the SLM proposes). Although the SLM's claim that children's L1 sound categories are less powerful attractors of L2 sounds than those of adults is well motivated on theoretical grounds and consistent with anecdotal observations of children's speech perception and production, it has not been subjected to rigorous empirical scrutiny (see Butcher, 1976, for an early attempt), nor have short- or long-term consequences of this interaction in L2 speech learning by children and adults been adequately investigated.

The first objective of this study was therefore to test whether children's L1 sound categories are less powerful attractors of L2 sounds than those of adults, causing children to be less likely to perceptually identify L2 sounds with L1 sound categories. To do so, in the first of five experiments, native Korean children and adults were asked to judge the similarity between English (L2) and Korean (L1) vowels in a cross-language identification task. The second objective of this study was to determine whether and how the interaction of the learner's L1 and L2 phonetic systems relates to both inexperienced and experienced child and adult L2 learners' processing of L2 speech. To address this question, assessment was made of the perception and production accuracy of Korean adults and children who differed in amount of experience with English—i.e., who had had 1 versus 9 years of residence in the U.S.

2. Cross-Language Identification
2.1. Method

To determine whether children and adults differ in their judgments of similarity between L1 and L2 sounds, which would demonstrate that the L1 and

L2 phonetic systems of children and adults interact differently, we asked 20 native Korean speakers (10 children and 10 adults) to judge English sounds as instances of Korean sounds in a cross-language perceptual identification task. In order to examine participants' cross-language judgments, we selected 8 English vowels. These vowels were selected because pairs of these vowels (i.e., English /i/-/ɪ/, /u/-/ʊ/, /æ/-/ɛ/, /ɑ/-/ʌ/) are often confused in perception and production by Korean learners of English (Flege, Bohn, & Jang, 1997). These English vowels were placed in 3 phonetic contexts in English monosyllabic CVC words (Table 1) in order to minimize the idiosyncratic effects of any single context on participants' judgments of cross-language similarity (Strange, Akahane-Yamada, Kubo, Trent, & Nishi, 2001).

Table 1: Stimuli Used in the Cross-Language Identification Test

/i/	/ɪ/	/ɛ/	/æ/	/u/	/ʊ/	/ʌ/	/ɑ/
beat	bit	bet	bat	boot	book	but	bought
neat	knit	net	gnat	nuke	nook	nut	not
heed	hid	head	had	who'd	hood	hut	hot

In this task, the stimuli were randomly presented 144 times (24 words × 3 talkers × 2 repetitions) for identification as one of the 10 vowels of standard Korean (/i/, /o/, /ɨ/, /y/, /œ/, /ɛ/, /e/, /ʌ/, /a/, and /u/). The participants, tested individually, heard each English vowel over headphones and were asked to judge to which Korean vowel it was most similar by selecting one of 10 response alternatives presented on a computer monitor. The Korean vowels were shown in Hangul characters in a forced-choice task requiring the participants to choose one of the Korean vowels as a response and to guess if unsure. In addition, the participants were asked to rate the degree of similarity between the Korean vowel they chose and the English vowel they just heard on a seven-point Likert scale, with "1" indicating that the sounds across the two languages sounded very different and "7" indicating that the sounds sounded very similar.

Table 2: Means and Standard Deviations for Chronological Age (Chron. Age), Age of Arrival (AOA), Length of Residence in Years (LOR), Amount of Self-Estimated Korean Daily Use (K. Use), and Self-Rating in English on a Scale from 1 to 10 (Rate E.)

	N	Chron. Age	AOA	LOR	K. Use	Rate E.
Adult+1	10	22.7 (1.6)	22.1 (1.4)	0.6 (0.5)	56%	5.1 (1.5)
Child+1	10	8.8 (1.1)	7.8 (1.3)	1.0 (0.5)	68%	4.4 (2.5)
Adult+9	15	28.1 (6.2)	19.0 (4.2)	8.5 (2.7)	55%	7.1 (1.0)
Child+9	15	17.8 (4.0)	8.6 (1.3)	9.0 (3.4)	31%	7.9 (1.3)
NE Child	10	20.7 (1.4)				9.4 (0.5)
NE Adult	10	8.7 (0.5)	.			10.0 (0.0)

The child and adult participants in this experiment were all monolingual native speakers of Korean who were beginning learners of English, having resided in the U.S. for about 1 year (average of 9 months). Among several language and demographic variables examined, the groups differed only in their chronological age: Korean children were on average 8.8 years old (range: 7-9 years), whereas Korean adults were on average 22.7 years old (range: 20-23 years). Hereafter, these groups will be referred to as the "Child+1" and the "Adult+1" groups, where "+1" indicates about 1 year of U.S. residence. (See Table 2 for a summary of pertinent information about the participants.)

2.2. Results

Analysis of the cross-language identification judgments revealed that both children and adults selected the same Korean vowel as the primary (modal) response alternative in their classification of each English vowel. The modal classifications of the 8 English vowels examined in this study were as follows (proportions are listed in parentheses for both adult [A] and child [C] groups): English /ɑ/—Korean /a/ (A: .73, C: .66); English /ʌ/—Korean /ʌ/ (A: .51, C: .42); English /i/—Korean /i/ (A: .92, C: .79); English /ɪ/—Korean /i/ (A: .68, C: .58); English /u/—Korean /u/ (A: .83, C: .61); English /ʊ/—Korean /u/ (A: .61, C: .39); English /æ/—Korean /ɛ/ (A: .67, C: .44); English /ɛ/—Korean /ɛ/ (A: .57, C: .39). Vowel-classification responses were analyzed by determining how many times each participant classified each English vowel token as its modal Korean response alternative. Similarity-rating responses were analyzed by calculating each participant's mean similarity rating between an English vowel and its modal Korean response alternative.

The adult and child participants seemed to perceive the same pattern of relationships between English and Korean vowels. These cross-language relationships fell into three types. The first type consisted of the members of the English vowel contrast /ɑ/-/ʌ/ which were each predominantly identified with a separate Korean vowel, Korean /a/ and /ʌ/, respectively. The second type represented a highly confusable contrast across the two languages—English /æ/-/ɛ/. Children and adults chose both Korean /ɛ/ and /e/ in response to both English vowels. Finally, the third type comprised two English contrasts both of whose members were identified with a single Korean vowel—English /i/-/ɪ/ with Korean /i/ and English /u/-/ʊ/ with Korean /u/. These patterns reveal that children's and adults' judgments of cross-language similarity are mediated by the acoustic-phonetic match between L1 and L2 sounds.

Despite the similarities in overall patterns of cross-language identification between the children and adults, the children were less likely than the adults to assign English vowels to their modal Korean vowel response alternatives (Figure 1). A two-way (group × vowel) ANOVA comparing the groups' frequency of identification of each English vowel with its modal Korean

response alternative yielded a significant main effect for group [F(1,58)=7.72, p=.007] and vowel [F(7,406)=28.79, p=.001] and a significant group × vowel interaction [F(7,406)=2.45, p=.018]. Tests of simple main effects revealed that the Child+1 group was less likely than the Adult+1 group to perceptually identify 5 of the 8 English vowels with their modal Korean vowel response alternatives—English /æ/, /ε/, /i/, /ʊ/, and /u/ with Korean /ε/, /ε/, /i/, /ʊ/, and /u/, respectively. Bonferroni tests (t-tests with α adjusted for number of pairwise comparisons) revealed that all comparisons were significant (p<.05). An identical analysis of cross-language similarity ratings yielded a significant main effect for vowel [F(7,105)=3.08, p=.005] and a significant group × vowel interaction [F(7,105)=3.14, p=.005]. Bonferroni tests revealed that the children rated the match between English /ɑ/, /ʌ/, /ε/ and Korean /a/, /ʌ/, /ε/, respectively, lower than did the adults (p<.05). Therefore, the Child+1 group either identified the English vowels in this study (except English /ɪ/) less frequently with, or judged them less similar to, Korean vowels than did the Adult+1 group (Figure 1; numbers above and below mean values represent the number of responses on which the means are based).
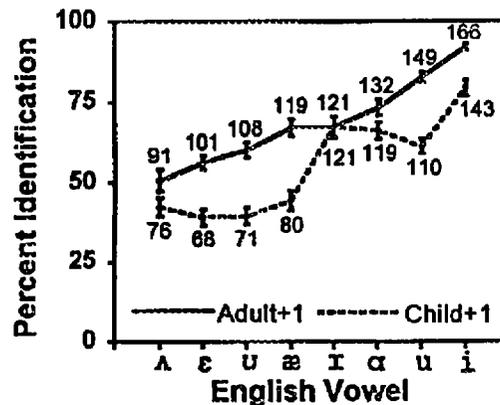
Figure 1: Frequency of Identification of Each English Vowel with its Modal Korean Response Alternative by Native Korean Children and Adults

Three additional analyses, to be described in turn, suggested that child-adult differences reported earlier were not due to children's inability to perform the experimental tasks. First, the number of Korean response alternatives selected by the children and adults in response to each English vowel were calculated. A two-way (group × vowel) ANOVA comparing the number of response alternatives chosen per participant per vowel yielded a significant main effect for vowel [F(7,126)=7.42, p<.001] but no main effect for group and no significant group × vowel interaction. This suggested that the children were not more likely than the adults to choose quantitatively more Korean response alternatives in response to English vowels. Second, to assess the variability of responses by the child and adult participants, an index of response consistency for each participant and each English vowel was calculated (Attneave, 1959; Hazan & Barrett, 2000). A two-way (group × vowel) ANOVA comparing these

indices yielded no significant main effect for group and no significant group × vowel interaction, suggesting that the children and adults were equally consistent in assigning L2 vowels to L1 sound categories. Finally, the Korean response alternatives chosen by the children and adults in response to each English vowel were analyzed. The children and adults selected qualitatively identical as well as acoustically and perceptually viable Korean vowel categories in response to English vowels. This indicated that the children were not more likely than the adults to choose inexplicable response alternatives.

Overall, the results of this experiment support the hypothesis that children are less likely than adults to treat L2 sounds as members of L1 sound categories. Importantly, these L2 sounds represent all types of cross-language relationships—from relatively non-confusable to highly confusable contrasts across the listener's native and second languages. This suggests that children's L1 sound categories are less powerful attractors of L2 sounds than those of adults, which may offer at least one reason why experienced child L2 learners are often more native-like than experienced adult L2 learners in their L2 perception and production.

3. Experienced Korean Learners of English

The purpose of this experiment was to determine whether children's and adults' judgments of cross-language similarity obtained in the cross-language identification experiment could explain and predict the perception and production performance of experienced L2 learners.

3.1. Method

The two groups of Korean participants examined in this set of experiments arrived in the U.S. at about the same age as the participants tested in the cross-language identification experiment, but had lived in the U.S. much longer (for an average of 9 years). The performance of these groups, designated "Child+9" and "Adult+9," where "+9" indicates about 9 years of U.S. residence, was compared to that of adult native English speakers, "NE Adult" (Table 2). These participants took part in two experiments involving vowel discrimination and production tasks. In the vowel discrimination task, the participants heard triads of the same English vowels used in the previous experiment in the English word pairs, *heed-hid, who'd-hood, had-head,* and *hot-hut.* The participants heard 3 instances of the vowels from the same vowel pair, with each word spoken by one of 3 native English speakers. The participant's task, when hearing a "different" trial (for example, *heed₂ . . heed₁ . . hid₃*, where the ellipses indicate an inter-stimulus interval of .8 sec and the subscripts indicate different speakers) was to choose the odd item out (the third token in the example given). However, the participant's task, when hearing a "catch" trial (for example, *heed₃ . . heed₂*

. . *heed₁*) was to push a fourth button marked "none," meaning none of the tokens was an instance of a different vowel. In this task, the dependent variable derived from the participants' responses was an A' score, used to reduce the effect of response bias.

A picture-naming task was used to elicit production of the same 8 English vowels that were used as stimuli in the vowel discrimination experiment. Ten English listeners identified the vowels spoken by the participants (Child+9, Adult+9, and NE Adult) by circling one of 4 key words that differed only in the vowel sound. The dependent variable examined in the production experiment was vowel intelligibility, operationalized as the percentage of the native English listeners who identified each vowel as its intended target.

3.2. Results

Analyses of the three groups' (Child+9, Adult+9, and NE Adult) perception and production yielded converging results. In perception, a two-way (group × contrast) ANOVA yielded a significant main effect for group [$F(2,27)=43.41$, $p<.001$] and contrast [$F(3,81)=14.78$, $p<.001$] and a significant group × contrast interaction [$F(6,81)=5.08$, $p<.001$]. Between-group comparisons followed by Tukey HSD post-hoc tests indicated that, after an average of 9 years of exposure to English, the Child+9 group did not differ significantly from the NE Adult group and outperformed the Adult+9 group in their discrimination of 3 of the 4 English contrasts—*heed-hid, who'd-hood,* and *had-head* ($p<.001$). Identical analyses of the three groups' production also yielded a significant main effect for group [$F(2,84)=55.59$, $p<.001$] and vowel [$F(7,588)=8.36$, $p<.001$] and a significant group × vowel interaction [$F(14,588)=4.99$, $p<.001$]. Again, the Child+9 group did not differ significantly from the NE Adult group and outperformed the Adult+9 group in their production of these same 6 English vowels ($p<.001$). In contrast, none of the three groups differed significantly in their perception and production of English /ɑ/ and /ʌ/ (Figure 2).

The L1-L2 relationships observed in the cross-language identification experiment may explain the differences in perception and production accuracy of the Child+9 and Adult+9 groups. In particular, after about 9 years of U.S. residence, adults may perceive and produce accurately only those contrasts whose members were each identified primarily with a different L1 vowel category (such as English /ɑ/ and /ʌ/ with Korean /a/ and /ʌ/, respectively). In such cases, adults presumably exploit perceptual similarity across their two languages to accurately perceive and produce L2 sounds. However, child L2 learners, as hypothesized in the introduction, are able to perceive and produce highly confusable L2 sounds more accurately than adult L2 learners matched for years of U.S. residence. In other words, the native language seems to exert less influence on L2 perception and production in children than in adults. One reason for this child-adult difference may be that child L2 learners may have

received better and more substantial L2 input than adults. Alternatively, as the cross-language identification experiment revealed, child L2 learners may have been less likely than adults to identify L2 sounds with L1 sound categories.
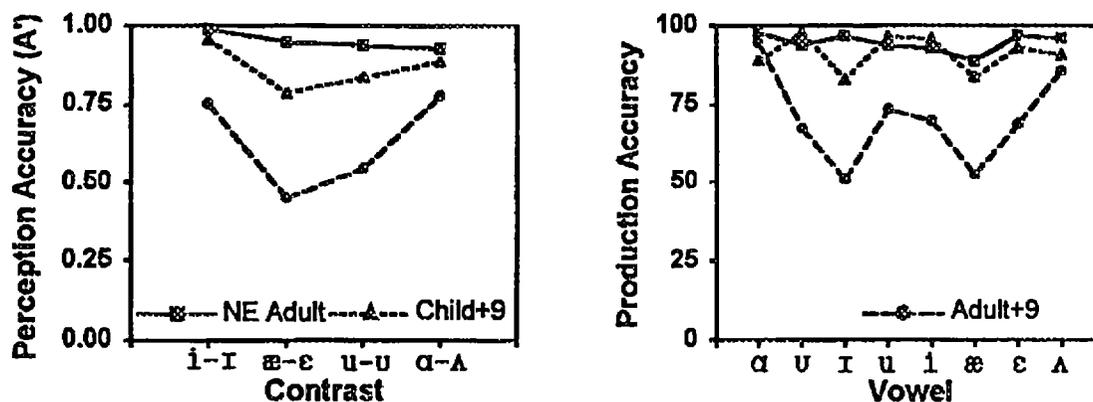
Figure 2: Perception and Production of English Vowels by Korean (Child+9, Adult+9) and English Adults (NE Adult)

4. Inexperienced Korean Learners of English
### 4.1. Method

The purpose of this experiment was to determine whether children's and adults' judgments of cross-language similarity obtained in the cross-language identification experiment explain and predict the performance of inexperienced L2 learners as well as they did the performance of experienced L2 learners. If so, this conclusion would extend the generality of our earlier findings and would reveal the extent to which a native language influences inexperienced child and adult L2 learners. Thus the Child+1 and the Adult+1 groups of native Korean speakers—the children and adults who participated in the cross-language identification experiment discussed above—were tested in the same tasks of vowel perception and production administered to experienced L2 learners. It was hypothesized that, if children are less likely than adults to identify L2 sounds with L1 sound categories and if this is an important predictor of their perception and production abilities, then its influence should be apparent even in the initial stages of L2 speech learning. In addition, the same native English adults (NE Adult) and an additional group of age-matched native English children (NE Child) participated as comparison groups (Table 2).

4.2. Results

Analyses of the Child+1, Adult+1 as well as both NE Child and Adult groups' perception and production accuracy yielded converging results. In perception, a two-way (group × contrast) ANOVA yielded a significant main effect for group [$F(3,36)=40.01$, $p<.001$] and contrast [$F(3,108)=14.33$, $p<.001$]

and a significant group × contrast interaction [F(9,108)=3.35, p<.001]. Tests of simple main effects indicated that the Child+1 and Adult+1 groups performed identically yet more poorly than the groups of age-matched native English children and adults in discriminating English *who'd-hood* and *had-head* (p<.001). Unlike Korean adults whose performance fell below that of age-matched native English adults, Korean children discriminated English *heed-hid* and *hot-hut* as accurately as the age-matched native English children (p<.001).

In production, a similar two-way (group × vowel) ANOVA yielded a significant main effect for group [F(3,113)=87.15, p<.001] and vowel [F(7,791)=10.37, p<.001] and a significant group × vowel interaction [F(21,791)=3.59, p<.001]. Overall, Korean children and adults produced English vowels less accurately than the age-matched native English participants (p<.001). In addition, Korean children tended to outperform Korean adults in production of all English vowels. This difference reached statistical significance for English /ɪ/, /ʊ/, and /ɑ/ (p<.01; Figure 3).
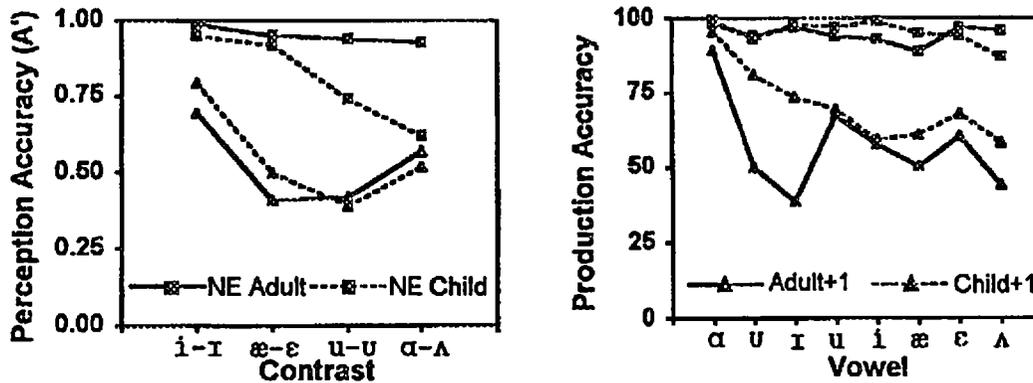
Figure 3: Perception and Production of English Vowels by Korean Children (Child+1), Korean Adults (Adult+1), English Children (NE Child), and English Adults (NE Adult)

These findings provide evidence of the superior capacity of inexperienced child L2 learners to perceive and produce largely unfamiliar L2 sounds. Following a relatively short exposure to English in the U.S. (about 1 year), Korean children equaled Korean adults in their perception and production abilities and in some cases (especially in production) even surpassed them. This pattern of results is striking given that the Korean adults, but not the Korean children, had all been exposed to English in Korea as part of middle- and high-school English instruction (although their input may not have been native). This pattern of results is also striking because children frequently perform more poorly than adults on a variety of native-language linguistic and non-linguistic perceptuomotor tasks (Allen & Wightman, 1992; Hazan & Barrett, 2000).

Combining these findings with the outcomes of the cross-language identification experiment—in which the same children and adults judged the

perceptual similarity of L1 and L2 sounds—it appears that children's capacity to accurately perceive and produce L2 sounds, even with a minimal amount of experience, is at least in part attributable to their being less likely to identify L2 sounds with L1 sound categories. In addition, further analyses comparing the Child+1, Adult+1, Child+9, and Adult+9 groups in their perception and production accuracy indicated that the Child+9 group was more accurate than the Child+1 group in their perception and production of all vowels ($p<.025$), whereas the Adult+9 group was only more accurate than the Adult+1 group in their perception and production of English /ɑ/ and /ʌ/ ($p<.05$). In other words, experienced adult L2 learners were only more accurate than inexperienced adult L2 learners for sounds that were initially perceived as similar and nonconfusable across the two languages. However, even with a minimal amount of L2 experience, the children were more accurate than adults in their production of L2 sounds that were highly dissimilar across the two languages (such as English /ɪ/ and /ʊ/). Again, these findings support a hypothesis which posits that the L1 phonetic system exerts a greater influence on the L2 speech processing of adult rather than child L2 learners, as indicated by the above-cited finding that children are less likely to judge L2 sounds as members of L1 sound categories.

5. General Discussion

The results of this study provide a possible explanation for child-adult differences in L2 speech learning. In particular, the results of this study support the hypothesis of the Speech Learning Model (Flege, 1995; 1999) that children's L1 sound categories, because they are still developing, are less powerful attractors of L2 sounds than those of adults. Derived from this hypothesis were the predictions that inexperienced child L2 learners are less likely than adult L2 learners to judge L2 sounds as members of L1 sound categories and that this tendency is associated with measurable benefits in L2 speech learning. As the results of the first experiment demonstrated, children were less likely than adults to identify L2 sounds with L1 sound categories and were less likely to do so for highly confusable and nonconfusable sounds across the two languages. And, as the subsequent experiments demonstrated, this tendency likely had short- and long-term consequences upon L2 speech learning. That is, children surpassed adults in their production of several L2 vowels after about 1 year of U.S. residence and were able to attain native-like accuracy in their perception and production of all L2 vowels in this study after about 9 years of U.S. residence. Adults, on the other hand, attained native-like perception and production accuracy only for those L2 vowels that were very similar to their L1 vowels.

The conclusion of this study is that the interaction between the L1 and L2 phonetic systems of child and adult L2 learners is at least one source of child-adult differences in L2 speech learning. This invites an important question

regarding the origin of these child-adult differences. One fundamental source of these differences may lie in neurobiologically based age-related changes in the plasticity of brain structures underlying language learning and use (e.g., Kim Relkin, Lee, & Hirsch, 1997). Although a "neural-plasticity" hypothesis cannot be ruled out, it is a difficult hypothesis to test given the multitude of factors involved and the methodology needed to do so. Another and perhaps easier hypothesis to test is the SLM's claim that child-adult differences in L2 speech learning are the result of the still-developing phonetic system of the child's L1. Because children's L1 sound categories are still developing (Hazan & Barrett, 2000), they are weaker attractors of L2 sounds, so children are less likely than adults to perceptually identify L2 sounds with L1 sound categories. (See however Walley & Flege, 1999.)

To test the claim that the developmental state of the L1 sound categories at the time of L2 speech learning is an important contributor to child-adult differences, it would be necessary to compare groups of L2 learners whose L1 categories are known to differ in their state of development. As a preliminary test, several of the inexperienced child (Child+1) and adult (Adult+1) participants of our study were tested in a discrimination task of naturally produced Korean vowels embedded in minimally paired CVC words. Results indicated that Korean children discriminated naturally produced Korean vowels significantly more poorly than Korean adults ([t(20)=2.48, p=.022]; child range: 74-99% correct; adult range: 93-100% correct). This finding suggested that the child participants in this study were still developing perceptual representations for L1 sounds, making them less likely to perceptually identify L2 sounds with L1 sound categories.

Overall, the results of this study support the conclusion that the interaction between the L1 and L2 phonetic systems of the L2 learner at the time of first exposure to an L2 is an important source of child-adult differences observed in L2 speech learning. Moreover, the results of this study implicate the developmental state of the learner's native language as at least one determinant of these differences. Whatever the ultimate cause of such child-adult differences, it is hoped that this study invites further investigation into child and adult second-language speech learning in particular, and into the processes underlying language learning in general.

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