Second-language Learning: The Role of Subject and Phonetic Variables

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Abstract
Many studies have shown that bilinguals’ accuracy in producing and perceiving a second language (L2) declines as their age of first exposure to the L2 increases. However, chronological age is typically confounded with other factors such as how much the native language (L1) is used and how long the L2 has been spoken. It is shown that both language use patterns and age influence performance in an L2. It appears that bilinguals’ L1 and L2 phonetic systems mutually influence one another. The interaction appears to occur at the level of position-sensitive allophones. Whether or not phonetic categories are established appears to depend on the perceived distance of an L2 sound from the closest L1 sound. A bilingual’s L2 categories may differ from those of monolinguals, however if the L2 sound for which a category has been formed is defined by a feature not exploited in the L1.

1. Variables confounded with Age
Many recent studies have focused on the role of age on the ability to produce and perceive a second language (L2). Such studies generally show that the later one begins to learn an L2, the greater will be the observed divergence from the phonetic norms of the target L2 as defined by the performance of a group of monolingual control subjects. Strong “age” effects have been found in many studies. Several will be reported below. Although the findings are straightforward, the interpretation of age effects remains controversial for two reasons.

The first reason why age effects are difficult to interpret is that it is not always clear what “age” refers to. In many studies, non-native subjects’ age of first exposure to a target L2 is the age variable. For studies carried out with immigrant populations, this is defined as subjects’ age of arrival (AOA) in a predominantly L2-speaking area. (It is rarely the case that immigrants are not soon “immersed” in their new language.) Subjects are often selected on the basis of AOA, that is to say, their age of first extensive non-academic exposure to a target L2. However, the chronological age variable in many studies is actually a surrogate for the real (but often unannounced) variable of interest. For some researchers, especially those who advocate a maturationally defined critical period for speech and language learning, the actual age variable of interest is the state of maturation of the language centers in the brain at the time first exposure to the L2 occurs. Many believe that speech learning beyond a certain stage of neural development is impeded by lost neural plasticity.

For those who focus on how the L1 and L2 systems interact, the age-related variable of interest is the state of development of the L1 system at the time L2 learning commences. This emphasis makes two implicit assumptions. The first is that the L1 system continues to develop through childhood. The second is that the more fully developed the L1 system is when L2 learning begins, the more strongly it will influence performance in the L2. The problem, of course, is that native language acquisition and neural development co-occur. The fact that they are inextricably confounded makes it difficult to study one independently of the other, or to disprove a theory, which emphasizes the role of either neural maturation, on the one hand, or language development and cross-language interference, on the other hand.

The second reason why age effects on L2 performance may be difficult to interpret is that age is typically confounded with other variables that might be expected to influence the outcome measures under investigation. This was apparent in two recent studies that examined native speakers of Italian and Korean who had immigrated to North America and learned English as a second language.

The first study examined 240 Italian/English (I/E) bilinguals living in Ottawa, Canada. The second study examined 240 Korean/English (K/E) bilinguals living in the Washington, DC area. The subjects in both studies were selected on the basis of their AOA to North America, which ranged from two to 23 years. Most of the subjects who arrived after the age of 12 years had studied English as an academic subject in school before their arrival in North America. However, for most subjects AOA represented the age at the time of first extensive exposure to and use of the English language.

The I/E bilinguals were older on average than the K/E bilinguals (44 vs. 26 years) and they had lived for a longer time in North America at the time they were tested (32 vs. 15 years on the average). However, two similar confounds were observed for both immigrant populations. The first confound pertained to the relation between AOA and chronological age. The later the I/E and K/E bilinguals arrived in North America, the older they were when tested ($r = 0.52$ for the I/E bilinguals and $0.68$ for the K/E bilinguals).

Second, the later the subjects arrived in North America, the shorter was their length of residence (LOR) in an English-speaking country ($r = -0.44$ for the I/E bilinguals and $-0.42$ for the K/E bilinguals). This means that the late-arriving subjects were disadvantaged in two ways with respect to early-arriving subjects: by their age.
of first exposure to English and by less experience using English. However, the importance of the confound between AOA and LOR was mitigated somewhat by the fact that subjects were required to have lived in North America for at least eight years to be admitted to either study. These two confounds seem to represent inherent features of immigrant populations.

The third confound evident in the two populations is of perhaps greater theoretical significance. The subjects were asked to evaluate how much they spoke their L1 and L2 in a variety of contexts. (The I/E bilinguals used percentages as well as rating scales; the K/E bilinguals used rating scales only.) The correlation between AOA and the average ratings were computed. The later the bilinguals arrived in North America the less they reported using English (r = -0.47 for the I/E bilinguals and -0.56 for the K/E bilinguals). Conversely, the later the bilinguals arrived in North America, the more often they reported using their native language (r = 0.44 for the I/E bilinguals and 0.66 for the K/E bilinguals).

As mentioned earlier, the later one learns a second language, the less native-like one is apt to produce and perceive the L2 as well as to comprehend the L2 in non-ideal listening circumstances [1]. One would expect a relatively late first exposure to impede L2 learning. So too, one would expect infrequent use of the L2 to impede L2 learning. Thus one possibility is that late bilinguals chose to speak their L2 less often than early bilinguals do because their control of the L2 is relatively poor. Another possibility is that late bilinguals have a relatively poor control of their L2 because they don’t get as much practice using it as do early bilinguals.

2. Degree of foreign accent

Two similar studies were carried out to examine the relation between AOA and overall degree of foreign accent. One examined the I/E bilinguals [2] and the other examined the K/E bilinguals [3]. The bilingual subjects and native English control subjects repeated short English sentences heard via a loudspeaker. The sentences were later digitized and presented randomly to native English-speaking listeners for foreign accent ratings. (A continuous scale was used in the I/E study, whereas a 9-point scale was used in the K/E study.)

If the ability to learn L2 speech ends or diminishes following the end of a critical period, then one would expect a sharp increase in the strength of foreign accents at the age of about 12 or 15 years. However, as shown in Figure 1, there was a strong linear relation between AOA and the I/E bilingual subjects’ degree of foreign accent (r = -0.845). A similar linear correlation (r = -0.854) was observed for the K/E bilinguals. Neither study revealed a discontinuity in the function relating AOA and overall degree of foreign accent near the beginning of adolescence. A substantial amount of variance in the foreign accent ratings was accounted for by AOA (71.3% for the I/E bilinguals, 72.9% for the K/E bilinguals). This might lead one to conclude that a

![Figure 1](image_url)
maturationally defined sensitive period exists for L2 speech learning. However, as mentioned earlier, age effects are difficult to interpret. Multiple regression analyses examined the predictive power of chronological age, LOR, and the bilingual subjects’ self-estimated use of English. These models accounted for slightly more variance in the foreign accent ratings (75% for both the I/E and K/E bilinguals) than did AOA alone.

A study was carried out to examine the accuracy with which the I/E bilinguals produced English vowels [4]. A similar study examined the K/E bilinguals’ vowel production [5]. Productions of each target vowel were presented in separate blocks in both studies. The native English-speaking listeners who rated the vowels always knew beforehand the identity of the vowel produced by 240 bilingual subjects and 24 English monolingual controls. Average ratings were obtained for all vowels examined (11 for the I/E bilinguals, five for the K/E bilinguals).

The pattern of results was similar to those obtained for global foreign accent in sentences. The later the I/E bilinguals arrived in Canada, the more foreign accented their English vowels were judged to be ($r = -0.71, df = 238, p < 0.001$). The later the K/E bilinguals arrived in North America, the more strongly accented were their vowels ($r = -0.80, df = 238, p < 0.001$). Also, the longer the subjects had lived in North America, the more accurately they were judged to have produced the English vowels ($r = 0.19$ for the I/E bilinguals and 0.43 for the K/E bilinguals). Finally, the more the bilingual subjects used English, according to self-report, the more accurately they were judged to have produced English vowels ($r = 0.47$ for the I/E bilinguals and 0.61 for the K/E bilinguals).

### 3. Controlling for confounds

The results presented thus far have shown that a complex set of inter-related subject variables predict how accurately highly experienced speakers of English as a second language pronounce English. The aim of analyses presented in this section is to begin untangling these variables. Post-hoc analyses were carried out to determine if variations in language use could account independently for variations in L2 pronunciation accuracy. In these analyses, we examined subgroups of subjects who were matched for AOA but differed according to language use patterns. In a second set of analyses, language use was held constant and AOA was allowed to vary.

In the first analysis, 13 I/E bilinguals each were assigned to one of four subgroups based on AOA and their self-reported percent use of Italian. The subjects in Early-Hi and Early-Lo were early bilinguals matched for AOA (4.8 years for both groups) and length of residence in Ottawa (34 and 35 years, respectively). These two subgroups differed according to their use of Italian. The Early-Hi subjects reported using Italian more often than did the Early-Lo subjects (42% vs. 6%). The Late-Hi and Late-Lo subjects were late bilinguals who were matched for AOA (19.1 and 19.7 years, respectively) and LOR (27 and 28 years, respectively) but differed according to their use of Italian (42% vs. 10%). The 240 I/E bilingual subjects’ self-estimates of Italian and English use showed a strong inverse correlation ($r = -0.93, df = 238, p < 0.001$). The “Italian use” variable used in the post-hoc test might therefore be regarded as an index of the relative frequency of L1 versus L2 use, or possibly even an as an index of the relative degree of activation of the L1 and L2 systems.

The question of interest was whether the subjects who spoke their L1 relatively often (and English relatively seldom) would have stronger foreign accents than the subjects who seldom spoke Italian. The foreign accent ratings obtained previously for the 52 selected subjects [2] were submitted to an AOA (early vs. late) by L1 Use (high vs. low) ANOVA. This analysis yielded a significant interaction ($F(1,48) = 4.25, p < 0.05$). Tests of simple main effects revealed that the Early-Hi and Early-Lo subjects did not differ significantly ($F(1,48) = 0.47, p > 0.10$) whereas the Late-Hi subjects had significantly stronger foreign accents than the Late-Lo subjects ($F(1,48) = 13.0, p < 0.001$).

The overall ratings of 11 English vowels obtained previously for the 52 subjects [4] were submitted to a similar ANOVA, which yielded a marginally significant AOA by L1 Use interaction ($F(1,48) = 0.069$). Simple effects tests revealed that the Early-Hi and Early-Lo subjects did not differ significantly ($F(1,48) = 0.17, p > 0.10$). However, the Late-Hi subjects’ vowels were judged to be more strongly foreign accented than were the Late-Lo subjects’ vowels ($F(1,48) = 9.24, p < 0.01$).

The results of the two post-hoc analyses just presented seem to suggest that amount of L1 use affects the pronunciation of an L2 for late but not early bilinguals. Such a conclusion, if valid, has important implications. For example, it might be the case that the early bilinguals examined in the post-hoc analyses had two separate language systems, one for the L1 and another for the L2. If such a functional separation existed, it may have enabled them to produce English without interference from Italian (and vice versa). Alternatively, one might speculate that the English subsystem was activated to a far greater extent than the Italian subsystem of the early but not the late I/E bilinguals. If so, this might explain why an influence of Italian was evident for the late but not the early bilinguals were.

It may be that neither of these speculative accounts is correct, however, for a more detailed analysis revealed L1 use effects for early bilinguals. A recent study [6] re-examined the degree of foreign accent in English sentences spoken by subgroups of early I/E bilinguals who were matched for AOA ($M = 5$ years) but differed according to self-estimate percentage use of Italian (Lo-Use = 3%, Hi-Use = 33%). Native English-speaking listeners rated sentences spoken by the I/E bilinguals and NE controls as having “definitely” or “probably” been spoken by a native speaker of English or Italian (four response categories in all). Unbiased measures of
the listeners' sensitivity to foreign accent in the L/E subjects' sentences (A-prime) were then calculated from the proportion of hits (correct identifications of L/E bilinguals' sentences as "Italian") and false alarms (incorrect identifications of NE subjects' sentences as "Italian").

Even though the L/E bilinguals had arrived in Canada as young children, both groups of L/E early bilinguals were found to have detectable foreign accents. Even more importantly, the subjects who used Italian more often had significantly stronger foreign accents than did the subjects who used English less often (p < 0.05). The presence of foreign accent in these two L/E groups could not be attributed to incomplete learning, for the subjects had been speaking English for over 30 years, on average, at the time they were recorded, and all of them used English more than Italian.

The foregoing analyses suggested that variation in the amount of L1 use may influence the accuracy with which the L2 is produced, although perhaps to a greater extent for late bilinguals than for early bilinguals. This raises the issue of whether an individual's age of first exposure to the L2 exerts an influence on L2 pronunciation accuracy that is independent of language use factors. Post-hoc analyses were carried out with matched groups of L/E and K/E bilinguals in an attempt to answer this question.

Two groups of 25 L/E bilinguals each were established. The subjects assigned to the two groups were matched for self-reported use of Italian (24% for both groups) but differed according to AOA (5.0 vs. 19.4 years). The two groups of subjects were also closely matched in terms of their self-reported use of English (72% vs. 74%) and length of residence in North America (32 vs. 31 years). An ANOVA revealed that English sentences spoken by the late bilinguals received significantly lower ratings than did sentences spoken by the early bilinguals (F(1,48) = 126.2, p < 0.001).

Very similar results were obtained in a post-hoc analysis of English sentences that had been spoken by two matched groups of 25 K/E bilinguals each. The subjects in these groups were matched for use of Korean (3.0 of a 5-point scale for both groups), use of English (4.0 vs. 3.9), and length of residence in North America (17 vs. 16 years) but they differed according to AOA (6.5 vs. 18.0 years). The sentences spoken by the late K/E bilinguals received significantly lower ratings than did the early bilinguals' sentences (F(1,48) = 62.2, p < 0.001).

To summarize so far, it appears that both the age of first exposure to the second language (as indexed by AOA) and the relative frequency of L1 and L2 use, influence bilinguals' L2 production accuracy independently. The relative importance of these two variables, as well other potentially important variables such as attitudes, motivation and the quality of L2 input, can not be determined on the basis of the data now available. However, it seems reasonable to accept as a working hypothesis the notion that the "age" variable in L2 studies represents at least two different dimensions. One is the state of development of the L1 system (and, in studies that examine children, at least, the co-varying degree of neural development). Successful learning may be promoted by a relatively undeveloped L1 system, for an undeveloped L1 system may be expected to interfere less with the acquisition of L2 structures. The other dimension is the relative strength, or degree of activation, of the L1 system. The stronger (or more activated) the L1 system is, the more it will influence performance - and perhaps also representations - in the L2.

4. Bi-directional influences

So far in this article we have focused on how the L1 influences the L2. However, it has been known for some time now [7] that cross-language phonetic interference is bi-directional, that is, the L1 and L2 systems mutually influence one another. A recent study examining the pronunciation of Korean sentences by the 240 K/E bilinguals and 24 monolingual speakers of Korean provided clear evidence of bi-directional influences [3]. Native Korean-speaking listeners rated the sentences for degree of English foreign accent. The later the 240 K/E bilinguals had arrived in North America, the more accurately they were judged to have pronounced the Korean sentences (r = 0.74). The ratings for the Korean and English sentences were inversely correlated (r = -0.65), that is, showed an "X" pattern when plotted together. Also as expected, the longer the K/E bilinguals had lived in North America, the more English-accented their Korean sentences were judged to be (r = -0.45). And the more often they spoke English, the stronger were their foreign accents in Korean (r = -0.52).

This study provided evidence that few, if any, bilinguals pronounce both of their languages without a detectable foreign accent. The English sentences spoken by just 16 (7%) of the K/E bilinguals received a rating that fell within +/- 2 SDs of the mean rating obtained for the 24 English monolinguals' sentences. All 16 of these subjects had arrived in North America by the age of 9 years. A total of 106 (44%) of the K/E bilinguals produced Korean sentences that received ratings within 2 SDs of the Korean monolinguals' mean rating. All of these subjects had arrived in North America after the age of 8 years. Only two K/E bilinguals managed to produce both English and Korean sentences that received ratings falling within 2 SDs of the English and Korean monolinguals.

In a recent unpublished study we examined the accuracy with which the K/E bilinguals produced four Korean consonants (/s ss t t/) in the initial position of one and two syllable Korean words. The words were randomly presented in eight blocks to eight native Korean-speaking listeners. The listeners rated the word initial consonants using a 4-point scale (wrong consonant = 0, distorted but identifiable production = 1, good production = 2, excellent production = 3). An analysis of the mean ratings revealed that the K/E bilinguals with
AOAs of 2 to 7 years (i.e., the first three groups), but not bilinguals who arrived later in North America produced Korean consonants less accurately than did the monolingual Korean controls.

5. The basis for cross-language interference

According to the Speech Learning Model [xx], the L1 and L2 mutually influence one another at the level of position sensitive allophones. L2 learners are more likely to produce an L2 vowel or consonant accurately – and, by extension, to have a better overall pronunciation of the L2 – if they establish a new phonetic category for the L2 vowel or consonant. According to the SLM, the likelihood of phonetic category formation decreases with age and increases with the perceived phonetic distance of an L2 phonetic segment from the closest L1 phonetic segment.

It is uncertain at present how, or if, the age and phonetic distance variables interact. To shed light on this issue, the ratings of English vowels spoken by the I/E bilinguals [4] were re-examined. Two sets of three vowels each were established. Of the 11 English vowels originally examined, /i e a/ were judged to be the most similar to Italian vowels in an unpublished study. (In that study, Italian monolinguals were asked to label English vowel tokens as being an instance of one of the seven vowels of Italian, or as “not Italian”. The vowels /i u ø/, on the other hand, were the only vowels which were produced less accurately in non-word than real-words in a recent study of English vowel production [8]. Also, of the 11 vowels examined, they were the only ones that apparently do not have a counterpart in any Italian dialect.

As shown in Figure 2, the accuracy with which the I/E bilinguals produced both sets of vowels decreased as AOA increased. The decrease was more precipitous for /i u ø/ than /i e a/. This yielded an interaction in the (11) Group by (2) Degree of Similarity ANOVA carried out to examine the mean ratings obtained for the two sets of vowels ($F(10,253) = 5.16$, $p < 0.001$). Average scores were computed for the first three and last three I/E groups. These two subgroups consisted of subjects having AOAs of about 2-8 and 16-22 years, respectively. The early bilinguals were found to have produced /i u ø/ significantly more accurately than /i e a/ ($p < 0.001$), whereas the reverse held true for the late bilinguals ($p < 0.001$). Also, the early bilinguals were found to have produced /i e a/ less accurately than the NE controls ($F(1,94) = 4.6$, $p < 0.05$), but they did not differ from the NE controls when producing the “new” vowels /i u ø/ ($p > 0.10$).

The sharp decline in production accuracy for the new vowels /i u ø/ as AOA increased might be taken as support for the hypothesis that category formation becomes less likely as AOA increases (see [9]). The less accurate production of /i e a/ by the early bilinguals than by the NE controls might be attributed to the influence of the closest L1 vowel on the production of “similar” English vowels in the absence of category formation. That is, the early I/E bilinguals might have produced /i e a/ as instances of categories that
merged the properties of similar but non-identical vowels found in their two languages (viz., Italian and English /i/, Italian and English /e/, Italian /a/ and English /o/).

The very strong foreign accent seen in the late I/E bilinguals' productions of /i e a/ as AOA increased can probably not be explained as the merger of the phonetic properties of similar L1 and L2 vowels, however. (I assume here that the unmodified use of Italian /i e a/ would sound only slightly foreign accented.) A recent unpublished study may provide some insight into why the late I/E bilinguals produced English vowels with even stronger foreign accents than vowels that do not occur in Italian. The study examined two groups of late K/E bilinguals who differed in English-language experience (1 vs. 14 years of residence in North America).

As expected from previous research [10], the experienced late bilinguals' productions of /i/ were identified as intended more often than those of the inexperienced subjects (79% vs. 56%). However, their /i/ tokens were identified less often than those of the inexperienced subjects (30% vs. 57%), usually as /i/. (This was also true for late-arriving I/E bilinguals.) One might speculate that, in the absence of category formation, an L1 category is restructured so as to encompass the variants that originally defined it along with the variants of a similar but non-identical L2 vowel.

How bilinguals restructure the vowel system depends in large part on whether or not new categories are established. This, in turn, depends on the perceived relation between L1 and L2 vowels, which must be determined empirically. As shown in [11], Japanese adults had great difficulty distinguishing /a/ vs. /I/ but not /i/ vs. /x/ in a categorial discrimination task. This asymmetry appeared at first to be paradoxical. The five-vowel Japanese system does not include any contrasts that are analogous to either English tense vs. lax contrast. Why should one be much more difficult than the other?

A mapping study provided an answer. Monolingual Japanese subjects identified the English vowel stimuli in terms of a Japanese vowel category and then rated the stimuli for goodness as an instance of the selected category. It appears that the /I/ vs. /x/ contrast was discriminated readily by the native Japanese subjects because instances of both English vowels may be identified as relatively good instances of two different Japanese categories. The English [i] tokens were usually heard as instances of Japanese /i/. The [x] tokens as instances of Japanese /e/, not /i/ as one might suppose from textbook descriptions. The difficulty of the English /a/ vs. /o/ distinction, on the other hand, appears to have arisen from the fact that both the English [u] and the [u] tokens were often heard as poor instances of the same Japanese categories (including /uI, /u/, and /e/).

6. A feature hypothesis

There is increasing evidence that bilinguals' production of vowels and consonants found in the L2 but not the L1 may be identical to productions by monolingual control subjects, even if the bilinguals establish a new category for the L2 vowel or consonant. A recent unpublished study examined the K/E bilinguals' production of two near minimal pairs (could vs. foot, food vs. shoot). The four words examined were produced in isolation following a tape-recorded model. The /I/ vs. /d/ contrast was of interest because Korean words end in a single series of voiceless stops. Despite this, the K/E bilinguals, regardless of their AOA, made vowels significantly longer before /d/ than /I/, and they sustained the closure of /I/ for a longer period than that for /d/. The lack of significant Group by Stop Consonant interactions (p > 0.10) indicated that the K/E bilinguals had learned to produce the English /I/ vs. /d/ contrast in much the same way as the native English controls. However, there was a strong effect of Group on the duration of closure voicing in /d/ (F(10,508) = 8.44, p > 0.001). All six K/E groups with subjects having AOAs greater than 10 years produced significantly less closure voicing (means of 24 to 33 msec) than did the NE controls (M = 48 msec) (Bonferroni p < 0.05).

The results just presented seem to support the hypothesis that is it easier to learn to produce the temporal properties of new L2 sounds than to produce non-temporal properties. However, the results of a number of studies, when taken in combination, suggest that another explanation may be more accurate. As hypothesized by the Speech Learning Model [9], it becomes more difficult for learners to make use of features not exploited in the L1 as AOA increases.

The I/E bilinguals' production of voiced and voiceless stops was examined acoustically [12]. Italian has very few words ending in stop consonants, and apparently no minimal pairs distinguished on the basis of the voicing feature in word-final stops. Despite this, even late arriving I/E bilinguals produced English /d/ and /g/ with much closure voicing as NE control subjects. The basis for the I/E bilinguals' success may have been the fact that, unlike in Korean, Italian words may be distinguished by the voicing feature of stops found in word initial and inter-vocalic positions. That is, the I/E bilinguals may have re-used a familiar phonetic feature in a new syllable position.

Work with native Mandarin and Spanish speakers of English [13] supports this interpretation. Mandarin does not possess word final obstruents, and those in initial position are all voiceless. Relatively experienced Mandarin late bilinguals (LOR = 5.5 years) produced less closure voicing in final /d/ than did a group of NE controls, and they did not differ significantly from a less experienced native Mandarin group (LOR = 0.9 years).
Spanish words do not end in obstruents, but Spanish obstruents found in word initial and medial positions may differ in terms of closure voicing. Relatively experienced native Spanish late bilinguals (LOR = 9.0 years) did not differ from the NE controls, and they produced significantly more closure voicing in final /d/ tokens than did a less experienced native Spanish group (LOR = 0.4 years).

If temporal dimensions in L2 vowels and consonants are especially easy to acquire, then native Spanish and English learners of Swedish should have little difficulty learning to produce and perceive the distinction between long vs. short vowels that exist in Swedish even if their L1 does not possess quantity distinctions. The preliminary results of a study examining Swedish vowel production and perception suggests otherwise, however [14].

Four Swedish long vs. short pairs were examined (one high, one low, and two mid). Each of the four phonological vowel length contrasts was tested in a production task. The production stimuli consisted of 40 common Swedish words (five words each with long and short vowels for each contrast). The subjects were asked to say each word aloud after hearing a definition of it. The 18 native Swedish subjects examined so far produced short Swedish vowels with duration values that were very similar to those produced by 10 native Swedish control subjects. They produced the long Swedish vowels with somewhat longer duration values, but their “long” vowels were substantially shorter than the native Swedish control subjects’ vowels (p < 0.01). The results seen in the production experiment were mirrored in a perception experiment. The stimuli were a Swedish phonetician’s productions of the 40 words used in the production task, and 40 non-words formed by changing the vowel in the real words from short to long or from long to short. The definitions of the 40 real words were randomly presented two times each, followed once by the real word, and the other time by the non-word formed by switching vowel length. The subjects were to decide if the test word had been spoken correctly or not. Native Swedish control subjects responded correctly in nearly every instance, whereas the native Spanish subjects responded correctly at rates that only slightly exceeded a chance. This was especially true for the two mid-vowel contrasts, which are accompanied by less spectral difference than the high and mid long vs. short contrasts examined.

In the production task, the native Spanish subjects were able to say the 40 test words recognizable when they heard the words defined. This indicated that they knew the words. However, in the perception task they were often unable to detect the substitution of a long vowel for a short vowel, or vice versa. One might conclude that the native Spanish subjects’ had not encoded vowel duration in their lexical representations for the Swedish words. They may not have used duration to distinguish Swedish vowels because duration does not serve such a function in Spanish.

A final study relating to features involved the perception of word-initial English /æ/ and /ʌ/ tokens by native speakers of English [15]. The primary aim of this study was to determine if Japanese late bilinguals who were highly experienced in English (LOR = 21 years) would identify English /æ/ as accurately as NE controls. Previous work had demonstrated that less experienced Japanese subjects have great difficulty producing and perceiving English liquids. A native-like level of accuracy in identifying naturally produced /æ/ might reasonably be taken as support for category formation. In fact, the experienced Japanese subjects, but not a group of relatively inexperienced subjects, identified English /æ/ much like the NE control subjects. However, they did so only for tokens found in English words such as read, right and rock that had been rated as being as familiar to the subjects as minimally paired words (lead, light, lock). The experienced Japanese subjects sometimes misidentified /æ/ in words that were less familiar than their minimal pair (e.g., rook vs. look).

Lexical bias effects are generally seen only for tokens that are phonetically ambiguous. However, the stimuli were clearly produced words that contained tokens of /æ/ that were unambiguous for the NE control subjects. Thus, the lexical bias effect seen for the Japanese subjects suggests that their English /æ/ category may not have been based on the same features as the NE control subjects’ category. One possibility is that their /æ/ was not defined on the basis of the third formant onset frequency, for this property does not serve to distinguish Japanese consonants.

7. **Summary**

Both subject and phonetic variables must be considered when attempting to understand L2 speech learning. One’s success in learning to produce and perceive an L2 is clearly not an all-or-nothing consequence of age. While performance accuracy generally declines as AOA increases, such age-related effects are not necessarily due a diminished capacity for speech learning. Other factors, such as the strength of L1 representations, or the degree of activation of the L1 system at the time performance in the L2 is observed, play a role. How large a role must be determined in future research.

Phonetic variables are also important. Take, for example, the difficulty one experiences in learning to produce and perceive vowels in an L2. The degree of difficulty is likely to depend on how, or if, the L2 vowels are related to vowels found in the L1 system, and also on whether the L2 vowels are defined in terms of the same set of features (or properties) used to distinguish vowels in the L1. It appears that early bilinguals are more likely to establish new categories than are late bilinguals. However, the category a bilingual establishes for an L2 vowel may differ from that of a monolingual if it is defined in terms of a feature not used in the L1.
The mutual influence of the L1 and L2 on one another suggests that the phonetic elements used to produce and perceive words in the L1 and L2 exist in a common phonological space. L2 phonic elements may undergo restructuring to ensure between-system phonetic contrast that would not be expected to influence the phonic elements of a monolingual.

A great deal of additional research is needed to better define the nature and magnitude of both between and within-system restructuring. Perhaps the single most important need is for research to assess the perceived relation between phonic elements in various L1-L2 pairs and the extent to which perceived cross-language mapping relations change as a function of experience populations of learners differing in AOA.

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