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The Acquisition of Segmental Timing by Children in a Japanese Immersion Program

A dissertation submitted in partial satisfaction of the requirements for the degree Doctor of Philosophy in Applied Linguistics

by

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To my grandfather

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ABSTRACT OF THE DISSERTATION

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Many previous studies have claimed that the earlier children are exposed to a second language in a naturalistic setting, the more likely they are to acquire native-like pronunciation (e.g., Flege, 1992; Oyama, 1976; Patkowski, 1994; Scovel, 1988). However, very little acoustic research has been done to give us any clue as to how early exposure in an immersion program might affect the acquisition of second language speech.

This cross-sectional and longitudinal study acoustically analyzed the production of voice onset time (/p, t, k/) and geminates (/pp, tt, kk/) in Japanese by English-speaking children in grades 1, 3, and 5 (N=19) in a Japanese immersion program. In addition, 52 native speakers of Japanese rated the contrast between single and geminate consonants produced by the immersion children.

The results show that the immersion children's Japanese VOT was significantly longer (58 to 67 ms) than monolingual Japanese children's VOT (28 to 30 ms). This suggests that Japanese VOT for the immersion children is influenced by their English VOT (85 to 89 ms), which is longer than Japanese VOT. However, interestingly, it has been found that although they have not reached the native speakers' norm with respect to VOT, they are found to distinguish clearly their Japanese VOT values for /p, t, k/ from those of their native English counterparts (58 to 67 ms vs 85 to 89 ms).

For single and geminate consonants, Han (1992) found that the duration of L1 English speakers' Japanese geminates is shorter than that of Japanese monolinguals. However, my results show that both the immersion children's geminates and their singletons were longer than those of the Japanese monolinguals. In addition, the immersion children's mean ratio for singletons to geminates was smaller (1.4 to 1.6) than that of the monolinguals (1.9 to 2.3).

The accent ratings by the Japanese native speakers suggest that the immersion children retain a noticeable L1 accent and there is no statistical difference in the scores of accentedness across the grade levels. Moreover, the degree of perceived accentedness for all the immersion children correlated fairly highly with their ratio of singletons to geminates ($r = 0.773$, $p < 0.0001$). This suggests that the ratio of singletons to geminates is a good measure of the acquisition of the phonemic contrast between them.

CHAPTER 1

INTRODUCTION

This is a cross-sectional and longitudinal study on the acquisition of segmental timing in Japanese; especially the voice onset time (VOT) of phrase initial voiceless stops and the closure duration of single and geminate stops by English-speaking children in a Japanese immersion program. Many previous studies have claimed that the earlier children are exposed to a second language in a naturalistic setting, the more likely they are to acquire native-like pronunciation (Flege, 1988b, 1991, 1992; Oyama,1976; Patkowski, 1990, 1994; Scovel, 1969, 1988, 1995); however, very little acoustic research gives us any clue as to how early exposure in a classroom situation affects the acquisition of second language speech and more specifically, to what extent children in an immersion program, who are still supposed to be biologically sensitive, reach the native speaker's phonetic norm.

This study acoustically analyzed the production of gemination and voice onset time in Japanese by English-speaking children in grades 1, 3, and 5 (N = 19) in a Japanese immersion program in Culver City, California. As a control group, Japanese native speakers (N = 12) from grades 1 and 5 at a school in Japan were tested. In addition, to investigate the nature of the input received by the learners, the immersion teachers (N = 5) also participated in this experiment. Finally, the degree of foreign accent was rated by Japanese monolingual speakers to investigate if acoustic measurement correlates with the perception of accent.

This study addresses the following research questions: 1) how does the Japanese immersion program affect the acquisition of Japanese VOT and

gemination of consonants? 2) how do native speakers of Japanese rate the geminate consonants produced by the immersion students? 3) what developmental changes are observed in the Japanese phonological systems of the immersion students during the two and a half months of the study? 4) is there an effect of the acquisition of Japanese on the children's English phonology? In other words, do the two phonological systems of the immersion students appear to be developing independently or are they interacting with each other? Also, this study tests Flege's (1995) Speech Learning Model (SLM) of second language sound acquisition.

1.1 Operational Definitions of Terms

VOT is defined as "the moment at which the voicing starts relative to the release of a closure" (Ladefoged, 1993). VOT, represented as either negative VOT values standing for "voicing lead (onset of glottal vibration prior to articulatory release)" or positive VOT values meaning "voicing lag (onset of glottal vibration following release)," is said to be one of the most important cues for distinguishing voiced from voiceless stops (Williams, 1980). For example, in utterance-initial voiced stops in Spanish, the voicing begins before the release of the stop closure, while in utterance-initial voiced stops in English, it more frequently begins shortly after the release of the closure. Utterance-initial voiceless stops in Spanish and English are identified in terms of VOT: in Spanish voiceless stops, the voicing starts shortly after the release of the closure, whereas in English it starts 60-80 ms after the release of the closure. In other words, "the English voiced stops fall roughly in the same acoustic space as the Spanish voiceless stops" (Deuchar and Clark, 1996). This can be illustrated as follows:

English stops:

	/b/ /d/ /g/	/p/ /t/ /k/
_____	0 _____	_____
(lead voicing)	(short lag)	(long lag)

Spanish stops:

/b/ /d/ /g/	/p/ /t/ /k/	
_____	0 _____	_____
(lead voicing)	(short lag)	(long lag)

Figure 1-1 Voice Onset Time

Closure refers to "an articulation where the contact between active and passive articulators obstructs the airstream through the mouth and/or nose" (Crystal, 1991, p. 58). More specifically, **closure duration** means the period between oral closure and its release. For example, acoustically the main phonetic realization of **geminates** (e.g., /pp, tt, kk/), which are defined as "two identical sounds pronounced next to each other" (Roach, 1992), is the longer closure duration than that which occurs for single consonants. Roach also mentions that "the problem with the notion of gemination is that there is often no way of discerning a physical boundary between the two paired sounds--more often, one simply hears a sound with greater length than the usual single consonant" (Roach, 1992, p. 46).

Immersion programs are defined as "a form of bilingual education in which students who speak the language of the majority of the population receive part of their instruction through the medium of a second language and part through their first language." (Genesee, 1987). In this sense, the immersion setting is much closer to a naturalistic setting than are traditional language teaching approaches. The Japanese immersion program studied in this research has the following features:

> In kindergarten and first grade, 100% of the instruction is conducted in Japanese [early total immersion]. Formal English reading and Language Arts are taught in second and third grade, where about 80% of the instruction is in Japanese and 20% is in English. By fourth and fifth

> grade, approximately 60% of the instruction is in Japanese and 40% is in English. (El Marino Language School, 1995)

The immersion program is a type of **sequential childhood bilingualism**, in which "the child learns one language first, and then a second language later in life," whereas simultaneous childhood bilingualism refers to "a child acquiring two languages at the same time early in life" (Baker, 1996, pp. 76-77). In addition, the immersion program possesses a feature of **additive bilingualism**, in which "the addition of a second language and culture is unlikely to replace or displace the first language and culture" (Baker, 1996, p. 66).

1.2 Limitations of the Study

One of the limitations of this study is that data were elicited only in one test task or a picture identification task. Clearly, types of language tasks or data eliciting methods may influence learner language variation. Bachman (1996) documents:

> ... the characteristics of the tasks used are always likely to affect test scores to some degree, so that there is virtually no test that yield only information about the ability we want to measure. The implication of this conclusion for the design, development, and use of language tests is equally clear: since we cannot totally eliminate the effects of task characteristics, we must learn to understand them and to control them so as to insure that the tests we use will have the qualities we desire and are appropriate for the uses for which they are intended. (p. 46)

In terms of phonology, this is always true. Tarone (1998) refers to Dickerson and Dickerson's (1977) research, in which Japanese speakers of English show their pronunciation variations according to three different elicitation tasks: word list reading, dialogue reading and free speech. Their pronunciation was most accurate on the word list reading and least accurate in free speech. From

this point of view, my study has an inevitable limitation, since it only focuses on the subjects' pronunciation of two-syllable words within a sentence frame. Therefore, the findings may not be generalizable to the general pronunciation ability of the subjects. But the fact that we cannot get rid of the effects of task characteristics forces us to compromise on elicitation methods. Although the findings cannot be generalized widely, the validity of this study is very high because I controlled for various factors so that we could look at what we really intended to examine, that is, VOT and gemination.

The second limitation is that all the data used in this study were not naturally elicited, but artificially collected in a strictly controlled situation, where the phonetic environments, the accent pattern, the vowel quality, the number of syllables are controlled for. This is in contrast with recent trends in the field of conversation and discourse analysis, where one elicits or simply records natural data. Acoustic features of a sound vary depending on adjacent segment quality, accentedness, the location within a word or a phrase. Thus, in order to compare a certain sound, we need to keep all these factors the same. Furthermore, as most introductory textbooks on phonetics say that even the same person cannot produce acoustically the exact same sound that he or she produced just a second ago. Thus, we need a large number of tokens produced in the exact phonetic environment. Therefore, it is extremely difficult to identify them using natural data, in which it may take tens of thousands of hours to obtain an adequate sample of target sounds. For these reasons, most previous acoustic studies on L2 speech acquisition have used controlled data (e.g., Flege, 1988b, 1991, 1992).

Finally, this is a longitudinal study which examines the two and a half month development of Japanese phonology in several young English

speakers, but we are not quite sure if this period is long enough to show any development of their phonological systems. It is generally reported that older is faster, but younger is better (Larsen-Freeman and Long, 1991):

> As revealed by long-term studies, younger is better in the most crucial area, ultimate attainment, with only quite young (child) starters being able to achieve accent-free, native-like performance in a SL. As revealed by short-term studies, older learners are at an advantage in rate of acquisition (adults faster than children, and older children faster than younger children). (p. 155)

"Older is faster" may suggest that the two and a half month interval was too short to show any sufficient development of the Japanese phonological system of young immersion students.

1.3 Contributions

While immersion students demonstrate native-like competence in listening, they are less likely to acquire native-like pronunciation (Genesee, 1987). On the other hand, it is generally assumed that if second language learners are exposed to a new language before the critical period ends, they are expected to reach native-like pronunciation. Assuming immersion children are still in the critical period, why don't they demonstrate native-like pronunciation? This study may shed light on this paradox.

The nature of the phonological systems of both simultaneous and additive bilinguals remains to be solved. Flege (1988b, 1991) suggests that at least early learners may be able to keep the L1 and L2 phonological systems separate, but he hypothesizes that a bilingual's phonetic category may be different from a monolingual's (Flege, 1995). This study will test these hypotheses and give us some insight into whether or not his hypotheses about the acquisition of L2 speech in a naturalistic setting will also apply to an

immersion setting, which is very close to a naturalistic setting.

As Cummins (1991) mentions, there are a great number of studies on immersion education. However, the researcher feels that many of them are program evaluations, which are mainly concerned with teaching methods, program models and their effectiveness. This is in contrast to basic research on linguistic and psychological acquisition processes. This basic research, which analyzes the phonological acquisition process, will help second language acquisition researchers establish solid theories about immersion education and SLA.

Also, this study will make contributions to the development and implementation of the immersion curriculum for speaking skills, above all, pronunciation. If we find that the Japanese immersion students acquire native-like pronunciation, we will be able to provide evidence that they learn pronunciation through exposure to content without any formal instruction. But if not, as Hammerly (1991) suggests, we may need to incorporate pronunciation activities into content such that learners will be able to pay more attention to their L2 pronunciation while studying subject matter.

CHAPTER 2

REVIEW OF RELEVANT STUDIES

2.1 Factors in Affecting Second Language Phonology

2.1.1 The Age Factor in SLA

The age of exposure to a second language has been considered one of the most crucial factors in second language acquisition or learning. In fact, it has been assumed that there is a critical period for language acquisition beyond which L2 learners cannot attain the ultimate native-like level of competence. Lenneberg (1967), the first to document a neurological basis for a critical period for language learning, claims that this limitation "may well be connected with the peculiar phenomenon of cerebral lateralization of function, which only becomes irreversible after cerebral growth-phenomena have come to a conclusion" (p.179). A number of studies which have examined the acquisition of morphology and syntax also suggest that their full, native-like acquisition can be attained only if learners begin to learn a second language before completion of the critical period (Patkowski, 1980; Newport, 1990). Johnson and Newport (1989) claim that morphological and syntactic L2 acquisition is directly related to age of arrival in a second language speaking community up to puberty, after which it is 'low and highly variable' and less relevant to other variables such as length of exposure.

The full acquisition of phonology has also been generally assumed to be impossible unless learners are exposed to a second language before a certain age (Larsen-Freeman & Long, 1991). Scovel (1988) terms this age-related loss in pronunciation or sound production ability the Joseph Conrad phenomenon after a Polish-born English novelist who retained his Polish

accent despite his sophisticated and professional writing skills. Scovel attributes this limitation to neuroplasticity being lost and lateralization being completed. This study concerns the issue of a critical period as well in the acquisition of phonology because if children in an immersion program are still biologically at a stage when the critical period has not ended, they can be expected to acquire native-like pronunciation, assuming the critical period hypothesis is truly valid.

Evidence for a Critical Period

Many previous studies have claimed that the earlier people are exposed to a second language, the more likely they are to acquire native-like pronunciation (Flege, 1988b, 1991, 1992; Oyama,1976; Patkowski, 1990, 1994; Scovel, 1969, 1988, 1995). These studies exhibit two different methodologies: impressionistic judgment studies (accentedness ratings) and phonetic based studies (acoustic analysis) of L2 pronunciation. The former studies, for example, include Oyama (1976), Scovel (1969), Patkowski (1990) and Flege, Munro and MacKay (1995a, 1995b). Oyama examined the pronunciation of 60 Italian-born male immigrants who learned English upon their arrival in the US, using the accentedness ratings. She found that there was a clear effect on the age of arrival, and showed that child arrivals performed as well as native speakers while those older than the age of 12 on arrival did not. Oyama's findings were replicated by Patkowski (1980) with a similar sample size, who also found an age-related decline in the accentedness ratings. Scovel (1969) had junior high school students rate speech samples and found that they could accurately identify those produced by L2 speakers who learned English "after childhood." Most recently, Flege, Munro and MacKay (1995a) made several large scale experiments on the production of English consonants by

Italian speakers of English, in which 240 adult Italian speakers participated. These participants immigrated to Canada between the ages of 2 and 23 years. Their word-initial, word-medial and word-final tokens of English stops were rated by native speakers of English. Except for word-final /t/ (which was produced correctly regardless of age group), the Italian subjects with an age of arrival (AOA) greater than that of about 17 years pronounced word-final /p, b, d, k, g/ significantly differently from the production of native speakers of English.

The largest and most carefully conducted acoustic studies of this issue are those of Flege (1988a, 1991) and Flege, Munro, and MacKay (1995a, 1995b). All these studies claim that early L2 learners, who are still sensitive to phonetic differences between L1 and L2 sounds, are likely to attain authentic pronunciation in a target language.[1] Flege (1991), for example, examined how age of learning affects the authenticity of VOT in stop consonants produced by Spanish-English bilinguals. The late L2 learners produced /t/ with intermediate VOT values while the early L2 learners' VOT values did not differ from those of native English speakers.

Although the previous studies cited above suggest that there is a maturational constraint on the acquisition of native-like pronunciation, it is uncertain when this deterioration begins to affect L2 speech learning. The proposed range of a critical period varies from study to study. Oyama's (1976) study suggests that this age could be as young as 6, while Long (1990) reports an age range of 6-12:

> SL [second language] phonological attainment is strongly conditioned by learner age. Specifically, a native-like accent is impossible unless first

[1] Flege (1995) hypothesizes that "the likelihood of phonetic differences between L1 and L2 sounds, and between L2 sounds that are non-contrastive in the L1, being discerned decreases as AOL increases."

> exposure is quite early, probably before 6 in many individuals and by about age 12 in the remainder. (p.266)

Biologically, Lenneberg (1967) claims that "foreign accents cannot be overcome easily after puberty" (p.176) and defines the age at which foreign accent emerges as 11-14. At the same time, this age differs depending on whether studies focus on the 'onset' age of a critical period or the 'offset' age of it. For example, Flege and Fletcher (1992) reports indirect evidence that English sentences produced by native Taiwanese adults who began learning English at an average age of 7.6 years were rated slightly but detectably accented even though they had lived approximately 12 years in the U.S. This finding suggests that foreign accent may emerge earlier than puberty and that it becomes evident in the speech of those who started learning a second language as early as 7 years of age. On the other hand, Scovel (1988) suggests the 'offset' age of a critical period is the key, claiming that if we start to learn a second language after about the age of 10 to 12, we are easily identified as nonnative speakers. More recently, however, Patkowski (1994) argues that the AOL offset is around the age of 15 years.[2]

Evidence against a Critical Period

On the other hand, there is also some counter evidence with respect to the critical period hypothesis. The first such evidence is that some adult learners can attain nativelike pronunciation even if they begin to learn a second language after puberty. In their judgment study, Snow & Hoefnagel-Hohle (1977) report that in a laboratory setting, the older the children are, the better they are at imitating foreign words under controlled input conditions. In a naturalistic setting, the older subjects had an initial advantage in

[2] For more discussion on the question of the 'onset' and 'offset' age of the critical period, see Flege, Munro, and MacKay (1995b).

pronunciation, but after a period of 10 to 11 months' learning, the younger children were better at pronouncing some words though age differences were not significant. Neufeld (1978) also provides evidence against the CPH. He gave university students three eighteen-hour pronunciation instruction programs in non-European languages and had native-speaking judges rate their speech after the instruction. His finding is that young adults seem to have acquired native or near-native pronunciation in the non-European languages.

However, only a few phonetic-based studies have shown that late learners can acquire nativelike pronunciation even if they start to learn a second language after puberty. For example, Gass (1984) examined ten adult ESL learners' VOT values of English /p/ and /b/ and found that they were similar to those of English monolinguals, though they were likely to "overcompensate for differences between the native and target languages."

A second piece of evidence against the critical period hypothesis is that acoustic data show that early learners can fail to achieve nativelike pronunciation even if they start to learn a second language before puberty. In fact, they seem to end up at an intermediate stage between L1 and L2. Caramazza, Yeni-Komshian, Zurif and Carbone (1973) report the acquisition of VOT by French-English bilinguals, who acquired English at no later than the age of 7; in speaking French, the bilinguals produced stops with VOT values similar to those of French monolinguals while in speaking English their VOT values were closer to the French monolinguals' distribution range. Williams (1980) reports a similar finding: Spanish-English bilinguals, who acquired English or Spanish as a second language either upon entering school in the primary grades or earlier, produced significantly more negative VOT

values for an English voiced stop /b/ than did the English monolinguals while his data show that the Spanish monolinguals' mean VOT value for /b/ was more negative than the Spanish-English bilinguals; in other words, the bilinguals' VOT values for English /b/ fall between the mean values for the monolingual Spanish and monolingual English stops. These findings suggest that even balanced bilinguals, who have acquired native-like pronunciation, tend to have their phonology affected by their dominant language in acoustic terms. This implies that there must be some phonological differences between monolinguals and bilinguals. Fokes, Bond and Steinberg (1985) further examined the acquisition of English VOT in initial positions and preconsonantal vowel duration by Arabic children and reported that the children were variable in their acquisition of voicing contrasts regardless of age and experience with English. If these findings are true, the Critical Period Hypothesis (CPH) cannot explain why those who started to learn a second language before puberty failed to acquire the authentic VOT, ending up at an intermediate stage.

A third piece of evidence against the CPH is that several judgment studies suggest that accent is detectable at an earlier age and emerges before puberty (Oyama, 1976; Flege, 1988a; Flege, 1992; Flege and Fletcher, 1992). Flege (1992) reports that "foreign accent first becomes evident at some time between the ages of five and seven years" (p.590).

Fourth, the age at which foreign accent becomes evident may be explained not by the critical period hypothesis, but by general cognitive development (Flege, 1992). Children between the ages of five and seven years learn to pay attention to more specific aspects of stimuli, which is called decentering (the pre-operations stage; Davenport 1992). This ability allows

children to focus their attention on segments rather than syllables and to establish "the core acoustic properties" of each phonetic category. In turn, this ability leads L2 learners to classify L2 sounds according to the L1 category, which results in a foreign accent (Flege 1992). This suggests that it may be more plausible to explain foreign accent in terms of cognitive development rather than the CPH.

Finally, the CPH would not explain variability in the acquisition of pronunciation. Williams (1980) observes that Spanish-English bilinguals produced significantly more negative VOT values than the English monolinguals only for one English voiced stop /b/, but not for /d, g, p, t, k/. This finding supports the claim that acquisition may vary across voicing and places of articulation. Furthermore, Flege, Munro and MacKay (1995a) claim that there are some variations according to place of articulation: they found that no Italian speakers of English differed significantly from the English native speakers regarding their values for /k/ while the Italians with an age of learning (AOL) greater than 17 years produced /p/ with significantly shorter VOT values than those of native English speakers, and those Italians with an AOL greater than 11 years produced /t/ with significantly shorter VOT values than those of the English native speakers. These findings show that the CPH fails to explain the pronunciation variability that occurs with reference to voicing and places of articulation.

2.1.2 Other Factors Affecting the Acquisition of Phonology

Although we have discussed five pieces of evidence supporting the claim that the CPH cannot always explain the acquisition of second language speech, there are still some other factors which are not directly related to the CPH; 1) developmental factors, 2) L2 input, 3) motivation and affective

factors and 4) social factors (Flege 1987a). First, physiological differences between children and adults may reveal a developmental effect on pronunciation. For example, Spanish adults produced English voiceless stops with longer VOT values than Spanish children (Flege 1987a). Since in general children's VOT is shorter than adults' this may mislead us to conclude that the adults have approximated more closely the English native speaker's norm. Second, the quality or quantity of L2 input may cause differences in pronunciation between adults and children. Usually, the amount of input inversely increases with age of arrival or learning, which may mistakenly lead one to the conclusion that early learners and early arrivals have a greater advantage than adults who usually receive less L2 input. Asher and Price (1967) support this view on L2 input, hypothesizing that "adult-child differences in pronunciation would disappear if L2 intake were truly equal for learners of different ages." Third, motivation and affective factors may be confounded with the CPH: learners who are well motivated to pronounce the L2 like native speakers may be more successful in L2 pronunciation (Celce-Murcia, Brinton and Goodwin, 1996). Also, based on the fact that affective factors (e.g., ego permeability, personality, type of motivation, degree of culture shock) may prohibit successful second language learning, Schumann (1975) suggests that affective variables are more important than biological maturation in second language acquisition. Fourth, if any speech community values good pronunciation very highly, there is a greater possibility that learners will attain a higher level of pronunciation.

Another factor in affecting the acquisition of phonology is the length of residence or stay (LOR) in a target language community. LOR has been claimed to be a factor which can predict how good ultimate L2 production is.

For example, Jun and Cowie (1994) found that Korean-English bilinguals with more L2 experience produced new L2 phones [ɪ, ʊ] more accurately than those with less experience. On the other hand, Flege (1988b) claims that LOR "has relatively little effect on L2 pronunciation." Using multiple-regression analyses, Flege, Munro, and Mackay (1995b) found that AOL "accounted for an average of 59% of variance in the foreign accent ratings" while LOR accounted for less than 2% of variance. More recently, Flege, Munro, and Mackay (1996) claim that AOL and language use factors accounted for 20% and 10% respectively of variance in the VOT values while the remaining 70% was unaccounted for.

Thus, since we have too many factors to control in our studies on foreign accent, we should not assume that the CPH is the only hypothesis that can explain why children or early learners perform better in L2 pronunciation. Also, even if the CPH is related to neuroplasticity and lateralization, which has often been assumed since Lenneberg's (1967) work, it cannot easily be falsified, and this makes it scientifically problematic.

2.1.3 An Alternative View of L2 Speech Learning

An alternative to the CPH is proposed by Flege (1981). This hypothesis is called 'the phonological translation hypothesis,' meaning that "children and adults possess the same general capability for learning to pronounce foreign languages and that one important cause of foreign accent is phonological translation between languages by speakers who already speak a first language." Recently, Flege has developed this hypothesis into a more sophisticated model, referred to as a "Speech Learning Model (SLM)" (Flege 1992, 1995). Flege's (1992) general hypothesis is that adults have the same perceptual ability as children do, but the difference is whether or not an L1

phonetic system has already been established:

> perceptual and sensorimotor processes that permit children to learn to pronounce their L1 without an accent *remain intact through the lifespan*, that is, do not deteriorate (or become inaccessible) as the result of neurological maturation. (p.591)

Flege and Eefting (1988) examined imitation of the VOT continuum from /da/ to /ta/ to see whether or not second language learners can establish a new phonetic category. The result showed that the native speakers of English and Spanish imitated the VOT continuum in a categorical manner. In other words, children and adults speaking Spanish produced stops with only lead and short-lag VOT values while English speakers produced them with only short-lag and long-lag VOT. On the other hand, Spanish speakers of English produced stops with three modal ranges (lead, short-lag and long-lag). They conclude that this could be interpreted as evidence that the Spanish speakers of English (both adults and children) established a phonetic category {t^h} for a voiceless aspirated [t^h] in English.

Flege and Schmidt (1995) carried out another experiment, in which they had native English speakers and Spanish speakers of English rate syllable-initial stimuli for goodness as the category /p/ in English. VOT values were varied "in a set of short-duration ('fast-rate') consonant-vowel (CV) stimuli and in a set of longer-duration ('slow-rate') CV stimuli." Their important finding is that Spanish speakers of English, regardless of their pronunciation ability, gave their highest ratings to stimuli with the same VOT values as the monolingual English speakers did, though Spanish /p/ is realized as short-lag VOT. The two studies support the claim that second language learners still have access to establishing phonetic categories for corresponding L2 sounds that are acoustically different. This ability may

enable second language learners to acquire native-like VOT even after what we call ‘a critical period.’

2.2 Bilingual Children’s Phonology

In this section of literature review, we will discuss 1) the characteristics of bilingual phonology in terms of production and perception, and 2) to what extent bilingual children keep the phonological systems of their two languages separate.

2.2.1 Production

Baptista (1992) acoustically examined the acquisition of the English vowel system by 11 Brazilian speakers of English over a period of six months. More specifically, this research looked at how new English vowels were added to their interlanguage (IL) system and how the older IL vowels were adjusted. It is reported that after an initial period where their native language schema was used in English, the learners’ IL vowel system started to approximate the target language system. The findings show the “link between the acquisition of the new TL [target language] vowels and the adjustment of the old vowels of the IL systems, in an attempt by the learners to maintain sufficient perceptual distance.” For example, the acquisition of /ɪ/ in English involved the lowering of /eɪ/ while the link between non-acquisition and insufficient adjustment was observed in the blocking by /eɪ/ of the lowering of /ɪ/ in the English vowel systems of the Brazilian English learners. Her study showed evidence for the “link between the adjustment of each vowel with that of the adjacent vowels” in terms of the acquisition of a new vowel in the target language. This result does not correspond to Schnitzer and Krasinski’s (1994) finding that the acquisition of vowels does not go through some systematic

stages.

A recent longitudinal study (Schnitzer and Krasinski, 1994) of a Spanish-English bilingual child aged 1;1 - 3;9 shows that there are some differences in the acquisition of segmental phonology between consonants and vowels; the researchers claim that the acquisition of consonants goes through some systematic stages while that of vowels does not. They report that there are four stages in consonantal acquisition: “presystematic variation, formation of a single system, separation into two systems corresponding to the two languages, and achievement of adult target values with later interference of one language in the other.” In the presystematic variation or introduction of phonetic type, for example, Spanish [p] was replaced by [m, k] and English [p] sometimes by [ʙ] until the age of 1;10. At the next stage, a unitary consonantal system was established, in which all the target labial sounds were represented by [p] at age 1;11 through 2;0 and allophonic variations were not yet acquired at this stage. By age 2;5, they observed a clear separation of languages, in which the child clearly distinguished Spanish [p] from English aspirated and unaspirated [p^h, p]. Then it is reported that at age 3;0 the subject had achieved adult target values such as Spanish [p, f] and English [p, p^h, f]. Interestingly, after acquiring the target phonological system, there is some interference between the initial language and L2. One of the examples is a replacement of Spanish [ʙ] in one context by [b] and in another by [v].

On the other hand, the study argues that vowels display neither a single-system stage nor a two-system stage. Evidence for this claim is that at age 1;11 English [0] and Spanish [o] are clearly distinguished and [ø] and [œ] occurred only in English. By about age 2;8, the subject reached the adult target

vowel values. Schnitzer and Krasinski do not interpret that there were two different vowel systems but that the subject “learned which vowels went with which words.”

This research has three important implications for the acquisition of phonology. First, the acquisition differences between vowels and consonants reveal an intrinsic difficulty with consonants. The production of consonants always requires not only precise place and manner of articulation but also timing between oral articulation and glottal articulation (e.g., voiced vs voiceless; short lag vs long lag vs lead VOT). On the other hand, vowels need to have a precise degree of constriction or a degree of opening between the roof of the mouth and the tongue. They also involve lip rounding. For example, [0] and [o] are not very different acoustically and difficult to learn. But since most vowels are voiced, there is no timing relation with respect to glottal articulation.

Second, the claim that bilingual children have two different consonantal systems but only one system for vowels raises the important issue of whether bilinguals have one or two systems of phonology, which will be discussed in detail later. Concerning the different systems for vowels and consonants, Hecht and Mulford’s (1982; cited in Lleo, 1995) hypothesis shows important insight into the transfer observed in the research discussed above. They hypothesize that transfer tends to occur in the acquisition of vowels, and developmental processes tend to occur in the acquisition of consonants. This hypothesis supports the possibility that bilingual children may have two different consonant systems.

Finally, the finding that there is some interference of one language with another indicates that complete mastery of second language phonology

is not impossible, but difficult; even if children are exposed to a second language at an early age. This finding also raises the question of a critical period hypothesis: though it is generally said that the critical period for phonology ends around the age of five or six, this evidence of interference may suggest that the period ends much earlier. Eilers, Oller and Benito-Garcia (1984) claim that whereas at the age of one no VOT differences for each place of articulation were acquired by Spanish and English learning infants, by the age of two both language groups approached values appropriate for each language. Concerning this age issue, Kent and Miolo (1995), in terms of first language acquisition, imply that children are sensitive to acoustic cues such as VOT even in the first year of life. Therefore, for bilinguals who are exposed to a second language after the age of one, it may be too late for them to acquire native-like VOT values. This would be the case because their L1 phonological norm for VOT has already been established.

2.2.2 Perception

Though research on speech production gives us a lot of insights into the theories of bilingual acquisition, studies on speech perception are also essential for balanced theories. Actually, bilingual perception has aspects different from monolingual perception. Caramazza et al. (1973) report that in an experiment of categorical perception, in which subjects identify speech-like stimuli having different VOT values (for example, /k/ or /g/), French-English bilinguals are less sensitive to VOT variations than English monolinguals, but they make more use of this acoustic cue than monolingual French speakers. This means that the perception pattern of bilingual speakers shows an intermediate position relative to monolingual speakers. This finding for perception has two significant implications for bilingual

phonology acquisition. First, though we may not see any big difference in production between bilinguals and monolinguals, bilinguals tend to have more interference from L1 in perception than in production. Second, bilinguals perceive both L1 input and L2 input in the same way only on one criterion. Caramazza, Yeni-Komshian and Zurif (1974) conclude as follows:

> French-English bilinguals, while markedly more sensitive to VOT than unilingual Canadian French speakers, are still less sensitive to this cue than those who speak only English. Bilinguals, then, may acquire two independent linguistic systems, but each seems to modify the other during the course of development. (p. 317)

2.2.3 Bilingual Phonological Systems: One or Two?

One of the most interesting issues in bilingual language acquisition is whether bilingual children have one or two phonological systems, an issue on which many researchers do not agree. There are three views on this issue; a one system hypothesis, a two system hypothesis and a phonetic category modification hypothesis.

Caramazza et al. (1973) have addressed this issue. Their acoustic analysis of VOT values for stop consonants in French-English bilinguals, in which their VOT values are closer to those of French monolinguals in the English mode, leads them to argue for one system in which bilinguals use the same phonetic criteria as L1.

> In general, it appears reasonable to suggest that the phonological processors the bilingual acquires for his second language are contaminated by properties accruing to his first language. (p. 427)

Wode (1978), based on the data from his four German children aged 4 to 9 years acquiring English, in which they substituted L1 pronunciations for the L2 equivalents, hypothesizes that L2 phonology is acquired “through the grid of the child’s L1 phonological system.” This finding implies that it is rare

for bilingual children to have two separate systems for L1 and L2 at the same time. But Wode's data includes several L2 segments /œ, ø, w, T, D/ which are quite different from L1 or which have no equivalents in German at all, which leads him to argue that not all L2 segments are acquired "through the grid of the L1 repertoire" and that though there must be an apparent interference from L1, "phonological acquisition is neither exactly alike in L1 & L2, nor entirely different."

Similarly, Caramazza et al. (1974) admit that there is a possibility that bilinguals may acquire two different systems. In addition, they propose a dynamic relationship exists between the two languages during their early period of language development.

These arguments are similar to the concept of interlanguage in late second language acquisition. It may be plausible that bilingual children's phonological acquisition, if not simultaneous bilingual acquisition, starts with the framework of L1 phonology while the new system continues to get closer to the adult target model during the course of development. Both Caramazza et al. (1974) and Wode (1978) support the notion that there must be a continuous development from the L1 phonological system to the L2. The one system view is not that children have only one system and produce L2 sounds on the single standard criteria, but that like adult SLA, the children's L2 system derives from L1 and continuously approaches the target model. As mentioned earlier, in terms of perception as well, it is plausible to argue that bilingual children do not possess "a double standard" for perceiving incoming speech.

On the other hand, Ingram (1981; cited in De Houwer, 1995), who studied phonological forms produced by an Italian-English bilingual child at

age two, argues for two separate phonological systems. De Houwer quotes Ingram as saying that "there is evidence for two phonological systems in the sense that there are specific tendencies in the output that help identify words as belonging to one lexicon or another" (p. 235). However, this argument does not seem plausible. The problem is that it is not clear how he interprets the relationship of lexicon with phonology. It is not always true that children have two phonological systems even if they have two separate lexical systems. Also, evidence from lexicon is not necessarily reliable enough to judge what bilingual phonology is like.

Recently, Bohn and Flege (1993) introduced an interesting model, referred to as "the phonetic category modification hypothesis," in which learning an L2 may have some influence on the pronunciation of L1 sounds. They claim, for example, that VOT values for Spanish speakers' /t/ get longer as they are exposed to long-lag English /t/. This hypothesis may suggest that bilinguals have two systems, part of which overlap and bidirectionally interact with each other. At the beginning the system starts with L1, which gradually separates into two systems with the overlapped part decreasing.

2.3 Immersion Education and SLA

2.3.1 Definition of Immersion Programs

Genesee (1987) defines immersion programs as follows:

> Immersion is a form of bilingual education in which students who speak the language of the majority of the population receive part of their instruction through the medium of a second language and part through their first language. Both the second language and the first language are used to teach regular school subjects, such as mathematics, science, or physical education, in addition to language arts. The same subjects are never taught using both languages concurrently or during the same academic year. Different subjects are taught through the

medium of each language. (p. 1)

The first immersion program started in the Montreal suburb of St. Lambert in 1965 (Genesee, 1987; Sternfeld, 1988). This program developed out of English-speaking parents' suggestion that they would like to have their children acquire communicative proficiency in French as part of their education. In this sense, the immersion program was designed to school language majority students in two languages. The St. Lambert immersion program had four goals: 1) to develop "functional competence" in French, 2) to maintain the students' development in the English language, 3) to achieve at the same or higher level in "academic subjects," 4) to understand "French Canadians, their language and culture" (Genesee, 1987). Since this innovation, French immersion programs have proliferated in Canada; immersion education has also been introduced to Kindergarten programs and elementary schools in the United States in the form of Spanish immersion programs. Recently, several schools in Southern California have started to implement Asian language immersion programs in Culver City and Long Beach. Both El Marino Language School in Culver City and Jackie Robinson School in Long Beach have a Japanese immersion program.

The theoretical rationales for starting second language instruction during the early elementary grades are based mainly on neuropsychological, psycholinguistic and socio-psychological research. Neuropsychologically, it has been assumed that there is a critical period for language acquisition beyond which L2 learners cannot attain the ultimate native-like level of competence. As mentioned in Section 2.1.1, Lenneberg's (1967) claim supports immersion education, in which second language instruction starts well before puberty. Psycholinguistically, some recent generative linguists believe that

human beings are born with an innate ability to facilitate language acquisition, what Chomsky (1968) calls the "Language Acquisition Device," and this capacity decreases with age. Immersion education, in which second language instruction starts at an early age, takes advantage of this nativist's view of language acquisition. Finally, socio-psychologically, Genesee (1987) mentions that "young English Canadian children would be more open to other languages and language groups in general" (p. 14) because of an immersion experience and this argument has lead educators to favor early second language instruction because it promotes socio-cultural understanding of a target language group. Thus, immersion education has neuropsychological, psycholinguistic and socio-psychological rationales.

More recently, Johnson and Swain (1997) identify eight defining features of a "prototypical" immersion program, each of which can be considered as occurring to various degrees along a continuum:

1. The L2 is a medium of instruction.
2. The immersion curriculum parallels the local L1 curriculum.
3. Overt support exists for the L1.
4. The program aims for additive bilingualism.
5. Exposure to the L2 is confined largely to the classroom environment.
6. Students enter with similar (and limited) levels for L2 proficiency.
7. The teachers are bilingual.
8. The classroom culture is that of the local L1 community.

#3 and #4 are the features that distinguish immersion education from L2 medium programs, where the development of L1 is usually not taken into account. Additive bilingualism means that the goal of L2 proficiency is not a native speaker's level, but a functional level. #6 is a feature which differentiates an "immersion" from a "submersion program," in which L2 speakers are instructed in a class with the majority of students being L1

speakers. Also, #7 is another feature distinguishing “immersion” from the “submersion program,” where teachers are unlikely to understand the students’ L2.

The most important features considered to distinguish immersion programs from each other are the grade level at which immersion is introduced and the extent of immersion. First, immersion programs can be identified in terms of when students begin and how much subject matter instruction they receive in the second language: “early immersion” starts in Kindergarten, “delayed immersion” in grade 4 or 5 and “late immersion” in grade 7 or 8 (Sternfeld 1988, p. 222). Second, in terms of the extent of immersion, immersion programs fall into two main types: total immersion where 100% of subject matter instruction is provided only in L2 for a year or more and partial immersion, in which less than 50% of the curriculum is taught in L2. In total immersion, L1 literacy development is introduced after L2 literacy training has begun, while in partial immersion literacy training occurs simultaneously in both L1 and L2 from grade 1 (Genesee, 1987; Johnson and Swain, 1997).

Immersion programs have been well-researched and reported to be successful (California State Department of Education, 1984; Genesee, 1987; Johnson and Swain, 1997). Cummins (1991: cited in Johnson and Swain, 1997) mentions that about one thousand studies on immersion have been done in Canada alone. In the sections to follow, the academic and second language outcomes will be discussed.

2.3.2 Academic Achievement in Immersion Education

Since this is not directly related to the present study, I will briefly go over the academic development of immersion students. Academic

achievement has been measured using various types of tests ranging from standardized tests to teacher-made tests. Genesee (1987) reports that immersion students do as well as English-speaking students in a regular curriculum on English math tests, except arithmetic problem solving, in which early immersion students do not score as well as their counterparts. But it is reported that once L1 literacy training has begun this lag disappears. Also, in science early immersion students scored as well as regular students, while the scores of late immersion students who had one-year of French language instruction before immersion were reported to be significantly lower than those of the English control group. But this difference was eliminated by the end of the second year (Swain, 1978). This means that immersion students usually end up doing as well as monolingual students in the regular curriculum in terms of academic achievement, though late immersion students may be delayed in some subjects. However, they can catch up rapidly (Collier, 1989; Genesee, 1987).

2.3.3 Second Language Acquisition in Immersion Program

L2 Proficiency in General

Genesee (1987) reports that French immersion students are likely to score as well as native French speakers in comprehension skills (listening and reading). This is especially true of early total immersion students. But students in the French immersion program did not do as well as native French speakers in speaking and writing. Their French subskills of oral production, such as pronunciation, grammar and vocabulary, were rated significantly lower than their comprehension skills, although compared with the English control group in a regular French language curriculum, the performance in French of the immersion students was better.

Despite their linguistic limitations, Genesee (1987) indicates that students in a French immersion program achieved "very high levels of functional proficiency in French." For example, the Montreal and St. Lambert evaluations, in which immersion students were asked open-ended questions in an interview format, found that their score ranged from "3.5 [to] 5 on a 5-point scale with 5 being nativelike" (Genesee, 1987, p. 48). Also, Pawley (1985) measured the L2 oral proficiency of French immersion students, using several well-known tests: e.g., Public Service Commission Tests, which applicants for government positions requiring French in Canada must take, and Foreign Service Interview Tests, similar to those administered by the Foreign Service Institute in the US. Grade 10 early immersion students and late immersion students at grades 10 and 12 scored Level B, which is the highest level in the Public Service Commission Tests, on reading, writing, and listening, but they scored the lower Level A, which is usually required for "some clerical and technical positions," on speaking. In the Foreign Service Interview Tests, the majority of the immersion students reached Level 2 or 2+, at which point they can meet "their routine social needs and limited work needs in French." It is also reported that many immersion students were proficient enough to manage "most ordinary conversations on practical, social or work-related subjects (Level 3 or 3+)," which is considered very good.

Phonological Acquisition

Although there is some research on the acquisition of morphology and syntax by immersion students (e.g., Cohen, 1976; Hammerly, 1987; Harley, 1984; Plann, 1978), little comprehensive and systematic research on the acquisition of pronunciation has been documented. But it is generally reported that immersion students are unlikely to demonstrate native-like

pronunciation. Hammerly (1991) gives a detailed description of English-accented speech by French immersion students:

> The results of immersion programs show that in the absence of specific pronunciation instruction, many years of communicative classroom interaction in an SL fail to result in accent-free speech. Early French immersion pupils, who enter the program at age five or six, still have an English accent 12 years later, though, to be sure, not nearly as marked as that of late immersion students who start at puberty. Many years of communicative interaction do not eliminate NL accent from the speech of SL students....As there is no communicative need for a native accent, it cannot be 'negotiated' into existence and thus the NL accent doesn't disappear. (pp. 59-60)

On the other hand, Flores (1973) evaluated very positively the phonological development of English-speaking children in a Spanish immersion program:

> In phonology, for instance, the heavy interference from the English sound system we noticed last year (kindergarten) has completely disappeared. Most of the children are now able to articulate the Spanish sounds with native like accuracy....the phonological development has also reached a point where most of the children sound native-like. (cited in Snow and Campbell, 1983, p. 20)

Genesee (1987) summarizes immersion students' overall pronunciation skills together with other skills, obtained from his longitudinal study (1978) on a French immersion program. The following tables show the results of early and late immersion students' pronunciation ratings based on oral interview tests:

Table 2-1 Pronunciation ratings of students in grades 4, 5, and 6 in an early immersion program

	Max	Immersion	English Control	French Control
Grade 4	5.00	4.03	3.17	4.92
Grade 5	5.00	4.00	2.01	5.00
Grade 6	5.00	4.01	3.40	5.00

Table 2-2 Pronunciation ratings of grade 9 for early immersion, one-year, and two-year late immersion students

Max	French Control	Early Immersion	Grade 7/8 Immersion	Grade 7 Immersion	English Control
5.00	5.00	3.98	4.12	3.84	2.85

The results indicate that although immersion students always outperform the English control groups, who are learning French in a traditional curriculum. In terms of their pronunciation skills, they never reach the native French speakers' level and no noticeable progress in pronunciation is observed from Grade 4 through Grade 6.

One of the studies most relevant to this study is Snow and Campbell (1983), in which they addressed several questions: 1) how native speakers of Spanish rate the pronunciation (of consonants) of English-speaking children in a Spanish immersion program, 2) whether or not there is any effect of different types of elicitation task on their pronunciation performance, 3) whether or not there is any difference across grade levels and 4) whether the "Interference Hypothesis" is confirmed. The subjects for their study consisted of 48 students (15 sixth graders, 17 third graders and 16 Kindergartners). They examined all Spanish consonants in all possible phonetic environments within 73 Spanish words and collected data using both imitation and production tasks. The speech samples were rated by two native-Spanish speaking consultants.

The consultants found that students at grade 3 were rated higher than the Kindergarten or grade 6 subjects and all three subject groups were rated more native-like in the imitation task than in the production task. The former result led the researchers to suggest that children in immersion programs are likely to regress in their pronunciation of the target language as

they get older. We see this pattern also in French immersion programs in Canada. The latter result from the imitation task gives us some important insights into how we should elicit data from L2 learners, which has been overlooked in the field of second language acquisition (Tarone, 1998).

Three of their four interference hypotheses based on contrastive analysis are supported by their data.[3] Finally, they conclude that while the Spanish phonology of the 48 children includes some nonnative forms, Spanish immersion children seem to be progressing toward a native-like pronunciation.

Although this research is very insightful, several considerations should be taken into account for future research. First, since speech is highly variable, we need a few repetitions of the same word so that we can get reliable data from subjects. It is not certain how many observations for each sound their data are based on. A more sophisticated methodology would allow researchers to make distinctions between learners' errors and simple slips or mistakes. Second, though accent rating seems to be an easy test, researchers must design the testing procedure carefully enough for listeners to easily pay attention to the target sound or acoustic cues; otherwise, different raters will judge a given token in terms of different phonetic features. Third, there are always limitations on subjective judgments of foreign accentedness due to a rater's native language background. In order to make up for this deficiency, second language researchers must depend on more objective acoustical measurements. Fourth, we need a longitudinal study of the bilingual acquisition of phonology in an immersion program to see how

[3] The four hypotheses go as follows: 1) "subjects will aspirate initial stops," 2) "will not produce the fricative allophone for medial stops", 3) "will produce retroflex or tap /-r-/ in medial position" and 4) "will produce alveolar (dark) /-l#/." The first three hypotheses are reported to be supported.

immersion students' L2 phonological systems develop and how they interact with their L1 phonological systems. Finally, a large amount of acoustical research on second language speech has been documented recently and various theoretical frameworks are provided. Therefore, future research will have to test these hypotheses about second language speech that have been derived mainly from research on second language acquisition occurring in a naturalistic setting, to see whether these hypotheses work in a classroom setting such as an immersion program.

2.4 Japanese Phonetics and Phonology

2.4.1 Japanese VOT

Aspiration and VOT in Japanese

Japanese has voiced and voiceless stops. Impressionistic descriptions show disagreement as to whether or not Japanese /p, t, k/ are aspirated. Vance (1987) quotes Sakuma (1929) as saying the Japanese voiceless stops are "almost always unaspirated" while others report that word-initial /p, t, k/ are usually more aspirated than the medial ones though the second stop of a geminate is unaspirated (Bloch, 1950; Hattori, 1951; Kawakami, 1977).

Acoustically, aspiration is defined in terms of voice onset time (VOT); a period of voicelessness after the stop articulation and before the start of the voicing for the vowel (Ladefoged, 1993). Homma (1980) measured the VOT of six Japanese disyllabic words spoken by three subjects, and found that the mean VOT of word-initial /t/ is 25 ms and concludes that it has much shorter VOT, compared with Lisker and Abramson's (1964) English data, in which mean VOT values for /t/ in isolated words are 70 ms. However, Homma's (1980) research is limited to only three subjects and word-initial voiced and

voiceless alveolar stops. Homma (1981) increased the number of test words and tokens and reported mean VOT values:

word-initial /p, t, k/
[p] = 24 ms [t] = 32 ms [k] = 45 ms
word-medial /p, t, k/
[p] = 7 ms [t] = 16 ms [k] = 24 ms
geminate /pp, tt, kk/
[pp] = 11 ms [tt] = 13 ms [kk] = 28 ms

The mean VOT value of initial /p, t, k/ was 37 ms while that of medial /p, t, k/ was 17 ms. Although some researchers (Han, 1992) report that gemination affects VOT, Homma mentions that there is no effect of gemination on VOT, showing that the mean VOT value of geminated /p, t, k/ was 17 ms. More recently, Han (1992) reports that word-medial VOT values, based on 12 tokens for each of ten subjects, are as follows:

[p] = 7.7 ms [t] = 12.0 ms [k] = 17.9 ms
[pp] = 6.3 ms [tt] = 8.1 ms [kk] = 11.1 ms

Although for initial VOT Han measured only voiceless velar stops in her data, the data show that mean VOT values for initial /k/ before /i/ range from 47.3 ms to 62.3 ms, which is longer than what was reported in Homma (1981).

English VOT and Japanese VOT by English Speakers

English has voiced and voiceless stops. Initial voiceless stops /p, t, k/ are aspirated, and initial voiced /b, d, g/ are not fully voiced, close to unaspirated stops. Lisker and Abramson (1964) report means of VOT values for initial voiceless stops both in isolation and in sentences:

in isolation:
[p] = 58 ms [t] = 70 ms [k] = 80 ms
in sentences:
[p] = 28 ms [t] = 39 ms [k] = 43 ms

Caramazza et al. (1973) also show similar means of VOT values for initial voiceless stops in isolation:

[p] = 62 ms [t] = 70 ms [k] = 90 ms

But we should note that mean VOT values vary according to segmental as well as suprasegmental environments (e.g., vowel height, manner and place of consonant articulation, degree of stress, intonation pattern, location of the syllable within a prosodic unit such as a word and a phrase, the length of the utterance). Flege (1991) measured VOT values for word-initial /t/ tokens spoken both in utterance-initial (e.g., take a textbook) and utterance-medial positions (e.g., take a textbook) and reports the different mean VOT values: utterance-initial /t/ = 51 ms and utterance-medial /t/ = 64 ms.[4]

Judging from these available English data, it is quite predictable that the VOT values of Japanese /p, t, k/ produced by English native speakers are longer than those of native Japanese speakers. Han (1992), though her data are limited to medial single stops and geminate stops, claims that Americans' VOT values for the Japanese voiceless stops were found to be longer than those of native Japanese speakers:

[p] = 15.6 ms [t] = 19.6 ms [k] = 30.8 ms
[pp] = 13.7 ms [tt] = 16.5 ms [kk] = 29.6 ms

But there are no available reports of English children's VOT values for

[4] In general, VOT values in a prosodic initial position are longer than those in a prosodic medial position (Fougeron & Keating, 1996; Jun, 1993, 1995; Pierrehumbert & Talkin, 1992). VOT in utterance medial position in Flege's study (e.g., Take a teabag) can be interpreted as a phonological phrase initial position. Therefore, we expect that the utterance initial VOT be longer than the utterance medial VOT in his study. We believe that the opposite result in Flege's study is due to the fact that the target consonant was influenced by different degrees of stress. In the carrier sentence, "Take a ___," the underlined word, being implicitly focused, would receive a nuclear pitch accent, the strongest stress of the sentence, while the sentence initial word "take" would receive either a pitch accent or no accent, i.e., a lesser degree of stress. It is well known that a consonant in a stressed syllable is hyperarticulated, i.e., strongly articulated (e.g., de Jong, 1995).

Japanese voiceless stops that are relevant to this research study.

2.4.2 Japanese Geminates

In Japanese, the basic syllable consists of a consonant plus a vowel. However, this syllable can also be closed by two kinds of consonants: nasals or geminates. Shibatani (1990) defines these geminates as "a non-nasal consonant followed by a homorganic consonant of the following syllable" and the second consonant of a geminate is usually a voiceless stop (it can be a voiced stop as well in loan words), an affricate or a fricative (Vance, 1987). This syllable-final consonant takes one beat or what we call one mora, but is a smaller timing unit than a syllable. The one mora functions as one syllable like syllabic [n̩] or [l̩] in a sequence such as [tn̩] (e.g., button) or [tl̩] (e.g., little) in English. Phonemically, the syllable-final consonant counting as one mora is transcribed as /Q/ and phonetically, the geminate is realized by holding the closure stage of the first consonant as long as one mora. The contrast between a single and geminate consonant is illustrated in the following way:

Phonological level	Phonetic level	# of syllables	# of moras
/ita/ (was)	[ita]	2	2
/iQta/ (went)	[itta]	2	3

Closure duration

One of the most important acoustic cues for distinguishing single from geminate consonants is the duration of the closure of a single or geminate consonant. But researchers do not agree as to the duration ratio of geminate to single consonants. The first view is that a geminate consonant consists of a moraic consonant + a single consonant and the total duration of these consonants is longer than that of two successive single consonants. Homma (1981) and Han (1992) support this view and claim that the duration ratio of

geminate to single consonants is 3:1. This position leads to evidence that the mora is an abstract type of timing in Japanese. On the other hand, Beckman (1982) refutes this view, arguing that the mean ratio is 2.25:1 when VOT is included as part of the stop and that the ratio is 2.79:1 when VOT is not included. In other words, whether or not VOT is included, the duration of the geminate is less than three times the single consonant.

Han (1992) measured native Japanese speakers' closure duration for both single and geminate consonants, using a set of ten minimal pairs as the *ita/itta* pair illustrated above. She found that [t] and [tt] have shorter durations than [p] and [pp], respectively and the overall average closure duration of each single and geminate consonant is reported as:

[p] = 74.5 ms	[t] = 60.7 ms	[k] = 66.7 ms
[pp] = 200.6 ms	[tt] = 198.6 ms	[kk] = 184.2 ms

The data clearly shows that the duration of the geminate consonant is more than twice as long as the single consonant.

The discrepancy between the two views may stem from a methodological difference or a measurement error. As Homma (1981) suggests, the closure duration for a word-initial stop can be difficult to measure because the occasional insertion of a pause keeps us from identifying the beginning of the closure of a stop.

Word Duration Ratio

Although the closure duration of a geminate consonant is an important cue to identifying geminates, there may be other factors that affect the identification of a single versus a geminate consonant because the segment duration varies according to phonetic environment. Another reliable cue is a relative word duration. Han's (1994) results show that the

average ratio of 2-mora words to 3-mora words (e.g., *ite* = being, *itte* = going) is 2.00:2.99 and that of 3-mora words to 4-mora words (e.g., *supai* = spy, *suppai* = sour) is 3.00:4.01. This completely supports the view that the mora is an abstract timing system in Japanese. She summarizes this abstract timing in terms of word durations:

> When word durations are viewed as relative values, the ratios show a striking resemblance to the corresponding mora values, supporting the hypothesis that this abstract unit, the mora, constrains word durations and thereby constrains both the mora and segment durations in Japanese. (p. 81)

Japanese Geminates Produced by English Speakers

English has double consonants across the morpheme boundary (e.g., cattail, get Tom), but they do not contrast with single consonants. In other words, there is no phonemic contrast between single and geminate consonants. This difference between the two languages leads us to predict that English learners of Japanese have difficulty acquiring this contrast. Although there is a limited amount of comprehensive acoustic research on the acquisition of Japanese geminates by native English speakers, Han (1992) analyzes the contrast between three-mora words with a single consonant and four-mora words with a geminate. Interestingly, some native speakers of English made a phonological distinction between the two sounds, but phonetically their closure duration for a single consonant was more overdifferentiated than that of native speakers of Japanese while the overall mean of geminate closure durations was shorter than that of the Japanese speakers. The following results show that the American subjects produced the single consonant with longer closure durations and the geminate consonants with shorter closure durations than Japanese native speakers:

Native Japanese speakers' mean closure duration (Han, 1992):

[p] = 74.5 ms	[t] = 60.7 ms	[k] = 66.7 ms
[pp] = 200.6 ms	[tt] = 198.6 ms	[kk] = 184.2 ms

American subjects' mean closure duration (Han, 1992):

[p] = 86.2 ms	[t] = 103.7 ms	[k] = 91.1 ms
[pp] = 179.2 ms	[tt] = 172.0 ms	[kk] = 173.8 ms

As a result, the overall ratio of the closure durations of a single to a geminate consonant was observed to be smaller (1.00:1.79) than that of the Japanese speakers. It is also necessary to examine the difference in the word durations between L1 and L2 Japanese speakers, but so far no data are available.

Acoustic Cues for Perception

Native speakers make the most of various acoustic cues to identify single and geminate consonants, two of which (e.g., closure duration, word duration) have been mentioned above. Also, research on perception gives us some suggestions regarding which acoustic cues are available to make a distinction between the two sounds. Hirata (1990a) distinguishes word-level from sentence-level perception, in which native Japanese speakers appear to use different acoustic cues. In word-level perception, Japanese speakers depend on the preceding vowel length as well as the closure duration of the stop in order to distinguish a single and geminate consonant. Her interpretation is that in the word-level perception, the ratio of the closure duration of the following consonant to the duration of the preceding vowel is a crucial cue: if this ratio is short, it is perceived as a single consonant and if it is long, it is perceived as a geminate. On the other hand, in the sentence level perception, the distinction depends on the speed of the following larger units. Those tokens perceived as including a single consonant at word-level perception can be perceived as a double consonant if the following utterances

are read fast or vice versa. This means that native speakers make effective use of such different cues as the duration of the preceding vowel, the closure duration of the stop, the word ratio and the speed of the following larger units, depending on whether perception occurs at the word level or the sentence level.

In terms of L2 speakers' word level perception of a single or a geminate consonant, Hirata (1990b) shows that both L1 and L2 Japanese speakers use the same acoustic cues, the durations of the preceding vowel and the stop, though the L2 speakers' categorical curve is not so steep as that of L1 Japanese speakers. However, for sentence level perception, while the native speakers of Japanese shift their acoustic cue to the speed of the following larger unit, the Japanese L2 learners showed confusion because they "tend[ed] to continue to listen for the length of /Q/ in the individual word instead of expanding the unit of perception to the sentence [level] like native Japanese" (Hirata, 1993).

CHAPTER 3

RESEARCH QUESTIONS AND HYPOTHESES

3.1 Production

Research Question 1-1 (Production of VOT and gemination)

Does the Japanese immersion program, which is the instructional setting closest to a naturalistic setting, help students approximate the L1 speaker's norm for the voice onset time (VOT) of /p, t, k/ and the gemination of /pp, tt, kk/ in Japanese?

Hypothesis 1-1a (for VOT)

Harada (1997) suggests in his VOT study of Chinese university students acquiring English that early arrivals have not completely reached the native speakers' "phonetic" norm but are at an intermediate stage between the native English subjects and the native Chinese late arrivals. Similarly, Japanese produced by the American children in the Japanese immersion program will end up with an intermediate stage between the Japanese norm and English norm, but not reaching the native Japanese speaker's phonetic norm.

Hypothesis 1-1b (for closure duration of gemination)

a. Although children exposed to Japanese in the immersion setting may be aware of the contrast between single and geminate consonants, they may fail to produce this contrast effectively due to phonetic interference. Alternatively, the duration of geminates produced by native English speakers of Japanese may be "underdifferentiated" from that of their singletons because the closure duration of English double consonants even across morpheme boundaries is shorter than that of

Japanese geminates (Han, 1992).

b. Although the main phonetic realization of Japanese geminates is acoustically the duration of a closure stage, another factor is the relative duration ratio of a whole word with a single or a geminate consonant. Han (1994) mentions that "when the word durations are converted into ratios, they are markedly similar to the mora values." For example, *itta* : *ita* = 3:2. Since English is a stress-timed language, the children in the immersion program may produce both these words with the same ratio or the word with a geminate consonant may be only slightly longer.

3.2 Perception of Geminates by Native Speakers

Research Question 1-2 (Accent rating)

How good is the contrast between single and geminate consonants produced by the Japanese immersion children according to the judgments of Japanese native speakers?

Hypothesis 1-2

As Genesee (1987) reports that immersion students are less likely to demonstrate native-like proficiency on the productive skills (e.g. speaking and writing), students in even the higher grades may produce speech that is accented though intelligible.

3.3 Variation in the Acquisition

Research Question 2-1 (Across grade levels)

Is there any variation in the children's production of Japanese VOT and closure duration for gemination across grade levels?

Hypothesis 2-1

Snow and Campbell (1983) report that due to sociological or

psychological factors there is regression among higher graders in their language acquisition, as it is already observed in French and Spanish immersion programs. Therefore, grade 5 subjects will produce less native-like VOT and closure duration than grade 3 subjects.

Research Question 2-2 (Over a period of time)

How does the acoustic correlate develop (for the VOT and the duration of geminates) from Time 1 through Time 2?

Hypothesis 2-2

As students at grades 4, 5 and 6 in an early French immersion program did not show any improvement (Genesee, 1987), little progress may be observed in grade 5 from Time 1 through Time 2, which can be attributed to the regression mentioned above. But students at grades 1 and 3 may show some improvement.

Research Question 2-3 (Across places of articulation)

Is there any variation in the order of acquisition of VOT and closure duration across places of articulation?

Hypothesis 2-3

Sander's (1972: cited in Menn & Stoel-Gammon, 1995) L1 acquisition study suggests that the 90% acquisition of English /p/ and /k/ is reached by ages 3 and 4 respectively, but that of /t/ is not reached until age 6. If this is correct, a similar order of acquisition may be observed in the production of VOT and closure duration by Japanese immersion students.

3.4 Effect on L1

Research Question 3 (An effect on English phonology)

How does the acquisition of Japanese in an immersion program affect students' production of English VOT?

Hypothesis 3

Flege (1987b) found the existence of L2 effects on L1 production: American speakers of French produced English /t/ with shorter VOT values than English monolinguals. Since VOT values of Japanese are shorter than those of English, the English-speaking Japanese immersion students may produce English stop consonants with shorter VOT values.

3.5 Bilingual Phonology

Research Question 4 (Flege's Hypothesis Testing)

Do Flege's (1995) following hypotheses for the acquisition of L2 speech in a naturalistic setting apply in an immersion program as well?

Flege's Hypothesis 1

The greater is the perceived phonetic dissimilarity between an L2 sound and the closest L1 sound, the more likely it is that the phonetic difference between the sounds will be discerned.

Flege's Hypothesis 2

Category formation for an L2 sound may be blocked by the mechanism of equivalence classification.[5] *When this happens, a single perceptual phonetic category will be used to process perceptually linked L1 and L2 sounds*

[5] Equivalence classification "permits the child, and even infants to group disparate phones into functional categories and perceive constancy in the face of acoustic phonetic variation due to factors such as talker gender, stress, and speaking rate" (Flege, 1992).

(diaphones). Eventually, the diaphones will resemble one another in production.

Hypothesis 4a (VOT)

Assuming that the voiceless stops in English and Japanese are similar except for the temporal difference shown in Table 3-1, the phonetic difference between the sounds may be hard to perceive. This phonetic similarity may prevent native English children learning Japanese from forming a category for Japanese voiceless stops because of "equivalence classification." This in turn leads to a difficulty in producing authentic VOT.

Table 3-1 Comparison of mean VOT values between Japanese and English voiceless stops (Lisker and Abramson, 1964; Homma, 1981) The value is in isolated words.

	[p]	[t]	[k]
Japanese	24	32	45
English	58	70	80

Hypothesis 4b (Closure duration)

In English, there is no phonological contrast between single and double consonants. Furthermore, the phonetic difference in duration between geminates in Japanese and two identical consonants in English lies only in the temporal distinction: the learners will not recognize the contrast because the closure duration of the two consonants even across morpheme boundaries is shorter in English than that of the geminates in Japanese (Han, 1992). Therefore, as Table 3-2 shows, the immersion children's ratio of single to geminate consonants will be smaller than the monolingual Japanese speakers'.

Table 3-2 Comparison of overall ratios of single to geminate consonants in English learners of Japanese and Japanese native speakers (Han, 1992)[6]

	Single	Geminate
Japanese Speakers	1	2.52
English Speakers	1	1.79

Research Question 5 (One or two phonological systems?)

Do the 2 phonological systems develop independently or interact with each other? In other words, do the students who have acquired more native-like pronunciation have one phonological system, two phonological systems or an intermediate phonological system?

Hypothesis 5

As Flege (1995) suggests, the L2 speaker's category may deviate from an L1 category "to maintain phonetic contrast between categories in a common L1-L2 phonological space" or the L2 category may be "based on different features, or feature weights, than a monolingual's."[7] Therefore, Japanese immersion students are expected to acquire an intermediate category for such features as VOT and closure duration.

[6] The table shows the ratios when VOT is not included.

[7] However, Flege (1988b, 1991) suggests that "complete separation of sounds in the L1 and L2 phonetic inventories is possible, at least for early learners" (Flege, 1991, p. 395).

CHAPTER 4

METHOD

4.1 Subjects

One group of English-Japanese bilingual children (N = 19), one group of English Japanese bilingual adults (N = 5), and one group of monolingual Japanese children (N = 12) participated as volunteer subjects. The data for the study were collected from (a) 19 children in a Japanese immersion program in Culver City, California and (b) 5 bilingual teachers in charge of this program. The immersion children consisted of 7 subjects from grade 1 (age 6), 6 subjects from grade 3 (age 8), and 6 subjects from grades 5 (age 10). These subjects were mainly from English-speaking families and had been exposed to Japanese only in the school setting. To investigate how input would contribute to the children's phonetic norms of Japanese VOT and geminates, data were also gathered from the 5 English-Japanese bilingual teachers in the Japanese immersion program.

The monolingual group consisted of 6 Japanese-speaking students each in grades 1 and 5 from an elementary school in Omiya, Saitama, Japan, which is located just to the north of Tokyo. The total number of subjects in the study was 36. Table 4-1 shows the number of subjects in each subject group.

Table 4-1 The number of subjects

	Subjects	**Grade 1**	**Grade 3**	**Grade 5**
Bilingual Children (Japanese & English)	19	7	6	6
Bilingual Teachers (Japanese & English)	5			
Monolingual Children (Japanese)	12	6		6
TOTAL	36			

For the developmental study, only the three groups of immersion

children participated as subjects. The total number of subjects in the longitudinal study was 19. Table 4-2 shows the profile of each subject. The first four columns indicate the immersion children learning Japanese as a foreign language and the rest of the four columns both the immersion teachers and the monolingual Japanese speakers. In the home language column, the first is a father's native language and the second a mother's native language.

Table 4-2 Subject profiles

ID#	GRADE	SEX	HOME LANGUAGE	ID#	GRADE	SEX	HOME LANGUAGE
G11	1	M	Japanese / English	IT1	Teacher	F	Japanese
G12	1	F	English / English	IT2	Teacher	F	English & Japanese
G13	1	F	Hebrew / English	IT3	Teacher	F	Japanese
G14	1	F	English / English	IT4	Teacher	F	Japanese
G15	1	F	English / Spanish	IT5	Teacher	F	Japanese
G16	1	M	English / English	MG11	1	M	Japanese / Japanese
G17	1	M	English / English	MG12	1	F	Japanese / Japanese
G31	3	F	English / English	MG13	1	M	Japanese / Japanese
G32	3	M	English / English	MG14	1	F	Japanese / Japanese
G33	3	F	English / English	MG15	1	F	Japanese / Japanese
G34	3	F	English / English	MG16	1	M	Japanese / Japanese
G35	3	M	Chinese / English	MG51	5	M	Japanese / Japanese
G36	3	F	English / Japanese	MG52	5	F	Japanese / Japanese
G51	5	F	English / English	MG53	5	F	Japanese / Japanese
G52	5	M	Japanese / English	MG54	5	M	Japanese / Japanese
G53	5	F	Hungarian (single mother) /	MG55	5	F	Japanese / Japanese
G54	5	F	English / English	MG56	5	M	Japanese / Japanese
G55	5	M	English / English				
G56	5	F	Chinese / English				

G1 = Immersion children in grade 1
G3 = Immersion children in grade 3
G5 = Immersion children in grade 5
IT = Immersion teachers
MG1 = Monolingual children in grade 1
MG5 = Monolingual children in grade 5

4.2 Procedures

The Japanese data for the bilingual children were collected two times (i.e., Time 1 and Time 2) with a two and a half month interval from the

children in grades 1, 3 and 5 (N=19) in the Japanese immersion program. Time 1 data were collected in March and April, 1998 and Time 2 data were collected two and a half months later. English data of the same bilingual children were also elicited only once between Time 1 and Time 2 to cross-sectionally compare their English and Japanese VOT. Each session consisted of a 20-minute face-to-face pronunciation elicitation test administered before or after school. Each child's data were audio-taped as he/she interacted with the experimenter in a quiet classroom. During each session the child was shown pictures of objects which had been designed to elicit words beginning with or including the target voiceless stop consonants. The recordings were made using a SONY tape recorder with a tie-clip type directional microphone. The data from the immersion teachers and the native speakers of Japanese were collected in June 1998, using the same method only once.

To maximize the children's attention span, each session for Japanese data was divided into two sub-sessions with a short break between them. In each of the Japanese sub-sessions, half (35 words) of the randomized words were elicited. But since the English VOT corpus was short, all 27 words were elicited in only one session. Also, to allow the subjects time to grow accustomed to the task, several non-target tokens were added before and after each sub-session.

4.3 Materials (Corpus)

Due to phonological differences between English and Japanese, I could not find lists of matched Japanese words in the same vowel environment. But the words were selected taking into consideration the following criteria: (1) the following vowel quality ([a] for Japanese words or [œ] for English

words) (the high vowels were excluded because they are likely to be devoiced in Japanese), (2) disyllabic words, (3) the same accent or stress pattern (HL for Japanese VOT data, LH for singletons and LHH for geminates, and stress on the first syllable for English VOT data) and (4) concrete words so that they can be easily elicited from children. Following a picture cue, the subjects were asked to say a word, inserting it in the Japanese carrier phrase *sore wa* _____ *desu* (=That is _____) or in the English carrier phrase "I see a _____ in the picture." The subjects were asked to repeat each word in the VOT and geminate corpus three times, while they repeated the words in the single consonant corpus four times to balance out the number of the tokens in each category. The corpus was as follows:

Japanese VOT corpus

Sentence frame: *Sore wa* _____ *desu* (=That is _____)

/p/[8]	/t/	/k/
papa (papa)	tako (octopus)	kame (turtle)
pari (Paris)	tane (seed)	kata (shoulder)
	tate (length)	kasa (umbrella)

English VOT Corpus

Sentence frame: I see a _____ in the picture.

/p/	/t/	/k/
panda	tablet	carrot
parrot	tadpole	camel
package	taxi	candy

[8] Only two lexicalized loan words were used for [p] of the VOT corpus in Japanese because [p] does not occur in initial position in Japanese words (Shibatani 1990, p. 163). Since *papa* is more lexicalized in Japanese than *pari*, the subjects were asked to repeat *papa* six times and *pari* three times, i.e. *papa* was used twice as a word with initial /p/.

Japanese Geminate Consonant Corpus

Sentence frame: Sore wa _____ desu (=That is _____)

/pp/	/tt/[9]	/kk/
kappa (imaginary animal)	batta (grasshopper)	mikka (the third day)
happa (leaves)	katta (bought)	yokka (the fourth day)
rappa (trumpet)	natta (rang)	makka (very red)

Japanese Single Consonant Corpus

Sentence frame: Sore wa _____ desu (=That is _____)

/p/[10]	/t/	/k/
papa (papa)[11]	hata (flag)	taka (hawk)
	kata (shoulder)[12]	saka (slope)

4.4 Data Measurement

VOT

Each of the experimental words occurred three times on each list. This means that the total number of tokens for the Japanese VOT corpus was 972 tokens at Time 1 (7 words x 3 repetitions x 36 subjects + 1 word x 6 repetitions x 36 subjects) and 513 tokens (7 words x 3 repetitions x 19 subjects + 1 word x 6 repetitions x 19 subjects) at Time 2. For the English corpus there were 648 tokens (9 words x 3 repetitions x 24 subjects). Tables 4-3 and 4-4 summarize the number of words and repetitions and the total number of tokens elicited

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[9] Except for *batta* (grasshopper), only verbs were possible in this phonetic environment because /ta/ is the past morpheme in Japanese. To elicit these abstract words, I used pictures and contextual cues.

[10] Shibatani (1990, p. 166) mentions that "the distribution of *p* is extremely limited in the native and Sino-Japanese vocabularies" and adds that "specifically, the distribution of *p* is limited to the environment of consonant clusters, e.g. *yappari* (as expected), *simpai* (worry)." Therefore, only one word with the intervocalic singleton /p/ was found in this phonetic environment (i.e., the word *papa*).

[11] Since there was only one word, eight repetitions of this word were required.

[12] The two words, *papa* (papa) and *kata* (shoulder) in the single consonant corpus have an accent pattern different from the other words in the corpus. But it was found in the pilot study that there is no effect of accent on the closure duration of a single consonant ($t = 0.597$, $df = 7$, $p = 0.57$).

for each group.

Table 4-3 The total number of tokens elicited for Japanese VOT

	p VOT	t VOT	k VOT	TOTAL
Words	2	3	3	
Repetitions	6 or 3	3	3	
Total Tokens	9	9	9	27
G1 (N = 7)	63	63	63	
x 2 times	126	126	126	378
G3 (N = 6)	54	54	54	
x 2 times	108	108	108	324
G5 (N = 6)	54	54	54	
x 2 times	108	108	108	324
MG1 (N = 6)	54	54	54	162
MG5 (N = 6)	54	54	54	162
IT (N = 5)	45	45	45	135
TOTAL				**1485**

G1 = Immersion children in grade 1
G3 = Immersion children in grade 3
G5 = Immersion children in grade 5
MG1 = Monolingual children in grade 1
MG5 = Monolingual children in grade 5
IT = Immersion teachers

Table 4-4 The total number of tokens elicited for English VOT

	p VOT	t VOT	k VOT	Total
Words	3	3	3	
Repetitions	3	3	3	
Total Tokens	9	9	9	27
G1 (N = 7)	63	63	63	189
G3 (N = 6)	54	54	54	162
G5 (N = 6)	54	54	54	162
IT (N=5)	45	45	45	135
TOTAL				**648**

The Computerized Speech Lab (CSL) was used for data measurement. The VOT of initial stops was measured to the nearest millisecond from the beginning of the release burst to the onset of voicing energy in F2 formants. Also, the waveform was used as secondary information. A total of 6 mean VOT values for initial /p, t, k/ were calculated for each immersion child at

both Time 1 and Time 2. For the cross-sectional study only the VOT data collected at Time 1 were used.

Closure Duration

For the cross-sectional study, in which the data collected at Time 1 were only used, the total number of tokens elicited for the geminate corpus was 972 tokens (= 9 words x 3 repetitions x 36 subjects) and 864 tokens (4 words x 4 repetitions x 36 subjects + 1 word x 8 repetitions x 36 subjects) for the single consonants. For the longitudinal study, the same procedures were repeated at Time 2 to observe the immersion children's development; therefore, the total number of tokens elicited for the geminate corpus was 513 tokens (= 9 words x 3 repetitions x 19 subjects) and 456 tokens (4 words x 4 repetitions x 19 subjects + 1 word x 8 repetitions x 19 subjects) for the single consonants. The number of tokens that were elicited for Japanese closure duration is illustrated in Table 4-5:

Table 4-5 The total number of tokens elicited for Japanese closure duration

	pp	tt	kk	p	t	k	TOTAL
Words	3	3	3	1	2	2	
Repetitions	3	3	3	8	4	4	
Total Tokens	9	9	9	8	8	8	
G1(N = 7) x 2 times	126	126	126	112	112	112	714
G3(N = 6) x 2 times	108	108	108	96	96	96	612
G5(N = 6) x 2 times	108	108	108	96	96	96	612
MG1(N = 6)	54	54	54	48	48	48	306
MG5(N = 6)	54	54	54	48	48	48	306
IT (N = 5)	45	45	45	40	40	40	255
TOTAL	495	495	495	440	440	440	**2805**

The Computerized Speech Lab (CSL) was used for data measurement. First, to verify that there is no significant difference in the speech rate of each subject between single and geminate consonants, the length of the sentence frames was compared. Also, as a reference of speech rate, a part of the

sentence initial word, /orewa/, was measured. The sentence initial /s/ was not included because the beginning point of a voiceless alveolar fricative /s/ was not always clear. The starting point of /o/ was identified by the beginning of F2 and the ending point of /a/ was defined by a cessation of energy in the region of F2 and higher formants. The reason for using the second formant as the criterion is that a high vowel F1 can be confused with F0 energy. Also, the waveform was used as a secondary reference.

The closure duration of both singletons and geminates was measured up to 0.1 ms. The voiceless stops, [p], [pp], [t], [tt], [k] and [kk], were identified by a gap on the spectrogram showing the stop closure. The beginning of the closure was defined by a cessation of F2 of the preceding vowel and the end of the closure by the burst of the following single or geminate consonant. When the burst was not visible, it was measured up to the beginning of frication. Also, VOT following the burst was not included in the closure duration of the stop because the target was the closure of the stops.

A total of 6 mean closure duration values were calculated for each subject. The 3 mean closure duration values for /pp, tt, kk/ were calculated based on 9 observations. The other 3 mean closure duration values for /p, t, k/ were obtained based on 8 observations. For the immersion children, the same number of the mean values was calculated for Time 2 as well as Time 1.

In addition, to examine the relation between moras and syllables, the duration of the second syllables for three 'two-mora two-syllable' words (e.g., *kata*) and three 'three-mora two-syllable' words (e.g., *katta*) was measured. For example, for the contrast between *kata* (shoulder) and *katta* (bought) the duration of the syllables /ta/ and /tta/ was measured to examine the

realization of the mora.[13] The duration of the whole target word beginning with a stop was not obtained since some subjects made a slight pause before it, which did not allow us to identify the beginning of the closure of the initial stop consonant.

Measurement reliability was evaluated with the test-retest approach. I remeasured 100 randomly selected sentence frame tokens and 96 randomly selected duration closure tokens one or two months later. The first and second sets of measurements were highly correlated ($r = 0.981$ for sentence frames, $p < 0.0001$; $r = 0.978$ for closure tokens, $p < 0.0001$).

[13] We are aware of the fact that the syllable boundary of the word is in the middle of the geminate (e.g., Tsujimura, 1996). Thus, phonologically, the first part of the geminate belongs to the preceding syllable, and the second part belongs to the following syllable. However, since there is no acoustic cue in the middle of the geminate corresponding to the syllable boundary, we measured the duration of the whole geminate and the following vowel as the duration of the second syllable.

CHAPTER 5

VOICE ONSET TIME

5.1 Acquisition of VOT: Cross-sectional study

Across grade levels

Figure 5-1 shows the mean VOT values for Japanese voiceless stops by the Japanese monolingual children (MJ), the immersion teachers (IJT), and the immersion children (IJ), and the mean VOT values for English counterparts by the immersion teachers (IET) and the immersion children (IE).

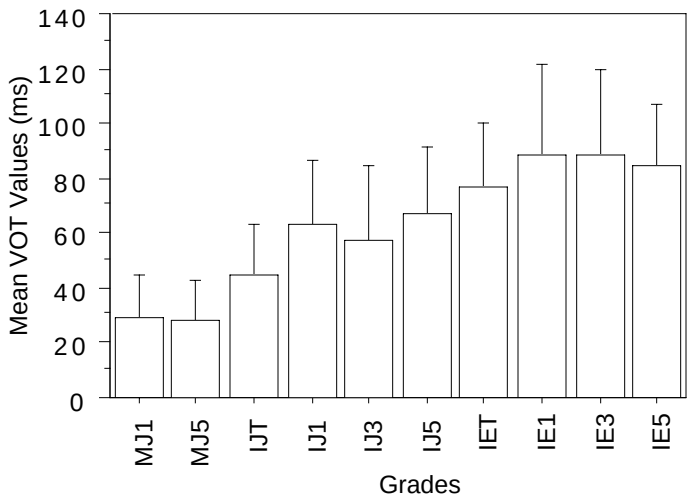

Figure 5-1 The mean VOT values for Japanese and English voiceless stops by the Japanese monolingual children, the immersion teachers, and the immersion children. The error bars enclose +/- one standard deviation.
Legend
Number in the end shows a grade level.
MJ = Japanese VOT values for monolingual Japanese children
IJT = Japanese VOT values for immersion teachers
IJ = Japanese VOT values for immersion children
IET = English VOT values for immersion teachers
IE = English VOT values for immersion children
X-axis = Grades
Y-axis = Mean VOT values (ms)

As expected, the monolingual Japanese speakers' voiceless stops had substantially shorter VOT values than those of the immersion children's English, including the immersion teachers (28 to 30 ms vs 85 to 89 ms). Also, all the Japanese immersion students produced Japanese voiceless stops with longer VOT values than both the monolingual Japanese children and the immersion teachers (58 to 67 ms vs 28 ms and 45 ms respectively), while the immersion students' Japanese voiceless stops had substantially shorter VOT values than their English voiceless stops (58 to 67 ms vs 85 to 89 ms). The mean VOT values obtained for each of the 36 subjects were submitted to a (10) Grade one-way ANOVA. The analysis yielded a significant group main effect [$F(9, 1606) = 147.635$, $p < 0.0001$]. Scheffe post hoc tests revealed that the immersion children produced Japanese voiceless stops with significantly longer VOT values than the monolingual Japanese children and the immersion teachers, but they produced them with significantly shorter VOT values than their English VOT ($p < 0.0001$). This suggests that the immersion students are making a phonetic distinction in VOT values between Japanese and English. In other words, the mean VOT values for Japanese voiceless stops produced by the immersion children are between their own English VOT values and the VOT values of the monolingual Japanese children.

The immersion children, who are at a stage when the critical period has not ended, have not completely reached the native speakers' phonetic norm and are at an intermediate stage between their native English norm and the native Japanese subjects' norm. These findings suggest that even those children who have acquired good pronunciation may tend to have their phonetic categories affected by their dominant language at the acoustic

level. For comparisons made only within the immersion children, one factor ANOVA analysis showed that there was a Grade main effect [$F(2, 502) = 5.668$, $p < 0.0037$]. The Scheffe post hoc test revealed that the children in grade 3 produced the voiceless stops with significantly shorter VOT values than those in grade 5. This may be attributed to the regression mentioned in Snow and Campbell (1983), in which the higher graders did not show any improvement.

Across places of articulation

The line plot (Figure 5-2) will demonstrate the differences in VOT values across places of articulation for all of the subjects.

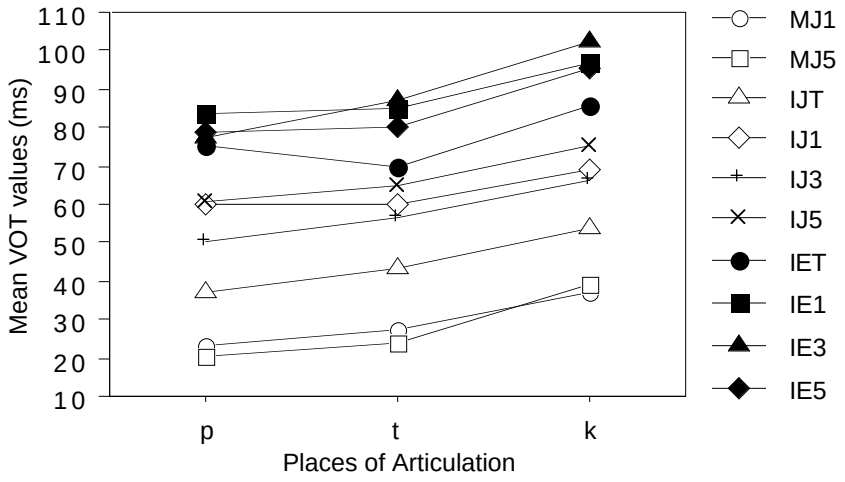

Figure 5-2 The differences in VOT values across places of articulation for all of the subjects.

The mean VOT values obtained for each of the 36 subjects were submitted to a (10) Grade and (3) Place of Articulation ANOVA, which yielded a significant grade main effect [Grade, $F(9, 1586)=160.734$, $p < 0.0001$; Place, $F(2, 1586) = 67.310$, $p < 0.0001$], but there was no interaction between Grade and Place [Grade * Place, $F(18, 1586) = 0.726$, $p = 0.7865$]. The duration pattern of VOT relative to the place of articulation is similar across all three grade levels:

VOT is shortest for /p/ and longer for /t/ and /k/ ($p < 0.05$). Therefore, regardless of the place of articulation, the mean VOT values produced by the immersion subjects were greater than those of the monolingual Japanese subjects. This finding does not support Williams' (1980) and Flege, Munro and MacKay's (1995a) claim that the acquisition of VOT varies across places of articulation.

Distinction between Japanese and English VOT

This study clearly suggests that the immersion children have not reached the native speaker's phonetic norm, but that they make a clear distinction between their Japanese and English phonetic norms. The mean Japanese and English VOT values for only the immersion children were submitted to a Group (6) one factor ANOVA and the results show that there was a significant main effect [$F(5, 1006) = 44.425$, $p < 0.0001$]. Scheffe post hoc tests revealed that there is a significant difference between the immersion groups' Japanese VOT and English VOT ($p < 0.0001$). Figure 5-3 illustrates that the immersion children make a distinction between the Japanese and English VOT values. This means that the immersion groups, who are at a stage when the critical period has not ended, have successfully established two different phonological systems, though their Japanese system is not the same as that of the native Japanese children. In other words, the bilingual children have two systems, one of which is at an intermediate stage in terms of the native speaker's norm for their Japanese system and the other is their L1 English system.

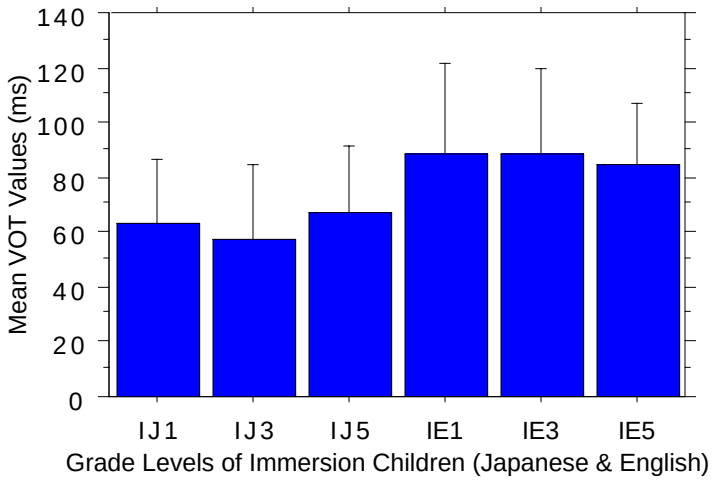

Figure 5-3 The mean Japanese and English VOT values for the immersion children. The error bars enclose +/- one standard deviation.

This finding supports the following hypothesis from Flege (1995):

> The L2 speaker's category may deviate from an L1 speaker's "to maintain phonetic contrast between categories in a common L1-L2 phonological space" or the L2 category may be "based on different features, or feature weights, than a monolingual's."

Therefore, it is plausible to conclude that Japanese immersion students have acquired an intermediate category for the features for VOT. As Flege (1991, p. 395) suggests, "complete separation of sounds in the L1 and L2 phonetic inventories" seems to be possible at least for such early learners as the immersion children.

5.2 Acquisition of VOT: Developmental study

Across grade levels

Figure 5-4 shows the mean VOT values for Japanese voiceless stops

produced by the immersion children at Time 1 and Time 2. The mean VOT value of Japanese monolinguals is given as a reference with a horizontal line just above 30 ms. Table 5-1 indicates the differences in VOT values between Time 1 and Time 2. Negative values in the difference column mean that the subjects have come closer to the native speaker's phonetic norm than they were at Time 1, and positive values show that these children were further away from the native speakers' norm and they made no improvement of the VOT values within a period of two and half a months.

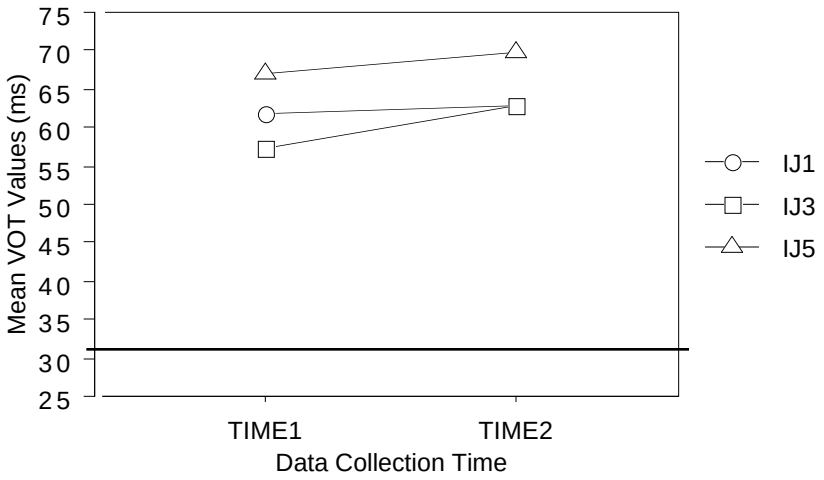

Figure 5-4 The mean VOT values for Japanese voiceless stops produced by the immersion children at Time 1 and Time 2.The line at 30 ms shows the native speakers' norm of the Japanese monolingual children.

Table 5-1
Mean VOT values (ms) at Time 1 and Time 2
and differences (ms) between them

	Time 1	Time 2	**Difference**
Grade 1	63.08	61.85	**-1.23**
Grade 3	57.68	62.99	**5.32**
Grade 5	66.97	70.02	**3.06**

At Time 2 as well, the Japanese immersion students produced longer

VOT values in Japanese (63 to 70 ms) than both the monolingual Japanese speakers (28 to 30 ms) and the immersion teachers (45 ms). The mean VOT values obtained for each immersion child at Time 1 and Time 2 were submitted to a Grade (3) repeated-measure ANOVA, which yielded a significant Grade and Development effect [Grade, $F(2, 474) = 7.126$, $p = 0.0009$; Development, $F(1, 474) = 5.216$, $p = 0.0228$], but there was no interaction between Development and Grade [$F(2, 474) = 0.923$, $p = 0.3981$]. Scheffe post hoc tests indicated that there was a significant difference in the VOT values between Time 1 and Time 2 and that the immersion children in Grade 5 produced Japanese voiceless stops with significantly longer VOT values at both Time 1 and Time 2 than the other grade groups. This suggests that since the VOT values significantly increased away from the Japanese norm within the period of two and a half months, the immersion students did not make any progress in the production of Japanese VOT and that Grade 5 students were producing longer VOT values than Grade 1 and 3 students, indicating that their production may be deteriorating in this area and becoming even more English-like.

Across places of articulation

Figure 5 shows the development of the mean VOT values across places of articulation for the immersion children at Time 1 and Time 2. Table 5-2 shows that for the bilingual immersion students there is only a small difference in Japanese VOT values of initial /p, t, k/ between Time 1 and Time 2. The difference varies from -4.92 to 11.72 ms with a range of 16.64 ms.

The line plot (Figure 5-5) clearly demonstrates no progress in VOT values within this period. Visual inspection of the figure shows that the VOT value of /p/ for only one group (Grade 1), indicated by an empty circle, has

begun to approximate the average VOT values of the Japanese monolinguals and the immersion teachers with 4.92 ms of improvement. But the other four VOT values (/k/ of Grade 1, /p, t/ of Grade 3 and /t/ of Grade 5) indicate an increase from Time 1 to Time 2, which means that the immersion students' performance has deteriorated. In addition, the remaining four VOT values (/t/ of Grade 1, /k/ of Grade 3 and /p, k/ of Grade 5) show almost no increase or decrease, in which cases we can observe no progress at all. These results suggest that no improvement in their production of the VOT values has been observed from Time 1 to Time 2.

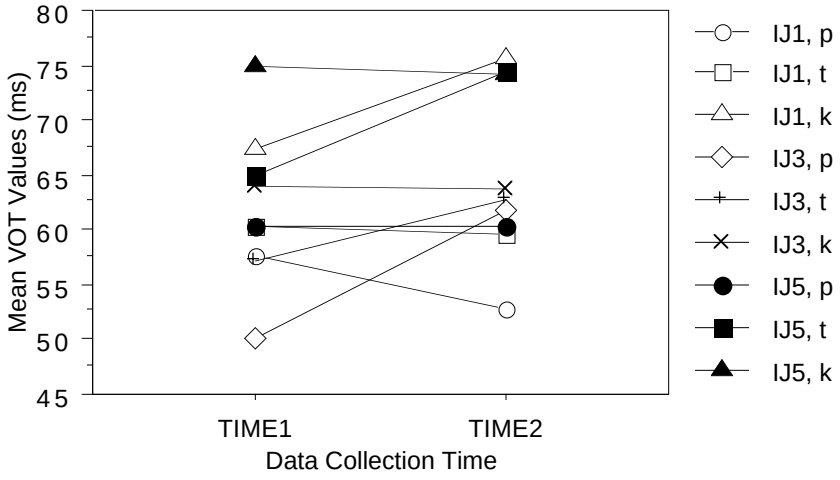

Figure 5-5 The development of the mean VOT values across places of articulation for the immersion children at Time 1 and Time 2.

Table 5-2

Mean VOT values (ms) for /p, t, k/ at Time 1 and Time 2 and differences (ms) between them

	/p/ Time 1	/p/ Time 2	**Difference**	/t/ Time 1	/t/ Time 2	**Difference**	/k/ Time 1	/k/ Time 2	**Difference**
Grade 1	57.64	52.72	**-4.92**	60.34	59.53	**-0.81**	67.47	75.74	**8.27**
Grade 3	50.10	61.82	**11.72**	57.19	62.67	**5.48**	63.85	63.64	**-0.21**
Grade 5	60.23	60.20	**-0.03**	64.81	74.34	**9.53**	74.97	74.27	**-0.70**

In order to see whether there is any significant difference in the VOT values of word initial /p, t, k/ in each group between Time 1 and Time 2, the mean VOT values obtained for each of the 19 subjects at both Time 1 and Time 2 were submitted to a (3) Place of Articulation repeated-measure ANOVA separately in each grade, which yielded a significant Development main effect [$F(1, 145)=6.755$, $p=0.0103$] in Grade 3 and no significant effect of Development [Grade 1, $F(1, 167)=0.111$, $p=0.7400$; Grade 5, $F(1, 156)=1.684$, $p=0.1963$] in both grades 1 and 5. Figure 5 shows that the immersion children in Grade 3 produced Japanese /p, t/ with significantly longer VOT values at Time 2 than at Time 1. In other words, their performance was worse at Time 2.

In sum, the immersion children at all grade levels have not significantly improved their production of VOT of initial stops during the period of two and a half months. The results show that there is no variation across grade levels in the development of VOT values nor any variation across places of articulation in the order of acquisition of VOT.

In addition, the fact that there was no progress at grades 3 and 5 may in part be attributed to the regression observed in previous studies (e.g., Genesee's, 1987; Snow & Campbell, 1983). On the other hand, there is a trend, not significant, that a slight improvement was observed in the production of /p/ by the first graders, which means that the immersion children in grade 1 produced /p/ with shorter VOT values at Time 2 than at Time 1. This finding may support the hypothesis which holds that younger is better (ultimate attainment) (Larsen-Freeman & Long, 1991). It is worth noting that a follow-up research study on the development of these immersion children's VOT may show how long it will take them to improve it and whether younger is

in fact better.

CHAPTER 6

CLOSURE DURATION

6.1 Speech Rate

The duration of any speech segment is very sensitive to speech rate; therefore, the duration of part of one adjacent word of the frame sentences, *orewa*, was measured for each utterance to examine if the speech rate was consistent. Two mean values for the duration of *orewa* followed by a target word with a singleton and a geminate respectively were compared using a t-test within speakers to see whether or not there was any significant difference in the speech rate between the utterances including singletons and those with geminates. Tables 6-1 and 6-2 show the mean duration values of the frame sentences for singletons and geminates and the results of the t-test procedure.

Table 6-1 Mean duration of part of the adjacent word, *orewa*, for singleton and geminate utterances for the monolinguals and immersion teachers

Time 1 or Time 2	Subject	Mean duration of geminate utterance (ms)	S.D.	Mean duration of singleton utterance (ms)	S.D.	t-value	p-value
Time 1	MG11	419.02	78.20	367.25	86.72	2.219	**0.031***
Time 1	MG12	375.04	95.99	325.14	69.10	2.094	**0.042***
Time 1	MG13	412.22	84.73	399.75	70.80	0.566	0.574
Time 1	MG14	398.08	46.48	388.92	36.06	0.779	0.439
Time 1	MG15	463.40	49.38	480.84	46.48	-1.283	0.206
Time 1	MG16	356.39	92.62	340.93	105.50	0.546	0.588
Time 1	MG51	316.17	26.39	303.10	29.13	1.681	0.099
Time 1	MG52	287.37	43.74	294.14	68.07	-0.425	0.673
Time 1	MG53	339.39	40.90	325.18	41.24	1.222	0.228
Time 1	MG54	466.57	35.35	475.43	30.49	-0.933	0.355
Time 1	MG55	277.64	53.82	245.73	47.53	2.143	**0.038***
Time 1	MG56	280.21	36.67	267.61	24.91	1.416	0.163
Time 1	IT1	279.06	55.80	285.74	88.39	-0.323	0.748
Time 1	IT2	312.77	28.74	308.07	37.82	0.493	0.624
Time 1	IT3	380.74	98.02	356.36	140.22	0.726	0.471
Time 1	IT4	288.80	58.45	261.14	27.84	2.049	**0.047***
Time 1	IT5	265.61	47.06	250.16	23.85	1.45	0.153

Table 6-2 Mean duration of part of the adjacent word, *orewa*, for singleton and geminate utterances for the immersion children

Time 1 or Time 2	Subject	Mean duration of geminate utterance (ms)	S.D.	Mean duration of singleton utterance (ms)	S.D.	t-value	p-value
Time 1	G11	304.00	97.23	267.63	57.85	1.597	0.117
Time 1	G12	778.30	118.49	842.72	144.58	-1.729	0.090
Time 1	G13	383.82	121.74	378.36	125.40	0.145	0.886
Time 1	G14	657.54	213.41	615.92	157.26	0.769	0.446
Time 1	G15	554.74	119.57	539.71	85.98	0.444	0.660
Time 1	G16	618.13	100.59	613.41	914.94	0.171	0.865
Time 1	G17	630.65	124.95	596.59	110.79	0.998	0.324
Time 1	G31	372.37	105.98	408.15	130.68	-1.055	0.297
Time 1	G32	420.46	215.50	332.83	217.90	1.23	0.227
Time 1	G33	416.61	69.24	438.65	139.12	-0.692	0.493
Time 1	G34	475.10	64.16	478.18	97.35	-0.135	0.894
Time 1	G35	476.08	143.71	501.94	186.36	-0.536	0.594
Time 1	G36	338.43	79.00	318.15	93.89	0.821	0.416
Time 1	G51	451.52	164.56	389.96	93.82	1.58	0.121
Time 1	G52	392.01	121.63	335.65	88.14	1.737	0.089
Time 1	G53	555.66	95.12	528.56	134.88	0.774	0.443
Time 1	G54	536.85	220.30	439.94	207.83	1.578	0.121
Time 1	G55	390.81	112.21	379.35	135.88	0.33	0.743
Time 1	G56	473.11	79.01	470.98	77.58	0.097	0.923
Time 2	G11	382.09	124.55	236.85	100.78	4.386	**< .0001***
Time 2	G12	635.28	132.87	627.72	108.64	0.218	0.829
Time 2	G13	371.61	82.56	365.79	89.98	0.236	0.814
Time 2	G14	419.82	119.86	395.87	148.74	0.636	0.527
Time 2	G15	455.35	176.28	338.97	96.09	2.755	**0.008***
Time 2	G16	552.11	69.39	564.70	83.20	-0.577	0.567
Time 2	G17	549.31	101.15	561.85	148.38	-0.347	0.730
Time 2	G31	374.49	117.01	339.40	54.15	1.318	0.194
Time 2	G32	472.34	159.99	454.78	155.98	0.391	0.697
Time 2	G33	363.09	107.98	330.64	108.03	1.05	0.299
Time 2	G34	475.86	51.68	473.47	49.77	0.168	0.868
Time 2	G35	394.56	84.31	461.65	151.99	-1.95	0.057
Time 2	G36	343.29	97.83	367.85	115.86	-0.812	0.421
Time 2	G51	372.00	80.77	377.02	124.33	-0.173	0.864
Time 2	G52	339.32	89.11	305.01	85.68	1.397	0.169
Time 2	G53	438.88	96.68	410.81	89.99	1.029	0.309
Time 2	G54	459.01	150.94	425.51	146.70	0.795	0.431
Time 2	G55	399.06	82.43	401.70	101.40	-0.103	0.919
Time 2	G56	538.15	117.80	470.23	73.64	2.432	**0.019***

The tables show that only 7 (12.7%) of the 55 subjects, including the data for

Time 2, produced utterances with singletons and geminates at significantly different speech rates. This tendency was observed through all the groups. Among these 7 subjects, 3 are from the monolinguals, 3 are from the immersion children, and 1 is from the immersion teachers. Therefore, we believe that it is safe to compare the closure duration values of these groups in absolute terms. This is verified in Section 6.3 by showing that the patterns found based on relative closure duration values are the same as those found based on absolute closure duration.

6.2 Absolute Closure Duration

Across grade levels

Figure 6-1 shows the results of the analysis of stop consonant closure duration for the monolingual Japanese speakers, the bilingual immersion teachers, and the Japanese immersion children. The x-axis indicates each subject group and the y-axis the mean closure duration. The figure shows that the monolingual Japanese speakers and the bilingual immersion teachers make a clear distinction between single and geminate consonants: their singletons were produced with much smaller duration values than the geminates. In terms of absolute values, the geminates were more than two times the length of the single consonants (MJ1, 188 ms vs 98 ms; MJ5, 168 ms vs 73 ms; IJT, 181 ms vs 75 ms) except for the monolingual first graders. Visual inspection shows that the monolingual Japanese speakers who were in grade 1 produced singletons with clearly longer closure duration values than the 5th graders and they also tended to make the geminates a little longer than the other monolingual group. On the other hand, the immersion students' mean duration values for the singletons are much longer than

those of the monolingual speakers and come closer to the values for the geminates produced by the monolingual speakers (IJ1, 222 ms vs 138 ms; IJ3, 193 ms vs 140 ms; IJ5, 224 ms vs 139 ms).

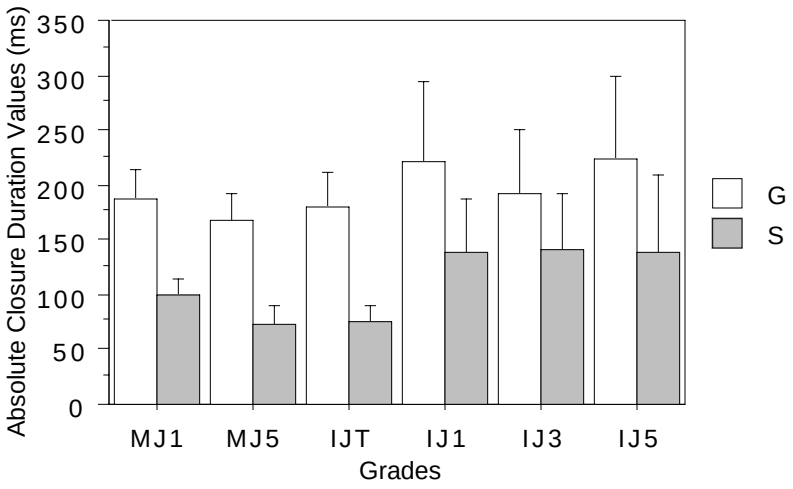

Figure 6-1 The mean closure duration of singletons and geminates for the monolingual Japanese speakers, the bilingual immersion teachers, and the Japanese immersion children. The error bars enclose +/- one standard deviation.

Legend
MJ1 = monolingual Japanese speakers in grade 1
MJ5 = monolingual Japanese speakers in grade 5
IJT = bilingual immersion teachers
IJ1 = bilingual immersion children at grade 1
IJ3 = bilingual immersion children at grade 3
IJ5 = bilingual immersion children at grade 5
G = geminates
S = singletons

Figure 6-2 clarifies the monolingual speakers' clear differentiation between the single and geminate consonants and the immersion students' tendency to produce both types of stops with longer values.

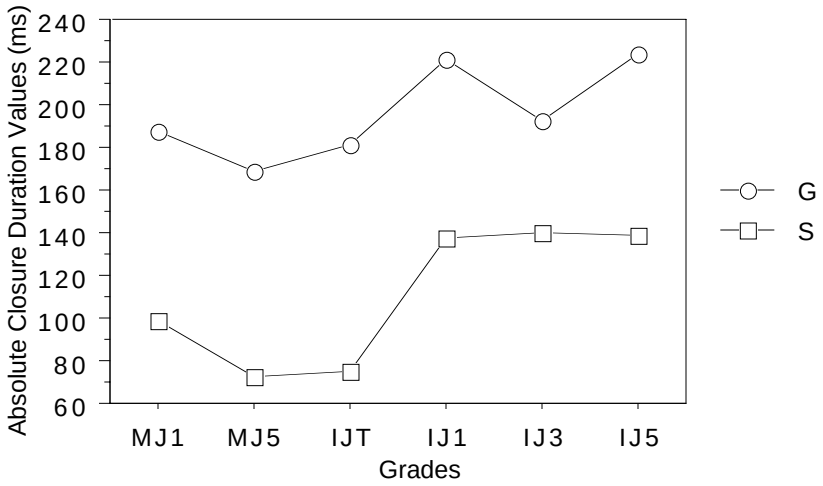

Figure 6-2 The monolingual speakers', the immersion teachers', and the immersion children's differentiation between the single and geminate consonants

Although the geminates of the immersion students were clearly longer than their singletons, the differences between them were much smaller than those of the monolinguals and the immersion teachers. The closure duration of the immersion children's single consonants ranged from 125 ms to 160 ms while their geminates varied from 180 ms to 240 ms. This means that the distinction made by the immersion children between the single and geminate consonants is not as acoustically clear a distinction as that made by the native Japanese speakers.

The mean duration values obtained for each of the 36 subjects who produced both single and geminate consonants were submitted to a (6) Grade X (2) Type two factor ANOVA, which yielded a significant group main effect of Grade and Type and a significant interaction between Grade and Type (singletons and geminates) [Grade, $F(5, 1748)=85.752$, $p < 0.0001$; Type, $F(1, 1748) = 1327.799$, $p < 0.0001$; Grade * Type, $F(5, 1748)=9.356$, $p < 0.0001$]. The

Scheffe post hoc test revealed that all the groups significantly differentiated between the single and geminate consonants ($p < 0.0001$), though the immersion children's duration values tended to overshoot the native speakers' norms.[14]

Across places of articulation

In terms of place of articulation, no clear difference was found in the monolinguals' data between three different places of articulation for both single and geminate consonants. Figure 6-3 shows that among the monolingual speakers and the immersion teachers there were no differences between /p, t, k/ while both of the groups produced /pp/ with slightly longer duration values than /tt/ or /kk/. This result supports Han's (1992) finding that [pp] has longer durations than the other geminates. However, this is contrary to the fact that [p] as well is longer than the other singletons.

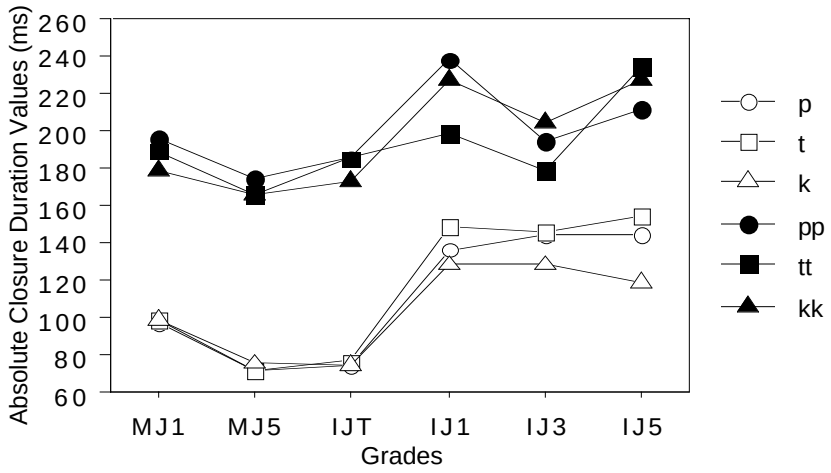

Figure 6-3 The mean closure duration of singletons and geminates across places of articulation for the monolingual Japanese speakers, the bilingual immersion teachers, and the Japanese immersion children.

[14] Since the difference in the closure duration values produced by the immersion children in grade 3 between the singletons and geminates was small, a Type (2) one-way ANOVA was conducted for their data separately, which yielded a significant main effect due to the types of consonants [$F(1, 284) = 66.007$, $p < 0.0001$].

The mean duration values obtained for each of the 36 subjects who produced both single and geminate consonants were submitted to a (6) Grade X (6) Place ANOVA, which yielded a significant main effect due to both Grade and Place and interaction between Grade and Place (types of stops: /p, t, k, pp, tt, kk/) [Grade, $F(5, 1724)=87.144$, $p < 0.0001$; Place, $F(5, 1724) = 273.515$, $p < 0.0001$; Grade * Place, $F(25, 1724)=3.721$, $p < 0.0001$]. The Scheffe post hoc test revealed that all the groups significantly differentiated between the single and geminate consonants in all places of articulation ($p < 0.0001$).[15] The Scheffe post hoc test also revealed that there were no significant differences between /p/, /t/ and /k/ and between /pp/, /tt/ and /kk/ (/p, t/, $p = .9975$; /t, k/, $p = .1376$; /p, k/, $p = .3632$: /pp, tt/, $p = .3450$; /tt, kk/, $p = .9361$; /pp, kk/, $p = .9076$). Although not statistically significant, the immersion children in Grades 1 and 5 produced an alveolar stop /t/ with slightly longer values than other places of articulation while only Grade 5 showed this pattern for the geminate stop, as show in Figure 6-3.

But with the singletons and geminates analyzed independently, the two-factor ANOVA showed significant main effects due to Grade and Place [Singletons: Grade, $F(5, 807) = 77.732$, $p < 0.0001$; Place, $F(2, 807) = 0.0038$] and [Geminates: Grade, $F(5, 917) = 28.858$, $p < 0.0001$; Place, $F(2, 917) = 0.1488$]. The Scheffe post hoc test showed that the immersion students' [k] was significantly shorter than their [p, t].

[15] Since the contrast between the singletons and geminates for grade 3 was not as clear as that of the other grades, their data were separately analyzed using a Place (5) one-way ANOVA, which revealed that there was a main effect due to Place. But Scheffe post hoc tests showed that there was no significant difference between /t/ and /tt/ ($p < 0.1219$). Since the Scheffe test was strict, it may be concluded that there was a tendency for them to make a difference between the two sounds.

Contrast between geminates and singletons

In order to examine the acoustic relation between the monolinguals' and immersion teachers' and the immersion children's production of both types of consonants, data have been collapsed into two categories; single and geminate consonants.

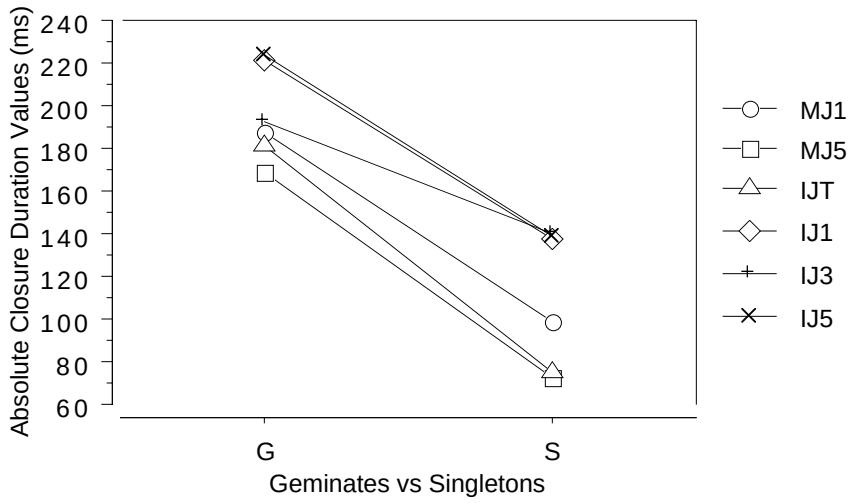

Figure 6-4 The contrast between geminates and singletons produced by the monolingual Japanese speakers, the bilingual immersion teachers, and the Japanese immersion children.

Figure 6-4 shows the differences in the production of closure duration between the 6 groups. S stands for a single consonant and G for a geminate. This figure clearly suggests that in terms of both single and geminate consonants the immersion students produced longer closure duration values than the monolingual children and the immersion teachers (except for the third graders in the geminates). This may suggest that the immersion children utilize a different phonetic category for the single and geminate consonants from that of both the monolinguals and the immersion teachers, though they can make a clear distinction between the two categories in their

phonological system. Also, for the immersion students it can be observed that the closure duration values for the geminates for grade 5 were longest, which makes these measures farthest from the monolingual speaker's norm while the geminates of grade 3 were shortest and closest to the monolinguals' values.

The Scheffe post hoc test revealed that all the immersion students performed differently from both the monolingual groups and the immersion teachers ($p < 0.0001$), though it also showed that the immersion children in grade 3 performed better in the production of geminates than the other two immersion groups ($p < 0.01$). But it should be pointed out that since the singletons of the immersion children in grade 3 are longer, and their geminates are closer to those of the monolinguals, the contrast between singletons and geminates is not as clear as that of the other two grades. In other words, they have not acquired the contrast.

6.3 Relative Closure Duration

Although the researcher controlled for rate of speech in collecting data from the subjects, it was observed that there had been some slight variations in the speech rate. To normalize these variations between subjects, the mean values of closure duration of /p, pp, t, tt, k, kk/ produced by each subject were converted first into the ratio with reference to the duration of part of the sentence frame, *orewa* and then the ratios of the single consonants were compared with those of the geminates by dividing the latter by the former. Figure 6-5 shows the ratios of the singletons and the geminates with reference to the sentence reference frame, *orewa*, for each group.

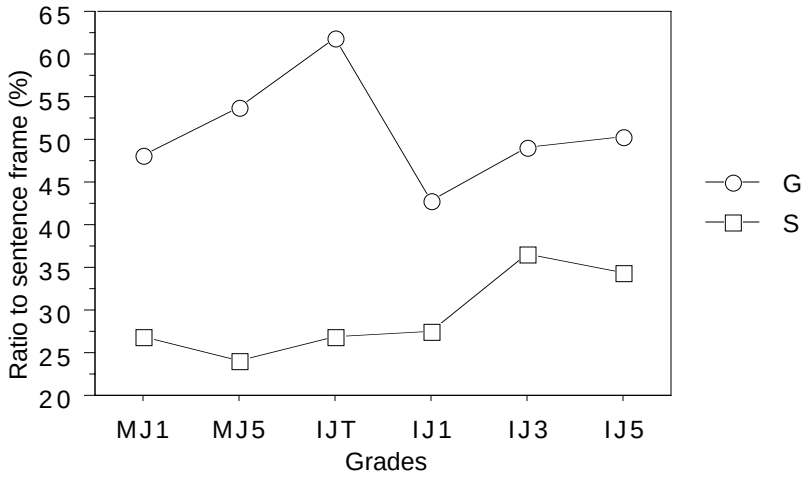

Figure 6-5 The ratios of the singletons and the geminates with reference to the sentence reference frame, *orewa*, for each group.

For the singletons, the first graders in the immersion program performed as well as the monolinguals and the immersion teachers. The immersion children in grades 3 and 5 produced single consonants with larger ratios with respect to the sentence reference frames than the other groups. On the other hand, the ratios for the geminates produced by the immersion children in grade 1 were smaller than those of the other groups. It was also noted that the immersion teachers' closure duration ratio values for the geminates were highest. In other words, the immersion teachers made the clearest phonetic distinction between the singletons and the geminates. This was different from their VOT data, in which their mean VOT values were longer than those of the monolingual speakers.

The mean ratios with reference to the sentence frame for both singletons and geminates were submitted to a (2) Type and (6) Grade two factor ANOVA. The analysis showed a significant Type and Grade main effect

and a significant interaction between Grade and Type [Grade, $F(5, 1738) = 20.069$, $p < 0.0001$: Type, $F(1, 1738) = 1112.911$, $p < 0.0001$; Grade * Type, $F(5, 1738) = 28.783$, $p < 0.0001$]. Sheffe post hoc tests revealed that the immersion children in grade 1 performed differently from the other two grades ($p < 0.0001$) and came close to the monolingual children in grade 1.

To examine the contrast between singletons and geminates in relative terms, the relative values obtained above were compared. Table 6-3 shows the ratios obtained by dividing the normalized closure duration of the geminates by that of the singletons.

Table 6-3
Mean ratios obtained by dividing normalized closure duration values of geminates by those of singletons

GROUP	RATIO	GROUP	RATIO
MJ1	1.79	IJ1	1.59
MJ5	2.24	IJ3	1.35
IJT	2.28	IJ5	1.47

The results indicate that the monolingual children and the immersion teachers had a ratio of geminates to singletons ranging from 1.79 to 2.28. On the other hand, it was clearly observed that the immersion children's ratios were smaller than those of both the monolinguals and the immersion teachers and that they ranged from 1.35 to 1.59. As we saw in Section 6.2 *absolute closure duration*, the ratio of grade 3 was smallest, which means that the third graders did not make as clear a distinction as the other two groups of the immersion children.

Figure 6-6 indicates the mean ratios of the geminates to the single consonants produced by the monolinguals, the immersion children and the immersion teachers.

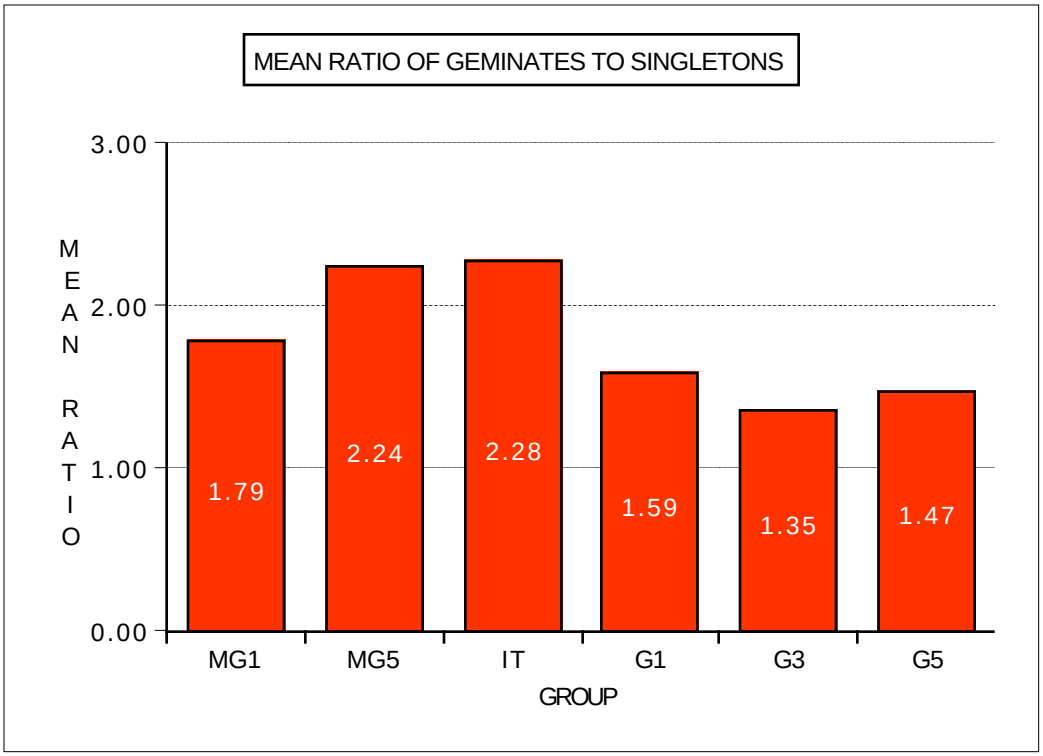

Figure 6-6 Mean ratios of geminates to singletons

The graph suggests that the geminate consonants produced by the monolingual children and the immersion teachers (adult bilinguals) are 1.8 to 2.3 times as long as their corresponding single consonants.[16] This result does not support Han's (1962) finding that geminates in word-medial position are 2.5 to 3.0 times as long as the singletons. Rather, the ratios obtained here are closer to those reported by Beckman (1982): 2.79 when VOT is not counted as part of the stop and 2.25 when VOT is included. Since in this research VOT is not included, the ratio (1.8 to 2.3) can be considered a little smaller than the ratio reported in previous studies.

[16] The short ratio of the monolingual first graders may be attributed to developmental factors.

6.4 Duration of Syllables and Moras

The duration of syllables in many languages tends to be isochronous while that of syllables in Japanese is not (Port, Dalby & O'Dell, 1987; Han, 1994). In Japanese, as Port, et al. (1987) report, the durations of two words with the same number of moras tend to be equal in spite of any differences in syllable structure. In order to examine the relationship in the durations of syllables and moras and how the immersion children acquire this timing feature, the durations of the second syllables for three two-mora words and for three three-mora words were compared across the groups of subjects in this study: two moras–pa<u>pa</u> (papa), ka<u>ta</u> (shoulder), sa<u>ka</u> (slope); three moras–ha<u>ppa</u> (leaves), ka<u>tta</u> (bought), and ma<u>kka</u> (very red). The mean durations of the second syllables of these words were compared, and then the ratios of the syllables, the 1 mora containing a single stop vs the 2 moras containing a geminate stop, were obtained, with the duration of the 1 mora syllable set to 1.00. Ratio data will be reported at the end of this section.

Across grade levels

Figure 6-7 shows the mean duration values of the second syllables of the words mentioned above produced by the monolingual Japanese speakers (MJ1 & MJ5), the immersion teachers (IJT) and the children in the Japanese Immersion Program (IJ1, IJ3 & IJ5). The duration values of the second syllables containing the single consonant produced by the monolingual Japanese speakers and the immersion teachers range from 170 ms to 218 ms, while those produced by the immersion children range from 270 ms to 310 ms. In contrast, the mean duration values of the second syllables containing the geminate range from 272 ms to 310 ms for the monolinguals and the immersion teachers while those for the immersion children are more varied

and show 321 ms to 395 ms. The comparison of the absolute values shows that the immersion children tend to overshoot both the monolinguals' and the immersion teachers' phonetic norms for both syllables containing singletons (one mora) and geminates (two moras).

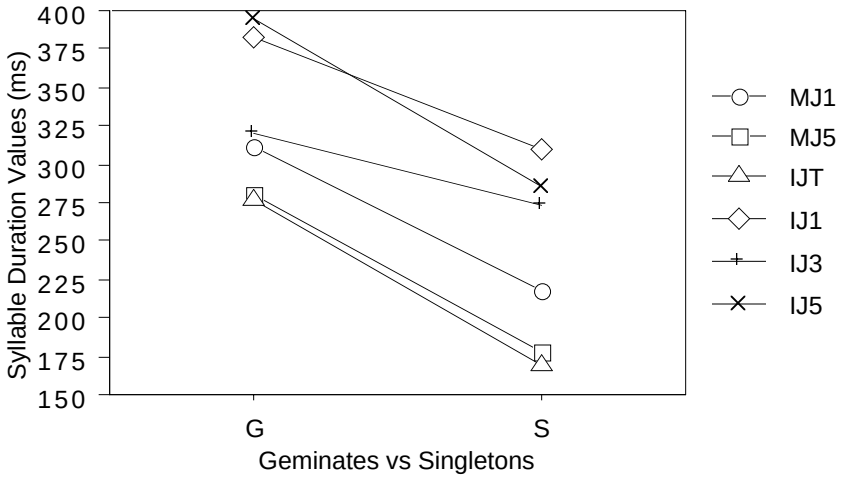

Figure 6-7 The mean duration values of one syllable containing one mora (singleton) and two moras (geminate).

A (2) Type and (6) Grade two factor ANOVA showed that there were significant main effects due to Type and Grade and a significant interaction between them [Type, $F(1, 738) = 276.529$, $p < 0.0001$; Grade, $F(5, 738) = 66.737$, $p < 0.0001$; Type * Grade, $F(5, 738) = 3.418$, $p < 0.0046$]. Scheffe post hoc tests revealed that all the immersion groups differed in the duration of the syllables from the monolingual children and immersion teachers ($p < 0.0035$). In other words, the immersion groups tended to produce both syllables with longer duration than the other groups. Also, the main effect due to the types of stops suggests that the immersion students can make a distinction between one syllable/one mora words and one syllable/two mora words, though the

differences between them tend to be smaller than those produced by the monolingual student and the immersion teacher groups. As observed in the previous sections, the third graders made a less clear distinction than the other two immersion groups.[17]

Across places of articulation

Figure 6-8 shows the duration of the 1 mora syllables containing a singleton and the 2 mora syllables containing a geminate for each group separated by places of articulation.

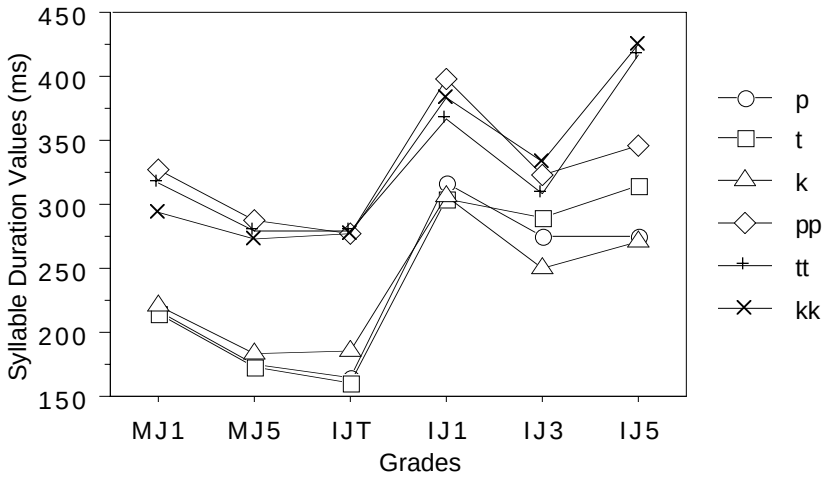

Figure 6-8 The mean duration values of one syllable containing one mora and two moras across places of articulation

A (6) Grade x (6) Place ANOVA was carried out to determine if the six groups of speakers differed significantly depending on different places of articulation for the stops. The analysis yielded a significant main effect due to Grade and Place [Grade, $F(5, 714) = 67.312$, $p < 0.0001$; Place, $F(5, 714) = 56.249$, $p < 0.0001$] and a significant interaction between Place and Grade [Grade * Place, F(25, 714)

[17] Since the contrast between the two types of consonants for grade 3 was small, the one-way ANOVA was conducted to see if there was a significant difference between them. Results showed that there is a significant effect of the type of consonants [$F(1, 122) = 11.055$, $p = 0.0012$].

= 1.785, p = 0.0109]. The Scheffe post hoc test revealed that the syllables containing a single consonant and a geminate were significantly different ($p < 0.0001$) but that there were no significant differences across places of articulation within the same type of stops (/p, t, k/ and /pp, tt, kk/) [n.s.].

The data for grade 5 was analyzed independently to check if there was any significant difference between the places of articulation within the same type of consonants. The (6) Place one-way ANOVA yielded a significant effect of Place [$F(5, 120)$, $p < 0.0001$] and the Scheffe post hoc test showed that there was a clear distinction between the single and geminate consonants and that there was no significant difference between /pp/, /tt/, and /kk/.

As Figure 6-8 shows that the third graders did not perform well. The mean values for the syllable duration only for this grade were independently submitted to a (6) Place one-way ANOVA to see if they can make a clear distinction between the singletons and the geminates in each place of articulation. The ANOVA yielded a significant Place main effect, but Sheffe post hoc tests did not indicate any significant difference between the two types of stops. This means that the immersion students in grade 3 had not acquired the contrast between the one syllable/one mora words and the one syllable/two mora words.

Ratio of one syllable/one mora words to one syllable/two mora words

Although the research design controlled for the rate of speech of the subjects, subjects did not always speak at a constant speed; therefore, in order to more accurately compare one-mora syllable with two-mora syllables, all the mean duration values of the second syllable were converted into a ratio, with the one-mora syllable set to 1.00. Tables 6-4 to 6-6 show the duration values and the duration ratio of a two-mora syllable to a one-mora syllable.

Table 6-4 Mean duration values of one-mora syllables

GRADES	/pa/	/ta/	/ka/
MJ1	217.2	214.2	221.4
MJ5	175.3	173.6	182.7
IJT	164.1	160.7	184.7
IJ1	317.7	305.0	306.3
IJ3	274.4	288.6	250.7
IJ5	275.5	313.6	270.7

Table 6-5 Mean duration values of two-mora syllables

GRADES	/ppa/	/tta/	/kka/
MJ1	326.1	315.9	294.0
MJ5	288.5	278.7	272.6
IJT	276.1	278.7	276.2
IJ1	397.1	366.9	382.8
IJ3	323.2	308.3	333.4
IJ5	346.8	415.7	425.5

Table 6-6 Duration ratio of a one-mora syllable to a two-mora syllable

GRADES	ppa/pa	tta/ta	kka/ka	Mean
MJ1	1.5	1.47	1.33	1.43
MJ5	1.65	1.61	1.49	1.58
IJT	1.68	1.73	1.5	1.64
IJ1	1.25	1.2	1.25	1.23
IJ3	1.18	1.07	1.33	1.19
IJ5	1.26	1.33	1.57	1.39

Since there are no statistical differences in places of articulation within both the singletons and the geminates in terms of absolute values, we can compare the mean values of the ratio of a one-mora syllable to a two-mora syllable regardless of the place of articulation, i.e. the rightmost column in Table 6-6. In the monolinguals' and the immersion teachers' utterances, the ratio ranges from 1.43 to 1.64. In other words, a two-mora syllable is realized as one and a half as long as a one-mora syllable. This result supports Han's (1994) finding that the mean relative duration of Japanese one-syllable words containing a single stop and a geminate stop is 1.00:1.46.

In the production of these two types of syllables by the immersion children, the ratio is 1.19 to 1.39, which is much smaller than those of the monolinguals and the immersion teachers. This can be attributed to the fact that the immersion children tend to overshoot the phonetic duration norms of the singleton but not to overshoot those of the geminates to the same degree. It was also observed that the third graders in the immersion program least clearly differentiated the one-mora syllable from the two-mora syllable.

6.5 Development of Closure Duration

In this section we will focus our discussion on the development of the immersion children's closure duration based on absolute duration data and examine to what extent they can improve their performance during the period of two and a half months.

Across grade levels

In order to examine how the acoustic correlates develop for the closure duration of singletons and geminates, mean closure duration values from Time 1 through Time 2 were compared for the immersion learners. Figure 6-9 shows the mean values of closure duration for singletons and geminates in Japanese produced by the immersion children at Time 1 and Time 2. Visual inspection shows that there are no clear differences in closure duration values of the single consonants between Time 1 and Time 2 except for the 5th graders in which case the decrease of 25 ms was observed at Time 2. On the other hand, for the production of geminate consonants, the mean values of closure duration for grade 1 and grade 5 decreased by 25 ms and 38 ms respectively.

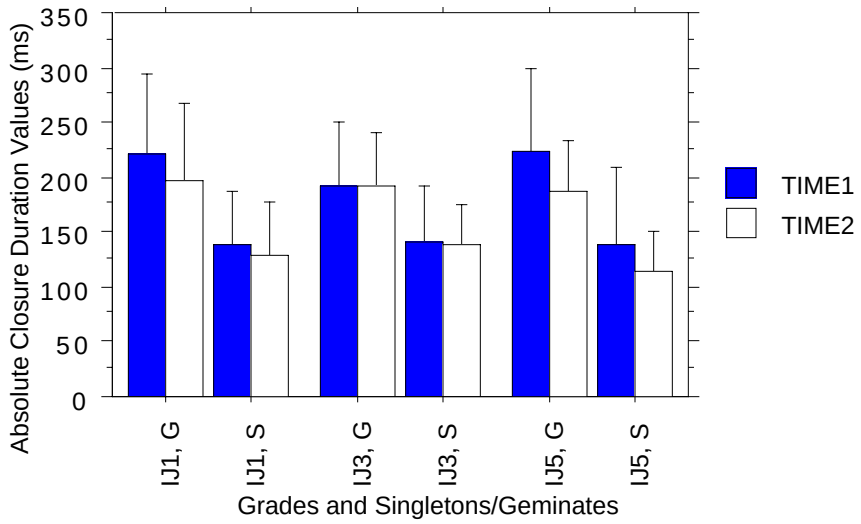

Figure 6-9 The development of the immersion children's closure duration. The error bars enclose +/- one standard deviation.

To see whether there is any significant difference in the closure duration values of singletons and geminates in the immersion groups between Time 1 and Time 2, the mean values for each of the 19 subjects at both times were submitted to a (3) Grade and (2) Type (singletons or geminates) repeated-measure ANOVA. Results showed that although it did not show any significant Grade, there was a significant Type effect and a significant interaction between Grade and Type [Type, $F(1,878) = 461.902$, $p < .0001$; Grade * Type, $F(2, 878) = 5.251$, $p = 0.0054$]. Also, the ANOVA showed that there was a Development main effect and an interaction with Grade [Development (of closure duration between Time 1 and Time 2), $F(1, 878) = 54.419$, $p < 0.0001$; Development (closure) * Grade, $F(2, 878) = 16.774$, $p < 0.0001$]. Scheffe post hoc tests revealed that there was a significant difference between Time 1 and Time 2 ($p < 0.0001$) for all grades. Figure 6-10 shows that

both singletons and geminates of Grade 1 and Grade 5 came closer to those of the monolinguals at Time 2 than at Time 1. This means that these two grades made some progress in the closure duration from Time 1 to Time 2.

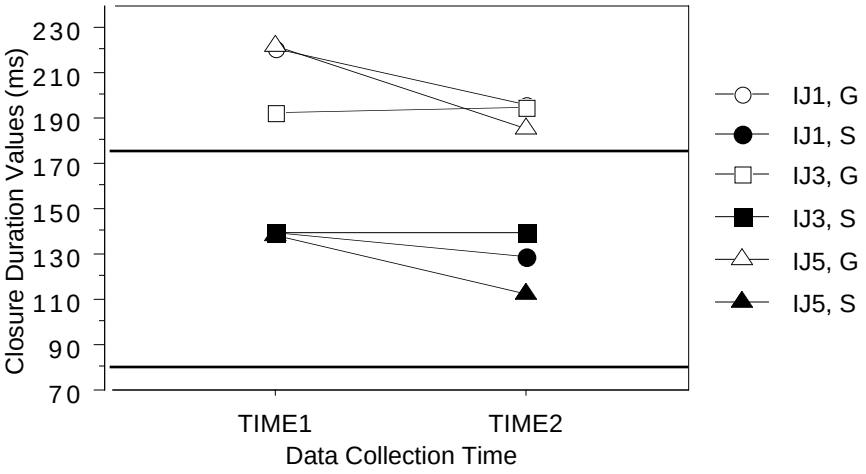

Figure 6-10 The closure duration of singletons and geminates produced by immersion children at Time 1 and Time 2. The lines at 80 ms and 180 ms show the native speakers' norms for the singletons and the geminates, respectively.

Across places of articulation

Table 6-7 indicates the differences in the mean values of the closure duration for each singleton and geminate between Time 1 and Time 2. Negative values in the difference row mean that the subjects decreased their closure duration at Time 2, compared to that of Time 1. This direction results in closure values closer to the natives' closure values which are in general shorter than those of the immersion children. For the same reason, positive values show increased closure duration at Time 2, suggesting no development or even deterioration of the values for closure duration within a period of two and a half months. The table clearly shows that almost no improvement in both the singletons and the geminates can be observed for the third graders. On the

other hand, the 1st and 5th graders decreased their closure duration at Time 2, which became closer to the monolinguals' norm. The 5th graders seem to improve more than the 1st graders.

Table 6-7 Differences in mean values of closure duration between Time 1 and Time 2

	p	**t**	**k**	**MEAN**	**pp**	**tt**	**kk**	**MEAN**
G1/TIME1	136.2	148.8	128.6	137.9	237.9	199.4	226.7	221.3
G1/TIME2	132.3	138.6	114.8	128.6	211.8	185.5	193.1	196.8
DIFFERENCES	-3.9	-10.3	-13.8	-9.3	-26.1	-13.9	-33.5	-24.5
G3/TIME1	145.2	145.5	128.3	139.7	195.3	178.6	203.8	192.6
G3/TIME2	142.2	146.0	127.3	138.5	190.8	183.8	199.8	191.5
DIFFERENCES	-3.0	0.5	-0.9	-1.1	-4.5	5.2	-3.9	-1.1
G5/TIME1	144.2	154.3	118.3	138.9	211.9	233.1	226.9	224.0
G5/TIME2	119.0	120.4	101.3	113.6	174.6	197.8	186.6	186.3
DIFFERENCES	-25.1	-33.9	-17.0	-25.3	-37.3	-35.3	-40.3	-37.6
MONOLINGUALS	84.7	84.9	86.9	85.5	184.8	177.2	172.0	178.0

The values of closure duration associated with the production of /p, t, k, pp, tt, kk/ were submitted to a (3) Grade and (6) Place repeated ANOVA, and it yielded a significant main effect of Place but not of Grade. Results also show a significant interaction between Place * Grade [Place, $F(5, 866) = 98.491$, $p < 0.0001$; Place * Grade, $F(10, 866) = 2.855$, $p = 0.0017$]. Also, the ANOVA indicated that there was a Development (of closure duration from Time 1 to Time 2) main effect and an interaction between Development (closure) and Grade [Development, $F(1, 866) = 53.702$, $p < 0.0001$; Development (closure) and Grade, $F(2, 866) = 16.607$, $p < 0.0001$]. The Scheffe post hoc test revealed that among the singletons and the geminates there are no significant differences between each place of articulation in the same category. In addition, the post hoc test showed that there is a significant difference in the development of the production of closure duration between Time 1 and Time 2 ($p < 0.0001$). This is due to the fact that the fifth graders have made progress in the production of the singletons and the first and fifth graders in the production

of the geminates.

Moreover, Table 6-7 shows that the significant interaction between Place * Grade was caused by the decrease in closure duration of /pp/ and /kk/ produced by the first graders and that of /p, t/ and /pp, tt, kk/ produced by the fifth graders.

Development of contrast between singletons and geminates

To examine the progress in the closure duration for each pair of single and geminate consonants from Time 1 through Time 2, the ratios of the singletons and geminates were compared. Table 6-8 and Figure 6-11 show the development of the mean ratios of the geminates to the singletons and the differences between Time 1 and Time 2. The differences in the table were obtained by subtracting the ratio at Time 1 from that at Time 2; therefore, positive values indicate an increase in the ratio, that is, progress in closure duration toward the direction of the monolinguals' ratio during the time between the two data collections.

Table 6-8

Differences in the mean ratio of singletons to geminates between Time 1 and Time 2

GROUP	MEAN RATIO	GROUP	MEAN RATIO	GROUP	MEAN RATIO
G1/TIME1	1.58	**G3/TIME1**	1.38	**G5/TIME1**	1.61
G1/TIME2	1.52	**G3/TIME2**	1.40	**G5/TIME2**	1.65
Differences	-0.06	**Differences**	0.02	**Differences**	0.04

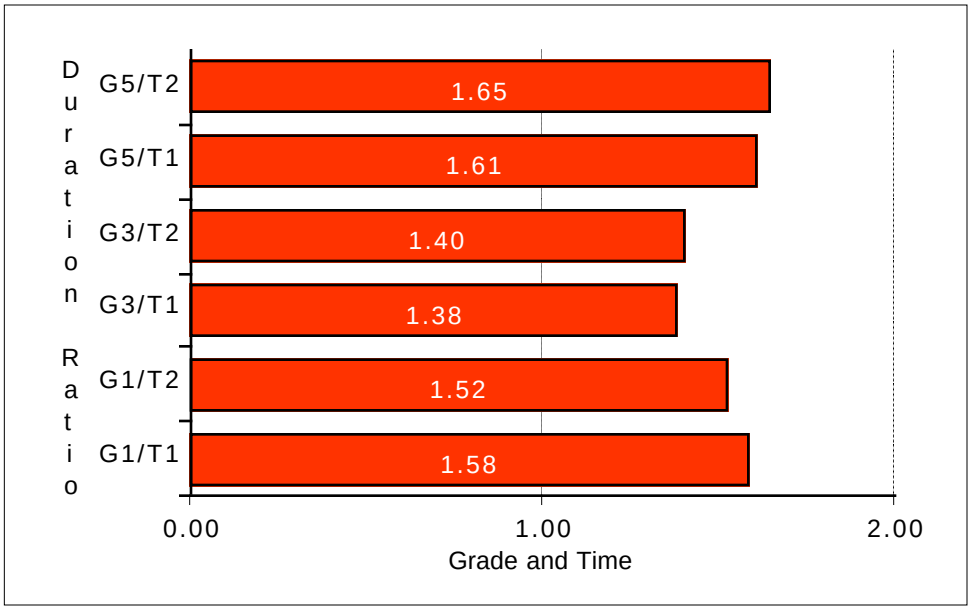

Figure 6-11 Differences in the ratio of geminates to singletons between Time 1 & Time 2

The results show that almost no differences in the ratio were observed between Time 1 and Time 2, although the immersion children in grade 5 made slight progress. Also, the children in grade 3 made slight progress in terms of the ratio but they performed worst due to the ambiguous contrast between the singletons and geminates. As we found in the previous section, although the first and fifth graders made some significant progress in the absolute values of both the singletons and the geminates, their ratios did not change drastically.[18] In terms of the acquisition of these two types of stops, the contrast rather than the absolute values of closure duration is crucial and,

[18] To verify the ratios obtained from the absolute duration values, those based on the relative values from the reference sentence frame were obtained. It was found that these two ratios were not different and no progress in the ratio of each grade was made between Time 1 and Time 2. Table 6-9 shows the differences in the mean ratio of geminates to singletons between the period, based on the relative values from the reference sentence frame.

Table 6-9 Differences in the mean ratio of geminates to singletons between Time 1 and Time 2, based on the relative values from the reference sentence frame.

GROUP	MEAN RATIO	GROUP	MEAN RATIO	GROUP	MEAN RATIO
G1/TIME1	1.59	G3/TIME1	1.35	G5/TIME1	1.47
G1/TIME2	1.38	G3/TIME2	1.35	G5/TIME2	1.55
Differences	-0.21	Differences	-0.00	Differences	0.08

therefore, we may conclude that the children could not improve the production of these sounds during the two and a half month period of time between the two data collections in this study. This means that the period is not long enough to observe any noticeable progress in the acquisition of the timing that accompanies the production of consonants.

CHAPTER 7

FOREIGN ACCENT RATING

7.1 Purpose of the Experiment

According to many research studies (e.g., Han, 1992; Hirata, 1993; Muraki and Nakaoka, 1990; Sugito, 1989; Toda, 1994, 1996, 1997), learners of Japanese often have difficulty acquiring the timing control required to produce moraic consonants such as geminates, and moraic nasals. Though it is generally assumed that children more easily acquire native-like pronunciation than adults, immersion children's acquisition of timing control remains to be studied because they receive less input than children learning in a naturalistic setting; the input to immersion children is provided only by their teachers, not from peers. Several studies suggest that immersion children tend to retain their L1 accent even after they have been exposed to a second language for five or six years (Genesee 1987; Hammerly, 1991).

This study measured the perceived degree of foreign accent attributed to children in the Japanese Immersion Program when producing the single and geminate consonants. Specifically, this accent rating study was conducted to examine 1) how good the contrast is between these two types of consonants produced by the Japanese Immersion children according to the judgments of Japanese adult native speakers and 2) how such subjective ratings correlate with the acoustic properties of the singleton and the geminate sounds produced by the immersion children.

7.2 Method

Subjects

The accent rating tests were administered at two different universities:

one in Tokyo and the other in a suburb of the greater Tokyo area. The group of raters in the former university consisted of 25 freshmen who were all from the vicinity of Tokyo and almost all of whom spoke the Tokyo dialect. The second group were 27 freshmen who were from different parts of the Kanto area, which includes 7 prefectures near the Tokyo area.[19] The total number of raters was 52. Their age ranged from 18 to 21.

Procedure and Materials for Accent Ratings

The data were drawn from the experiment described in the previous chapters, in which the single and geminate consonants were produced by the immersion children in a sentence frame *sore wa* ___ *desu* (That is ___). The second repetition of each word was selected for the accent rating, and each place of articulation for both types of the consonants was included. Here is a list of words used for the accent rating:

<u>Singletons:</u>

papa (papa)	kata (shoulder)	saka (slope)

<u>Geminates:</u>

happa (leaf)	katta (bought)	mikka (the third day)

Sentences containing these tokens were digitized on a PC. A tape was made where sentence stimuli were blocked by a speaker. Six sentences produced by each speaker were randomized within each speaker block. Each speaker block begins with a double beep sound generated by sinewaves and ends with a single beep sound. There was an 8 second silence between each speaker block, during which raters evaluated the degree of accent for the speaker. The same six sentences produced by three Japanese monolingual children were

[19] The subjects from Ibaraki Prefecture were excluded because they speak an accentless dialect of Japanese, in which "there is no native speaker recognition of the pitch pattern, though phrases are normally pronounced in a flat tone with a slight rise in the middle" (Shibatani, 1990, p. 213).

included as a control. Here is an example of one speaker block on the tape:

Beep
Beep
Sore wa papa desu.
Sore wa tako desu.
Sore wa happa desu.
Sore wa mikka desu.
Sore wa kata desu.
Sore wa katta desu.
Beep

The rating was done in a language lab. Raters heard 132 sentences (6 sentences x 19 immersion children + 6 sentences x 3 Japanese monolingual children) via headphones only one time. The raters were told that most but not all sentences had been spoken by English-speaking children at an elementary school where the children are learning Japanese as a foreign language. However, the raters were not told what the ratio was of native to nonnative speakers. An additional two sets of sentences were used for practice.

The raters were instructed to rate the degree of the contrast between singletons and geminates, and foreign accentedness, based on the six sentence tokens while paying attention to segmental quality, that is, the presence or absence of a geminate and ignoring the factors of speech rate, pitch accent and intonation. They marked a rating on an 11-interval scale that ranged from 0 (entirely no contrast between the singletons and geminates and heavy foreign accent) to 10 (clear contrast between the singleton and geminate and native speaker pronunciation). They marked only one accent rating for each speaker based on the six tokens. The whole rating session lasted from 15 to 20 minutes.

7.3 Results

The score range is from 0 to 10 and the highest possible score is 520 points (10 points from each rater x 52 raters). The total score of each speaker was obtained by adding all the scores given by each rater. Since the accent rating tests were administered in two different locations at different times, the consistency between the two test administrations was checked with a Wilcoxon Signed Rank Test. Table 7-1 gives the descriptive statistics and Table 7-2 shows that there is no significant difference between the two rater groups (z = -0.438, p = 0.6612).

Table 7-1 Results of accent ratings administered in two locations

	University A	University B
Mean	178.455	176.727
Std. Dev.	57.848	63.210
Std. Error	12.333	13.476
Count	22	22
Minimum	88.000	86.000
Maximum	249.000	270.000
# Missing	0	0

Table 7-2 Results of the Wilcoxon Signed Rank Test

# 0 Differences	0
# Ties	8
Z-Value	-.438
P-Value	.6612
Tied Z-Value	-.439
Tied P-Value	.6610

Also, to examine interrater reliability, a Spearman rank correlation coefficient was obtained between each two raters. The *Rho* values corrected

for ties range from 0.921 to 0.514 ($p < 0.05$). Applying the lowest estimate, 0.514, to the Spearman-Brown prophecy formula, a high interrater reliability ($r = 0.98$) for all accent ratings was obtained. Since the number of raters was 52 and the interrater reliability between each two raters was high, the rating procedure was judged to be reliable across raters.

Table 7-3 Descriptive statistics for accent ratings

GRADE	ID #	HOME LANGUAGES (Mother/Father)	TOTAL SCORES	MEAN	SD	MAX	MIN
G1	G11	Japanese / English	373	7.17	2.69	10	0
G1	G12	English / English	208	4.00	2.39	9	0
G1	G13	Hebrew / English	278	5.35	2.35	10	0
G1	G14	English / English	249	4.79	2.05	9	0
G1	G15	English / Spanish	470	9.04	1.53	10	3
G1	G16	English / English	305	5.87	2.21	9	0
G1	G17	English / English	200	3.85	1.97	8	0
G3	G31	English / English	303	5.83	2.33	10	0
G3	G32	English / English	258	4.96	2.07	9	0
G3	G33	English / English	174	3.35	1.95	6	0
G3	G34	English / English	477	9.17	1.59	10	3
G3	G35	Chinese / English	302	5.81	2.41	9	0
G3	G36	English / Japanese	277	5.33	1.77	9	0
G5	G51	English / English	196	3.77	1.86	7	0
G5	G52	Japanese / English	502	9.65	0.86	10	6
G5	G53	Hungarian (single parent) /	440	8.46	2.03	10	0
G5	G54	English / English	324	6.23	2.47	10	0
G5	G55	English / English	461	8.87	1.85	10	1
G5	G56	Chinese / English	474	9.12	1.59	10	2
G5	NS1	Japanese / Japanese	512	9.85	0.72	10	5
G5	NS2	Japanese / Japanese	519	9.98	0.14	10	9
G1	NS3	Japanese / Japanese	512	9.85	0.72	10	5

Table 7-3 shows the descriptive statistics for the accent ratings of the 22 speakers, which included the 19 immersion children and 3 Japanese monolingual children. The three Japanese monolingual children (NS1, 2, 3) scored on average more than 9.85 each (512 total points out of 520 points). Furthermore, the small standard deviations suggest that the raters unanimously agreed on the scores of the Japanese monolingual speakers' tokens. Out of the 19 immersion children, four scored more than an average of 9 (468 total points or more); one from grades 1 and 3 each and two from

grade 5.

Comparison between Individuals

G15 (1st grade) scored 9.04 points on average (470 points) on the accent rating. In her language background questionnaire, G15 reported that her mother speaks English and her father speaks Spanish. She does not speak Japanese outside of school at all, but she listens to Japanese through audio or video tapes. Records also show that she was exposed to Japanese at preschool (Japanese Buddhist Language School) before she entered the Japanese Immersion Program.

G34 (3rd grade) obtained a high average score of 9.17 (477 points). Although G34's parents are native speakers of English, they are Japanese Americans who do not speak Japanese functionally.[20] The amount of time she speaks Japanese outside school is 0-20%; she sometimes speaks Japanese with Japanese friends and grandparents and listens to Japanese from audio or video tapes. It is also worth noting that she participated in a Japanese summer school before she entered the Japanese immersion program and was exposed to Japanese there.

G56's (5th grade) mean score was 9.12 (474 total). Her mother's native language is Chinese and her father's (Japanese American) native language is English but he speaks Japanese fluently. Although she reports that she does not speak Japanese outside school, she has opportunities to speak Japanese with grandparents. Also, her mother reported that her father sometimes spoke to her in Japanese before she entered school.

G52 (5th grade) scored an average of 9.65 (502 total). His mother's native language is Japanese and his father's native language is English, and he does

[20] Her mother reported that she understands Japanese a little, but her father does not speak Japanese at all.

not speak Japanese at all. This subject is a little different from the rest of the children who scored high on the test in that he uses Japanese outside school for 20-40% of his daily life. Also, he has a chance to listen to Japanese outside school from his mother, the TV or radio, or the audio or video tapes and speaks Japanese with his siblings.

This description of those children who scored high on the accent ratings shows that they are all exposed to some Japanese outside school. For example, it may be the case that even though their parents do not understand Japanese at all, their grandparents may speak Japanese. Originally, the research design for this study proposed that all subjects should be selected from children whose family language background had nothing to do with Japanese, but the Japanese Immersion Program had a limited number of children and, to make matters worse, it was extremely difficult to obtain subjects from only English-speaking families. In the Los Angeles area, though many parents speak English as a native language, grandparents are likely to speak another language. The ideal selection of subjects would have been possible only if this research had been done in another part of the US where monolingual English speakers are the norm. In other words, the findings suggest that Japanese input only in class is not sufficient for children to acquire nativelike pronunciation even though the children are still in the so-called critical period.

But ironically it is not guaranteed that children can acquire completely nativelike pronunciation even if they are exposed to Japanese outside school, and even if one of their parents is a native speaker of Japanese. G11's and G36's scores support the claim that children, at least one parent of whom is a native speaker of Japanese, do not always succeed in their acquisition of

Japanese pronunciation. G36 does not take advantage of the fact that her father speaks Japanese. During the data collection, I personally spoke with G36's grandmother who speaks Japanese as an L1 and she told me that she often spoke with her granddaughter in Japanese. Also, G51 (Japanese American), who speaks Japanese outside school for 20-40% of her daily life and gets some Japanese input from her grandparents, scored the second lowest (3.77: total 196). In contrast, it is noteworthy that several children with non-Japanese backgrounds (e.g., G53, 55) who do not get any Japanese input outside school achieved good pronunciation scores (8.46 and 8.87: totals 440 and 461). This is another piece of evidence that additional Japanese input outside school does not necessarily mean that children will acquire nativelike pronunciation.

Comparison between groups

Table 7-4 shows the mean score and the standard deviation of the accent rating for each grade. Grades 1 and 3 share almost the same mean scores, although Grade 5 seemed to perform better in terms of the mean scores. The larger standard deviation in Grade 5 indicates that there is more variation across subjects at grade 5. Actually, a visual inspection of Table 1 suggests that G51's mean score (3.77: total 196) was much lower than those of all the other children in the grade and lowered the group mean. This result may imply that there will be no improvement until the fifth grade in terms of subjective evaluation by native listeners. However, this is contrary to the findings, obtained from the acoustic data described in the previous chapter, that the first graders also made a clear distinction between the singletons and geminates. Also, it is possible that since the accent rating is based on the whole sentence, the 5th graders were better at other parts of the sentence and

general prosody.

Table 7-4 Mean scores and standard deviations for each grade

	Number of subjects	**Mean**	**Standard Deviation**
Grade 1	7	5.72	1.85
Grade 3	6	5.74	1.91
Grade 5	6	7.69	2.25

To test whether or not there is any significant difference in the scores of the accent ratings between three school grades, the mean ratings for the immersion children were submitted to a (3) Grade one factor ANOVA, with repeated measures on raters. The main effect of Group was not found to be significant for the three grades [$F(2, 816) = 1.946$, $p = 0.1752$]. Although the mean score of Grade 5 was higher than the other two groups, the negatively skewed distribution of Grade 5 led to their showing no significant difference from the other groups. Figure 7-1 clearly shows this result. But it should be noted that though not statistically significant, there seems to be some tendency toward improvement of pronunciation by the end of the immersion program.

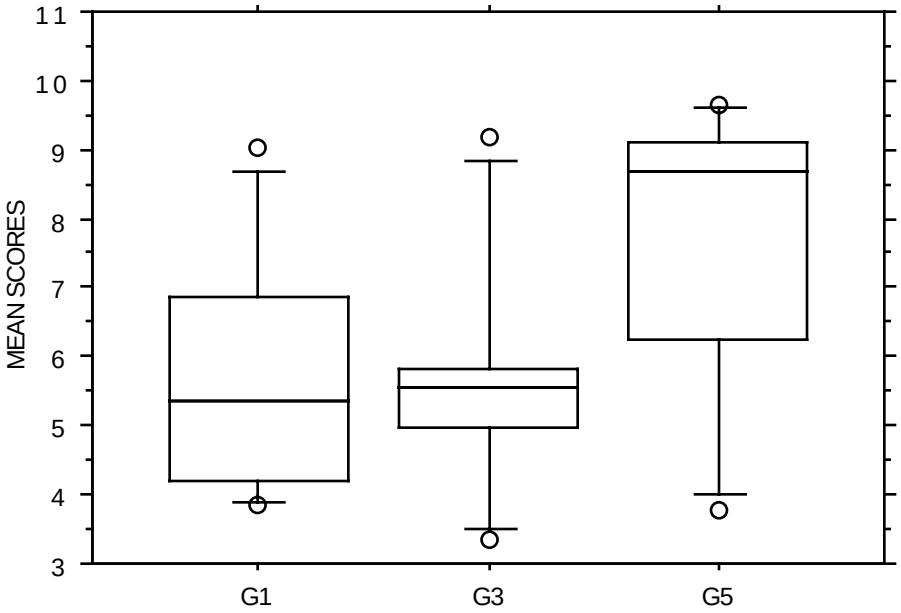

Figure 7-1 Box plot showing the distributions of the mean scores of the 19 speakers

Despite the limited number of the speakers and the few exceptions (G51, 54) observed, we can conclude that most immersion children may develop good pronunciation in the long run–possibly being perceived as a nativelike pronunciation–though they do not acoustically reach the native speaker's norm. Also, the results show that there is great variability in L2 pronunciation achievement even in young children in an immersion program. Some of these children, for reasons of gender, cognitive style, or socio-cultural experiences, are simply better language acquirers than others.

Correlation with acoustic data

Since the accent rating is supposed to measure the degree of contrast between the immersion students' Japanese singletons and geminates, this section will discuss to what extent the ratings by Japanese native speakers correlate with the acoustic ratio of single to geminate consonants produced by

the immersion children. The mean ratios for each subject were based on 8 observations for each singleton /p, t, k/ and 9 observations for each geminate /pp, tt, kk/. But in the accent rating the raters listened to six tokens only (one for each place of articulation, /p, t, k, pp, tt, kk/); therefore, the acoustic ratios presented according to place of articulation in the previous chapter were collapsed into one mean ratio for each single and geminate consonant by obtaining the mean closure duration values and converting them into the ratios.[21] Table 7-5 shows the mean closure duration values for the singleton and geminate consonants and the acoustic ratio for each subject. For comparison with the ratio, the ratings for the immersion children are included in the table.

Like Han's (1992) finding, the nonnative speakers' ratio of the geminates to the singletons varied a great deal, ranging from 0.97 to 2.03, which is clearly less than that of Japanese monolinguals speakers (1.8 to 2.3). Although ratios of less than 1.8 showed variations in the accent rating across speakers, ratios of over 1.9 consistently corresponded to a rating of 8 or 9 points. But it is worth noting that the accent ratings and the acoustic properties do not exhibit a one-to-one relationship. For example, the ratios of students G12 and G17 were 1.69 and 1.63 respectively and those of students G13 and G35 were 1.21 and 0.97 respectively. But the latter subjects, having much smaller ratios, scored higher on the accent rating. The raters may have been distracted by some other acoustic features such as vowel quality and overall prosodic features when they judged the degree of accentedness of these immersion students' singleton/geminate production.

[21] The collapse into one mean ratio for each single and geminate consonant is justified by the acoustic finding that there was no significant difference within these types of consonants across places of articulation.

Table 7-5 Mean closure duration, their acoustic ratios, and mean rating for each subject

ID#	GEMINATES (ms)	SINGLETONS (ms)	RATIO	MEAN RATING
G11	134.35	71.67	1.87	7.17
G12	261.17	154.78	1.69	4.00
G13	209.14	172.87	1.21	5.35
G14	190.02	130.12	1.46	4.79
G15	276.41	137.50	2.01	9.04
G16	266.46	165.34	1.61	5.87
G17	223.83	137.16	1.63	3.85
G31	225.88	148.97	1.52	5.83
G32	137.19	95.02	1.44	4.96
G33	194.64	170.06	1.14	3.35
G34	208.35	108.74	1.92	9.17
G35	167.82	172.73	0.97	5.81
G36	208.96	140.93	1.48	5.33
G51	200.08	185.52	1.08	3.77
G52	189.58	94.02	2.02	9.65
G53	304.70	168.34	1.81	8.46
G54	231.09	180.59	1.28	6.23
G55	188.25	92.93	2.03	8.87
G56	234.41	116.66	2.01	9.12

To examine the relation between the ratio and the rating of each speaker, a correlation coefficient was obtained. Figure 7-2 shows the regression plot of the ratio to the mean rating score of each subject. The results show that the degree of perceived accentedness for the immersion children correlated fairly highly with each child's ratio of singletons to geminates ($r = 0.773$, $p < 0.0001$). This means that about 60% ($r^2 = 0.597$) of the variance for the degree of perceived accent can be accounted for by the ratio of singletons to geminates. This suggests that the ratio may be a good measure of the acquisition of the contrast between single and geminate consonants in Japanese.

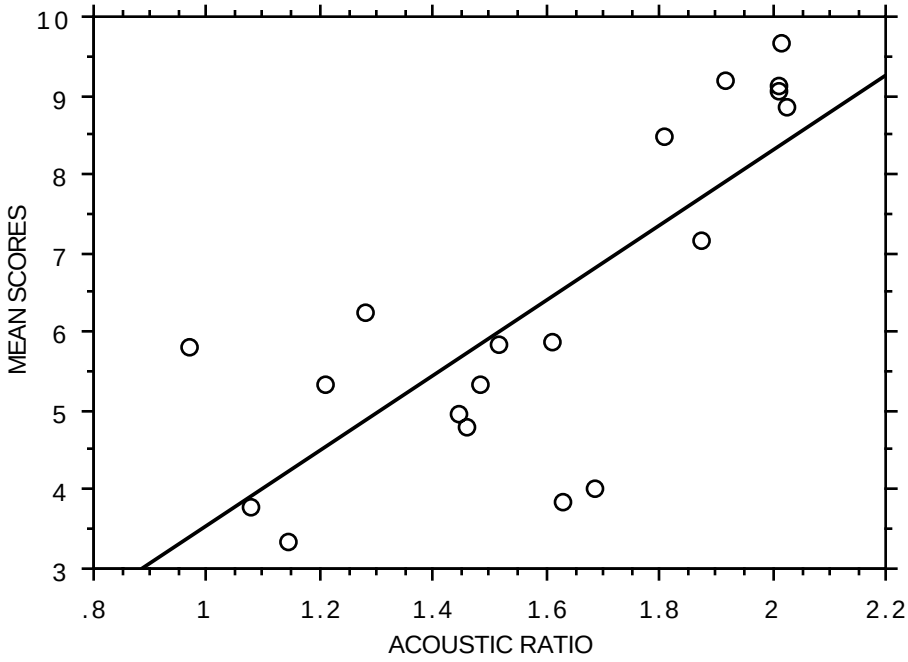

Figure 7-2 Regression plot of the ratio to the mean rating scores

To see whether or not there is any difference in the relation of the mean rating with the mean ratio across the grades, it was examined how the ratings for each grade correspond to their ratios. Table 7-6 shows the mean values and standard deviations of the ratings and the mean ratios for each grade.

Table 7-6 Mean values and S.D. of the ratings and ratios for each grade

		RATIO	MEAN RATING
GRADE 1	Mean	1.64	5.72
	S.D.	0.26	1.85
GRADE 3	Mean	1.41	5.74
	S.D.	0.33	1.91
GRADE 5	Mean	1.70	7.68
	S.D.	0.42	2.25

As we saw in the previous chapter, the ratio of the students in Grade 3 was significantly smaller than those of the students in the other two grades; the accent ratings, however, showed similar scores across the 1st and 3rd grades.

Also, there was a tendency for students in the higher grades to have better ratings, though as shown in the previous section there were no statistical differences between the grades. Also, the table suggests that students in Grade 5, who had the highest ratio, received the best score on the accent rating.

In addition, the correlation coefficients between the ratio and the ratings for each grade were obtained to check if there was any difference in their relation across the grades. Table 7-7 shows the correlation between the acoustic ratio and the mean scores of the accent rating within each grade.

Table 7-7 The correlation between the ratio and the mean scores according to the grades

	Correlation	**r squared**	**p-value**
Grade 1	0.626	0.392	0.1413
Grade 3	0.733	0.537	0.1056
Grade 5	0.971	0.943	0.0003

Since the number of students in each group is small, we cannot jump to conclusions, but the data for the fifth grade show that the acoustic ratio is very highly correlated with the accent rating ($r = 0.971$, $p = 0.0003$) and a very high percentage of the variance (94%) for the degree of perceived accent can be explained by the ratio of singletons to geminates. Taking into account the fact that the ratio of the 5th graders is closer to that of the Japanese monolingual children and the immersion teachers, this may well be the main factor for determining the perceived degree of contrast between the singletons and geminates. This is evidenced by the decrease in the variation of the ratings across speakers who have similar ratios with the increase of their acoustic ratios between single and geminate consonants: the ratios of over 1.9 consistently corresponded to a rating of 8 or 9 points. Also, when the ratio was smaller, the rating varied a great deal (Table 7-5). This must have resulted from the raters' relying on acoustic features other than closure duration.

Therefore, it seems that the correlation coefficients of Grades 1 and 3 were lower because their acoustic ratios were so small that the raters depended on acoustic features other than the ratio of the geminates to the singletons when making their ratings.

In sum, the results of the ratings imply that although not statistically significant there is some tendency for the degree of perceived accent to decrease as the immersion children move to higher grades. Moreover, the ratio of geminates to singletons is a very good measure for determining whether students have acquired the contrast between these sounds in Japanese. Finally, the ratings correlate highly with the ratio of the closure duration of geminates and singletons, which was reported in the previous chapter.

CHAPTER 8

THEORETICAL IMPLICATIONS FOR SECOND LANGUAGE ACQUISITION

8.1 L1 and L2 speakers' VOT and Closure Duration

This study shows that Japanese monolingual children produced voiceless stops in Japanese with a VOT range of 20ms to 40ms while both the immersion teachers and immersion children who speak English produced them with longer VOT values, i.e. 45 ms to 67 ms. However, interestingly, it has been found that the immersion children never use their English phonological norms when they produce Japanese stops. In other words, although they have not reached the native Japanese speakers' norm with respect to VOT, they are found to distinguish clearly the Japanese VOT norms (45-67 ms) from their native English counterparts (85 to 89 ms). Also, compared with the VOT values of adult Japanese speakers (24 to 45 ms: Homma, 1981), those of the immersion teachers have been found to be longer (35 to 60 ms). This suggests that English probably affects their Japanese phonology. The research finding that both of these groups of bilinguals have their phonetic norms of Japanese affected by the interaction of their L1 and L2 phonology can be attributed to the fact that English VOT values are clearly longer than those of Japanese (Han, 1992; Homma, 1980; Lisker and Abramson, 1964; Sakuma, 1929; Vance, 1987).

As for the stop closure duration, the immersion students tended to produce single stops in Japanese with longer values (120 to 155 ms) compared to the Japanese monolingual children who produced them with 70 to 100 ms. In addition, the immersion children's closure duration of geminates was also

longer in absolute terms (180 to 238 ms) than that of the Japanese monolinguals (165 to 195 ms) and the immersion teachers (170 to 185 ms). However, the immersion children's mean ratio for geminates to singletons ranged from 1.4 to 1.6 while that of the monolinguals and immersion teachers ranged from 1.8 to 2.3. Contrary to the expectation that the duration of English speaker's geminates would be shorter than that of the monolinguals (Han, 1992), they were actually overshot. Also, it should be pointed out that the tendency of the immersion children's single stops to be longer than those of the monolinguals resulted in obscuring the clear distinction between singletons and geminates. Looking at the relation between syllables and moras, this tendency becomes much clearer. Results show that the duration ratio of a two-mora syllable to a one-mora syllable in the immersion children's production ranges from 1.2 to 1.3 while the ratio in the monolinguals and immersion teachers is between 1.4 and 1.6. It is worth noting that although the way the immersion children distinguish singletons from geminates in acoustic terms is different from that of the Japanese monolinguals children, findings show that the immersion children make a clear distinction between the phonetic norms for single and geminate consonants.

In sum, we can conclude that the immersion children, who are still biologically sensitive prior to the end of the critical period, have the ability to establish two separate systems for English and Japanese VOT values as well as separate norms for single and geminate consonants in Japanese, though values are still intermediate, compared with the norms of the monolingual speakers.

8.2 Age Factor: Critical Period Hypothesis

The findings of this research may or may not support the Critical Period Hypothesis, which holds that the earlier one is exposed to a second language, the more likely one is to acquire native-like pronunciation (e.g., Oyama, 1976; Scovel, 1969, 1988). First, the issue is how we define the term 'native-like.' Does native-likeness rely on subjective or objective judgment? Subjective ratings of the immersion children by the immersion teachers and visitors to the school (personal communication) indicate that their pronunciation is completely comprehensible and sounds near nativelike, though retaining some foreign accent features (e.g., in rhythm, accent and intonation). A visiting professor in psychology from a university in Japan interviewed several of the fifth graders right after they graduated from the Japanese immersion program and observed that their oral proficiency level was very high and their pronunciation sounded very natural. On the other hand, while working as a volunteer teacher, the researcher had a chance to see a drama production performed by the immersion children in grade 5 and realized that they clearly had problems with segmental timing (e.g., the distinction between single and geminate consonants) and suprasegmental features. In this sense, subjective evaluation of the nativelikeness of their pronunciation varied across judges and situations.

Although there has been no documentation of objective (that is , instrumental) evaluation of immersion children's pronunciation in any language so far, this acoustic research indicates that these children's phonetic norms are far from being similar to those of L1 speakers. This finding does not support the hypothesis that if they start to learn a second language before the critical period ends, people acquire the "nativelike" phonological system

in a strict sense, because it shows that acoustically the immersion children clearly use a different set of norms from those of L1 speakers. But if we define the term “nativelike” in the sense that the immersion children can separate their L1 from their L2 system and establish the two separate categories (e.g., single and geminates consonants) which do not exist in their native language, we can conclude that they are sufficiently sensitive to allow for the complete separation of the two phonological systems.

8.3 Bilingual Phonological Systems

On the basis of the results reported above, I argue that the critical period hypothesis with respect to the acquisition of L2 phonology should be revised as follows: if learners are exposed to a second language before a certain age, they are more likely to acquire two completely separate phonological systems, producing an L2 system that is intermediate between the L1 system and the L2 system; however, such learners may retain some of the L1 acoustic features, which may be subjectively identified. This means that once people have established their L1 phonetic norm, they cannot possibly develop an L2 phonetic norm identical to that of L1 speakers no matter how early they begin to get exposed to a second language. This may be the case in a naturalistic setting as well as in an educational setting like an immersion program. Harada (1997) argues that Chinese university students acquiring English in a naturalistic setting failed to reach the English monolingual speaker’s norm even if they arrived in the US as early as the age of two to five. This finding entirely supports Flege’s (1995) hypothesis that the L2 speaker’s category may deviate from an L1 category “to maintain phonetic contrast between categories in a common L1-L2 phonological space” or the L2 category may be

"based on different features, or feature weights, than a monolingual's." In other words, the immersion students have acquired the two phonological systems, one of which is intermediate from that of Japanese monolinguals, with different acoustic features for VOT and closure duration.

8.4 Other Factors which Affect Immersion Children's Acquisition of L2 Phonology

What conclusions will be attributed to the fact that the immersion children who started to learn Japanese as a form of total immersion in Kindergarten did not reach the native speakers' phonetic norm and clearly retained some features of their L1 accent? Larsen-Freeman and Long (1991, p. 163) list several possible explanations for age-related differences: 1) the input explanation, 2) the socio-psychological explanation, and 3) the cognitive explanation. In terms of these three points, we will discuss why the immersion children in this study succeeded in the complete separation of the English and Japanese phonological systems, but failed to reach the phonetic norms of the monolingual Japanese children.

8.4.1 Input Explanation

Input Quantity

The crucial difference in input between the immersion setting and the naturalistic setting is that the amount of input is limited only to the classroom. Outside of class most of the students have no chance to be exposed to Japanese. This is supported by the language background information on the language environment in their homes. Table 8-1 shows their parents' native language and what language they are most likely to use when they communicate with their children.

Table 8-1 Immersion children's home language and dominant language background. In the home language column the left indicates the mother's native language and the right the father's.

GRADE	HOME LANGUAGE	DOMINANT LANGUAGE
G11	Japanese / English	English
G12	English / English	English
G13	Hebrew / English	English
G14	English / English	English
G15	English / Spanish	English
G16	English / English	English
G17	English / English	English
G31	English / English	English
G32	English / English	English
G33	English / English	English
G34	English / English	English
G35	Chinese / English	English
G36	English / Japanese	English
G51	English / English	English
G52	Japanese / English	English
G53	Hungarian (Single mother) /	English
G54	English / English	English
G55	English / English	English
G56	Chinese / English	English

As this table shows, the dominant language at home is clearly English except for student G53, whose home language is Hungarian.[22] Each grade has only one subject (G11, 36, 52), one of whose parents understands Japanese. These subjects may have different input quality / quantity from other subjects. But due to difficulty in finding enough subjects, we decided to keep these subjects. Since each group has only one such subject, we believe their inclusion will not affect the results.

Another issue is the amount of time the immersion children speak Japanese outside of school. Results of the questionnaire show that they do not have access to any significant amount of Japanese outside of the immersion class. Only one child in grades 1 and 3 each and two in grade 5 (4 out of 19;

[22] In the language background questionnaire, this subject's mother answers that the child most frequently speaks English at home. The researcher observed that the mother speaks English very fluently. This is probably due to the fact that she came to the States at the age of 13.

21%) spend 20 to 40% of their time using Japanese out of school. The rest of the children (15 out of 19; 79%) have no exposure to Japanese at all outside school. This may be considered one of the factors which influence the children to retain their L1 accent and not to reach the Japanese monolinguals' phonetic norm.

In addition, it is worth noting how many hours the immersion children have spent in classes conducted in Japanese. Table 8-2 is the approximate amount of time calculated from the number of days they are supposed to attend school and the percentage of instruction conducted in Japanese.

Table 8-2 Approximate amount of time spent on Japanese instruction in the immersion program

	% of Japanese instruction	**Weekly class time (hours)**	**Yearly class time in Japanese (hours: 179 days = 36 weeks)**	**Cumulative amount of time already spent on Japanese instruction (hours)**
Kindergarten	100%	17	598	598
Grade 1	100%	28	1001	1598
Grade 2	80%	28	801	2399
Grade 3	80%	28	801	3200
Grade 4	60%	28	600	3800
Grade 5	60%	28	600	4401

Up to the end of the fifth grade, children in the Japanese immersion program are supposed to be exposed to classroom Japanese for about 4400 hours, which would be equivalent to one year spent on first language acquisition (12 hours x 365 days = 4380 hours).[23] Compared with the acquisition of children's L1 phonology, the period of time the immersion students have spent on Japanese instruction is extremely limited. This may explain why the immersion children could not acquire the native speakers' phonetic norms.

In contrast, since even students in grade 1 can separate the two

[23] Roffwarg, Muzio, and Dement (1966) report that the total amount of daily sleep for 2 to 3 year-old children is around 12 hours, which implies that they are exposed to first language for more or less 12 hours a day.

phonological systems, only about 1500 hours can be considered long enough to allow young learners to establish a new phonological system. This amount of time is equivalent to the time required for adult English learners of Japanese to reach 1+ to 2 on the ILR (Interagency Language Roundtable) scale or intermediate high or advanced on the ACTFL (American Council on the Teaching of Foreign Languages) scale (Hadley, 1993).

Input Quality

The immersion program researched for this study is a one-way immersion program, in which the only input in Japanese comes from one main classroom teacher and one assistant teacher. To examine the nature of input, we will discuss the language background of the five teachers who participated in this study. In Table 8-3 we find that only one immersion teacher was born in Japan and arrived in the US at the age of 27 while the rest of the teachers were second generation Japanese Americans.

Table 8-3 Language background of the immersion teachers

ID#	TEACHER (TYPE)	NATIVE LANGUAGE(S)	NATIONALITY
IT1	Main	Japanese	Japanese American
IT2	Main	English & Japanese	Japanese American
IT3	Sub	Japanese	Japanese
IT4	Main	Japanese	Japanese American
IT5	Main	Japanese	Japanese American

The difference between Japanese and Japanese Americans is more clearly observed in the production of VOT rather than that of closure duration for single and geminate consonants. The mean VOT value (27 ms) of /p, t, k/ produced by IT3, who was born in Japan, is statistically shorter than those (40 to 60 ms) of the other immersion teachers who were exposed to English at an earlier age ($p < .0001$). The VOT values of the immersion teachers are at a stage between those of the monolingual and the immersion children. Since

the immersion children did not reach even the immersion teachers' phonetic norm, which was already an intermediate stage, the bilingual children would probably not have acquired the L1 speaker's phonetic norm even if a monolingual Japanese teacher had taught this Japanese immersion program. In other words, we may conclude that authentic native input alone will not always allow second language learners who are still young and within the critical period to reach the L1 speaker's phonetic norm in a classroom setting after they have established their L1 phonology.

Interestingly, as mentioned earlier, the difference between the Japanese immigrant (IT3) and the Japanese Americans (IT1, 2, 4, 5) was observed in the production of VOT rather than the production of closure duration of singletons and geminates. In Japanese, closure duration plays a functional role while VOT does not. One tends to pay more attention to functional differences in language acquisition while not attending to nonfunctional features. This means that closure duration in Japanese is more discernible than VOT. This finding supports Flege's (1987b) hypothesis that "equivalence classification prevents experienced L2 learners from producing similar L2 phones, but not new L2 phones, authentically." For the Japanese American teachers described here, the features of VOT in their Japanese and English must be categorized as "similar," because the differences are not crucial to establishing the phonological system while the differences between single and geminate consonants may be considered to be "new"; therefore, the bilingual immersion teachers could perceive the phonetic differences faster and approximated the norm of the monolingual speakers. This may apply to the production of both VOT and closure duration by the immersion children. During the short period of two and a half months, no development of their

VOT values was observed while slight progress in the production of closure duration was seen by the fifth grade. This may mean that the children paid more attention to the functional feature (the closure duration) than the nonfunctional one (VOT), so that the children in grade 5 may be considered to have started to improve the functional aspect even with the short period.[24]

8.4.2 Socio-psychological Explanation

In this section the acquisition of L2 phonology by immersion students will be discussed in terms of socio-psychological factors. Generally speaking, children are considered to excel in second language acquisition because they are less inhibited and have less firmly established their identify as a speaker of a certain L1 than adults (Brown, 1987; Long, 1991). The findings of this research partially support this socio-psychological explanation in that the Japanese immersion students have succeeded in the separation of the two phonological systems. However, the findings do not completely support this view because the immersion students have not reached even the phonetic norms of the immersion teachers who were their main sources of input.

The next question is: can immersion children be really less inhibited than adolescents or adults? The researcher observed several different Japanese immersion classes while volunteering as a teacher's aid and found that even children in higher grades, who had already been exposed to Japanese for four or five years, always talked to their peers in English and might stick to English even when a teacher spoke to them in Japanese. This may have been due to peer pressure. In contrast, in the setting where peers were not present, the degree of inhibition was reduced. To collect data for this

[24] The development of the production of closure duration by the fifth graders may have been attributed to the test effect caused by the short interval between the two data collections. But since the development of VOT was not observed, the test effect may not explain the progress of the immersion children in grade 5.

research, I interviewed each child and asked them several personal questions in Japanese. I found that they seemed more comfortable speaking Japanese with me when we were alone. This observation may show that the children always feel peer pressure to some extent in class and are thus more inhibited than in their L1 acquisition. This peer pressure may also have kept them from acquiring a genuinely native-like pronunciation.

This peer pressure and inhibition help us explain why the third graders performed better in the production of VOT than the children in the fifth grade. The older the immersion children become, the more aware they become of peer pressure and of their identity as English speakers. This awareness may have discouraged the children in grade 5 from focusing on and imitating accurate pronunciation of the nonfunctional features of VOT.[25]

These socio-psychological factors may have resulted from immersion teachers' roles in class. In the Japanese immersion program studied for this research, the same teachers served as both Japanese and English teachers. This dual role of the teachers will tempt the immersion children to use more English, so that the amount of output will be limited. It is usually reported that one language to one teacher is ideal in immersion education:

> Someone other than the classroom teacher should teach English. Immersion teachers required to teach the English portion of the curriculum report that they experience difficulty in getting students to return to an all-immersion language atmosphere in the classroom once English instruction is completed (Met and Lorenz, 1997).

This dual role of the immersion teachers in the Culver City Program may also have influenced the children's acquisition of Japanese pronunciation.

[25] This regression by age may also be accounted for by the 5th graders' decrease of input or the time for instruction in Japanese which decreases from 80% to 60%.

8.4.3 Cognitive Explanation

The failure of the immersion children to reach the native norm in Japanese despite their complete separation of the two language systems may have resulted from their cognitive development or their attainment of Piaget's formal stage of operations, which is considered to negatively affect second language acquisition (Krashen, 1982; Long, 1991).[26] Children, between the ages of two and seven, at the pre-operations stage (Davenport, 1992) tend to pay more attention to segments than to syllables, which allows them to establish "the core acoustic properties" of each phonetic category (Flege, 1992). The immersion children, when first exposed to Japanese at the age of 5, were still at such a pre-operations stage, and they attained the two separate phonological systems, but they have failed to reach the same norm as L1 speakers possibly because they were getting close to the end of this stage. Certainly more research is needed to establish this.

8.5 Development Rate

Since the interval between the first and the second data collection was only two and a half months, we did not see a noticeable development in either VOT or closure duration. This may also be explained in terms of the development rate, which differs between children and adults. Long-term studies show that younger is better in terms of ultimate attainment while short-term studies suggest that older learners are better in their rate of acquisition. Although the interval was short, our results on the progress of closure duration by the children in grade 5 can still show that the 5th graders

[26] There is some disagreement as to when the formal operations stage starts. Piaget claims that the age is between 14 and 15 while Ausubel mentions that it is 10 to 12 and others claim that some individuals never reach this stage (Long 1991).

(older) are faster than the 1st graders. But to verify this finding, follow-up studies will help observe the development of the production of voiceless consonants by the immersion children.

8.6 Effect of Second Language Learning on L1 Phonology

Since English data from monolingual English speakers (5 to 10 years of age) were not available in this study, the findings can only be suggestive as to how the acquisition of L2 phonology might affect the already existing L1 phonology. Several researchers report that L1 phonology is affected by the acquisition of L2 phonology. Bond, Eddey, and Bermejo (1980) found that a Spanish-speaking child learning ESL had her Spanish VOT values affected by the English ones. Also, Streeter and Landauer (1976) show that Kikuyu-speaking children learning English used VOT values in Kikuyu that are non-phonemic in their L1. Recently, Flege (1987b) argues that bilingual experience can change VOT values in L1 to more second-language-like VOT values; he cites the fact that American speakers of French tend to produce shorter VOT values than do English monolinguals. Clearly, L2 experience readily affects the production of VOT in L1.

In order to look at the effect of Japanese on English phonology, we compare English VOT values produced by both the immersion teachers and immersion children with the monolingual data from the literature (Lisker and Abramson, 1964; Snow, 1997). To judge whether VOT values are adult-like, the “magnitude criterion” proposed by Snow (1997) was used, in which they are considered adult-like when VOT values for voiceless stops in English exceed 60 ms. He selected this 60 ms criterion for the following two reasons:

> First, the main developmental change in young children’s production of word-initial stops is the increase in VOTs for long-lag voicing targets.

> Second, 60 msec is the lower bound of the lag time region appropriate for voiceless stops that has been documented in studies of English-speaking adults and children. (Snow, 1997, p. 45)

Table 8-4 shows mean VOT values and standard deviations for English voiceless stops by English monolingual 6-year-old children (Zlatin & Koenigsknecht, 1976) and English monolingual adults (Lisker and Abramson, 1964) in comparison with those values for English voiceless stops produced by the immersion children and teachers during the first data collection in this study.[27]

Table 8-4 English VOT values and SD for monolingual children, immersion children, monolingual adults and immersion teachers

		/ p /	/ t /	/ k /
Monolingual children	Mean VOT	68.00	68.47	80.17
	SD	25.86	23.23	25.36
Immersion children	Mean VOT	80.05	84.17	98.03
	SD	27.5	28.21	29.43
Monolingual adults	Mean VOT	58.00	70.00	80.00
	Range	20-120	30-105	50-135
Immersion teachers	Mean VOT	75.52	69.83	85.97
	SD	28.29	19.36	17.69

Since all mean VOT values for the immersion children meet the 'magnitude criterion,' they can be considered to have reached the adult-like VOT norm. Mean VOT values for English voiceless stops produced by the immersion children are consistently longer than those of monolingual English children with similar standard deviation values. Also, mean VOT values produced by the immersion teachers who speak both Japanese and English are similar to those of adult monolingual speakers except for / p / . Contrary to several previous studies, these observations do not support the hypothesis that a second language has an effect on the acquisition of L1 phonology. However, we cannot jump to conclusions because the reference data were not always

[27] In Lisker and Abramson (1964), only the range is available.

collected with the same segmental and suprasegmental factors controlled for (e.g., adjacent consonants and vowels, speech rate, number of syllables, different sentence frames).

8.7 Future Research

First, due to time constraints, only two data collections were conducted for a longitudinal study, and we have found that there is no improvement of the children's production of VOT within the interval of two and a half months. However, there was a significant progress in the closure duration of the children in grade 5 during the interval, although they did not reach the monolingual speaker's phonetic norm. It is generally assumed that although children are better at language learning, adults are faster than children; therefore, to verify the improvement of the children's pronunciation, follow-up research with an interval of at least one year is definitely necessary. The longer interval between the data collection will also eliminate the test effect which may have been the cause of the development of closure duration at Time 2 in this study.

Second, in the preceding section we are not quite sure whether or not L2 phonology will affect L1 phonology through bilingual experience because equivalent monolingual English speakers' data were not available. Since the data show that Japanese immersion teachers, who have been speaking English for a long time, use longer VOT values for Japanese voiceless stops than those of monolingual Japanese speakers, more research is needed on the effects of early and late acquisition of second languages on native language phonological systems. Though transfer from L1 to L2 has been well documented, the opposite type of transfer–L2 to L1– remains an issue for

further study.

Third, the nature of the input from the immersion teachers raises the question of whether the Japanese immersion students would have reached the same phonetic norm as that of monolingual Japanese children, if they had received the same input as monolinguals. Research on the nature of input should be carried out in two different ways. 1) We could research the production of Japanese voiceless stops by examining American children learning Japanese in an elementary school in Japan, where a teacher is a monolingual Japanese speaker. 2) We can also focus on this issue by investigating the acoustic features of children in a two-way immersion program, where peer input comes from monolingual children. In order to understand why the immersion children did not reach the native speaker's norm, it is crucial to investigate the effects of the quality of immersion teachers' speech input on the acquisition of the children's Japanese pronunciation.

Fourth, this research has looked at a Japanese immersion program in the U.S. However, research on English immersion has not been well documented yet; above all, no such research on the acquisition of English phonology has been done. As a result of the need for cross-cultural communication and internationalization, an English immersion program has been introduced recently in Japan as well. It would be worth studying how Japanese children in the English immersion program acquire an English phonological system, which is crucially different from their L1 phonology. Will they acquire an intermediate English phonology?

Fifth, the researcher has grown increasingly interested in the phonological relationship between L1 and L2 in heritage language learners

and simultaneous bilinguals as opposed to sequential bilinguals such as immersion children. For example, heritage language learners (e.g., second generation Japanese Americans) first get exposed to Japanese as their native language at home, but outside their home they are usually instructed in English; consequently, some may even lose their L1. But what type of phonological systems are possessed by those who maintain two languages in a balanced way? In addition, it is interesting to study the acquisition of L2 phonology by simultaneous bilinguals both of whose parents speak different languages to them. Future research is needed to investigate to what extent both heritage language learners and simultaneous bilinguals maintain the acoustic phonetic norms (e.g., VOT, closure duration, vowel quality) of each language and how they differentiate between the two systems.

CHAPTER 9

PEDAGOGICAL IMPLICATIONS

9.1 General Issues

What is an appropriate age to start to learn a foreign language?

This question is not easy to answer because second/foreign language learning has many facets that one must seriously consider to decide when we should start to learn another language. This research study focused only on the acquisition of L2 pronunciation; therefore, we will consider an optimal age in terms of L2 speech learning. Generally speaking, it has long been assumed that there exists a specific optimal age for learners to get exposed to a foreign language so that they can acquire a nativelike pronunciation. Thirty years ago, Asher (1969, p. 340) reported that Cuban immigrants, "who came to the US between one and six years of age and lived in this country between five and eight years," reached a "near-native" English pronunciation. More recently, Nunan (1999) points out that there is an assumption that younger is better and that this "rarely appears to be questioned at the level of [language] policy."

> Behind the drive to introduce English at younger and younger ages is the assumption that younger is better, that a child who begins learning English (or any other language, for that matter) at the age of 5 will be more proficient in the language at 12 than will a child who begins learning at age 8. (Nunan, 1999, p. 3)

In terms of pronunciation, this kind of assumption is often misleading because it gives us the impression that those children who start to learn another language at this early stage do not retain their L1 accent. However, it should be emphasized that no matter how early one starts to get exposed to a second language, one almost always retains an L1 accent to a greater or lesser

degree. Asher (1969) already claimed the following:

> No matter what the age of the child when he or she came to the United States and no matter how long the child lived here from one to eight years, not one of the 71 Cuban children achieved a native English pronunciation. (p. 340)

The current study also confirms this: the immersion children, who have been exposed to Japanese from the age of six, have not reached a native Japanese pronunciation even after five or six years of immersion instruction in Japanese. We may conclude that once we have established an L1 phonology it is almost impossible to achieve native pronunciation in L2 no matter how early one starts to learn a second language. In this sense, it can be claimed that there is no optimal age to start a new language so as to acquire native pronunciation.

Why introduce a second language at an early stage?

Although there is no optimal age for achieving native pronunciation, there are still big advantages to starting a new language at an early age. One of the most important findings is that immersion children can clearly distinguish one sound in Japanese from a similar one in English. In other words, children given sufficient exposure to their L2 will establish two distinct productive phonological systems, which will avoid confusion at the phonemic level. In terms of pronunciation, this is clearly the crucial reason for introducing a foreign language when children are young. The main purpose of learning another language is to be functional in the target language, which should be met by acquiring the core linguistic system of the language. For example, the immersion students' contrast between singletons and geminates was established even though the acoustic duration was significantly different from that of Japanese monolingual speakers. This

acquisition of two separate systems will lessen any phonemic confusion and eventually lead to effective communication. Therefore, the rationale for introducing a foreign language at an early age should not rely on native or native-like pronunciation but on the functional separation of the two phonological systems.

Do children acquire L2 speech in no time?

Parents as well as teachers tend to expect children to acquire nativelike pronunciation in no time, if they start to learn a second language early in life. Unfortunately, this research indicates that this is not the case. In addition, there is no significant difference in the accent rating across the grades, though there is a tendency for the fifth graders to perform better and for their contrast between singletons and geminates to be clearer than that of the children in the lower grades. Parents and teachers should recognize that even immersion students who receive much more input than students in a traditional foreign language program have not acquired the native-like Japanese norm after five years of Japanese instruction, though they were successful in establishing a clear contrast between singleton and geminate consonants. Parents and teachers should thus be patient when it comes to teaching pronunciation.

Pronunciation is not the only objective of foreign language education.

Nunan (1999) reports that “in each country (Costa Rica, Thailand, and Italy), the government has recently made English compulsory at the elementary level of the schooling system.... Around the world, children are being compelled to learn English at younger and younger ages” (p. 3). In support of this proposal, children’s good pronunciation is often cited as one of the reasons for teaching a foreign language early to children. For example, the Ministry of Education in Japan proposed to introduce English in the

elementary school curriculum, arguing for children's aptitude for learning pronunciation (Koike, 1995). We should discuss whether or not we should have children learning a second language in elementary school from educational, societal, psychological, developmental, economical, and political perspectives. If children's ultimate achievement of good pronunciation is emphasized too much, the goals of other skills in foreign language education will be distorted. As this research shows, there is always an inevitable limitation to the acquisition of native pronunciation in a non-naturalistic setting, no matter how early we start to learn a foreign language; therefore, it is not realistic to put the acquisition of nativelike pronunciation at the center of the curriculum.

Why immersion education?

Although the immersion children did not reach the native speakers' phonetic norms, they succeeded in establishing the two different and functional phonological systems. This advantage probably resulted from a large amount of exposure to Japanese. This study did not look at a control group who are learning Japanese in a traditional curriculum such as FLES (Foreign Language in Elementary School) or FLEX (Foreign Language Experience). However, when Genesee (1987) compared the French pronunciation of children in an immersion and a FLES program, he reported that the immersion students outperformed those in the regular foreign language program. This can be accounted for by a much larger amount of input in the immersion program. As mentioned earlier, the immersion children spent 60 to 100% (17 to 27 hours) of their weekly class time getting instruction in Japanese, while in the Japanese FLES program children spend 93.6 to 130.5 minutes per week on average on Japanese instruction (Kataoka,

Furuyama and Fretz, 1999). The amount of exposure of the immersion children is about 11 to 12 times greater. Since even the first graders have started to establish a complete separation of the two phonological systems after about 1,500 hours of exposure, an equivalent amount of time would be required for the complete separation of the two phonological systems. This implies that students in the FLES program will fail to establish two different phonological systems because they are exposed to Japanese for only about 56 to 78 hours (93.6 to 130.5 minutes x 36 weeks) per year, which is equivalent to just three weeks of exposure in the immersion program. The amount of input in the FLES program cannot be compared with that of immersion education. In other words, the immersion program may have the advantage of preparing students to acquire two distinct and functional phonological systems.

9.2 Curriculum

Realistic goals

As the accent ratings show, the immersion children clearly retain many features of their L1 accent. There are many reasons to explain this, but part of this problem is caused by too much focus on content, which often tends to occur in content-based language instruction. In immersion education, realistic goals should be set in order for teachers to systematically focus on pronunciation and raise students' awareness of problematic features.

In the traditional curriculum, correctness was the goal of pronunciation instruction while in extreme forms of communicative teaching, pronunciation teaching has been completely ignored. This research study indicates that both extreme types of curricula are not pedagogically

ideal. Correct pronunciation, or what we call ‘nativelikeness,’ is clearly beyond the reach of most second language learners, which is supported by the current finding that immersion education, which comes closest to a naturalistic setting, was not sufficient to allow the children to acquire nativelike pronunciation. In addition, our results suggest that some immersion children more clearly retain their L1 accent than others.

To see how pronunciation is incorporated into the whole curriculum, I interviewed several immersion teachers and found that specific goals for pronunciation had not been set and the curriculum seemed to include only the goal of content. Immersion teachers must pay more balanced attention to both language and content and should be required to develop the realistic goals according to grade level so that children can get rid of the most noticeable accent features that may interfere with their communication skills in the L2.

Systematic approach with built-in recycling

Once the goals are set for the pronunciation curriculum, the objectives should be specified based on a comparison between the children’s L1 and L2 phonology. First, teachers must do research on what sounds and phonological aspects of the target language will cause difficulties for the students. For example, English learners of Japanese have difficulty controlling timing (e.g., singletons and geminates, short and long vowels, simple nasals and moraic nasals) because this type of timing control is not required in the English language. Then, if one of the goals in the curriculum is to acquire all phonemic contrasts in Japanese and one objective is to learn the contrast between single and geminate consonants, its presentation and practice should be assigned to an appropriate grade level.

But, unfortunately, this research shows that the process and rate of the acquisition of pronunciation takes a lot of time and effort since even two of the fifth graders have not acquired a clear contrast between singletons and geminates, as their acoustic ratios of 1.08 and 1.28 showed. This means that in addition to the systematic approach, we definitely need to recycle the target pronunciation objectives for students to raise their awareness of them again and again in different grades. Therefore, the basic concepts of any pronunciation curriculum have to be grounded on a systematic approach with provisions for recycling.

9.3 Teaching Methodology

More focus on form

Immersion education, which is one form of content-based education, tends to be content-heavy, and teachers usually find it hard to integrate language into the curriculum. When it comes to teaching pronunciation, this appears to be even harder. Even though immersion education comes closest to mirroring a naturalistic setting, the amount of input is so limited that children are provided with few chances to get feedback on their pronunciation compared with those who are learning a second language in a naturalistic setting. This suggests that some focus on pronunciation in classroom activities (e.g., via drama productions) is essential. When I observed several immersion classes, some teachers had children repeat some Japanese sentences in practice for a drama production. These classroom activities seemed to be designed to reinforce content rather than to provide students with linguistic feedback. Although this research study did not look at how an instructional method will influence the acquisition of pronunciation,

it may be pointed out that giving little or no focus on pronunciation in an immersion program will result in students' retaining their L1 accent as well as preventing them from reaching the phonetic norms of L1 speakers, as Hammerly (1991) suggests.

Constant focus on form for a developmental reason

This research has shown that there is no significant difference in the acquisition of VOT and the contrast between singletons and geminates across the grade levels. This implies that children make very slow progress in the acquisition of pronunciation. Moreover, feedback given once or twice will not always work. Teachers in the immersion program must be patient enough to give students multiple forms of feedback and to wait a long time to see their gradual progress, even though they outperform children in the FLES program in the ultimate acquisition of pronunciation.

9.4 Implementation of Immersion Programs

Types of immersion

This study looked at the acquisition of L2 speech by children in a total immersion program. Since there is no control group in a partial immersion program, we are not quite sure if there would be any difference between these two programs. But at least we can suggest that total immersion may seem to allow students sufficient exposure to establish a separation of the two phonological systems. In other words, total immersion may have provided the children with sufficient input for the separation of the systems. The amount of input may be so crucial that we should maximize it by putting as many target language volunteers and teachers' aids as possible in class. Also, the results of this research are not relevant to the effect of a two-way

immersion program on the acquisition of L2 pronunciation, but this type of immersion may provide children with more input from peers as well as teachers. Further research will be necessary to establish the effect of two-way immersion education on the acquisition of L2 speech.

Teachers' input and models for pronunciation

People assume that native speakers are better teachers of pronunciation than nonnative speakers and that learning pronunciation from native speakers allows learners to acquire good pronunciation. This assumption has rarely been questioned or challenged. But if this assumption were plausible, the immersion students would at least have reached the phonetic norms of the immersion teachers, if not those of the monolingual speakers. This research implies that even if Japanese monolingual teachers had taught in this immersion program, the children might not have reached the phonetic norms of the monolingual speakers. This experimental result of this research may challenge the assumption that native teachers outperform nonnative teachers in the teaching of pronunciation, although further investigation is called for to see if there is any significant effect of native and nonnative teachers' input on learners' acquisition of pronunciation.

If we assume that the ultimate goal of teaching pronunciation is to have learners acquire the phonemic or functional contrasts and establish a new phonological system, nonnative teachers who have acquired the L2 phonological system, even if slightly deviant from that of monolingual speakers, may help learners establish the new system. This is evidenced by the findings that L2 learners' phonology does not overlap with that of the input sources (i.e., the immersion teachers) even after long-term instruction in Japanese. In other words, it is not a matter of students' imitating the teacher's

pronunciation.

Anecdotally, this may also be plausible. Several discussion sections in the Japanese foreign language program at UCLA are taught by nonnative TA's who have a good level of Japanese proficiency, but I have never observed any clear difference in the pronunciation of the students between those who had a native TA and those who had a nonnative TA. Although this remains an issue for further study, language teachers and administrators should not unquestionably accept the assumption that native teachers are always better at teaching pronunciation and are the best models for pronunciation.

9.5 Pronunciation Evaluation

Is native pronunciation a criterion of evaluation?

Native speaker ability with reference to both accuracy and fluency measures, has often been considered as a norm in scales prepared for language tests. For example, the Interagency Language Roundtable (ILR) Scale defines the highest level, that is, 5 as a "native or bilingual proficiency" (Hadley, 1993). According to the findings of this research, even children, who are biologically sensitive, cannot completely reach the native speaker's norm. This implies that in the testing of pronunciation a scale based on native speaker pronunciation for the highest rating is not realistic, since this is a level no second or foreign language learners can possibly reach. This view is also supported in the literature on language testing. Bachman (1990) argues that it is not appropriate to define the native speaker's ability as a criterion for a scale of language testing:

> The language use of native speakers has frequently been suggested as a criterion of absolute language ability, but this is inadequate because native speakers show considerable variation in ability, particularly with

> regard to abilities such as cohesion, discourse organization, and sociolinguistic appropriateness. For these reasons, it seems neither theoretically nor practically possible to define either an absolutely 'perfect' level of actual language performance, or an individual with 'perfect' language ability. (p. 39)

His view on native speaker's ability is totally acceptable. In the present research we saw several variations in mean VOT and closure duration values within and across the monolingual child groups and between the monolingual speakers and the Japanese English bilingual immersion teachers. Therefore, a specific scale for pronunciation evaluation must be developed to determine whether the students have achieved the language goals and objectives described in an ideal curriculum.

Rater Reliability

The results of the accent ratings showed that acoustically similar ratios of singletons to geminates were rated differently. This may have resulted from raters' focusing on different phonetic features. Moreover, raters do not usually find the holistic rating of pronunciation difficult because their subjective impressions are reliable. But when they are asked to analytically rate speech samples, they pay attention to different features unless they are well trained. Therefore, rating the contrast between singletons and geminates, while ignoring some other phonetic aspects (e.g., accent, speech rate), may have caused some difficulty for the raters.

In summative and placement assessments the holistic rating of a learner's pronunciation works well, while in formative and diagnostic assessment, analytic scoring is more likely to be required. For example, to develop a new curriculum that integrates pronunciation into content in immersion education, we must start with a needs analysis. A diagnostic test

should be administered to spot students' pronunciation difficulties, in which case the rating must be based on an analytic approach: trained raters should be required to distinguish different aspects of pronunciation (e.g., vowels, consonants, syllables, rhythm, accent and intonation). This skill is also required when we teach pronunciation in the classroom. Teachers are expected to spot students' errors quickly and to recognize what caused the errors. Therefore, teachers should be trained to listen both subjectively and objectively to students' speech so that they can make reliable ratings and provide effective pronunciation instruction.

The current research investigated only the acquisition of segmental timing in Japanese, focusing on the production of VOT and geminates. To fully solve L2 learning, however, we believe other phonetic features such as vowels and prosodic features should also be researched.

One of the most insightful findings in this research is that children who start to learn a second language at an early stage can establish a new phonetic category for L2 sounds acoustically, whether or not they are new or similar relative to their L1 phonological system, although their new phonetic category is different from that of L1 speakers. Pedagogically, this finding may also support children's second language learning starting at an early age. Finally, this research will serve as a milestone for L2 speech learning theories for both adults and children as well as for the development and implementation of pronunciation curriculums in second and foreign language education.

APPENDIX 1: COVER LETTER

Tetsuo HARADA
3777 Mentone Ave. #314
Los Angeles, CA 90034
(310)838-0618
tharada@ucla.edu
February 6, 1998

Dear Parents,

As a graduate student at the University of California, Los Angeles, I am working on a study relevant to second language learning and immersion education, above all, how Japanese Immersion children learn speaking skills. I am writing to recruit several children who will participate in this research. The study consists of three face-to-face speaking tests with a two or three month interval between tests.

The actual process involved will be a twenty-minute audio-recording session in school where I ask your child to describe pictures using Japanese or English. The sessions will be held in February, March and May or June. The tests will be administered in a quiet classroom before or after school so that they will not interfere with the student's usual academic activities.

This study will be conducted with the approval of but not under the auspices of the school. It is not part of the child's regular curriculum and therefore the child's grade is not affected by a decision whether or not to participate. The data obtained in this study is strictly confidential. Your child's name will not be mentioned in the report of results. In addition, when I have completed the data analysis, I will report findings about your child's development of Japanese speaking skills to you as a way of thanking you for your child's time and participation. Results reported to the child's teacher will be kept anonymous.

I would appreciate it if you would consider my request and allow your child to participate in this study. If you are willing to consent to your child's participation, please read and sign the enclosed parental permission form, fill in a language background information sheet and turn them in to your child's teacher using the enclosed envelope by **Wednesday, February 18**. Also, please take the time to read out the enclosed assent form to your child and ask him or her to sign it. If your child does not volunteer to be in this study, please check an appropriate box on the enclosed form and return it to the teacher. If you have any questions or concerns about the research, please feel free to contact me at (310)838-0618. Thank you.

Sincerely yours,

Tetsuo Harada
Doctoral student in the UCLA Program in Applied Linguistics

APPENDIX 2: CONSENT FORM

CONSENT TO PARTICIPATE IN RESEARCH

The Acquisition of Speaking Skills by Children in a Japanese Immersion Program

Child's name: _____

You and your child are being asked to participate in a research study conducted by Tetsuo Harada, a doctoral student from the program in Applied Linguistics at the University of California, Los Angeles. The results will contribute to a Ph.D. dissertation. You and your child were selected as possible participants in this study because she/he attends a Japanese Immersion program in Culver City, California.

PURPOSE OF THE STUDY
This study is designed to assess how Japanese Immersion children learn speaking skills.

PROCEDURES
If your child volunteers to participate in this study, I would ask her/him to do the following things:
The data for this study will be collected from your child at three different times with a two or three-month interval between collections. Each session will consist of a 20-minute face-to-face speaking test administered before or after school. The child's performance will be audio-taped as he/she sits in a quiet classroom with the researcher. During each session the child will be shown pictures of objects and asked to label and describe them in Japanese or English.

Before your child participates in this study, I would ask you to fill in the enclosed language background information sheet. This questionnaire discusses the language background of your child and his/her parents. It will take you about 15 minutes to fill in this form.

POTENTIAL RISKS AND DISCOMFORTS
None.

POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY
Parents will be informed of the child's development of Japanese speaking skills.

Results of this study will contribute to the design, planning and implementation of immersion curricula and to research on the bilingual acquisition of second language speech by children. Therefore, your child's teacher will have access to the anonymous test results.

PAYMENT FOR PARTICIPATION
This study will be conducted on a volunteer basis and the children will receive no payment.

CONFIDENTIALITY
Any information that is obtained in connection with this study and that can be identified with your child will remain strictly confidential and will be disclosed only with your permission or as required by law. Confidentiality will be maintained by coding your child's data with a random number and only the researcher will have access to the name and number.

You and your child have a right to review the tapes and when the data analysis is done, the tapes will be erased.

PARTICIPATION AND WITHDRAWAL

This study will be conducted with the approval of but not under the auspices of the school. It is not part of the child's regular curriculum and therefore the child's grade is not affected by a decision whether or not to participate. Your child can choose whether to be in this study or not. If your child volunteers to be in this study, he/she may withdraw at any time without consequences of any kind. Your child may also refuse to answer any questions he/she doesn't want to answer and still remain in the study. The investigator may withdraw your child from the research if circumstances arise which warrant doing so.

IDENTIFICATION OF INVESTIGATORS

If you have any questions or concerns about the research, please feel free to contact Mr. Tetsuo Harada (the researcher) or Prof. Marianne Celce-Murcia (faculty sponsor):

Mr. Tetsuo HARADA
3777 Mentone Ave. #314
Los Angeles, CA 90034
(310)838-0618
tharada@ucla.edu

Prof. Marianne Celce-Murcia
University of California, Los Angeles
Department of TESL & Applied Linguistics
P.O. Box 951531, 3315 Rolfe Hall
405 Hilgard Ave.
Los Angeles, CA 90095-1531
(310)206-1320
celce-m@humnet.ucla.edu

RIGHTS OF RESEARCH SUBJECTS

You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you have questions regarding your rights as a research subject, contact the Office for Protection of Research Subjects, UCLA, Box 951694, Los Angeles, CA 90095-8714.

SIGNATURE OF RESEARCH SUBJECT OR LEGAL REPRESENTATIVE

I understand the procedures described above. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

_____
Name of Subject (your Child)

_____
Name of Parent or Legal Representative

_____ _____
Signature of Parent or Legal Representative Date

APPENDIX 3: ASSENT FORM

ASSENT TO PARTICIPATE IN RESEARCH

The Acquisition of Speaking Skills by Children in a Japanese Immersion Program

1. My name is Tetsuo Harada.

2. I am asking you to take part in a research study because I am trying to learn more about your speaking skills in Japanese.

3. If you agree to be in this study, you will do the following:
1) You will take part in the speaking test three times, in February, March and May or June.
2) Each test will take about 20 minutes.
3) You will be shown pictures of objects and asked to label and describe them in Japanese or English.
4) Your speech sample will be audio-taped.

4. There are no risks to you that may come from participation in the research.

5. I will let you know about the progress of your Japanese speaking skills when I complete the data analysis. I will also discuss your Japanese speaking skills with your parents. My reports to your teacher will not tell her any students' names.

6. Please talk this over with your parents before you decide whether or not to participate. I will also ask your parents to give their permission for you to take part in this study. But even if your parents say "yes" you can still decide not to do this.

7. If you don't want to be in this study, you don't have to participate. Remember, being in this study is up to you and no one will be upset if you don't want to participate or even if you change your mind later and want to stop.

8. You can ask any questions that you have about the study. If you have a question later that you didn't think of now, you can ask me at school.

9. Signing your name at the bottom means that you agree to be in this study. You and your parents will be given a copy of this form after you have signed it.

_____ _____

Name of Subject Date

APPENDIX 4: LANGUAGE BACKGROUND INFORMATION SHEET

The following data will be used only for my research on how Japanese Immersion children learn speaking skills. All information you will provide here is strictly confidential. Please take a few minutes to fill in this form and return it to me with the enclosed parent consent form. Thank you for your understanding and cooperation. February 6, 1998

Tetsuo Harada

INFORMATION ON <u>YOUR CHILD</u>:

1. Name _____, _____ _____
(last) (first) (middle)

2. Sex (Circle one): Male Female

3. Grade level: _____

4. Teacher's name: _____

5. When did your child start to join the Japanese Immersion program? _____

6. Birth date: _____ _____ _____ (month/date/year) Age: _____

7. Birth place: _____ (city), _____ (country)

8. Did your child live for more than six months in Japan and other countries, but not including the US ? Please indicate the city, the country, his/her age when he/she began to live and the length of residence.

_____ (city), _____ (country), _____ (age), _____ (length)

_____ (city), _____ (country), _____ (age), _____ (length)

9. Nationality _____

10. Native language(s) _____

11. Other language(s) spoken & understood well _____

12. Amount of time your child speaks <u>English</u> outside school.
(Circle one) 1. 0 - 20 % 2. 20 - 40% 3. 40 - 60% 4. 60 - 80% 5. 80 - 100 %

13. Amount of time your child speaks <u>Japanese</u> outside school.
(Circle one) 1. 0 - 20 % 2. 20 - 40% 3. 40 - 60% 4. 60 - 80% 5. 80 - 100 %

14. Does your child get a chance to <u>listen</u> to Japanese outside school?
No Yes: if yes, what does he/she listen to? Please circle all that apply.

a. parent(s) b. sibling(s) c. grandparent(s) d. Japanese friend(s)

e. TV or radio f. audio or video tapes g. other: _____ (please specify.)

15. Does your child speak Japanese outside school?
No Yes: if yes, who does he/she speak with?
a. father b. mother c. sibling(s) d. grandparent(s) e. neighbors

f. Japanese friends g. other: _____ (please specify.)

16. Did your child begin to learn or get exposed to Japanese before he/she entered the Japanese Immersion program?
No Yes: if yes, indicate the age of first exposure to Japanese: _____

17. What language does your child most frequently speak at home? _____

INFORMATION ON MOTHER:

18. Name _____, _____ _____
(last) (first) (middle)

19. Birth place: _____ (city), _____ (country)

20. Where was the child's mother brought up? Please indicate the city and the country where she spent her childhood?
_____ (city), _____ (country)

21. Mother's nationality _____

22. Mother's native language(s) _____

23. Other language(s) mother speaks and understands well _____

24. Does the child's mother speak Japanese? Yes No (if no, skip 25 and 26.)

25. Was she instructed in Japanese at least through the end of elementary school? Yes No

26. How old was the child's mother when she was first exposed to or learned Japanese? If Japanese is the child's mother's native language, please answer 0. _____ (age)

27. If the child's mother lived in Japan, what were her starting age of residence in Japan and its length of residence?
Starting age of residence: _____ Length of residence: _____

28. Does the child's mother speak English? Yes No (if no, skip 29.)

29. Was she instructed in English at least through the end of elementary school? Yes No

30. How old was the child's mother when she was first exposed to or learned English? If English is the child's mother's native language, answer 0. _____ (age)

31. What were her starting age of residence in an English-speaking country and its length of residence?
Starting age of residence: _____ Length of residence: _____

32. What language does the child's mother most frequently speak at home? _____

INFORMATION ON FATHER:

33. Name _____, _____ _____
(last) (first) (middle)

34. Birth place: _____ (city), _____ (country)

35. Where was the child's father brought up? Please indicate the city and the country where he spent his childhood?
_____ (city), _____ (country)

36. Father's nationality _____

37. Father's native language(s) _____

38. Other language(s) father speaks and understands well _____

39. Does the child's father speak Japanese? Yes No (if no, skip 40 and 41.)

40. Was he instructed in Japanese at least through the end of elementary school? Yes No

41. How old was the child's father when he was first exposed to or learned Japanese? If Japanese is the child's father's native language, please answer 0. _____ (age)

42. If the child's father lived in Japan, what were his starting age of residence in Japan and its length of residence?
Starting age of residence: _____ Length of residence: _____

43. Does the child's father speak English? Yes No (if no, skip 44.)

44. Was he instructed in English at least through the end of elementary school? Yes No

45. How old was the child's father when he was first exposed to or learned English? If English is the child's father's native language, please answer 0. _____ (age)

46. What were his starting age of residence in an English-speaking country and its length of residence?
Starting age of residence: _____ Length of residence: _____

47. What language does the child's father most frequently speak at home? _____

CONTACT INFORMATION:

Parent's name: _____

Address: _____

Phone: _____ E-mail: _____ Date: _____

Thank you very much for taking time. I really appreciate your help. Tetsuo Harada
Phone: (310)838-0618 E-mail: tharada@ucla.edu

APPENDIX 5: CONSENT FORM
(Japanese Version)

児童の日本語習得に関する調査依頼

調査の主旨

本研究はアメリカのカリフォルニア州で行われている日本語イマージョン教育（対象は英語を母語とする児童で、幼稚園、小学校１年生では日本語のみでほぼ１００％教科指導を行い、それ以降の学年では７０％前後を日本語で行う）において、英語を母語とする児童がどのように日本語の話しことばを習得するかを、日本人の子供の場合との類似点と相違点に焦点を当て考察する。なお、本調査はカリフォルニア大学ロサンゼルス校(UCLA)の倫理委員会の承諾を既に得ており、同校応用言語学部の博士論文の一部となる予定。

日程

１９９８年６月２２日から２７日までの四日間または五日間
（この日程が不可能な場合は６月２９日から７月４日までの週）

対象となる児童

１）人数
小学校１年生：男子４人、女子４人（合計８人）
小学校５年生：男子４人、女子４人（合計８人）
２）選抜方法（重要な条件順に記載）
a) 海外に３ヵ月以上滞在したことがない児童
b) 英語を習ったことがなく、また現在も英語を勉強していない児童
c) 埼玉県で生まれ育った児童
d) 両親が関東近辺で育った児童

調査の方法

本調査は録音とアンケートの二つの部分からなる予定。
１）児童との１対１のインタビューをオーディオテープに録音
a) 昼休みまたは放課後、１人１５分程度
b) 昼休み２人、放課後２人程度で一日合計４人
（児童が放課後４０－５０分学校に残ってもよい場合は、放課後に４人、一日合計６人録音し、三日で終了可能）
c) 児童は絵を見て、そこに描かれている物または動物を何と言うか日本語で答える。
例　私：「これは何ですか。」（「たね」の絵を見せる）
児童：「それはたねです。」
d) 上の短い会話を３５枚の絵により行い、数分の休憩をとり、後半も同じ会話を同数の絵をヒントに行う。
２）可能であれば、録音に参加した児童の保護者への短いアンケートを実施
a) アンケートの内容は児童、家族の簡単な言語背景等とする。（別紙参照）
b) １年生には保護者にアンケートを依頼し、５年生には児童本人に直接質問することも可能。

秘密厳守

この調査で録音したテープ、アンケートで得た情報はすべて秘密厳守とする。調査の結果を発表する際は、個人のデーターは使わず、全体の統計上のデーターのみを使用する。

参考

上記の録音とアンケートの順序を逆にすることも可能。すなわち、上記の選抜方法に記されている条件を満たす児童を簡単に探すために、最初にアンケートを１年生と５年生の各クラスの保護者に配布し、アンケートと同時に父兄から録音の承諾を得ることができた児童だけを選抜する。

APPENDIX 6: LANGUAGE BACKGROUND INFORMATION SHEET (Japanese Version)

私はアメリカのカリフォルニア州にありますカリフォルニア大学ロサンゼルス校(UCLA)で外国語習得を専攻している者です。この調査では、アメリカの小学生の日本語習得と、日本の小学生の母語習得を比較対照するため、日本の小学生のデーターが必要となり、日本の小学生の児童の方とそのご父兄の方にご協力をお願いしている次第です。このアンケートは日本人の子供がどのように日本語の話しことばを習得するかを調べるための予備資料となるものです。このアンケートをもとに、数人のお子様に録音を依頼させていただきたいと思っています。録音の方法はある絵を見て、それが何かを日本語で答える１５分程度の簡単な作業です。この調査で録音したテープ、アンケートで得られた情報はすべて秘密厳守とします。調査の結果を発表する際は、個人のデーターは使わず、全体の統計上のデーターを使用するのみです。

下記の質問に回答し、ご署名の上担任の先生にお返しください。ご協力ありがとうございました。

原田哲男

アンケート

１　お子様(ふりが)の名前(な)：＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿

２　性別：　男　　女　（どちらかに○をつけてください。）

３　小学校の名前：＿＿＿＿＿＿＿市＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿小学校

４　学年：＿＿＿＿　　５　生年月日：＿＿＿＿＿＿＿　　６　年齢：＿＿＿＿＿

７　生まれた場所：＿＿＿＿＿＿＿都／道／府／県　＿＿＿＿＿＿＿市／区／郡

８　最も長く生活した場所：＿＿＿＿＿＿＿都／道／府／県　＿＿＿＿＿＿＿市／区／郡

９　海外に３ヵ月以上滞在したことがありますか。　はい　いいえ

１０　英語などの外国語を習ったことがありますか、または現在習っていますか。　はい　いいえ
「はい」の場合は週何回、何時間、何年間かを記入してください。　週＿＿＿回　＿＿＿時間　＿＿＿年間

１１　お母さんの生まれた場所：＿＿＿＿＿＿＿都／道／府／県　＿＿＿＿＿＿＿市／区／郡

１２　お母さんが子供の時最も長く生活した場所：＿＿＿＿＿＿＿都／道／府／県　＿＿＿＿＿＿＿市／区／郡

１３　お父さんの生まれた場所：＿＿＿＿＿＿＿都／道／府／県　＿＿＿＿＿＿＿市／区／郡

１４　お父さんが子供の時最も長く生活した場所：＿＿＿＿＿＿＿都／道／府／県　＿＿＿＿＿＿＿市／区／郡

上記児童の録音を承諾し、アンケートと録音の両資料が将来、教育または研究の目的で匿名で使用されることがあることを同意いたします。

保護者氏名：＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿　日付：＿＿＿＿＿＿＿＿

APPENDIX 7: FOREIGN ACCENT RATING SHEET
(Japanese Version)
日本語発音評価

私はアメリカのカリフォルニア州にありますカリフォルニア大学ロサンゼルス校(UCLA)で外国語習得を専攻している者です。この調査は、アメリカの小学生の日本語習得と、日本の小学生の母語習得を比較対照するためのものです。貴重なお時間をお取りいただき、大変申し訳ありませんが、１０分程度の日本語のテープを聞いていただき、その発音を評価していただきたく思います。なお、テストの結果は、個人の名前を使用せず、統計的に平均値等を見るのみですので、個人情報が公開されることは一切ありません。ご協力ありがとうございます。

カリフォルニア大学ロサンゼルス校
応用言語学科
原田哲男

問題指示：　小さい「っ」がある場合とない場合の聞き取り

これから、日本語を外国語として学習している小学生の発音と日本語を母国語としている小学生の発音を順不同に聞いていただきます。同一の話者が発音した小さい「っ」を含む文が三つ、小さい「っ」を含まない文が三つ、合計六つの文が順不同に、連続してテープから流れます。その際、小さい「っ」があるか、ないかに注目してください。その区別がどの程度できているかを、０から１０までで採点してください。スピード、アクセント、イントネーション等の他の要素は考慮に入れないでください。評価基準は次の通りです。

１０　＝　小さい「っ」があるか、ないかの区別が完全にできていて、日本語話者だと思われる場合。
５　＝　そのどちらとも判断し難い場合（区別ができている場合とできていない場合がある）
０　＝　まったくその区別が完全に混同されていて、明らかに外国人訛りだと思われる場合

なお、ブザーが１回鳴ったら回答を書きはじめてください。それから、８秒後に、ブザーが２回鳴り、次の話者の発音が流れます。各話者の発音は１回しか聞けません。また、話者の番号は録音されていませんから、注意深く聞いてください。

例題１：日本語を外国語として学習している小学生の発音

それは　かった　です。 それは　さか　です。x それは　パパ　です。x それは　かた　です。x それは　みっか　です。 それは　はっぱ　です。	**区別がまったくできていない（明らかに外国語訛り）**　　**どちらとも判断が難しい**　　**区別が完全にできている（明らかに日本人の発音）** **０　１　２　３　４　⑤　６　７　８　９　１０**

例題２：日本語を母国語としている小学生の発音

それは　はっぱ　です。 それは　みっか　です。 それは　かた　です。 それは　パパ　です。 それは　たこ　です。 それは　かった　です。	**区別がまったくできていない（明らかに外国語訛り）　どちらとも判断が難しい　区別が完全にできている（明らかに日本人の発音）** **０　１　２　３　４　５　６　７　８　９　⑩**

話者１

それは　パパ　です。 それは　たこ　です。 それは　はっぱ　です。 それは　みっか　です。 それは　かた　です。 それは　かった　です。	**区別がまったくできていない（明らかに外国語訛り）　どちらとも判断が難しい　区別が完全にできている（明らかに日本人の発音）** **０　１　２　３　４　５　６　７　８　９　１０**

話者２

それは　みっか　です。 それは　はっぱ　です。 それは　かた　です。 それは　パパ　です。 それは　かった　です。 それは　さか　です。	**区別がまったくできていない（明らかに外国語訛り）　どちらとも判断が難しい　区別が完全にできている（明らかに日本人の発音）** **０　１　２　３　４　５　６　７　８　９　１０**

話者３

それは　みっか　です。 それは　はっぱ　です。 それは　かった　です。 それは　さか　です。 それは　かた　です。 それは　パパ　です。	**区別がまったくできていない（明らかに外国語訛り）　どちらとも判断が難しい　区別が完全にできている（明らかに日本人の発音）** **０　１　２　３　４　５　６　７　８　９　１０**

話者 4

それは　さか　です。 それは　かた　です。 それは　パパ　です。 それは　かった　です。 それは　はっぱ　です。 それは　みっか　です。	**区別がまったくできていない（明らかに外国語訛り）　どちらとも判断が難しい　区別が完全にできている（明らかに日本人の発音）** **0　1　2　3　4　5　6　7　8　9　10**

話者 5

それは　はっぱ　です。 それは　かた　です。 それは　みっか　です。 それは　かった　です。 それは　パパ　です。 それは　さか　です。	**区別がまったくできていない（明らかに外国語訛り）　どちらとも判断が難しい　区別が完全にできている（明らかに日本人の発音）** **0　1　2　3　4　5　6　7　8　9　10**

話者 6

それは　はっぱ　です。 それは　さか　です。 それは　パパ　です。 それは　かた　です。 それは　かった　です。 それは　みっか　です。	**区別がまったくできていない（明らかに外国語訛り）　どちらとも判断が難しい　区別が完全にできている（明らかに日本人の発音）** **0　1　2　3　4　5　6　7　8　9　10**

話者 7

それは　かった　です。 それは　はっぱ　です。 それは　みっか　です。 それは　さか　です。 それは　かた　です。 それは　パパ　です。	**区別がまったくできていない（明らかに外国語訛り）　どちらとも判断が難しい　区別が完全にできている（明らかに日本人の発音）** **0　1　2　3　4　5　6　7　8　9　10**

話者８

それは　パパ　です。 それは　かった　です。 それは　さか　です。 それは　はっぱ　です。 それは　みっか　です。 それは　かた　です。	**区別がまったく　　どちらとも　　区別が完全に** **できていない　　判断が難しい　　できている** **（明らかに　　（明らかに** **外国語訛り）　　日本人の発音）** **０　１　２　３　４　５　６　７　８　９　１０**

話者９

それは　かた　です。 それは　みっか　です。 それは　はっぱ　です。 それは　さか　です。 それは　かった　です。 それは　パパ　です。	**区別がまったく　　どちらとも　　区別が完全に** **できていない　　判断が難しい　　できている** **（明らかに　　（明らかに** **外国語訛り）　　日本人の発音）** **０　１　２　３　４　５　６　７　８　９　１０**

話者１０

それは　はっぱ　です。 それは　かった　です。 それは　みっか　です。 それは　かた　です。 それは　パパ　です。 それは　さか　です。	**区別がまったく　　どちらとも　　区別が完全に** **できていない　　判断が難しい　　できている** **（明らかに　　（明らかに** **外国語訛り）　　日本人の発音）** **０　１　２　３　４　５　６　７　８　９　１０**

話者１１

それは　さか　です。 それは　パパ　です。 それは　みっか　です。 それは　かった　です。 それは　かた　です。 それは　はっぱ　です。	**区別がまったく　　どちらとも　　区別が完全に** **できていない　　判断が難しい　　できている** **（明らかに　　（明らかに** **外国語訛り）　　日本人の発音）** **０　１　２　３　４　５　６　７　８　９　１０**

話者１２

それは　たこ　です。 それは　はっぱ　です。 それは　パパ　です。 それは　かた　です。 それは　かった　です。 それは　みっか　です。	**区別がまったくできていない（明らかに外国語訛り）　どちらとも判断が難しい　区別が完全にできている（明らかに日本人の発音）** **０　１　２　３　４　５　６　７　８　９　１０**

話者１３

それは　かった　です。 それは　かた　です。 それは　はっぱ　です。 それは　さか　です。 それは　みっか　です。 それは　パパ　です。	**区別がまったくできていない（明らかに外国語訛り）　どちらとも判断が難しい　区別が完全にできている（明らかに日本人の発音）** **０　１　２　３　４　５　６　７　８　９　１０**

話者１４

それは　さか　です。 それは　みっか　です。 それは　パパ　です。 それは　はっぱ　です。 それは　かた　です。 それは　かった　です。	**区別がまったくできていない（明らかに外国語訛り）　どちらとも判断が難しい　区別が完全にできている（明らかに日本人の発音）** **０　１　２　３　４　５　６　７　８　９　１０**

話者１５

それは　みっか　です。 それは　はっぱ　です。 それは　かった　です。 それは　パパ　です。 それは　かた　です。 それは　さか　です。	**区別がまったくできていない（明らかに外国語訛り）　どちらとも判断が難しい　区別が完全にできている（明らかに日本人の発音）** **０　１　２　３　４　５　６　７　８　９　１０**

話者１６

それは　パパ　です。 それは　さか　です。 それは　かた　です。 それは　みっか　です。 それは　はっぱ　です。 それは　かった　です。	**区別がまったくできていない（明らかに外国語訛り）　どちらとも判断が難しい　区別が完全にできている（明らかに日本人の発音）** **０　１　２　３　４　５　６　７　８　９　１０**

話者１７

それは　かった　です。 それは　はっぱ　です。 それは　パパ　です。 それは　さか　です。 それは　みっか　です。 それは　かた　です。	**区別がまったくできていない（明らかに外国語訛り）　どちらとも判断が難しい　区別が完全にできている（明らかに日本人の発音）** **０　１　２　３　４　５　６　７　８　９　１０**

話者１８

それは　みっか　です。 それは　はっぱ　です。 それは　かった　です。 それは　パパ　です。 それは　かた　です。 それは　さか　です。	**区別がまったくできていない（明らかに外国語訛り）　どちらとも判断が難しい　区別が完全にできている（明らかに日本人の発音）** **０　１　２　３　４　５　６　７　８　９　１０**

話者１９

それは　かた　です。 それは　かった　です。 それは　さか　です。 それは　みっか　です。 それは　パパ　です。 それは　はっぱ　です。	**区別がまったくできていない（明らかに外国語訛り）　どちらとも判断が難しい　区別が完全にできている（明らかに日本人の発音）** **０　１　２　３　４　５　６　７　８　９　１０**

話者２０

それは　はっぱ　です。 それは　みっか　です。 それは　かた　です。 それは　かった　です。 それは　さか　です。 それは　パパ　です。	**区別がまったくできていない（明らかに外国語訛り）　どちらとも判断が難しい　区別が完全にできている（明らかに日本人の発音）** **０　１　２　３　４　５　６　７　８　９　１０**

話者２１

それは　さか　です。 それは　パパ　です。 それは　はっぱ　です。 それは　かた　です。 それは　かった　です。 それは　みっか　です。	**区別がまったくできていない（明らかに外国語訛り）　どちらとも判断が難しい　区別が完全にできている（明らかに日本人の発音）** **０　１　２　３　４　５　６　７　８　９　１０**

話者２２

それは　たこ　です。 それは　パパ　です。 それは　みっか　です。 それは　かった　です。 それは　かた　です。 それは　はっぱ　です。	**区別がまったくできていない（明らかに外国語訛り）　どちらとも判断が難しい　区別が完全にできている（明らかに日本人の発音）** **０　１　２　３　４　５　６　７　８　９　１０**

アンケート

下記の項目で答えたくない質問がある場合は抜かしても結構です。ただし、１３は必ず答えてください。

１　名前（ふりがな）：＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿　２　性別：　男　女（該当するものには○）

３　大学名：＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿大学　＿＿＿＿＿＿＿＿＿＿＿＿＿＿学部

４　学年：＿＿＿＿　　５　生年月日：＿＿＿＿＿＿＿　　６　年齢：＿＿＿＿＿

７　生まれた場所：＿＿＿＿＿＿＿＿＿＿＿都／道／府／県　＿＿＿＿＿＿＿市／区／郡

８　最も長く生活した場所：＿＿＿＿＿＿＿都／道／府／県　＿＿＿＿＿＿＿市／区／郡

９　海外に６ヵ月以上滞在したことがありますか。　はい　いいえ

１０　母国語は何語ですか：＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿

１１　母親の出身地：＿＿＿＿＿＿＿都／道／府／県　＿＿＿＿＿＿＿市／区／郡

１２　父親の出身地：＿＿＿＿＿＿＿都／道／府／県　＿＿＿＿＿＿＿市／区／郡

１３　今受けた聞き取りテストで、途中でついて行けなくなった箇所がありますか。
ある　　ない

上記の聞き取りテストとアンケートの両資料が将来、教育または研究の目的で匿名で使用されることがあることを同意いたします。

署名：＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿＿　日付：＿＿＿＿＿＿＿＿

ご協力ありがとうございました。

APPENDIX 8: ANOVA RESULTS
VOT at Time 1 across grade levels

ANOVA Table for VOT(ms)
Row exclusion: VOT DATA FILE/TIME1

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
GRADE	9	771165.026	85685.003	147.635	<.0001	1328.713	1.000
Residual	1606	932098.451	580.385				

Means Table for VOT(ms)
Effect: GRADE
Row exclusion: VOT DATA FILE/TIME1

	Count	Mean	Std. Dev.	Std. Err.
MJ1	168	29.503	15.628	1.206
MJ5	167	28.362	14.194	1.098
IJT	136	45.013	18.061	1.549
IJ1	184	63.076	23.394	1.725
IJ3	157	57.678	26.846	2.143
IJ5	164	66.968	24.284	1.896
IET	133	77.051	23.078	2.001
IE1	185	88.424	33.145	2.437
IE3	161	88.896	31.094	2.451
IE5	161	84.939	22.078	1.740

Scheffe for VOT(ms)
Effect: GRADE
Significance Level: 5 %
Row exclusion: VOT DATA FILE/TIME1

	Mean Diff.	Crit. Diff	P-Value	
MJ1, MJ5	1.141	10.845	>.9999	
MJ1, IJT	-15.510	11.448	.0003	S
MJ1, IJ1	-33.573	10.591	<.0001	S
MJ1, IJ3	-28.175	11.017	<.0001	S
MJ1, IJ5	-37.465	10.895	<.0001	S
MJ1, IET	-47.548	11.519	<.0001	S
MJ1, IE1	-58.921	10.577	<.0001	S
MJ1, IE3	-59.393	10.946	<.0001	S
MJ1, IE5	-55.436	10.946	<.0001	S
MJ5, IJT	-16.652	11.463	<.0001	S
MJ5, IJ1	-34.714	10.607	<.0001	S
MJ5, IJ3	-29.317	11.033	<.0001	S
MJ5, IJ5	-38.606	10.911	<.0001	S
MJ5, IET	-48.689	11.534	<.0001	S
MJ5, IE1	-60.063	10.594	<.0001	S
MJ5, IE3	-60.535	10.962	<.0001	S
MJ5, IE5	-56.577	10.962	<.0001	S
IJT, IJ1	-18.063	11.223	<.0001	S
IJT, IJ3	-12.665	11.626	.0176	S
IJT, IJ5	-21.954	11.510	<.0001	S
IJT, IET	-32.038	12.103	<.0001	S
IJT, IE1	-43.411	11.210	<.0001	S
IJT, IE3	-43.883	11.559	<.0001	S
IJT, IE5	-39.925	11.559	<.0001	S
IJ1, IJ3	5.398	10.783	.8937	
IJ1, IJ5	-3.892	10.658	.9865	
IJ1, IET	-13.975	11.296	.0022	S
IJ1, IE1	-25.348	10.333	<.0001	S
IJ1, IE3	-25.820	10.710	<.0001	S
IJ1, IE5	-21.862	10.710	<.0001	S
IJ3, IJ5	-9.289	11.081	.2186	
IJ3, IET	-19.373	11.696	<.0001	S
IJ3, IE1	-30.746	10.769	<.0001	S
IJ3, IE3	-31.218	11.132	<.0001	S
IJ3, IE5	-27.260	11.132	<.0001	S
IJ5, IET	-10.083	11.581	.1699	
IJ5, IE1	-21.457	10.644	<.0001	S
IJ5, IE3	-21.929	11.011	<.0001	S
IJ5, IE5	-17.971	11.011	<.0001	S
IET, IE1	-11.373	11.283	.0458	S
IET, IE3	-11.845	11.629	.0408	S
IET, IE5	-7.887	11.629	.5539	
IE1, IE3	-.472	10.697	>.9999	
IE1, IE5	3.486	10.697	.9942	
IE3, IE5	3.958	11.062	.9884	

APPENDIX 9: ANOVA RESULTS
VOT at Time 1 across places of articulation

ANOVA Table for VOT(ms)
Row exclusion: VOT DATA FILE/TIME1

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
GRADE	9	777551.938	86394.660	160.734	<.0001	1446.605	1.000
PLACE	2	72358.441	36179.220	67.310	<.0001	134.620	1.000
GRADE * PLACE	18	7026.422	390.357	.726	.7865	13.072	.550
Residual	1586	852476.768	537.501				

Means Table for VOT(ms)
Effect: GRADE * PLACE
Row exclusion: VOT DATA FILE/TIME1

	Count	Mean	Std. Dev.	Std. Err.
MJ1, p	54	22.922	11.151	1.517
MJ1, t	54	27.339	15.074	2.051
MJ1, k	60	37.373	16.390	2.116
MJ5, p	54	20.594	9.885	1.345
MJ5, t	53	23.747	13.351	1.834
MJ5, k	60	39.428	11.093	1.432
IJT, p	45	37.367	17.383	2.591
IJT, t	45	43.491	17.907	2.669
IJT, k	46	53.983	15.055	2.220
IJ1, p	63	59.656	23.120	2.913
IJ1, t	56	59.884	22.360	2.988
IJ1, k	65	69.142	23.656	2.934
IJ3, p	54	50.104	23.804	3.239
IJ3, t	49	56.731	27.140	3.877
IJ3, k	54	66.113	27.492	3.741
IJ5, p	54	60.454	22.122	3.010
IJ5, t	52	64.810	22.106	3.066
IJ5, k	58	74.967	26.163	3.435
IET, p	44	75.518	28.285	4.264
IET, t	45	69.827	19.357	2.886
IET, k	44	85.973	17.693	2.667
IE1, p	60	83.470	30.076	3.883
IE1, t	63	84.773	34.249	4.315
IE1, k	62	96.929	33.693	4.279
IE3, p	53	77.183	29.880	4.104
IE3, t	54	87.256	29.821	4.058
IE3, k	54	102.033	28.942	3.938
IE5, p	53	79.051	21.392	2.938
IE5, t	54	80.381	16.310	2.219
IE5, k	54	95.274	24.328	3.311

Scheffe for VOT(ms)
Effect: PLACE
Significance Level: 5 %
Row exclusion: VOT DATA FILE/TIME1

	Mean Diff.	Crit. Diff	P-Value	
p, t	-3.565	3.491	.0440	S
p, k	-14.850	3.440	<.0001	S
t, k	-11.285	3.455	<.0001	S

Scheffe for VOT(ms)
Effect: GRADE
Significance Level: 5 %
Row exclusion: VOT DATA FILE/TIME1

	Mean Diff.	Crit. Diff	P-Value	
MJ1, MJ5	1.141	10.437	>.9999	
MJ1, IJT	-15.510	11.017	.0001	S
MJ1, IJ1	-33.573	10.192	<.0001	S
MJ1, IJ3	-28.175	10.602	<.0001	S
MJ1, IJ5	-37.465	10.485	<.0001	S
MJ1, IET	-47.548	11.086	<.0001	S
MJ1, IE1	-58.921	10.179	<.0001	S
MJ1, IE3	-59.393	10.534	<.0001	S
MJ1, IE5	-55.436	10.534	<.0001	S
MJ5, IJT	-16.652	11.032	<.0001	S
MJ5, IJ1	-34.714	10.208	<.0001	S
MJ5, IJ3	-29.317	10.617	<.0001	S
MJ5, IJ5	-38.606	10.500	<.0001	S
MJ5, IET	-48.689	11.100	<.0001	S
MJ5, IE1	-60.063	10.195	<.0001	S
MJ5, IE3	-60.535	10.549	<.0001	S
MJ5, IE5	-56.577	10.549	<.0001	S
IJT, IJ1	-18.063	10.801	<.0001	S
IJT, IJ3	-12.665	11.188	.0101	S
IJT, IJ5	-21.954	11.077	<.0001	S
IJT, IET	-32.038	11.648	<.0001	S
IJT, IE1	-43.411	10.788	<.0001	S
IJT, IE3	-43.883	11.124	<.0001	S
IJT, IE5	-39.925	11.124	<.0001	S
IJ1, IJ3	5.398	10.377	.8680	
IJ1, IJ5	-3.892	10.257	.9823	
IJ1, IET	-13.975	10.871	.0010	S
IJ1, IE1	-25.348	9.944	<.0001	S
IJ1, IE3	-25.820	10.307	<.0001	S
IJ1, IE5	-21.862	10.307	<.0001	S
IJ3, IJ5	-9.289	10.664	.1693	
IJ3, IET	-19.373	11.256	<.0001	S
IJ3, IE1	-30.746	10.364	<.0001	S
IJ3, IE3	-31.218	10.713	<.0001	S
IJ3, IE5	-27.260	10.713	<.0001	S
IJ5, IET	-10.083	11.145	.1273	
IJ5, IE1	-21.457	10.244	<.0001	S
IJ5, IE3	-21.929	10.596	<.0001	S
IJ5, IE5	-17.971	10.596	<.0001	S
IET, IE1	-11.373	10.858	.0293	S
IET, IE3	-11.845	11.192	.0257	S
IET, IE5	-7.887	11.192	.4919	
IE1, IE3	-.472	10.294	>.9999	
IE1, IE5	3.486	10.294	.9922	
IE3, IE5	3.958	10.645	.9847	

APPENDIX 10: ANOVA RESULTS
Development of VOT across grade levels

ANOVA Table for DEVELOPMENT
Row exclusion: VOT DATA FILE/T1&2/DEVELOPMENT

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
GRADE	2	12112.742	6056.371	7.126	.0009	14.252	.945
Subject(Group)	474	402854.404	849.904				
DEVELOPMENT/TIME	1	2329.697	2329.697	5.216	.0228	5.216	.621
DEVELOPMENT/TIME * GRADE	2	824.285	412.143	.923	.3981	1.846	.202
DEVELOPMENT/TIME * Subject(Group)	474	211698.857	446.622				

Means Table for DEVELOPMENT
Effect: DEVELOPMENT/TIME * GRADE
Row exclusion: VOT DATA FILE/T1&2/DEVELOPMENT

	Count	Mean	Std. Dev.	Std. Err.
IJ1, TIME1	170	61.935	22.794	1.748
IJ1, TIME2	170	62.926	32.812	2.517
IJ3, TIME1	148	57.185	26.248	2.158
IJ3, TIME2	148	62.732	24.328	2.000
IJ5, TIME1	159	67.104	24.595	1.951
IJ5, TIME2	159	69.957	19.638	1.557

Scheffe for DEVELOPMENT
Effect: GRADE
Significance Level: 5 %
Row exclusion: VOT DATA FILE/T1&2/DEVELOPMENT

	Mean Diff.	Crit. Diff	P-Value	
IJ1, IJ3	2.472	5.691	.5665	
IJ1, IJ5	-6.100	5.585	.0281	S
IJ3, IJ5	-8.572	5.782	.0014	S

Scheffe for DEVELOPMENT
Effect: Category for DEVELOPMENT
Significance Level: 5 %
Row exclusion: VOT DATA FILE/T1&2/DEVELOPMENT

	Mean Diff.	Crit. Diff	P-Value	
TIME1, TIME2	-3.025	2.689	.0275	S

APPENDIX 11: ANOVA RESULTS
Development of VOT across places of articulation

ANOVA Table for DEVELOPMENT
Row exclusion: VOT DATA FILE/T1&2/DEVELOPMENT

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
GRADE	2	11212.274	5606.137	7.057	.0010	14.115	.942
PLACE	2	26912.355	13456.177	16.939	<.0001	33.879	1.000
GRADE * PLACE	4	3308.888	827.222	1.041	.3853	4.165	.322
Subject(Group)	468	371768.270	794.377				
DEVELOPMENT	1	2347.530	2347.530	5.347	.0212	5.347	.632
DEVELOPMENT * GRADE	2	916.898	458.449	1.044	.3528	2.088	.224
DEVELOPMENT * PLACE	2	290.999	145.499	.331	.7181	.663	.101
DEVELOPMENT * GRADE * PLACE	4	5884.521	1471.130	3.351	.0102	13.402	.852
DEVELOPMENT * Subject(Group)	468	205487.415	439.076				

Means Table for DEVELOPMENT
Effect: DEVELOPMENT * GRADE * PLACE
Row exclusion: VOT DATA FILE/T1&2/DEVELOPMENT

	Count	Mean	Std. Dev.	Std. Err.
IJ1, p, TIME1	58	57.640	21.290	2.795
IJ1, p, TIME2	58	52.721	25.388	3.334
IJ1, t, TIME1	52	60.340	22.571	3.130
IJ1, t, TIME2	52	59.527	29.362	4.072
IJ1, k, TIME1	60	67.468	23.634	3.051
IJ1, k, TIME2	60	75.738	37.900	4.893
IJ3, p, TIME1	49	50.100	24.408	3.487
IJ3, p, TIME2	49	61.820	22.459	3.208
IJ3, t, TIME1	47	57.194	27.594	4.025
IJ3, t, TIME2	47	62.672	24.266	3.540
IJ3, k, TIME1	52	63.854	25.393	3.521
IJ3, k, TIME2	52	63.644	26.429	3.665
IJ5, p, TIME1	49	60.233	23.032	3.290
IJ5, p, TIME2	49	60.204	15.504	2.215
IJ5, t, TIME1	52	64.810	22.106	3.066
IJ5, t, TIME2	52	74.340	19.137	2.654
IJ5, k, TIME1	58	74.967	26.163	3.435
IJ5, k, TIME2	58	74.267	20.513	2.693

Scheffe for DEVELOPMENT
Effect: GRADE
Significance Level: 5 %
Row exclusion: VOT DATA FILE/T1&2/DEVELOPMENT

	Mean Diff.	Crit. Diff	P-Value	
IJ1, IJ3	2.472	5.502	.5445	
IJ1, IJ5	-6.100	5.399	.0220	S
IJ3, IJ5	-8.572	5.590	.0009	S

Scheffe for DEVELOPMENT
Effect: PLACE
Significance Level: 5 %
Row exclusion: VOT DATA FILE/T1&2/DEVELOPMENT

	Mean Diff.	Crit. Diff	P-Value	
p, t	-6.246	5.587	.0238	S
p, k	-13.221	5.426	<.0001	S
t, k	-6.975	5.473	.0078	S

Scheffe for DEVELOPMENT
Effect: DEVELOPMENT
Significance Level: 5 %
Row exclusion: VOT DATA FILE/T1&2/DEVELOPMENT

	Mean Diff.	Crit. Diff	P-Value	
TIME1, TIME2	-3.025	2.666	.0262	S

APPENDIX 12: ANOVA RESULTS
Absolute closure duration at Time 1 across grade levels

ANOVA Table for CLOSURE(ms)
Row exclusion: CLOSURE DATA FILE/TIME1

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
TYPE (S or G)	1	3174443.330	3174443.330	1327.799	<.0001	1327.799	1.000
GRADE	5	1025060.078	205012.016	85.752	<.0001	428.760	1.000
TYPE (S or G) * GRADE	5	111839.444	22367.889	9.356	<.0001	46.780	1.000
Residual	1748	4179042.504	2390.757				

Means Table for CLOSURE(ms)
Effect: TYPE (S or G) * GRADE
Row exclusion: CLOSURE DATA FILE/TIME1

	Count	Mean	Std. Dev.	Std. Err.
G, MJ1	160	187.815	26.521	2.097
G, MJ5	160	168.171	23.458	1.855
G, IJT	133	180.626	31.562	2.737
G, IJ1	177	221.608	72.944	5.483
G, IJ3	148	192.578	57.561	4.731
G, IJ5	157	224.072	75.860	6.054
S, MJ1	141	98.448	15.390	1.296
S, MJ5	139	72.622	16.190	1.373
S, IJT	116	74.584	16.075	1.493
S, IJ1	157	137.711	50.588	4.037
S, IJ3	138	139.899	51.661	4.398
S, IJ5	134	138.984	70.607	6.100

Scheffe for CLOSURE(ms)
Effect: TYPE (S or G)
Significance Level: 5 %
Row exclusion: CLOSURE DATA FILE/TIME1

	Mean Diff.	Crit. Diff	P-Value	
G, S	84.939	4.581	<.0001	S

Scheffe for CLOSURE(ms)
Effect: GRADE
Significance Level: 5 %
Row exclusion: CLOSURE DATA FILE/TIME1

	Mean Diff.	Crit. Diff	P-Value	
MJ1, MJ5	22.200	13.299	<.0001	S
MJ1, IJT	14.727	13.952	.0305	S
MJ1, IJ1	-36.219	12.944	<.0001	S
MJ1, IJ3	-21.207	13.449	<.0001	S
MJ1, IJ5	-38.938	13.390	<.0001	S
MJ5, IJT	-7.473	13.974	.6732	
MJ5, IJ1	-58.420	12.967	<.0001	S
MJ5, IJ3	-43.407	13.471	<.0001	S
MJ5, IJ5	-61.139	13.412	<.0001	S
IJT, IJ1	-50.946	13.637	<.0001	S
IJT, IJ3	-35.934	14.117	<.0001	S
IJT, IJ5	-53.665	14.061	<.0001	S
IJ1, IJ3	15.012	13.122	.0128	S
IJ1, IJ5	-2.719	13.061	.9928	
IJ3, IJ5	-17.731	13.562	.0020	S

APPENDIX 13: ANOVA RESULTS
Absolute closure duration at Time 1 across places of articulation

ANOVA Table for CLOSURE(ms)
Row exclusion: CLOSURE DATA FILE/TIME1

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
PLACE	5	3203707.604	640741.521	273.515	<.0001	1367.577	1.000
GRADE	5	1020719.849	204143.970	87.144	<.0001	435.718	1.000
PLACE * GRADE	25	217920.053	8716.802	3.721	<.0001	93.024	1.000
Residual	1724	4038668.695	2342.615				

Means Table for CLOSURE(ms)
Effect: PLACE * GRADE
Row exclusion: CLOSURE DATA FILE/TIME1

	Count	Mean	Std. Dev.	Std. Err.
p, MJ1	45	97.820	14.322	2.135
p, MJ5	43	71.619	18.472	2.817
p, IJT	37	73.370	12.736	2.094
p, IJ1	55	136.175	49.605	6.689
p, IJ3	48	145.181	49.809	7.189
p, IJ5	46	144.176	60.706	8.951
t, MJ1	48	98.454	14.791	2.135
t, MJ5	48	71.335	15.088	2.178
t, IJT	40	76.775	17.468	2.762
t, IJ1	50	148.840	59.173	8.368
t, IJ3	46	145.524	58.899	8.684
t, IJ5	44	154.259	92.677	13.972
k, MJ1	48	99.031	17.146	2.475
k, MJ5	48	74.808	15.149	2.187
k, IJT	39	73.490	17.534	2.808
k, IJ1	52	128.635	40.626	5.634
k, IJ3	44	128.255	44.238	6.669
k, IJ5	44	118.280	47.622	7.179
pp, MJ1	54	196.165	25.494	3.469
pp, MJ5	53	173.440	20.955	2.878
pp, IJT	45	185.307	28.680	4.275
pp, IJ1	61	237.905	71.063	9.099
pp, IJ3	50	195.316	60.431	8.546
pp, IJ5	51	211.937	70.398	9.858
tt, MJ1	52	188.606	26.742	3.708
tt, MJ5	53	165.823	24.787	3.405
tt, IJT	43	184.679	36.973	5.638
tt, IJ1	58	199.402	62.695	8.232
tt, IJ3	49	178.606	56.920	8.131
tt, IJ5	52	233.058	72.130	10.003
kk, MJ1	54	178.704	24.816	3.377
kk, MJ5	54	165.304	23.990	3.265
kk, IJT	45	172.073	27.348	4.077
kk, IJ1	58	226.676	79.817	10.480
kk, IJ3	49	203.755	53.332	7.619
kk, IJ5	54	226.880	83.833	11.408

Scheffe for CLOSURE(ms)
Effect: PLACE
Significance Level: 5 %
Row exclusion: CLOSURE DATA FILE/TIME1

	Mean Diff.	Crit. Diff	P-Value	
p, t	-2.281	13.750	.9975	
p, k	9.650	13.762	.3632	
p, pp	-87.124	13.329	<.0001	S
p, tt	-77.911	13.399	<.0001	S
p, kk	-82.320	13.329	<.0001	S
t, k	11.931	13.737	.1376	
t, pp	-84.843	13.303	<.0001	S
t, tt	-75.630	13.374	<.0001	S
t, kk	-80.039	13.303	<.0001	S
k, pp	-96.774	13.316	<.0001	S
k, tt	-87.561	13.387	<.0001	S
k, kk	-91.970	13.316	<.0001	S
pp, tt	9.213	12.941	.3450	
pp, kk	4.804	12.867	.9076	
tt, kk	-4.409	12.941	.9361	

Scheffe for CLOSURE(ms)
Effect: GRADE
Significance Level: 5 %
Row exclusion: CLOSURE DATA FILE/TIME1

	Mean Diff.	Crit. Diff	P-Value	
MJ1, MJ5	22.200	13.164	<.0001	S
MJ1, IJT	14.727	13.811	.0276	S
MJ1, IJ1	-36.219	12.814	<.0001	S
MJ1, IJ3	-21.207	13.314	<.0001	S
MJ1, IJ5	-38.938	13.255	<.0001	S
MJ5, IJT	-7.473	13.832	.6632	
MJ5, IJ1	-58.420	12.836	<.0001	S
MJ5, IJ3	-43.407	13.335	<.0001	S
MJ5, IJ5	-61.139	13.277	<.0001	S
IJT, IJ1	-50.946	13.499	<.0001	S
IJT, IJ3	-35.934	13.975	<.0001	S
IJT, IJ5	-53.665	13.919	<.0001	S
IJ1, IJ3	15.012	12.989	.0114	S
IJ1, IJ5	-2.719	12.929	.9924	
IJ3, IJ5	-17.731	13.425	.0017	S

APPENDIX 14: ANOVA RESULTS
Relative closure duration at Time 1

ANOVA Table for CLOSURE RATIO(%)
Row exclusion: CLOSURE DATA FILE/RATIO

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
GRADE	5	18677.009	3735.402	20.730	<.0001	103.650	1.000
TYPE (S or G)	1	202068.811	202068.811	1121.397	<.0001	1121.397	1.000
GRADE * TYPE (S or G)	5	26509.433	5301.887	29.423	<.0001	147.116	1.000
Residual	1731	311915.605	180.194				

Means Table for CLOSURE RATIO(%)
Effect: GRADE * TYPE (S or G)
Row exclusion: CLOSURE DATA FILE/RATIO

	Count	Mean	Std. Dev.	Std. Err.
MJ1, G	160	48.073	10.591	.837
MJ1, S	141	26.830	7.235	.609
MJ5, G	160	53.752	12.944	1.023
MJ5, S	139	23.976	7.169	.608
IJT, G	131	61.825	16.425	1.435
IJT, S	116	27.025	8.237	.765
IJ1, G	174	42.843	16.150	1.224
IJ1, S	155	27.354	12.785	1.027
IJ3, G	145	49.170	18.465	1.533
IJ3, S	134	36.451	13.748	1.188
IJ5, G	156	50.234	15.674	1.255
IJ5, S	132	34.300	14.499	1.262

Scheffe for CLOSURE RATIO(%)
Effect: TYPE (S or G)
Significance Level: 5 %
Row exclusion: CLOSURE DATA FILE/RATIO

	Mean Diff.	Crit. Diff	P-Value	
G, S	21.296	1.264	<.0001	S

Scheffe for CLOSURE RATIO(%)
Effect: GRADE
Significance Level: 5 %
Row exclusion: CLOSURE DATA FILE/RATIO

	Mean Diff.	Crit. Diff	P-Value	
MJ1, MJ5	-1.788	3.651	.7519	
MJ1, IJT	-7.360	3.839	<.0001	S
MJ1, IJ1	2.576	3.567	.3280	
MJ1, IJ3	-4.940	3.716	.0015	S
MJ1, IJ5	-4.809	3.686	.0021	S
MJ5, IJT	-5.572	3.845	.0003	S
MJ5, IJ1	4.364	3.573	.0056	S
MJ5, IJ3	-3.152	3.722	.1593	
MJ5, IJ5	-3.021	3.692	.1911	
IJT, IJ1	9.936	3.765	<.0001	S
IJT, IJ3	2.420	3.907	.5130	
IJT, IJ5	2.551	3.878	.4411	
IJ1, IJ3	-7.515	3.639	<.0001	S
IJ1, IJ5	-7.385	3.608	<.0001	S
IJ3, IJ5	.130	3.756	>.9999	

APPENDIX 15: ANOVA RESULTS
Closure duration of one syllable containing one mora (singleton) and two moras (geminate)

ANOVA Table for SYLLABLE(ms)
Row exclusion: CLOSURE DATA FILE/TIME1

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
TYPE (S or G)	1	1444577.175	1444577.175	276.529	<.0001	276.529	1.000
GRADE	5	1743161.798	348632.360	66.737	<.0001	333.686	1.000
TYPE (S or G) * GRADE	5	89269.352	17853.870	3.418	.0046	17.088	.918
Residual	738	3855282.112	5223.960				

Means Table for SYLLABLE(ms)
Effect: TYPE (S or G) * GRADE
Row exclusion: CLOSURE DATA FILE/TIME1

	Count	Mean	Std. Dev.	Std. Err.
G, MJ1	53	311.926	31.118	4.274
G, MJ5	55	279.800	35.073	4.729
G, IJT	44	276.952	37.779	5.695
G, IJ1	58	382.255	122.208	16.047
G, IJ3	60	320.550	88.110	11.375
G, IJ5	55	395.076	114.873	15.490
S, MJ1	74	217.559	21.177	2.462
S, MJ5	74	177.164	20.602	2.395
S, IJT	61	169.782	23.353	2.990
S, IJ1	81	309.948	84.886	9.432
S, IJ3	64	272.484	72.537	9.067
S, IJ5	71	285.697	96.426	11.444

Scheffe for SYLLABLE(ms)
Effect: TYPE (S or G)
Significance Level: 5 %
Row exclusion: CLOSURE DATA FILE/TIME1

	Mean Diff.	Crit. Diff	P-Value	
G, S	89.039	10.456	<.0001	S

Scheffe for SYLLABLE(ms)
Effect: GRADE
Significance Level: 5 %
Row exclusion: CLOSURE DATA FILE/TIME1

	Mean Diff.	Crit. Diff	P-Value	
MJ1, MJ5	36.018	30.144	.0076	S
MJ1, IJT	42.250	31.807	.0016	S
MJ1, IJ1	-83.178	29.601	<.0001	S
MJ1, IJ3	-38.801	30.444	.0031	S
MJ1, IJ5	-76.501	30.321	<.0001	S
MJ5, IJT	6.232	31.695	.9944	
MJ5, IJ1	-119.196	29.481	<.0001	S
MJ5, IJ3	-74.819	30.327	<.0001	S
MJ5, IJ5	-112.519	30.204	<.0001	S
IJT, IJ1	-125.428	31.179	<.0001	S
IJT, IJ3	-81.051	31.980	<.0001	S
IJT, IJ5	-118.751	31.864	<.0001	S
IJ1, IJ3	44.377	29.787	.0002	S
IJ1, IJ5	6.677	29.662	.9895	
IJ3, IJ5	-37.700	30.503	.0048	S

APPENDIX 16: ANOVA RESULTS
Closure duration of one syllable containing one mora (singleton) and two moras (geminate) across places of articulation

ANOVA Table for SYLLABLE(ms)
Row exclusion: CLOSURE DATA FILE/TIME1

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
GRADE	5	1747542.550	349508.510	67.312	<.0001	336.558	1.000
PLACE	5	1460346.936	292069.387	56.249	<.0001	281.247	1.000
GRADE * PLACE	25	231717.834	9268.713	1.785	.0109	44.626	.992
Residual	714	3707367.694	5192.392				

Means Table for SYLLABLE(ms)
Effect: GRADE * PLACE
Row exclusion: CLOSURE DATA FILE/TIME1

	Count	Mean	Std. Dev.	Std. Err.
MJ1, p	26	217.181	23.429	4.595
MJ1, t	24	214.162	17.735	3.620
MJ1, k	24	221.367	22.021	4.495
MJ1, pp	18	326.117	26.824	6.322
MJ1, tt	17	315.853	29.347	7.118
MJ1, kk	18	294.028	29.394	6.928
MJ5, p	25	175.344	17.572	3.514
MJ5, t	25	173.644	21.006	4.201
MJ5, k	24	182.725	22.698	4.633
MJ5, pp	18	288.472	35.168	8.289
MJ5, tt	18	278.739	33.487	7.893
MJ5, kk	19	272.589	36.497	8.373
IJT, p	21	164.148	16.278	3.552
IJT, t	20	160.745	19.574	4.377
IJT, k	20	184.735	26.528	5.932
IJT, pp	15	276.100	30.688	7.924
IJT, tt	14	278.664	49.503	13.230
IJT, kk	15	276.207	34.088	8.801
IJ1, p	29	317.666	88.551	16.444
IJ1, t	25	304.964	84.142	16.828
IJ1, k	27	306.274	84.183	16.201
IJ1, pp	20	397.100	109.717	24.533
IJ1, tt	20	366.945	115.390	25.802
IJ1, kk	18	382.772	145.618	34.323
IJ3, p	22	274.432	54.685	11.659
IJ3, t	23	288.648	97.837	20.400
IJ3, k	19	250.663	48.849	11.207
IJ3, pp	19	323.174	45.205	10.371
IJ3, tt	23	308.339	101.667	21.199
IJ3, kk	18	333.383	104.976	24.743
IJ5, p	25	275.524	50.635	10.127
IJ5, t	22	313.636	155.940	33.247
IJ5, k	24	270.683	48.228	9.845
IJ5, pp	19	346.753	107.280	24.612
IJ5, tt	18	415.661	86.434	20.373
IJ5, kk	18	425.500	134.985	31.816

Scheffe for SYLLABLE(ms)
Effect: GRADE
Significance Level: 5 %
Row exclusion: CLOSURE DATA FILE/TIME1

	Mean Diff.	Crit. Diff	P-Value	
MJ1, MJ5	36.018	30.055	.0073	S
MJ1, IJT	42.250	31.713	.0015	S
MJ1, IJ1	-83.178	29.514	<.0001	S
MJ1, IJ3	-38.801	30.354	.0029	S
MJ1, IJ5	-76.501	30.232	<.0001	S
MJ5, IJT	6.232	31.602	.9943	
MJ5, IJ1	-119.196	29.394	<.0001	S
MJ5, IJ3	-74.819	30.238	<.0001	S
MJ5, IJ5	-112.519	30.115	<.0001	S
IJT, IJ1	-125.428	31.088	<.0001	S
IJT, IJ3	-81.051	31.887	<.0001	S
IJT, IJ5	-118.751	31.770	<.0001	S
IJ1, IJ3	44.377	29.700	.0002	S
IJ1, IJ5	6.677	29.575	.9894	
IJ3, IJ5	-37.700	30.414	.0046	S

Scheffe for SYLLABLE(ms)
Effect: PLACE
Significance Level: 5 %
Row exclusion: CLOSURE DATA FILE/TIME1

	Mean Diff.	Crit. Diff	P-Value	
p, t	-2.945	28.399	.9997	
p, k	2.084	28.452	>.9999	
p, pp	-88.482	30.347	<.0001	S
p, tt	-88.453	30.268	<.0001	S
p, kk	-91.098	30.593	<.0001	S
t, k	5.029	28.893	.9969	
t, pp	-85.536	30.761	<.0001	S
t, tt	-85.508	30.682	<.0001	S
t, kk	-88.152	31.004	<.0001	S
k, pp	-90.566	30.810	<.0001	S
k, tt	-90.537	30.732	<.0001	S
k, kk	-93.181	31.053	<.0001	S
pp, tt	.028	32.494	>.9999	
pp, kk	-2.616	32.798	>.9999	
tt, kk	-2.644	32.724	>.9999	

APPENDIX 17: ANOVA RESULTS
Development of closure duration across grade levels

ANOVA Table for CLOSURE(ms)
Row exclusion: CLOSURE DATA FILE/DEVELOPMENT

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
GRADE	2	13631.567	6815.784	1.502	.2233	3.003	.308
TYPE (S or G)	1	2096467.213	2096467.213	461.902	<.0001	461.902	1.000
GRADE * TYPE (S or G)	2	47663.569	23831.784	5.251	.0054	10.501	.844
Subject(Group)	878	3985044.417	4538.775				
DEVELOPMENT/CLOSURE(ms)	1	116640.226	116640.226	54.419	<.0001	54.419	1.000
DEVELOPMENT/CLOSURE(ms) * GRADE	2	71908.061	35954.031	16.774	<.0001	33.549	1.000
DEVELOPMENT/CLOSURE(ms) * TYPE (S or G)	1	6551.330	6551.330	3.057	.0808	3.057	.398
DEVELOPMENT/CLOSURE(ms) * GRADE * T…	2	6185.713	3092.857	1.443	.2368	2.886	.298
DEVELOPMENT/CLOSURE(ms) * Subject(Gro…	878	1881896.611	2143.390				

Means Table for CLOSURE(ms)
Effect: DEVELOPMENT/CLOSURE(ms) * GRADE * TYPE (S or G)
Row exclusion: CLOSURE DATA FILE/DEVELOPMENT

	Count	Mean	Std. Dev.	Std. Err.
IJ1, G, TIME1	173	221.575	73.343	5.576
IJ1, G, TIME2	173	195.779	70.102	5.330
IJ1, S, TIME1	147	139.889	50.703	4.182
IJ1, S, TIME2	147	128.788	51.177	4.221
IJ3, G, TIME1	146	192.836	57.782	4.782
IJ3, G, TIME2	146	194.841	49.173	4.070
IJ3, S, TIME1	135	139.793	52.071	4.482
IJ3, S, TIME2	135	139.069	37.254	3.206
IJ5, G, TIME1	153	222.826	75.336	6.091
IJ5, G, TIME2	153	186.078	45.206	3.655
IJ5, S, TIME1	130	138.473	71.094	6.235
IJ5, S, TIME2	130	112.958	31.674	2.778

Scheffe for CLOSURE(ms)
Effect: GRADE
Significance Level: 5 %
Row exclusion: CLOSURE DATA FILE/DEVELOPMENT

	Mean Diff.	Crit. Diff	P-Value
IJ1, IJ3	6.828	9.549	.2157
IJ1, IJ5	6.244	9.531	.2758
IJ3, IJ5	-.584	9.837	.9895

Scheffe for CLOSURE(ms)
Effect: TYPE (S or G)
Significance Level: 5 %
Row exclusion: CLOSURE DATA FILE/DEVELOPMENT

	Mean Diff.	Crit. Diff	P-Value	
G, S	69.431	6.304	<.0001	S

Scheffe for CLOSURE(ms)
Effect: DEVELOPMENT/CLOSURE(ms)
Significance Level: 5 %
Row exclusion: CLOSURE DATA FILE/DEVELOPMENT

	Mean Diff.	Crit. Diff	P-Value	
TIME1, TIME2	16.786	4.322	<.0001	S

APPENDIX 18: ANOVA RESULTS
Development of closure duration across places of articulation

ANOVA Table for CLOSURE(ms)
Row exclusion: CLOSURE DATA FILE/DEVELOPMENT

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
GRADE	2	13856.051	6928.026	1.571	.2084	3.142	.321
PLACE	5	2171420.980	434284.196	98.491	<.0001	492.456	1.000
GRADE * PLACE	10	125881.475	12588.148	2.855	.0017	28.549	.981
Subject(Group)	866	3818512.584	4409.368				
DEVELOPMENT/CLOSURE(ms)	1	115751.378	115751.378	53.702	<.0001	53.702	1.000
DEVELOPMENT/CLOSURE(ms) * GRADE	2	71591.019	35795.510	16.607	<.0001	33.214	1.000
DEVELOPMENT/CLOSURE(ms) * PLACE	5	14135.577	2827.115	1.312	.2568	6.558	.460
DEVELOPMENT/CLOSURE(ms) * GRADE * PL…	10	13625.066	1362.507	.632	.7871	6.321	.333
DEVELOPMENT/CLOSURE(ms) * Subject(Gro…	866	1866603.811	2155.432				

Means Table for CLOSURE(ms)
Effect: DEVELOPMENT/CLOSURE(ms) * GRADE * PLACE
Row exclusion: CLOSURE DATA FILE/DEVELOPMENT

	Count	Mean	Std. Dev.	Std. Err.
IJ1, p, TIME1	51	140.808	47.066	6.591
IJ1, p, TIME2	51	133.053	53.782	7.531
IJ1, t, TIME1	46	150.826	61.264	9.033
IJ1, t, TIME2	46	138.491	58.527	8.629
IJ1, k, TIME1	50	128.890	41.424	5.858
IJ1, k, TIME2	50	115.510	37.672	5.328
IJ1, pp, TIME1	59	236.847	71.905	9.361
IJ1, pp, TIME2	59	210.356	76.176	9.917
IJ1, tt, TIME1	56	200.200	63.442	8.478
IJ1, tt, TIME2	56	185.171	52.152	6.969
IJ1, kk, TIME1	58	226.676	79.817	10.480
IJ1, kk, TIME2	58	191.191	77.124	10.127
IJ3, p, TIME1	47	144.702	50.236	7.328
IJ3, p, TIME2	47	142.828	39.021	5.692
IJ3, t, TIME1	45	145.204	59.524	8.873
IJ3, t, TIME2	45	145.247	37.129	5.535
IJ3, k, TIME1	43	128.765	44.631	6.806
IJ3, k, TIME2	43	128.495	33.836	5.160
IJ3, pp, TIME1	49	195.078	61.033	8.719
IJ3, pp, TIME2	49	194.649	50.794	7.256
IJ3, tt, TIME1	48	179.400	57.248	8.263
IJ3, tt, TIME2	48	187.431	44.683	6.449
IJ3, kk, TIME1	49	203.755	53.332	7.619
IJ3, kk, TIME2	49	202.292	51.552	7.365
IJ5, p, TIME1	42	143.090	61.558	9.499
IJ5, p, TIME2	42	122.190	37.866	5.843
IJ5, t, TIME1	44	154.259	92.677	13.972
IJ5, t, TIME2	44	114.641	28.506	4.297
IJ5, k, TIME1	44	118.280	47.622	7.179
IJ5, k, TIME2	44	102.461	25.123	3.787
IJ5, pp, TIME1	49	209.735	70.418	10.060
IJ5, pp, TIME2	49	176.171	35.559	5.080
IJ5, tt, TIME1	50	231.278	69.886	9.883
IJ5, tt, TIME2	50	195.274	55.348	7.827
IJ5, kk, TIME1	54	226.880	83.833	11.408
IJ5, kk, TIME2	54	186.554	41.386	5.632

Scheffe for CLOSURE(ms)
Effect: GRADE
Significance Level: 5 %
Row exclusion: CLOSURE DATA FILE/DEVELOPMENT

	Mean Diff.	Crit. Diff	P-Value
IJ1, IJ3	6.828	9.412	.2062
IJ1, IJ5	6.244	9.395	.2656
IJ3, IJ5	-.584	9.696	.9892

Scheffe for CLOSURE(ms)
Effect: PLACE
Significance Level: 5 %
Row exclusion: CLOSURE DATA FILE/DEVELOPMENT

	Mean Diff.	Crit. Diff	P-Value	
p, t	-3.583	18.889	.9953	
p, k	17.519	18.818	.0873	
p, pp	-67.129	18.203	<.0001	S
p, tt	-58.544	18.286	<.0001	S
p, kk	-68.453	18.096	<.0001	S
t, k	21.101	18.990	.0180	S
t, pp	-63.547	18.380	<.0001	S
t, tt	-54.961	18.462	<.0001	S
t, kk	-64.871	18.274	<.0001	S
k, pp	-84.648	18.308	<.0001	S
k, tt	-76.063	18.391	<.0001	S
k, kk	-85.972	18.201	<.0001	S
pp, tt	8.585	17.760	.7614	
pp, kk	-1.324	17.564	>.9999	
tt, kk	-9.910	17.650	.6226	

Scheffe for CLOSURE(ms)
Effect: DEVELOPMENT/CLOSURE(ms)
Significance Level: 5 %
Row exclusion: CLOSURE DATA FILE/DEVELOPMENT

	Mean Diff.	Crit. Diff	P-Value	
TIME1, TIME2	16.786	4.334	<.0001	S

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