Phonetic evidence for early language differentiation: Research issues and some preliminary data

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Abstract

Although evidence is now available from several domains of language acquisition research that bilingual (BFLA) children differentiate their languages from the time of their earliest productions, studies in the phonetics-phonology domain have been sparse until recently. In this paper we first highlight some methodological issues that impact phonetic-phonological data collection and interpretation. These issues include language context, bilingual versus monolingual mode, and adult listening bias. After suggesting types of acoustic evidence that can be used to determine whether the phonological modules of a young bilingual child are separate, we focus on voice onset time (VOT). We discuss methodological issues specific to a VOT study, including segmental context, rate of speech, and the position of word stress. We also present preliminary data from two BFLA children, ages four and two, learning Japanese and English. Separate recordings were made of the two children as they were asked to identify various pictures. Each child's VOTs were calculated and compared across languages. Results showed that the two-year-old had no significant difference between languages. However, the *t*-test results for the four-year-old indicated that, for /p/ and /t/, VOT for English was of significantly longer duration than VOT for Japanese.

Key words

phonetic acquisition

phonological acquisition

voice onset time (VOT)

1 The state of the art

We can now hypothesize with some confidence that children raised bilingually from birth[1] realize from the beginning that they are learning more than one language, and their language representations, constraints, and rules are in keeping with this recognition. Evidence is now available from several domains of language acquisition research that bilingual (BFLA) children need not go through a stage in which they have a single representation system for their two input languages (Genesee's, 1989, Unitary Language System hypothesis) but rather differentiate their languages from the time of their earliest productions.[2] By early

[1] In this paper we will use the term "bilingual," for the sake of ease and simplicity, to refer to children who are exposed in a relatively balanced way to two languages from birth. This is what De Houwer (1990) terms "bilingual first-language acquisition," or "BFLA." We recognize that many children grow up hearing and learning more than two languages simultaneously.

[2] Differentiation does not entail that the two language systems are completely autonomous or that bilingual children have systems identical to those of two monolingual children. See, for example, Grosjean (1985, 1998) and Paradis (2001) for discussion.

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in their second year, bilingual children have translation equivalents in their two languages and appropriately choose when to use words in each language, though this is dependent on the child's total lexical resources (Deuchar & Quay, 2000; Genesee, Boivin, & Nicoladis, 1996; Genesee, Nicoladis, & Paradis, 1995; Johnson & Lancaster, 1998; Lanza, 1992, 1997; Pearson, Fernández, & Oller, 1995; Quay, 1995). Evidence for separate systems early in language acquisition is even more robust by the time children start to combine words and use the morphosyntactic systems of their languages (e.g., De Houwer, 1990, 1995; Meisel, 1989; Paradis & Genesee, 1996, 1997). Production data also demonstrate that bilingual children attempt to differentiate their sound systems by age two years, and possibly from the earliest words, though evidence in the phonetics-phonology domain has been sparse until the last few years (Ingram, 1981/82; Johnson & Lancaster, 1998; Paradis, 1996, 2001; Schnitzer & Krasinski, 1994, 1996).

A new surge of investigation of BFLA children's acquisition of their sound systems, attested by the papers in this volume, suggests that this is an opportune moment to clearly state the issues involved, working toward the eventual development of research paradigms for bilingual acquisition studies, in keeping with suggestions from Grosjean (1998, p. 144). Our goals in this paper are twofold: first, to highlight some methodological issues that impact data collection and data interpretation, and, second, to suggest some types of acoustic evidence that can be brought to bear on the central question of whether the phonological modules of a young bilingual child are separate. As an example, we critically present some preliminary data about one acoustic measure: voice onset time (VOT), in this case as shown by two BFLA children learning Japanese and English.

Before raising methodological issues, we briefly mention some key theoretical issues, which are discussed in depth elsewhere. Major theoretical issues come to bilingual research from the field of monolingual phonological development, where they have been discussed for many years. Most researchers of bilingual phonological development do not take a stance on these issues, but rather make assumptions related to them. We note, however, that some recent studies have been constructed explicitly within the framework of named phonological theories that specify a stance on some of the issues—such as optimality theory (e.g., Lleó, this volume) or metrical theory (e.g., Paradis, 2001). Because theory determines what the appropriate data must be, BFLA researchers must be very clear about their theoretical stance before collecting and interpreting children's speech data. As examples, we raise the following issues and refer readers to sources where these are discussed in detail: (1) what is meant by "phonological development" (Macken, 1992); (2) the nature of the representation of the first 50 words (Ferguson & Farwell, 1975; Macken, 1979, 1992; Menn, 1978; Vihman, 1996; Waterson, 1971); (3) what should count as a word (Menn, 1976; Vihman, 1996; Vihman & McCune, 1994); (4) whether variable pronunciation should be accounted for (Ingram, 1976; Macken & Ferguson, 1983); (5) the status of individual differences in the developmental account (Macken, 1992; Menn, 1978); and (6) whether the child's lexical representation is consistent with a single-lexicon model, a two-lexicon model, or a revised connectionist framework two-lexicon model (Bernhardt & Stemberger, 1998; Johnson & Lancaster, 1998; Menn & Matthei, 1992).

Issues (2) through (5) taken together demonstrate the interdependence of lexical and phonological learning in the earliest stages. There is no evidence for phonological contrast until words exist to be contrasted. To find the earliest evidence for language differentiation, the researcher must make a decision about when children's forms are words. Because of this importance of the word template, the earliest evidence for BFLA language differentiation may be the first translation equivalents. Segment-level and prosodic-rule (e.g., truncation) differentiation are likely to be measurable only as children approach age two years or older, whereas translation equivalents can be in children's lexicons early in the second year (e.g., Quay, 1995; Wilson, 1998). As stated above, explicit mention of theoretical perspective gives investigators the framework for deciding what data are relevant and it also licenses interpretation of the data.

2 Methodological issues

Studies of bilingual phonological acquisition also raise numerous methodological issues. Some of these are in common with other areas of bilingual first-language acquisition. For example, the nature of the bilingual input can be quite different, even if approximately equal in quantity, and needs to be specified. In the case of a Norwegian-English learning child reported by Johnson and Lancaster (1998), the Schnitzer and Krasinski (1994, 1996)'s children (see Section 3), Hildegard in Leopold's (1939, 1947/1970) classic study, and the two Japanese-English bilingual children we present in the VOT section (just to mention a few), the language input to the children followed a balanced one-parent, one-language pattern, a pattern discussed in detail by Döpke (1992). Note, though, that in many one-parent one-language cases, when the parents speak to each other in a common language, one parent uses a language other than his or her first language. (This was not the case though for the two Japanese-English children; their parents usually engaged in "dilingual" conversations, one speaking exclusively English, the other speaking exclusively Japanese.) This raises other methodological issues that will be discussed later. For other children, such as Vihman's (1985) Estonian-English children and Deuchar's (Deuchar & Quay, 2000) Spanish-English BFLA daughter, the language input was also balanced, but situationally determined instead. The model of language input may not make a difference to the outcome of the language-learning task, but it does make a difference to how the data are collected and analyzed.

Other methodological issues are relevant to both monolingual and bilingual studies of phonology. For example, analysis of speech data requires a series of data reduction steps, which include (1) constraining the recording setting, (2) choosing what should be transcribed, and (3) transcribing. Theoretically motivated decisions made at each of these steps (whether conscious and explicit or not) importantly influence the results of a phonological study. In the next section we raise issues relevant to data collection, transcription, and interpretation.

2.1 *Issues of data collection and transcription*

Language context: An issue for both lexical and phonological studies is how to assign a child's words to a specific language, and how to set up the data collection context to allow some confidence in this assignment. This is part of the first step of data reduction, constraining the recording setting. Definition of language context is not as straightforward as it seems, and many researchers have made dubious assignments of context. For example, Wanner (1996), who studied his Japanese-English son's language acquisition, assigned the child's words to the native language of the person his son was looking at while speaking. The obvious problem here is that children often do not look at anyone while speaking, and this method does not take into account the fact that the child may be making concessions to someone else in the room during his or her speech.

Johnson and Lancaster (1998) recorded Andreas in separate English and Norwegian contexts, defined by speakers present, and used this context as one way to report the data. The data were additionally reported according to target language, with categories "Both" (for words like *bunny*, used by both Norwegian and English speakers) and "Ambiguous" for close cognates such as English *apple* and Norwegian *eple*. Deuchar and Quay (2000) used a similar contextual data collection procedure, but in both their case and Johnson and Lancaster's, there is a factor that impacts on the data: Deuchar was present at some of the Spanish and the English recording sessions, and Manuela knew she could speak both languages. Likewise, Andreas's father, who speaks Norwegian, was present for some of the English-language recordings analyzed by Johnson and Lancaster. This fact raises another confounding factor: Even if there is only one adult present, if that person is at least receptively bilingual, and if the bilingual child knows this, then the child is more likely to use more than one language (Quay, 1998).

Wilson (1998, p. 7) summarized factors complicating the assignment of language to a given child utterance: (1) the native language of the interlocutor; (2) the language that the interlocutor happens to be speaking in that conversation (to the child or someone else); (3) the child's knowledge of which languages the interlocutor understands; (4) the language that the child has been instructed to speak to that particular interlocutor; and (5) the language that others are observed to speak to the interlocutor. In his 1998 study, Wilson tried to get around the word-assignment problem and actively elicit translation equivalents by asking his oldest daughter the metalinguistic question, "And what does Mommy/Daddy say?" Schnitzer and Krasinski (1994, 1996) solved the language-assignment problem by choosing clear exemplar words for each target phone; on the other hand, this choice limited the generalizations they could make because their audience does not have access to much of the children's lexicons. There may not be a perfect way to collect and sort data. A minimum criterion is explicitness in reporting, which at least allows the reader to interpret appropriately.

Bilingual and monolingual mode: In Grosjean's (1985, 1998) terms, the children in these studies might have been operating in bilingual "mode," which refers to the "state of activation of the bilingual's languages and language processing mechanisms" (1998, p. 136); that is, both languages are activated. A bilingual child is most likely to operate in a monolingual mode in either language when the interlocutors and context are exclusive to one of the languages. In this case the other language is least likely to be activated, and the child will speak most like a monolingual. As we pointed out earlier, a bilingual may never be truly like a monolingual. The question is whether the bilingual can ever totally suppress one of the languages. Investigation of language differentiation by BFLA children necessitates that data collection contexts are as monolingual as possible. Avoidance of bilingual mode may be most possible in focused experimental studies, such as those by Paradis (e.g., 2001).

Adult listening bias: Transcription issues include representing speech sounds produced by young children with immature and changing vocal tracts and articulatory control, and the interaction of this challenge with adults' listening biases. An example of this adult listening bias is discussed by Macken (1980, p. 154). She noted that adults' categorical perception does not allow them to "hear" children's subphonemic contrasts such as the acoustically attested voicing contrast within the short-lag region in what she calls stage two of voicing acquisition (described in more detail later).

In this section we focused on some key methodological issues relevant to data collection (with particular reference to "mode"), and transcription. As we go on to discuss specific aspects of phonetic and acoustic evidence for language differentiation, we raise further specific methodological issues.

3 Phonetic evidence

What might count as evidence that children are attempting to differentiate their phonologies? In our view, the most convincing evidence to date comes from studies that focus on prosodic development (e.g., Lleó, this volume; Paradis, 1996, 2001). Instead of focusing on the word level though, we ask what we can usefully find out at the segmental level, before children are 2 or 2;6. Given some of the difficulties we have mentioned—for example, the immaturity of children's speech mechanisms, the poverty of their lexicons and consequent code mixing, adults' difficulty discriminating phones (e.g., English prevoiced /b/ vs. short lag /b/) that do not cross adult phonological boundaries, and the plentitude of theoretical and methodological choices at every turn—it would seem impossible to make inferences about the bilingual child's phonological development. The child's task in all this is to learn to discriminate, understand, and produce two languages, in this instance, the sound systems of those languages. How can we use phonetic measures to track developmental progress?

We start by briefly mentioning a necessary first step in analyzing the distinctions between two target phonologies: that is, identifying and focusing on just those phonological segments that are different in the two languages (Ingram, 1981/82; Johnson & Lancaster, 1998). For example, consider the set of Japanese–English consonant contrasts relevant for analyzing the phonologies of the two Japanese–English bilingual children who participated in the VOT pilot study described in the next section. Some of the phonemes of Japanese that are absent in English are /t^s/, /ɽ/, and /ɴ/. On the other hand, Japanese does not have some English phonemes such as /f/, /v/, /θ/, /ð/, /ɹ/, /l/, etc.

A problem with this analysis for young children is that the differentiating segments are typically those that are learned late, even by monolingual children (Johnson & Lancaster, 1998). Johnson and Lancaster reported that Andreas actually did produce some of the segments exclusive to both Norwegian and English at age 1;8; to some extent his productions honoured the target language, but not frequently or exclusively enough for the authors to say much more than he seemed to be paying attention to phonetic detail, perhaps more so than a monolingual child.

In any case, focus on these segments may show no more than the fact that the child is capable of a large, diversified phonetic inventory, a possibility mentioned by Schnitzer and Krasinski (1994). Neither do such comparisons show the *phonetic* contrasts between the two languages, e.g., that the English alveolar consonants represented by [t], [d], and

[s] are rather dental in many other languages (e.g., Japanese, Norwegian, Romanian, Spanish, etc.), or that the voiced-voiceless stop contrasts represented by the same symbols in two languages may have very different voice onset times, as in Spanish, Japanese, or French, compared with English.

A second segment-level analysis that may illuminate whether children are trying to learn two separate phonologies is how they maintain a distinction between the languages, even if the productions are not adultlike. Charles Ferguson paid great attention to evidence of this sort when trying to determine what phonological contrasts monolingual children were making. As a bilingual example, Schnitzer and Krasinski's Fernando substituted [ɸ] for /f/ in Spanish (but not English) for three months at age 2;2–2;4, before [f] was a stable pronunciation. In English, on the other hand, he continued to substitute [p] for /f/ until age three. He also avoided the [dʒ] pronunciation variant of Spanish /ʝ/ until age 2;8, even though he used [dʒ] in English from age 2;2. Adding up evidence of this sort, we might disagree with Schnitzer and Krasinski's conclusion that Fernando did not have separate Spanish and English consonant systems until he was 2;7.

One way to avoid some of the methodological pitfalls mentioned above is to examine aspects of production that can be measured acoustically. We consider one possibility here: how the child solves the stop consonant voicing contrast problem when both languages have the contrast but cued by different phonetic values.

4 Acquisition of Voice Onset Time (VOT)

Lisker and Abramson (1964) were the first researchers to propose that VOT is an acoustically salient measurement that enables us to categorize stop consonants in any given language.[3] Examining data from 11 languages, Lisker and Abramson concluded that VOT distribution is trimodal, with ranges centering at –100 ms ("lead"), + 10 ms ("short lag"), and + 75 ms ("long lag"). Languages with two categories of stops differ in which of the three types of VOT is used. English and Cantonese, for example, both have short-lag and long-lag stops, while Spanish has lead and short-lag stops. Japanese has been said to be like Spanish in having lead and short-lag stops, but published data are scarce and show a lack of agreement (see Vance, 1987, pp. 18–19, for a summary; Lisker & Abramson did not analyze Japanese). Table 1 illustrates crosslinguistic differences in VOT. Each of the three languages shown is a two-category language, but each language divides its categories in a different place. The VOT range is noted to emphasize that with any given speaker the VOT of any given stop varies from token to token. This variability occurs naturally in phonetics, in both acoustic signal and articulatory gestures.

The English and Spanish data in Table 1 (opposite) generally conform to Lisker and Abramson's proposed trimodal distribution; the Japanese data lie between these categories, with word-initial voiceless-stop VOT values between the short- and long-lag

[3] Lisker & Abramson (1964, p. 389) defined VOT as the time interval from the release of the stop (i.e., "where the pattern shows an abrupt change in overall spectrum") to the onset of voicing (i.e., "the first of the regularly spaced vertical striations which indicate glottal pulsing"). If voicing begins before the stop release, VOT is a negative number and we say there is a voicing lead. On the other hand, if voicing begins after the stop release, VOT is a positive number and there is a voicing lag.

Table 1

Mean VOT in ms (with range in ms values) for word-initial stops in English, Spanish, and Japanese

	Labial		Alveolar [e]		Velar	
	/p/	/b/	/t/	/d/	/k/	/g/
English adults [a]	58 (20:120)	1 (0:5)	70 (30:105)	5 (0:25)	80 (50:135)	21 (0:35)
Spanish adults [b]	4 (0:15)	-138 (-235: -60)	9 (0:15)	-110 (-170: -75)	29 (15:55)	-108 (-165: -45)
Japanese adults [c]	27 (14:43)	no data	32 (16:53)	-35 (not given)	53 (35:63)	14 (8:20)
Japanese children [d]	28 (not given)	-14 (not given)	32 (not given)	-7 (not given)	40 (not given)	7 (not given)

[a] From Lisker & Abramson (1964) – 4 adult speakers (but 3 speakers for voiced stops)
[b] From Lisker & Abramson (1964) – 2 adult speakers of Puerto Rican Spanish
[c] From Homma (1981) – 4 adult speakers; value for /d/ from Homma (1980) – 3 adult speakers
[d] From Miura (1986) – combined means of ten 3-year-olds, ten 4-year olds and ten 5-year olds
[e] Although "alveolar" is being used to describe /t/ and /d/, it should be noted that Japanese /t/ and /d/ are actually dentals. Also, monolingual English children's productions of /t/ and /d/ are usually dental until about age 6 (Joe Stemberger, p.c.)

categories. The Japanese voiced stops present something of a problem: /g/ is short lag, but /d/ is lead, although much shorter lead than the average for lead stops reported by Lisker and Abramson. Unfortunately, no adult data are given for /b/. The monolingual Japanese child-language data from Miura (1986) also show this tendency for voiceless stops to lie between long lag and short lag, and for voiced stops to be either "short lead" or short lag.

The acoustic properties of VOT are straightforward, whereas the phonological representation of VOT categories depends on one's assumptions about how phonology is represented. If we look at VOT in terms of phonological features, we can see variations in VOT characterized by the value of pairs of binary features: either [+ aspiration] or [– aspiration] (Ladefoged, 1997, p. 608) and either [+ voice] or [– voice]. Under this representation, we might see bilinguals transfer features from one language to another, or acquire certain features before others. However, if our representation of phonology holds articulatory gestures to be the atomic units (Browman & Goldstein, 1989; Goldstein & Browman, 1986), we can view degrees of VOT simply as the result of varying the timing of the glottal gesture. In this case, we might expect transfer of timing patterns used in one language to the other.

4.1
VOT data collection issues

Researchers must be aware of a number of factors that significantly influence VOT, including: segmental context of the stop, rate of speech, and the position of word stress or pitch accent:

1. *Segmental context:* Even if one limits oneself to looking only at word-initial stops in isolated or sentence-initial words, the sound that immediately follows the stop affects VOT. In English, for example, Fujimura and Erickson (1997, pp. 76–77) found that voiceless stops have a much longer VOT (often 100 ms or more) when they are followed by a liquid (/l/ or /r/) than when followed by a vowel. The vowel following the word-initial stop also affects the VOT of that stop. Homma (1985) showed this to be true to some degree in Japanese. Additionally, even a consonant beginning the following syllable can have an effect on the VOT of the word-initial stop. Using nonsense words with the stress (pitch accent) on the first syllable, Homma (1981) showed that the average VOT of the initial /k/ in *kaga* is 61 ms while that of the initial /k/ in *kaka* is 45 ms.

2. *Rate of speech:* Generally, the faster the speech, the shorter the VOT. Kessinger and Blumstein (1997) confirmed this for English, French, and Thai. Interestingly, stops with voicing lead or long lag were significantly affected, but short-lag stops were minimally affected. However, in Japanese it seems that short-lag stops, too, are affected by rate of speech. Homma (1982) found that for Japanese adults producing word-initial /t/, the VOT is 27 ms at natural speaking rate, contrasting with 44 ms for slow rate of speech and 16 ms for fast speech. Rate of speech can be influenced by how tired or uninterested the subjects become. Thus, when collecting speech samples from children, it is important to monitor the children's fatigue and interest levels. If the rate of speech is held fairly constant during data collection, then accurate comparisons between the VOT of two (or more) languages of a given bilingual subject can be made.

3. *Stress:* Lisker and Abramson (1967) first established that stress increases VOT. More recently, Sundberg and Lacerda (1999) confirmed this for both Swedish infant- and adult-directed speech. Homma (1981) found a similar effect in Japanese, a language that has pitch accent but not stress accent. Specifically, she showed that VOT for word-initial stops is longer in syllables that have higher pitch.

4.2 Monolingual VOT acquisition

Macken and Barton (1979, 1980) published seminal studies of the development of the voicing contrast by both English and Spanish monolingual children. In agreement with many other researchers (including Jakobson, 1941/1968, who first observed this), Macken and Barton (1979) found that English-learning children first use voiceless unaspirated, or short-lag stops in their earliest productions. The four children they studied acquired a relatively adultlike voicing contrast at each place of articulation (labial, alveolar, and velar) at different times, but all children acquired contrasts at all three places of articulation by ages 1;9 to 2;6. This result was corroborated by Snow (1997), who found that nine of 10 monolingual English-speaking children acquired a relatively adultlike voicing contrast by age 1;9. Macken and Barton (1980) found that, like English-learning children, four children learning Mexican Spanish first produced short-lag stops. Even by age four, these monolingual Spanish-speaking children did not produce lead-voicing stops; instead, they used spirantization to contrast the voiced and voiceless stops by early in their third year. As an attempt to define some absolute or statistical universals, Macken and Barton (1979) proposed three developmental stages for the voicing contrast: the child has 1) no contrast between voiced and voiceless stops; 2) a contrast but adults cannot perceive it because both voiced and voiceless stops have VOTs that fall within the short-lag region; 3) an adultlike contrast.

Miura (1986) conducted a phonetic study of vowels and stop consonants of 30 monolingual Japanese children, five girls and five boys each at three, four, and five years old. His results for VOT showed that, unlike Spanish-speaking children, the average Japanese three-year-old has already made the lead/short-lag distinction. His results also showed no significant difference between the three different age groups. (See Table 1 for averages for all three ages grouped together.) Miura (1986, p. 7) stated that "the absolute values of voicing lead for voiced sounds and voicing lag for voiceless sounds are small compared to those of adults." However, since he did not cite any Japanese adult VOT studies, it is unclear which studies he was comparing his child data to. If we compare the child data to the adult data from Homma (1980, 1981) in Table 1, the two data sets are virtually identical for /p/ and /t/, but the child data have a shorter VOT for /k/. For the voiced stops, the absolute value of the child VOT data is shorter for /d/ and slightly shorter for /g/. No adult data were available for /b/.

4.3
Bilingual VOT acquisition

If BFLA children are acquiring languages that differ in the types of VOT present, these children's VOT productions can reveal whether or not the children are making a distinction between their languages. Grosjean (1982) strongly stated that bilinguals are not two monolinguals in one body. We can ask whether they ever acquire VOT values in the monolingual range, or whether their languages always affect each other so much that the VOT values are pulled out of the normal monolingual range. In research on second language (L2) acquisition, Flege (1991) showed that the majority of L2 learners do not ever acquire monolingual-like VOT values. L2 acquisition and BFLA, although seemingly related, are two different kinds of language acquisition, and VOT studies of BFLA children can illustrate these differences. Unfortunately, there is a paucity of published studies on bilingual VOT acquisition, especially research that focuses on BFLA. In this section, we briefly review VOT studies done to date and then present pilot data on two Japanese-English BFLA children.

Deuchar and Clark (1996; also see Deuchar & Quay, 2000) analyzed the VOT of Manuela's stop consonants when this Spanish–English bilingual child was ages 1:7, 1;11, and 2;3. At 1;7, all Manuela's stops were in the short-lag region: 0–20 ms for labials and alveolars, and 0–40 ms for velars. At 1;11, mean VOT for English voiceless stops was longer than for voiced stops, but still much shorter than adult values. There was no such distinction for the Spanish stops, and Manuela did not use spirantization to signal the voicing contrast. By age 2;3, Manuela produced even longer lag voiceless stops in English, with values within the adult ranges reported by Lisker and Abramson. There was a beginning contrast among the pairs of Spanish stops, but with the values still in the short-lag region for voiceless stops and no lead voicing for the voiced stops. Deuchar and Clark concluded that the voicing contrast developed differently in Spanish and English, with no evidence at any stage for a single, unified system. Based on the stages proposed by Macken and Barton (1979), we could describe Manuela as being at stage two in English at 1;11 and stage three at 2;3, while she was at stage one in Spanish at 1;11 and stage two at 2;3. This kind of mismatch in developmental schedule has been used by other child phonology researchers (e.g., Paradis, Fonte, Petitclerc, & Genesee, 1997) as evidence for separate phonological systems, in the areas of phonetic inventories and word shapes.

In a carefully designed study using 45 children (15 monolingual English, 15 monolingual French, and 15 BFLA English–French), Watson (1990, 1991) showed that BFLA children's productions are perceptually no different from monolingual children's. It must be noted that the 15 bilingual children in his study were not as young as the children in the studies cited above: five 6-year-olds, five 8-year-olds, and five 10-year-olds. Interestingly, these bilingual subjects tended to produce voiceless stops with similar VOT in each language—but still perceived by adults to be within the range of normal child values in each language. Watson (1991, p. 45) interpreted this as "indicative of an economy in the use of phonetic, articulatory routines." If we assume that articulatory complexity equals cognitive complexity, then by lessening the number of differences in VOT production between English and French, the children would be lessening the cognitive processing required. This economic approach only works, though, if the children are still perceived as native speakers of each of their native languages.

Khattab (2000) found that three English–Arabic bilingual children (aged 5–10) had acquired distinct VOT patterns for each of their languages. However, even at this older age, VOT in each of their languages was slightly different from monolingual children's. In this study, bilingual children, just like monolingual children, showed a delay for certain distinctions (e.g., voicing lead in Arabic was replaced with short lag).

Kehoe, Lleó, and Rakow (2001) discovered two distinct VOT patterns in the speech of four two-year-old German–Spanish BFLA children. While all of the children were able to distinguish productively between voiced and voiceless stops within each of their languages, only two of the children made a significant distinction between languages. The authors concluded that "the phonological/phonetic systems of these bilingual children do not develop totally independently but influence each other." An interesting result in their study was that one child had a high prevalence of lead voicing for German voiced stops, an influence from the Spanish system. Although it may appear that the child was making the most extreme acoustic opposition, it should be noted that that child was exposed to German spoken by the Spanish mother (i.e., German spoken with a Spanish accent).

4.4
VOT Data from two Japanese-English bilingual children

In this section we offer an example of the use of VOT as a measure of BFLA children's early language differentiation with pilot data from two sisters, Nanami and Hinata, both born in Japan and raised bilingually in English and Japanese from birth. These data were originally collected with a different focus—to determine whether young BFLA children produce word-initial voiceless stops with aspiration in English but no aspiration in Japanese, as is the norm for adults—and before we began the exploration of methodological issues presented earlier. Thus, in addition to providing some preliminary Japanese–English acquisition VOT data, this pilot study demonstrates the complexity of some of these issues we discussed earlier and how this affects the results. To this end, we will comment on our methodology as we describe the study.

The children studied (daughters of the second author), lived in Tokushima, Japan until Nanami was 2;11 and Hinata was 1;1, at which time their family moved to Canada. At the time of data collection, they had been living in Vancouver for slightly less than two years. Both children had been exposed to relatively equal amounts of English and Japanese at home, English primarily from their father and Japanese primarily from their mother. The father is a native speaker of Canadian English, the mother of standard Japanese. Each parent speaks the other language quite well, but with a noticeable accent. The father lived in Japan for eight years; at the time of data collection, the mother had been living in Canada for about two years. When the parents speak to each other, each person usually uses his or her first language, but they sometimes converse entirely in English, and occasionally entirely in Japanese. The children have definitely heard their parents speaking their respective second languages, their mother speaking English more often than their father speaking Japanese. Note that this pattern of language choice in the home predisposes the children to use a bilingual mode of language activation and speaking (Grosjean, 1985, 1998). Outside of the home, the language of the community is English. However, at the time of data collection, the children and their mother met with Japanese-speaking friends at least once per week, and both girls attended a Japanese preschool once a week for two-and-a-half hours.

Recordings of the subjects were made during three separate sessions. The first two sessions were one week apart, recorded in a soundproof room at a speech research laboratory when Nanami was 4;8 and Hinata was 2;10. Both parents were present for Hinata's sessions, but only the father was present for Nanami's sessions. The third session was recorded approximately two-and-a-half months later in a quiet room in the children's house, with both parents present for both Nanami (4;11) and Hinata (3;0). The third session was recorded to provide Japanese /p/-initial words, and VOT calculations were limited to these.[4] Note that development may have taken place between Sessions 2 and 3; however, no stop was analyzed across the two sessions, so this would only affect how acquisition of VOT for Japanese /p/ was ordered relative to other stops. During all three sessions, each parent was recorded saying the same words that the children had recorded earlier. Each parent's VOTs were measured for his or her native language, and these values were used to make comparisons to the children.

Our method of data collection took advantage of the fact that both children showed metalinguistic awareness, knowledge of the fact that their father speaks English and their mother speaks Japanese. Both children were able to identify objects selectively using English/Japanese when asked what their father/mother would call the object. The father (speaking in English) asked one of the following questions to get the children to identify a pictured object: (1) What's this? (2) What does Mommy say? (3) What does Daddy say? The children most often gave one-word answers, after which the father usually asked for one or two repetitions of the word in each language. Note that this method of elicitation (as well as the presence of both parents at recording sessions and the pattern of language use in the home, mentioned earlier) predisposed the children to be in bilingual mode.

4 A set of kanji (Chinese character) flashcards had been used to collect data in the first two sessions. In very early Japanese, /p/ was weakened into /f/, with the result that there are now no kanji words that begin with /p/. Modern Japanese does have /p/-initial words, but many of these are borrowings from other languages.

Table 2

Mean VOT in ms (with number of tokens) in English and Japanese by place of articulation, for Hinata, Nanami, and their father and mother

Speaker(s)	Place of articulation	English "voiceless"	English "voiced"	Japanese "voiceless"	Japanese "voiced"
Father (English native speaker)	labial /p,b/	68 (*N*=18)	12 (*N*=12)	—	—
	alveolar /t,d/	75 (*N*=18)	12 (*N*=3)	—	—
	velar /k,g/	80 (*N*=24)	24 (*N*=5)	—	—
Hinata – age 2;10 to 3;0 (bilingual exposure since birth)	labial /p,b/	127 (*N*=9)	15 (*N*=5)	121 (*N*=20)	2 (*N*=3)
	alveolar /t,d/	59 (*N*=7)	17 (*N*=2)	80 (*N*=10)	16 (*N*=4)
	velar /k,g/	98 (*N*=13)	—	87 (*N*=24)	—
Nanami – age 4;8 to 4;11 (bilingual exposure since birth)	labial /p,b/	138 (*N*=14)	11 (*N*=5)	109 (*N*=26)	8 (*N*=2)
	alveolar /t,d/	121 (*N*=11)	17 (*N*=1)	63 (*N*=10)	10 (*N*=3)
	velar /k,g/	115 (*N*=10)	22 (*N*=1)	105 (*N*=16)	—
Mother (Japanese native speaker)	labial /p,b/	—		24 (*N*=26)	-15 (*N*=8)
	alveolar /t,d/	—		30 (*N*=13)	-28 (*N*=8)
	velar /k,g/	—		64 (*N*=38)	-33 (*N*=2)

Notes: 1. See Table 1 for typical English and Japanese VOT values from other studies of adults and children.
2. There are many more tokens of voiceless stop-initial words than voiced stop-initial words, due to the original focus of the study.

This would minimize separation of the languages, thereby presenting a conservative picture of the children's ability to separate Japanese and English.

Sessions were recorded using a Sony ECM-ZS90 electret condenser microphone positioned on a tabletop and plugged into a Sony MZ-R37 minidisc recorder. After recording, sound files were transferred to an iMac computer, where acoustic analysis was performed using Praat 4.0.[5] All words spoken at an abnormally fast or slow rate were eliminated from analysis. Words with a liquid (/l/ or /r/) immediately following the word-initial stop were eliminated for reasons stated earlier.

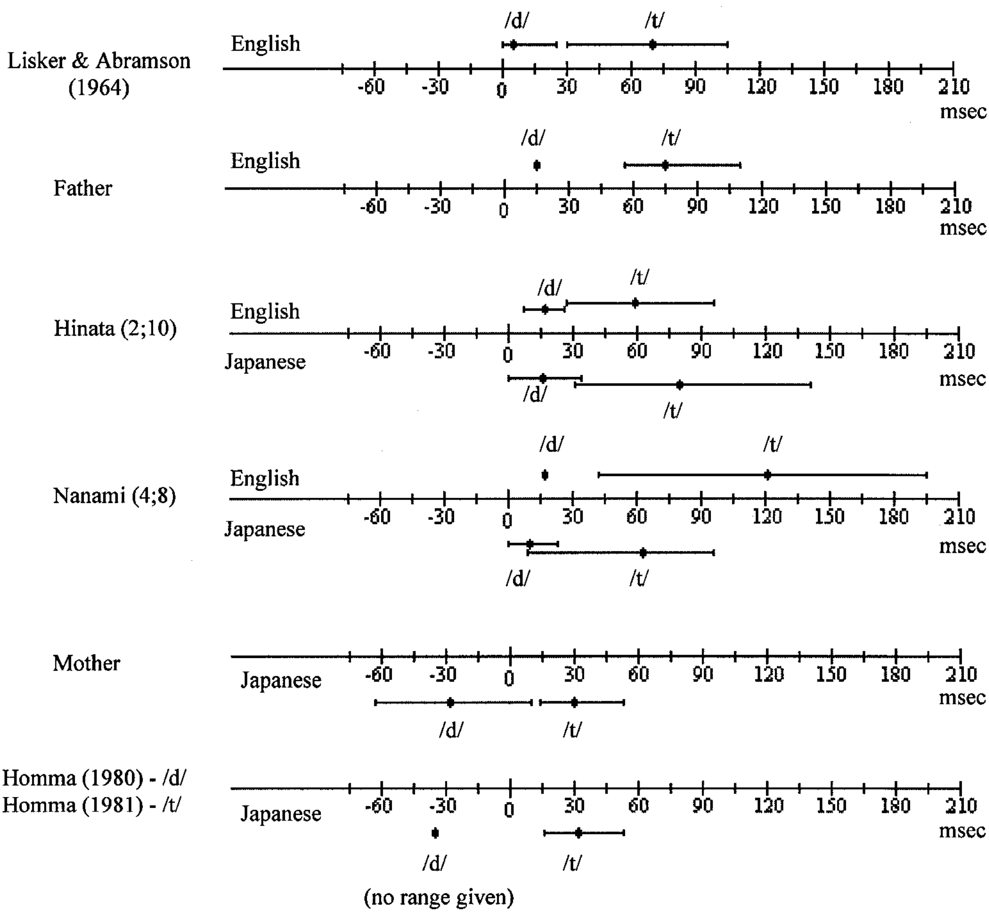
Results of the VOT analysis are shown in Table 2. The father's mean VOT is similar to the mean VOTs reported by Lisker and Abramson (1967), except for /p/ and /b/, which are slightly longer. The mother's voiceless stops are very similar to the Japanese reference points (Homma, 1980, 1981). However, her voiced stops are all clearly prevoiced, which differs from the velar stop value reported by Homma. Unfortunately, no adult value for Japanese /b/ was reported in any of the literature consulted.

In each language both Hinata and Nanami differentiated between voiced and voiceless stops. This can be seen most clearly in Figure 1, a pictorial version of the alveolar data in Tables 1 and 2. Although the number of tokens is small, it is also clear that the subjects on average did not prevoice their Japanese stops. In fact, none of the tokens used to compute the mean VOT for Nanami were negative values (prevoicing), and only one of Hinata's tokens

5 PRAAT (a system for doing phonetics) was developed by Paul Boersma and David Weenink at the Phonetic Sciences department at the University of Amsterdam. See < http://www.fon.hum.uva.nl/praat/> for more details.

Figure 1

VOT data for alveolar stops in English and Japanese



had prevoicing (VOT = −8 ms). Since the children produced all voiceless stops (both English and Japanese) in the long-lag category and all voiced stops (both English and Japanese) in the short-lag category, at first glance it appears that the children did not differentiate between Japanese and English in their VOT production. For each subject, t-tests were performed, comparing voiceless stops in Japanese to those in English (at each place of articulation). Results confirmed that the younger child, Hinata, had no significant difference between languages ($p > .1$ at each of the three places of articulation). However, the t-test results for Nanami indicated that, for /p/ and /t/, VOT for English was of significantly longer duration than VOT for Japanese ($p < .005$ for each of /p/ and /t/).

It is interesting to note that the children's VOT for voiceless stops was much longer than their parents' VOT in both English and Japanese (with the exception of Hinata's English /t/). Menyuk and Klatt (1975) found that 11 three- and four-year-old monolingual English-speaking children's average long-lag VOTs were generally longer than adults' were (but not to a significant degree). Although this could be a trait of children's VOT in general, Watson's (1991, p. 39) data showed that it might be especially true of bilingual children. He noted that the VOT for his French-English bilingual child subjects in each of their languages was longer than the average for his monolingual child subjects.

One possible reason for the bilinguals' tendency to produce normally short-lag voiceless stops of Japanese and French as long-lag stops is that the subjects have not yet acquired prevoicing of voiced stops in these languages, but they want to clearly differentiate between voiced and voiceless phonemes. Because the bilinguals are pronouncing the voiced stops as short-lag stops, they produce voiceless stops with a longer VOT to make them completely distinct from voiced stops. Another possible reason for the longer VOTs of Nanami and Hinata's Japanese voiceless stops is that the community language is English. Sancier and Fowler (1997) showed that ambient (community) language has a strong effect on the VOTs of *both* L1 and L2 in second language learners.

To summarize, in this pilot study, two Japanese-English BFLA children were shown to be at different stages of developing VOT. Although both children could differentiate Japanese from English lexically and pragmatically, and both children sounded to adults like native speakers of each of their languages, only the four-year-old had the phonetic ability to differentiate her two languages in terms of the VOT of initial voiceless stops. Both children produced significantly different VOT values for voiced versus voiceless stops in each language at each place of articulation (i.e., English /p/ vs. /b/, Japanese /p/ vs. /b/, etc.). However, results were not so clear cut when comparing the same place of articulation across languages. The four-year-old produced significantly different VOTs for English versus Japanese /p/ and /t/. She did not do this for /k/, but this may be because in Japanese adult speech—and particularly the speech of the child's mother—the VOT of /k/ is considerably longer (and thus closer to English /k/) than the VOT for /t/ or /p/. The two-year-old did not produce significantly different VOTs for English versus Japanese at any place of articulation. This is understandable if we see this as simply immaturity of motor control (Kent, 1992). The two-year-old was still learning the correct timing of laryngeal speech gestures and was unable to control these finely enough to vary the length of VOT other than categorically (i.e., phonologically voiced vs. voiceless). Neither child produced the prevoiced stops of Japanese. This is not surprising, given the difficulty manipulating air pressure in the vocal tract for prevoiced stops and the fact that Spanish speakers acquire these stops late (Macken & Barton, 1980; but see Miura, 1986, for contrasting results). Even though the four-year-old in our study did not have the phonetic ability to produce adultlike prevoiced stops in Japanese, it was very interesting that she did have the ability to differentiate between English and Japanese by producing different lengths of long-lag stops. This implies that children will do what they are physically capable of doing to phonetically differentiate their languages, even if they are not yet able to match adultlike speech production values. Based on our pilot study, along with studies of children learning Spanish, we conclude that VOT can be a useful measure of language differentiation, but not until children are about three years old.

A number of issues specific to VOT studies were raised in the section on VOT data collection issues. There are a few other factors specific to our study that need to be mentioned. First, when calculating VOT of Japanese stops, one needs to be aware that often after voiceless stops Japanese high vowels are fully (or partially) devoiced. This devoicing has the effect of making VOT, by its strict definition, much longer than average. These tokens were not included in the calculation of mean VOT. Second, some of the Japanese words chosen in this study are actually English borrowings (especially /p/-initial words). On the one hand this could have the effect of the child pronouncing them with an English accent (i.e., longer VOT); on the other hand the child might want to pronounce them as unlike English as possible (i.e., with a shorter VOT) to emphasize her choice of language. Third, in the data collection context in this study, the subjects were asked to identify a picture in one language then immediately in the other language. This alternation between two languages for every word perhaps makes it more likely that the children will not differentiate VOT. Thus, if they do differentiate, then the evidence of phonological separation is that much stronger.

5 Conclusion and directions for future research

To sum up, we are not surprised that so far there has not been much study of bilingual children's developing phonologies. This is a difficult task on both theoretical and methodological grounds. We do think this is an important and worthwhile enterprise, and at the segmental level, we would like to encourage more studies that use acoustic analysis. One example we have mentioned is a VOT study, although this is not likely to capture the earliest means of phonological differentiation. In carrying out these studies, it is important to keep in mind a number of factors that may influence the results, including segmental context, rate of speech, stress position, and many other factors that influence the choice of stimuli depending on the phonological feature or phonetic process under analysis.

In our pilot study of two Japanese–English bilingual children, it was discovered that a child can be differentiating two languages in her speech production, even though it may be at a level that is not perceivable by adult listeners. Hence, the importance was confirmed of systematic acoustic analysis, a level of analysis that is often neglected in studies of language acquisition. In the future much more research, both phonetic and phonological, needs to be done in the area of bilingual first language acquisition. In addition to the acoustic analyses mentioned above, articulatory analyses could also be attempted, depending on the ages and level of cooperation from the children. Examples of this type are video analysis of lip rounding, use of a nasometer for measuring degree of nasality, and the use of ultrasound to see real-time movements of the tongue surface. These three methods of articulatory data collection are all safe and noninvasive, and they have the potential to provide us with a wealth of new data.

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