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The Acquisition of Japanese Stops by Japanese-Mandarin Bilingual Children*

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Early bilinguals—those exposed to their second language (L2) during early childhood or who grew up bilingually from birth—are regarded as *bilingual first language acquisition* (BFLA) children. This paper investigates the production of word-initial Japanese stops by Japanese-Mandarin BFLA children growing up in southern Taiwan. Examination of Japanese word stop voice onset times (VOTs) by these bilingual children, aged 3-6 years old, revealed three important findings: (1) They tended to replace Japanese voiceless stops with Mandarin aspirated stops as well as Japanese voiced stops (except voiced stops with negative value) with Mandarin unaspirated stops; (2) Some children as young as three years old were able to produce prevoicing in Japanese voiced stops; and (3) Error patterns including aspiration and devoicing also suggest that they have established a unique phonetic system, the result of a mixture of both languages.

Key words: bilingual, Japanese, Mandarin, stops, VOT

1. Introduction

A primary question in the study of bilingual phonetic systems is whether or not bilingual individuals can produce native-like speech production. The effect of age in bilingual vowel and consonant perception and production has been investigated in a number of studies (e.g. Mack 1989, Johnson & Wilson 2002, Aoyama et al. 2004, Flege & Mackay 2004, Baker & Trofimovich 2005, Riney et al. 2007, Oh et al. 2011). "Early bilinguals," bilingual children who grew up bilingually from birth or who were exposed to their second language (L2) in early childhood, what De Houwer (1990) refers to as "bilingual first language acquisition" (BFLA), have shown more monolingual-like speech in both of their languages than "late bilinguals" (Mack 1989). However, the assumption still remains that L2 sounds of early bilinguals or BFLA children can never be identical to that of native speakers from either language, i.e., both language systems will show variation from native speakers.

According to the Speech Learning Model (SLM) developed by Flege (1995), a phonetic category for an L2 sound will assimilate with an existing L1 sound when a new category fails to be established for an L2 speech sound. If instances of an L2

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speech category keep being perceived as instances of an L1 category, a merged category will develop due to the process of "equivalence classification". On the other hand, the SLM model claims that new phonetic categories for L2 sounds will be established if there is a perceived phonetic dissimilarity between an L1 and the target L2 sound. In addition, the SLM assumes that the earlier individuals are exposed to L2, the more likely they are to develop new L2 phonetic categories and ultimately produce authentic sounds in their L2. In other words, early phonetic awareness might lead individuals to acquire new phonetic categories, thus enabling them to produce target words correctly. To sum up, perception and discrimination of phonetic categories, phonetic dissimilarity between the L1 and L2, and the age of L2 acquisition are three crucial factors in bilingual phonological research.

In this study, the production of word-initial Japanese stops by BFLA children who have been raised in mixed families where one parent is a native speaker of Taiwanese Mandarin and the other parent is a native Japanese speaker is examined. All of the children have been growing up in southern Taiwan, where most residents speak Mandarin as well as Taiwanese.

Acquisition of the contrast between voiced and voiceless consonants for Mandarin L2 learners and the pronunciation of Mandarin aspirated sounds for Japanese L2 learners has been discussed as a critical issue in phonetic research. In particular, the bilabial /p^h/, alveolar /t^h/ and velar /k^h/ sounds in Mandarin are produced at almost the same place of articulation as Japanese voiceless stops for the bilabial /p/, alveolar / t/ and velar /k/ groups. Therefore, both Japanese and Mandarin learners are likely to substitute those L1 sounds for their counterpart L2 sounds (Mizutani 1974, Hosino & Yasuda 2004). Having discussed the above possible phonetic variation (or deviations) of Japanese and Mandarin L2 learners, one important question is what problems, based on the assimilation of two languages' phonetic systems, will Japanese-Mandarin bilingual children display. The SLM hypothesis predicts that if a perceived phonetic dissimilarity exists between two languages, a different phonetic category is likely to be developed in each language. According to the SLM, it is thus hypothesized that bilingual children will produce Japanese sounds accurately if they perceive a phonetic dissimilarity between the sounds of their two languages. On the other hand, it is also hypothesized that bilingual children will assimilate the sounds of their two languages if they are unable to discriminate a Japanese sound that is perceptually similar to a sound in Mandarin.

For the acoustic analysis, the study of voice onset time (VOT) in stops by bilingual individuals has been presented cross-linguistically, including English-Spanish (Flege & Eefting 1987, Fabiano-Smith & Bunta 2012), English-Korean (Baker & Trofimovich 2005), and English-Japanese (Johnson & Wilson 2002,

Aoyama et al. 2004, Harada 2007). The examination of VOT is able to illustrate voicing features and the intensity of VOT visually. In addition, the acquisition of VOT differentiation can be observed after about three years of age. Although in general a well-documented area of inquiry, there is a lack of studies focusing specifically on stop consonants in Japanese-Mandarin bilingual children. The purpose of the present study is to examine and better understand the sound features, in particular, the phonological development of stops in Japanese-Mandarin BFLA children; therefore, the following two research questions are explored: (1) To what extent does Japanese-Mandarin bilingual children's production of Japanese stops demonstrate differences from stop productions of monolingual Japanese and Chinese speakers? (2) What language-specific errors do early bilinguals show in the processes of Japanese stop acquisition? The former question concentrates on a comparison of bilinguals and monolinguals by examining evidence of cross-language influence within the two sound systems, while the later focuses on bilingual children's phonological development of stops.

2. Literature review

2.1 The voicing contrast in Japanese and Mandarin

The stop contrast in Japanese has two categories: short lead (voiced stops) and short lag (voiceless stops). The voicing contrast is defined by the condition of the glottis during the interval between oral closure and the onset of stop release. While the presence of vocal vibration during closure is voiced, voiceless stops do not involve glottal vibration. Japanese, like English, differentiates two phonation types: /b, d, g/ for voiced stops and /p, t, k/ for voiceless stops. In English, voiced stops are voiced in the word-medial position, but they appear (voiceless) unaspirated in the word-initial position whereas Japanese voiced stops are clearly voiced (Shimizu 1989). Moreover, voiceless English stops are aspirated in the syllable-initial position when they occur immediately before a stressed vowel (with no sound in between); therefore, they might be aspirated in the word-medial position (e.g. oppose [əpʰówz]). For Japanese voiceless stops, there has been debate regarding (a) whether they fit into the short lag, the long lag or neither category; and (b) whether they are not aspirated, aspirated or moderately aspirated. A number of the earlier studies claim that the VOT of voiceless stops in Japanese occurs between the short lag and the long lag ranges (e.g. Homma 1981, Shimizu 1989, Riney et al. 2007, Ogasawara 2011).

In comparison with Japanese, Mandarin stops are phonetically voiceless and differentiated by aspiration: (a) aspirated and (b) unaspirated. The aspiration gesture is marked by glottal adduction at or after the release of the oral closure. Maximizing the

glottal opening at the point of stop release differentiates aspirated from unaspirated sounds. Cho & Ladefoged (1999) provided a more detailed range for voiceless stops, which are named as (a) “unaspirated” (velar stops with a mean VOT of around 30 ms); (b) “slightly aspirated” (with a mean VOT of around 50 ms); (c) “aspirated” (with a mean VOT of around 90 ms); and (d) “highly aspirated” (with a mean VOT of over 90 ms). According to their study, therefore, Mandarin voiceless aspirated stops are classified as unaspirated for /p, t, k/ and as highly aspirated for /p^h, t^h, k^h/ while English /p, t, k/ fall into the aspirated category.

Table 1 shows the means and ranges (if available) for VOT in English, Japanese and Mandarin. The data for Japanese stops has been summarized from five studies. The range of VOT with prevoicing /b, d, g/ is between -57 ms and -72 ms for adults, and VOT for unaspirated stops /p, t, k/ is between 22 ms and 68 ms. This shows Japanese unaspirated stops could belong to the *slightly aspirated* category according to Cho & Ladefoged (1999). Four prior studies on VOT for Taiwanese Mandarin stops indicate the range of aspirated stops / p^h, t^h, k^h / is between 62 ms and 92 ms, which belongs to long-lag category. VOT for unaspirated stops /p, t, k/ ranges 9 ms to 27 ms, which belongs to the short-lag category. Notice that /b, d, g/ refers to voiced unaspirated stops, /p^h, t^h, k^h/ represents voiceless aspirated stops and /p, t, k/ refers to voiceless unaspirated stops.

Table 1. Means and ranges of VOT (ms) for Japanese and Mandarin in comparison with English

		Bilabial			Alveolar			Velar		
English		b	p	p^h	d	t	t^h	g	k	k^h
Lisker & Abramson (1964)/AE	Word initial 4 speakers	1 (0-5)	58 (20~120)	N/A	5 (0~25)	70 (30~105)	N/A	21 (0~35)	80 (50~135)	N/A
Docherty (1992)/BE		15 (0~50)	42 (10~80)	N/A	21 0~50	64 (30~110)	N/A	27 (10~60)	62 (30~150)	N/A
Japanese (adults)		b	p	p^h	d	t	t^h	g	k	k^h
Homma (1981)	Word initial	N/A	27 (14~43)	N/A	-35 (N/A)	32 (16~53)	N/A	14 (8~20)	53 (35~63)	N/A
Shimizu (1989)	Word initial 6 speakers	-72 (-45~-95)	44 (15~60)	N/A	-58 (-10~-70)	27 (15~90)	N/A	-64 (-20~-105)	68 (45~100)	N/A
Riney et al. (2007)	Word initial 13 speakers	N/A	30.8 (N/A)	N/A	N/A	28.5 (N/A)	N/A	N/A (N/A)	56.7	N/A
Ogasawara (2011)	Word initial /a/ 10 speakers	N/A	N/A	N/A	9.79/ -61.10	22.56	N/A	16.41/ -70.79	40.05	N/A
	Word initial /o/ 10 speakers	N/A	N/A	N/A	12.84/ -60.10	24.72	N/A	21.52/ -57.39	41.17	N/A

Table 1. (Continued)

		Bilabial			Alveolar			Velar		
Japanese (children)		b	p	p^h	d	t	t^h	g	k	k^h
Miura (1986)	Word initial (3-5 years old) 30 speakers	-14	28	N/A	-7	32	N/A	7	40	N/A
Harada (2007)	Word initial /a/ (grade 1 and 5) 10 speakers	N/A	20.1 (G1) 18.2 (G5)	N/A	N/A	23.8 (G1) 20.5 (G5)	N/A	N/A	35.9 (G1) 37.7 (G5)	N/A
Mandarin		b	p	p^h	d	t	t^h	g	k	k^h
Ogasawara (2011)/TM	Word initial in phrase 10 speakers	N/A	9.25 (NA)	62.87 (NA)	N/A	11.40 (NA)	62.98 (NA)	N/A	20.82 (NA)	76.80 (NA)
Chao & Chen (2008)/ TM	Word initial 11 speakers	N/A	14 (7~65)	82 (35~147)	N/A	16 (7~33)	81 (45~123)	N/A	27 (15~65)	92 (50~138)
Chen, Chao & Peng (2007)/TM	Word initial 36 speakers	N/A	13.9 (NA)	77.8 (63~90)	N/A	15.3 (NA)	75.5 (65~87)	N/A	27.4 (NA)	85.7 (74~98)
Chao, Khattab & Chen (2006)/ TM		N/A	14 (NA)	82 (NA)	N/A	16 (NA)	81 (NA)	N/A	27 (NA)	92 (NA)
Chen, Hsiao & Fang (2010)/ TM	Girl (45 months)		27			28			42	
Chen, Kuo & Lee (2013)/TM	Boy (50.5 months)	N/A	9.8	74.7	N/A	13.0	62.1	N/A	28.1	85.9

Note: The number in parentheses shows the range of VOT.
AE = American English; BE = British English; TM = Taiwanese Mandarin

2.2 Error patterns associated with stop productions

Jakobson (1968) supposed that all children would follow the same developmental process of phonological acquisition across various languages. In his theory, stops are in general acquired earlier than other phonemes such as fricatives, and thus often replace fricatives and affricates, i.e., stopping. Alveolar stops are likely to substitute for velar stops as front stops are acquired earlier than back stops, a phenomenon known as “velar fronting.” For example, a Swedish child may say *tata* instead of “kaka”, a German child *topf* instead of “kopf,” an English child *tut* instead of “cut,”

and Japanese children change /k/ to /t/ (Jakobson 1968:47). Moreover, stops in the initial position tend to be devoiced or deaspirated due to early acquisition of unaspirated stops compared to voiced or aspirated stops, phenomena known as "devoiced and deaspirated." A number of studies report that English-speaking children usually use stops to replace fricatives at the same or similar place of articulation. For example, /p/ is used for /f/, /b/ for /v/, /t/ for /θ, s, ʃ, ʧ/ and /d/ for /ð, z, ʒ, ʤ/ as the stopping phonetic process.

The most typical errors in relation to stops realized by Putonghua (Mandarin Chinese)-speaking children include stopping and deaspiration (Hua & Dodd 2000). 63% (1; 6-4; 6) of stopping errors was the replacement of affricates by stops at the same place or nearest place of articulation: /t, d, t^h/ for /tɕ, tɕ^h, tʂ, tʂ^h, ts, ts^h/, /k, g/ for /x/ and /t, d/ for /ɕ, n, l, ʂ/. Deaspiration (56%) was a more common type of error than aspiration (32%), and the deaspiration process usually occurred with deaffrication and fronting: /t, d/ for / tʂ^h, ts^h, t^h/, /k/ for /k^h/ and /p/ for /p^h/. Compared with English-speaking children, who tend to realize velar stops as alveolar stops (fronting), a lower percentage of Putonghua-speaking children (16%) made such errors.

So & Dodd (1995) also reported that /f, s, ts, tsh/ being incorrectly realized as stops were responsible for 88% of all stopping errors made by Cantonese-speaking children. Younger children tended to pronounce the unaspirated /t/ in place of either the unaspirated continuant /ts/ or the aspirated continuant /ts^h/. Children aged 2 yr 6 mo – 3 yr 5 mo tended to produce the aspirated continuant /ts^h/ as the aspirated stop /t^h/. Younger children also often replaced velar stops /k, k^h / with the front unaspirated stop /t/, but as they developed aspiration sounds, /k^h/ was substituted by /t^h/ instead of /t/. The process of deaspiration appeared together with stopping and fronting. The phonological error pattern of deaspiration is frequently found for both Putonghua and Cantoneses-speaking children.

Japanese-speaking children also demonstrate specific error patterns in relation to stop production. According to Yoneyama, Beckman, & Edwards (2003), alveolar backing (/t/ to /k/) occurred more often than velar fronting, and substitutions of /tʃ/ or /dʒ/ for /k/ occurred more frequently than those of /t/ or /d/, which differs from Jakobson's findings. For example, *kora* for "tora" demonstrates the backing of a dental stop, *keeki* for "tʃe:ki" shows substitution of affricates by stops. They claim that Japanese children acquire /k/ earlier than /t/ due to the input pattern in child-directed speech. In their study, more errors occurred when /t/ and /k/ were followed by the vowel /e/, as /te/ or /ke/ sounds were found to be less frequent in their child-directed speech. It may be that the frequency of phonemes influences the error patterns of Japanese children.

3. Methodology

The present experiment, in examining the production of Japanese voiced-voiceless stops by simultaneous bilingual children, aims to document Japanese-Mandarin BFLA children's phonetic characteristics in producing Japanese stops by comparing them with Japanese and Mandarin monolinguals. The production data to be analyzed was transcribed manually.

As noted earlier, in Mandarin there are aspirated and unaspirated stops whereas Japanese consists of voiced and voiceless stops. Thus, it is important to investigate how the contrasts of aspiration and voicing in the two languages influence Japanese-Mandarin bilinguals' stop acquisition and production. In particular, the study focuses on stops in the word-initial position.

3.1 Participants

The subjects for the present study included a group of 29 Japanese-Mandarin BFLA children composed of 12 boys and 17 girls. Of the 29 children, 24 had Japanese mothers and Taiwanese fathers while five had Taiwanese mothers and Japanese fathers. The children were all raised in southern Taiwan; as a result, the participants were also likely to have experienced some level of Taiwanese language input. The subjects were further divided into four age groups from three to six years old, as shown in Table 2. All the children were raised bilingually with Mandarin and Japanese from birth. As a result, most of the children showed considerable metalinguistic awareness in that they were able to identify which language to use and code switch according to the interlocutor's language. Prior to the experiment, the researcher obtained parental consent in informal verbal form to ascertain any possible impairment to the subjects' hearing abilities.

Table 2. Age groups

6 yr (n = 9)		5 yr (n = 10)		4 yr (n = 6)		3 yr (n = 4)		Total
Boy	Girl	Boy	Girl	Boy	Girl	Boy	Girl	
4	5	4	6	3	3	1	3	29

3.2 Materials

The target consonants were word-initial stops followed by five vowel contexts, five vowel phonemes /i, e, a, o, ɯ=u/ in Japanese (e.g. *doa* "door"). The word-lists were developed using the same methodology as was used in the paidologos project

(http://learningtotalk.org/node/24), a large cross-linguistic investigation of phonological development conducted at Ohio State University, the University of Wisconsin-Madison, and other universities in several countries other than the United States. The number of tokens for Japanese target consonants was “t” for 12 tokens, “d” for 9 tokens, “k and kj” for 24(12/12) tokens and “g” and “gj” for 15(12/3) tokens. Bilabial stops were not included in the present study because these sounds are typically among the first consonants acquired in canonical babbling cross-linguistically. Thus, the study focused on lingual obstruents. There were 60 tokens in total for each participant except one four-year-old who recorded only half of a data set. (See Appendix 1 for the list of Japanese words used). All the Japanese words selected were authentic words, not monosyllabic or non-word words, in order to make the words more meaningful to the children. While some of the younger subjects seemed not to recognize some of the words, they repeated all target words without any problems. The target words were presented in random order.

A TASCAM recorder and a microphone were used for the recordings. Individual participants were asked to repeat target words recorded by an adult female native speaker in isolation after they had heard the words from a computer and seen word-matched pictures on the screen. A practice section in each language was completed before the experiment in order to ensure that each child produced sounds at an appropriate volume and consistent speaking rate.

The mothers were surveyed to ascertain the participants’ ages and language environments in both languages. The language background scale for bilinguals of Japanese and Mandarin, revised by the present author, was based on Baker (1992) for bilingual speakers of English and Welsh, Law & So (2006) for bilinguals of Cantonese and Mandarin, and Shih (2012) for bilinguals of Mandarin and Taiwanese.

3.3 Procedure

Participants were instructed to repeat target words presented on a computer together with visual stimuli. In such cases where the children were unable or refused to produce the target sounds, they were given opportunity to hear the same word a second time. Prior to the test, there were 10 practice tasks in Japanese to ensure that all participants understood the procedure. Instruction was provided in Japanese for obtaining Japanese sounds by the present researcher, a native speaker of Japanese. Together the practice session and the experimental session lasted approximately 15-20 minutes. The test was administered individually only one time in a quiet room. After the recording, each child received a small toy and some snacks as a reward.

3.4 Data analysis

3.4.1 Transcription

Evaluation of whether accurate production had been achieved relied on transcriptions of the children's production and was judged by the present researcher. The researcher exclusively relied on her subjective perception while spectrographic and waveform measurements using Praat Software (Boersma & Weenink 2014) were used to extract valid data for the analysis. The researcher first listened to the recordings and marked "1" as a correct stop production or "0" as an incorrect production, except for voicing inaccuracies, and "V" as an incorrect production in voicing (i.e., "V" was marked when a child pronounced "t" for "d") for the target consonants and following vowels. Furthermore, in cases of inaccurate production, which were marked "0" or "V", a dollar mark "$" plus a possible substitute sound was added for the target CV. Errors in point of articulation (e.g. /k/ for /t/), voicing (e.g. /t/ for /d/), and aspiration (e.g. /t/ for /t^h/) were included, whereas non-stop production (e.g. /t/ for /r/), tokens of deletion, and unclear and/or untranscribable sounds due to severe noise were excluded. Table 3 summarizes the transcription system.

Table 3. Markers used for transcription analysis

Transcription marks	Meaning	Examples
1	Correct stop production	"t" for "t"
0	Incorrect manner and place of articulation	"t" for "r"
V	Incorrect production in voicing	"t" for "d"
$	Substitution	"t" for "t^h" = $$t^h$

3.4.2 VOT analysis

Acoustic analyses were conducted using Praat Softwear. Three tags were aligned to acoustic events for analyzing each production burst, voicing onset and vowel end. By the inspection of the spectrogram image, focusing on 1st formant, 2nd formant, and wave form, along with the researcher's impressionistic judgment as a native speaker, interpretations were made.

If a voiceless stop was pronounced, the first tag was placed at the start of the burst (burst) followed by the onset of voicing (vot) and at the end of the vowel (vEnd). If a voiced stop was produced, an indication of voicing (vot) appeared before the burst (burst). Figure 1 shows examples of voiceless stops (short lag VOT) and voiced stops

(lead VOT). VOTs were measured by subtracting the time of the burst from the time of onset voicing: VOT = Voice onset – Burst. The measured VOTs were converted into a log scale in milliseconds.

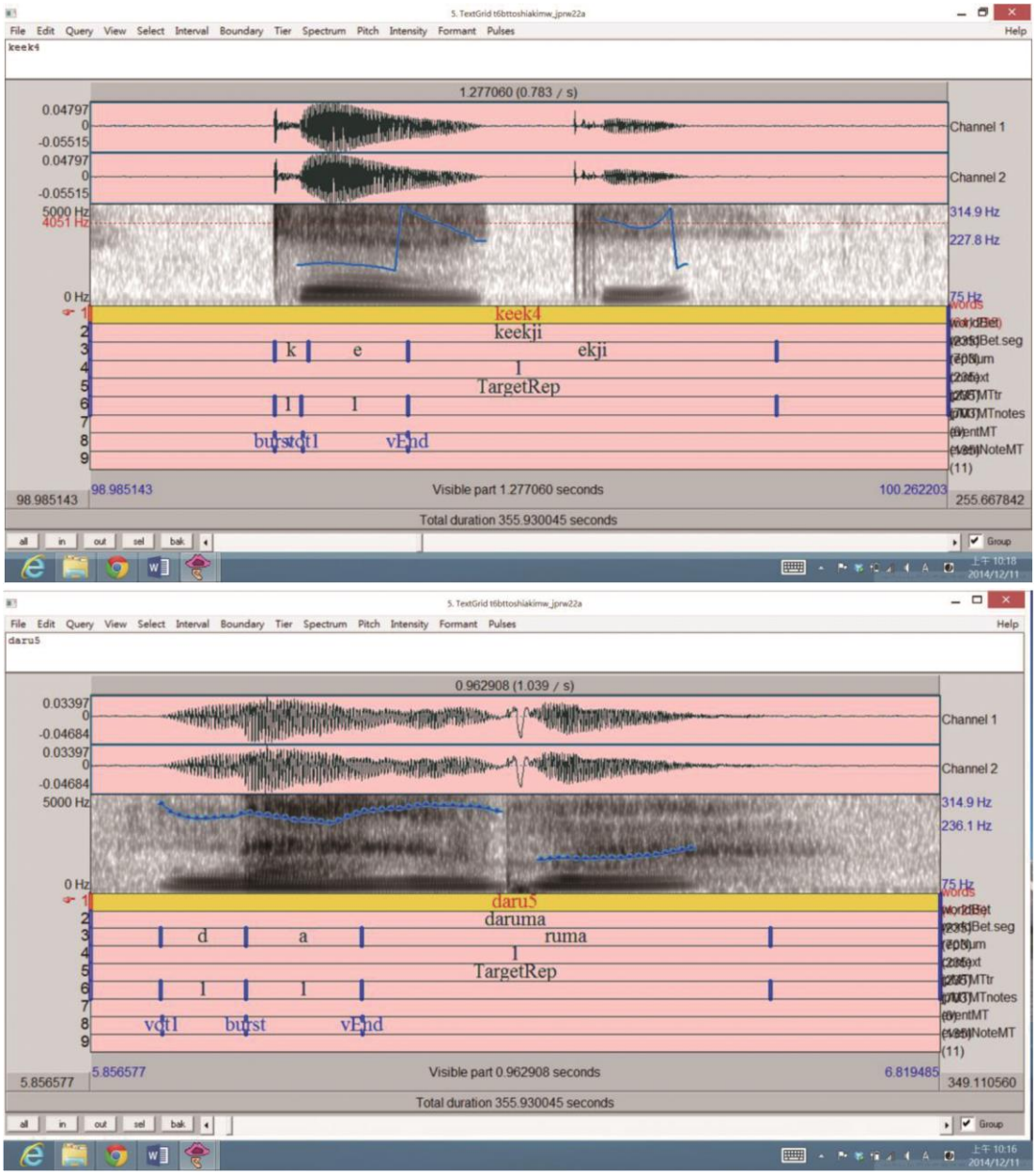

Figure 1. Screenshots of event marking. The top figure shows an example of a voiceless stop (Japanese *keeki* 'cake') and the bottom figure shows an example of a voiced stop (Japanese *daruma* 'tumbler')

3.4.3 Language use questionnaire

The language use questionnaire used is a 5 point Likert scale consisting of three parts. The 5 options of the scale are as follows: 5 = use Mandarin most, 4 = use

Mandarin more often than Japanese, 3 = use both Mandarin and Japanese equally, 2 = use Japanese more often than Mandarin and 1 = use Japanese most. The first part concerns which language the bilingual children use when they talk to various people (e.g. mother and father). The second part concerns which language different interlocutors use when talking to the bilingual children. The last part concerns which languages the bilingual children use while participating in daily activities, including watching TV and reading books. Figure 2 shows a summary of the language background survey (See Appendix 2 for the complete language background scale).

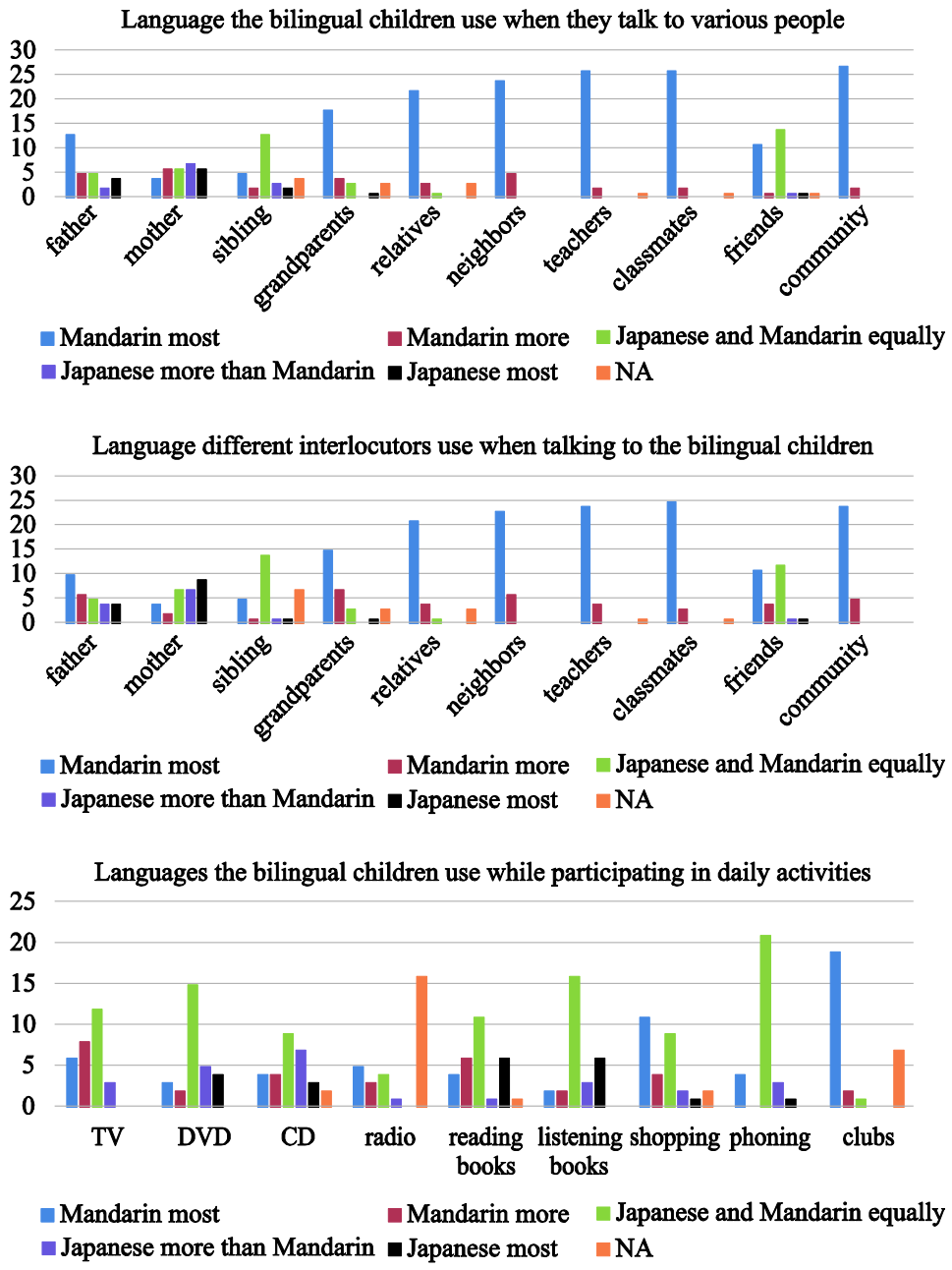

Figure 2. Summary of language background scale

The parental role of the mother, including the mother's native language, is surely a key factor in a BFLA child's phonological acquisition. As Figure 2 illustrates, these BFLA children used Japanese to communicate with their Japanese parents while Mandarin was the dominant language used for most other interlocutors. In Japanese culture, the rearing of children is largely seen as the responsibility of the mother; thus, mothers are typically common interlocutors of young children. In other words, "the central relationship is between mother and child" (White 1987:21). In fact, all the mothers of these BFLA children reported being the primary caregivers when the children were not at school. Thus, it is possible that this strong bond and frequent communication might facilitate the majority of the children in acquiring Japanese speech characteristics.

The social environment is surely another key factor affecting the speech production of BFLA children. Although these BFLA children all go to Mandarin language-speaking kindergarten or elementary schools, Figure 2 shows that they use both languages in daily activities outside of school. Taiwanese society is largely tolerant of code-switching into other languages, including Japanese (Beaser 2006); as a result, there is relatively minor social and peer prohibition about speaking Japanese. Thus, all the BFLA children aged between three and six years old were able to produce Japanese words without hesitation. It should be noted that their language production habits will probably continue to change as the social environment changes around them since the sounds of both languages mutually influence one another in bilingual children across their life span (Flege 2002).

4. Results

The current experiment involved two approaches: analysis of Japanese stop VOTs produced by the Japanese-Mandarin BFLA children and errors in Japanese stops produced by three-, four-, five- and six-year old bilingual children. Table 4 shows VOT in Japanese stops produced by the participants. The Japanese voiced stops /d/ and /g, gj/ were divided into two categories: (a) short lag and (b) short lead VOTs. According to the resulting data, the average of voiced stops /d/ and /g, gj/ with negative VOTs was -46.15ms and -46.99ms respectively, which is slightly shorter than the previous data for Japanese VOTs (the range is between -57ms and -72ms). The average of voiced stops /d/ and /g, gj/ with positive values showed 18.91ms and 30.96ms respectively, which is much longer than Ogasawara's (2011) Japanese data (9.79ms and 21.52ms). The average of voiceless stops /t/ and /k, kj/ was 55.28ms and 75.10ms respectively, which also indicates longer VOTs than the Japanese data in Table 1 (the range is between 22ms and 68m).

Table 4. Mean VOTs (ms) and standard deviation of Japanese stops produced by Japanese-Mandarin bilingual children

	6yr (n = 9)		5yr (n = 10)		4yr (n = 6)		3yr (n = 4)		Average (n = 29)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
t	50.78	12.50	61.24	24.2	54.98	17.48	50.07	28.44	55.16	19.93
d (+)	18.69	7.13	19.75	11.41	19.42	12.69	16.17	4.57	18.86	9.41
d (−)	-67.51 (22)	11.74	-44.89 (11)	39.19	-47.34 (5)	45.1	-6.5 (1)	N/A	-51.01	32
k/kj	69.72	8.9	82.97	32.12	77.04	16.57	68.88	29.66	75.69	23.13
g/gj (+)	20.65	7.81	33.06	11.97	32.37	11.69	32.80	4.24	29.03	11.07
g/gj (−)	-59.91 (32)	15.82	-60.4 (13)	20.81	-56.16 (7)	17.27	N/A	N/A	-59.31	15.82

Note: The number in parenthesis next to VOTs refers to the number of instances in which prevoicing was produced.

Table 5 presents the substitution patterns for the target Japanese stops. The data was extracted from Praat after the transcription process. The first column of the table shows error patterns in both place of articulation and manner of articulation. “Not clear” refers to unclear sounds due to significant background noise. The second column represents specific types of substitutions. The number under each age shows the average percentage of substitutions made by each group. For example, the six-year-old subject group made more fronting errors than the other age groups. As Table 5 shows, the most frequent errors the children made were aspiration, /t/→ /t^h/ (31.3%; n = 107) and /k, kj/→ /k^h/ (15.8%; n = 108) followed by devoicing, /g/→/k/ (6.4%; n = 22) and /d/→/t/ (6.6%; n = 17) errors.

5. Discussion

Two research questions guided this project: (1) To what extent does Japanese-Mandarin bilingual children’s production of Japanese stops demonstrate differences from stop productions of monolingual Japanese and Chinese speakers? (2) What language-specific errors do early bilingual children show in the process of Japanese stop acquisition? The following discussion will be divided into two sections based on these research questions.

Table 5. Substitution patterns for target stops

Error patterns	Error types	6 yr (n = 9)	5 yr (n = 10)	4 yr (n = 6)	3 yr (n = 4)	Total
Fronting	/d/→/b/	1.2%	1.1%		2.8%	1.2%
	/g/→/d/	3.7%				1.2%
	/gj/→/ʤ/	3.7%				1.2%
	/k/→/t/	7.4%				2.3%
	/kj/→/ʤ/				2.1%	0.3%
	/k/→/p/	0.9%				0.3%
Backing	/t/→/k/	1.6%	2.5%	7.6%	4.2%	3.5%
	/t/→/r/			1.5%		0.3%
Aspiration	/k, kj/→ /k^h/	10.6%	25.8%	11.4%	8.3%	15.8%
	/t/→ /t^h/	26.8%	45.8%	25.8%	12.5%	31.3%
Voicing	/k/→/g/		0.8%			0.3%
Devoicing	/d/→/t/	1.2%	4.4%	14.3%	13.9%	6.6%
	/g/→/k/	0.9%	11.7%	7.6%	4.2%	6.4%
	/gj/→/k/		3.3%			1.2%
Affrication	/kj/→/ ʨ/	1.6%	0.8%	4.5%		1.8%
	/k/→/ʃ/				2.1%	0.3%
	/t/→/ʨ/	1.6%				0.6%
Lenition	/k/→/ɸ/	0.9%				0.3%
	/k/→/h/			3%		0.6%
	/kj/→/ç/				2.1%	0.3%
	/t/→/h/	0.9%				0.3%
Deletion	/d/				2.8%	0.4%
	/g/	1.9%				0.6%
	/k/				6.3%	0.9%
	/t/				8.3%	1.2%
Others	/kj/→/k/	0.9%	1.7%	1.5%		1.2%
Not clear	/d/	1.2%				0.4%
	/g/	3.7%				1.2%
	/k/	3.7%				1.2%
	/kj/	1.9%				0.6%
	/t/	3.7%				1.2%

5.1 Japanese-Mandarin bilingual production of Japanese stops

Firstly, concerning the VOTs between the BFLA children in the present study and Japanese monolinguals in the previous normative studies (Table 1), both groups (Japanese monolinguals and BFLA children) produced longer velar stops than alveolar stops. This is in accordance with the universal pattern, in which velar or uvular stops have longer VOT than coronal stops and bilabial stops. The prevoiced sounds, /d/ and /g, gj/ had been acquired by children as young as three years old in the present study. Although the number of short lags for voiced stops produced was much more than that of short leads, it suggests that Japanese-Mandarin bilingual children begin to acquire a sound system much like that of monolingual adults. The SLM hypothesis explains that dissimilar sounds are easier to acquire than similar sounds. Prevoiced sounds being typologically more salient than voiceless sounds, it follows then that the bilingual children would acquire the voicing contrast early on.

In addition, the participants tended to produce voiceless stops /t/ and /k/ with a breathy voice. Their Japanese voiceless stops can be categorized as long lag like Mandarin aspirated stops. The substitution of aspirated sounds for unaspirated voiceless sounds in this case can be explained by the reflection of the children's internal lexicon representation. When children don't have perceptual acoustic patterns that differentiate the target sound from the replacement sound, apparent substitutions might occur, a phenomenon that is referred to as perceptually based interpretation (Beckman, Yoneyama & Edwards 2003). Since aspiration does not differentiate meaning within the Japanese lexicon, bilingual children might group aspirated and unaspirated stops into one category in Japanese production. They are, therefore, unlikely to discriminate the contrast of aspiration.

Second, Japanese stops produced by the target children were compared with Mandarin monolingual production. The Table 1 data shows that the range of Mandarin /t/ and /k/ was between 11.40ms and 42ms, which is very similar to the average VOT of voiced stops /d/ (18.91ms) and /g/ (30.96ms) with positive values. The BFLA children pronounced Japanese voiced stops with positive VOTs as Mandarin unaspirated stops. Moreover, the bilingual children tended to replace Japanese voiceless stops with Mandarin aspirated stops. Hoshino & Yasuda (2004) state that the bilabial /p^h/, alveolar /t^h/ and velar /k^h/ groups of aspiration sounds in Mandarin are pronounced at almost the same place of articulation as Japanese voiceless stops in the bilabial /p/, alveolar /t/ and velar /k/ groups. Therefore, both Japanese and Mandarin L2 learners are likely to substitute those L1 sounds for their counterpart L2 sounds. As the SLM hypothesis indicates, bilinguals are unable to discriminate an L2 sound which is perceptually similar to a substitute sound in L1,

and therefore the Japanese-Mandarin bilingual children replaced Japanese voiced stops with positive VOTs with Mandarin unaspirated stops as well as Japanese voiceless stops with Mandarin aspirated stops.

5.2 Early bilingual Japanese stop acquisition language errors

The production errors identified were more often regarding manner of articulation than place of articulation. Aspiration and devoicing were the main errors found in the present experiment. Regarding aspiration, as noted above, the children tend to aspirate Japanese voiceless stops, that is, the children substituted Mandarin aspirated stops for Japanese voiceless stops. The five-year-old group made more aspiration errors and had longer VOT values than the other age groups. This was largely due to the excessive production of aspiration made by two of the ten five-year-old participants. One girl and one boy pronounced 88.9% and 55.6% of the target unaspirated stops as aspirated stops, which accounts for 27.4% and 17.1% of the total in the age group respectively. The researcher found that these two children seemed especially nervous and excited during the recording sessions; consequently, they lengthened the target stops.

Additionally, the bilingual children produced voiced alveolar /d/ and velar /g, gj/ either as short lags or short leads. Homma (1998) states that Japanese word-initial voiced stops often overlap in the short lag and the short lead categories in adult speech. In other words, Japanese voiced stops do not necessarily have negative VOT values. A number of people, particularly female speakers, produce short lag values in VOT. According to the language use questionnaire, most participants of this study hear Japanese sounds merely from their mothers. Therefore, the mothers' speech might have influenced the present children's VOTs of voiced stops.

Among place of articulation errors, alveolar backing frequently occurred. This error pattern is in accordance with the previous finding that Japanese children tend to substitute the velar stop /k/ for alveolar stop /t/. For example, the bilingual children pronounced *kikappu* for "tikappu" and *kegami* for "tegami". Moreover, substitution of the affricate /tɕ/ for stop /kj/ is another specific error pattern that the children made such as *tɕiro* for "kjiro". Yoneyama, Beckman, & Edwards (2003) claimed that Japanese children acquire /k/ earlier than /t/ due to its frequent occurrence in child-directed speech. Thus, the frequency of phonemes in a mother's speech likely influences error patterns found in Japanese-Mandarin bilingual children.

Likewise, velar fronting errors occurred at almost the same rate as alveolar backing errors. Table 5 shows that the six-year-old group made alveolar backing errors more frequently than the younger children. These prominence of these errors

can be attributed to one boy who made 80% of the total errors in the six-year-old group. This boy frequently demonstrated fronting of velar stops: substituting /t/ for /k/ (e.g. *toara* for "koara"). He didn't place the back of his tongue in the velum position, but instead made contact between the front of the tongue and the alveolar ridge when producing velar stops. This process is consistent with language-specific processes in Mandarin. Monolingual Mandarin children tend to show fronting (Liu-shea 2011). However, this is common among younger children but rare after the age of 6. It is difficult to ascertain whether or not this child had a phonological disorder without further observation and evaluation of his Mandarin speech.

Additionally, the three-year-old children tended to produce weak sounds and delete initial consonant due to a developmental cause. Their articulatory and laryngeal systems are not sufficiently developed to produce sounds constantly, which is known as articulatory based interpretation (Beckman, Yoneyama, & Edwards 2003). This pattern, initial consonant deletion, also illustrates a language-specific error. Deletion of initial consonants appears in the speech of Japanese- and Mandarin-speaking children whereas English-speaking children typically demonstrate final consonant deletion (Liu-shea 2011).

Although the present findings do not provide a clear systematic picture of developmental acquisition processes for these BFLA children across different age groups, they do reveal substitution patterns that can be traced to individual differences. Bilinguals who simultaneously acquire two languages process a complex pattern of phonetic categories that are child-specific (e.g. articulatory immaturity), language-specific (e.g. the frequency of the lexical input), and related to universal patterns (e.g. the salience of sounds such as prevoicing and aspiration). Whether these individual errors are caused by a phonological disorder or delay is difficult to determine as there are so few studies which have focused on the phonological development of Japanese-Mandarin BFLA children.

6. Conclusion

The present study investigated BFLA children's production of Japanese alveolar and velar stops in the word initial position. In particular, the research compared Japanese-Mandarin bilingual individuals' Japanese stops with the stops of Japanese native speakers as well as those of Mandarin native speakers. The significant findings were the replacement of Mandarin aspirated stops for Japanese voiceless stops and Mandarin unaspirated stops for Japanese voiced stops with positive values. In addition, some children were able to produce adult-like prevoicing in Japanese voiced stops. Errors in the children's language developmental course also showed characteristics of

BFLA children's phonetic development. Aspiration and devoicing were the major errors found in the present study. As language specific errors, alveolar backing, velar fronting and word-initial consonant deletion were found to frequently occur in Japanese-Mandarin bilingual stop production. Indeed, these Japanese-Mandarin BFLA children, from the age of 3 to 6 years, show evidence of possessing a unique phonetic category, one composed of features from both languages as well as universal tendencies. Thus, the results of this study will hopefully contribute to a future, more complete understanding and framework for Japanese-Mandarin BFLA speech assessment.

6.1 Limitations and suggestion for further research

In order to enrich the present findings on Japanese language stops in Japanese-Mandarin BFLA children, the Mandarin language stops in these same children should also be carefully examined and compared. The influence of stop productions of parents in child-directed speech is also crucial in understanding bilingual phonetic acquisition. In a recent study of VOT in mother-infant interaction, Cheng (2014) found differences in stop production between infant-directed speech and adult-directed speech in Hakka language speakers. Additionally, longitudinal studies are necessary to observe the influence and evolution of the social environment over time on the phonetic development of these BLFA children. In other words, the changes in bilinguals' phonetic characteristics need to be studied in relation to their linguistic environment as well as in pertaining to individual motivation.

Pedagogically, the current findings on the production of contrasting voiced-voiceless stops and acquisition of aspiration have a significant implication for Mandarin learners of L2 Japanese and Japanese learners of L2 Mandarin. The identification of difficulties and problems in L2 speech production could help practitioners develop appropriate training and pedagogical materials to improve learners' L2 production accuracy.

Appendix 1. Japanese wordlist

WorldBet	English gloss	Target stops	Vowels
tiikappu	tea cup	/t/	/i/
tiiSatsu	t-shirt	/t/	/i/
tiSSue	tissue	/t/	/i/
tebukuro	glove	/t/	/e/
tempura	tempura	/t/	/e/
tegami	letter	/t/	/e/
tako	octopus	/t/	/a/

WorldBet	English gloss	Target stops	Vowels
tamago	egg	/t/	/a/
taNqpopo	dandelion	/t/	/a/
tomato	tomato	/t/	/o/
tooFu	bean curd	/t/	/o/
tora	tiger	/t/	/o/
keekji	cake	/k/	/e/
kemuri	smoke	/k/	/e/
keSigomu	eraser	/k/	/e/
kaba	hippo	/k/	/a/
kame	turtle	/k/	/a/
karasu	crow	/k/	/a/
koara	koala	/k/	/o/
kodomo	child	/k/	/o/
koppu	cup	/k/	/o/
kuma	bear	/k/	/u/
kuri	chestnut	/k/	/u/
kuruma	car	/k/	/u/
kjiiro	yellow	/kj/	/i/
kjimono	kimono	/kj/	/i/
kjiriNq	giraffe	/kj/	/i/
kjabetsu	cabbage	/kj/	/a/
kjappu	cap	/kj/	/a/
kjarameru	caramel	/kj/	/a/
kjoodai	sibling	/kj/	/o/
kjoosoo	competition	/kj/	/o/
kjorokjoro	restless eyes	/kj/	/o/
kjuu	nine	/kj/	/u/
kjuukjuuSa	ambulance	/kj/	/u/
kjuuri	cucumber	/kj/	/u/
deNqkji	electricity	/d/	/e/
dekoboko	uneven	/d/	/e/
depaato	department store	/d/	/e/
daikoNq	white radish	/d/	/a/
daNqgo	dumpling	/d/	/a/
daruma	tumbler	/d/	/a/
doa	door	/d/	/o/

WorldBet	English gloss	Target stops	Vowels
doNqguri	acorn	/d/	/o/
doonatsu	doughnut	/d/	/o/
geemu	game	/g/	/e/
geNqkji	energy	/g/	/e/
geta	wooden clogs	/g/	/e/
gakkoo	school	/g/	/e/
garasu	glass	/g/	/a/
gasu	gas	/g/	/a/
goma	sesame	/g/	/o/
gomi	garbage	/g/	/o/
gorira	gorilla	/g/	/o/
gumi	soft candy	/g/	/u/
guruguru	round and round	/g/	/u/
guu	stone	/g/	/u/
gjidzagjidza	jag	/gj/	/i/
gjiNqkoo	bank	/gj/	/i/
gjitaa	guitar	/gj/	/i/

Note: WorldBet is a sound description system like IPA.
Capitalized words 'S, N, F' in WorldBet indicate /ʃ/, /ŋ/ and /ɸ/ respectively.

Appendix 2. Bilingual Children's Language Background Scale

1. Name: _____
2. Date of birth: year _____ month _____ day
3. Year in school: None / K1 / K3 / K5/ 1st grader
4. Gender: Male / Female
5. How many brothers? Elder brother(s)_____ / Younger brother(s)_____
6. How many sisters? Elder sister(s)_____ / Younger sister(s)_____
7. Father's ethnicity: Japanese / Taiwanese
8. Mother's ethnicity: Japanese / Taiwanese
9. Which language(s) do you use in the family? (you can choose more than one)
   Japanese / Mandarin / Other:_____

Instructions: The questions are about the language in which your child talks to different people, and the languages in which certain people speak to your child. Please answer as honestly as possible. There is no right or wrong answer. Please tick the correct box, and put a cross (X) if a question does not apply to your child.

PART A: In which language(s) does your child speak to the following people?

	Always in Mandarin	More often in Mandarin	Equal use of both languages	More often in Japanese	Always in Japanese	In another language (please specify)
Father						
Mother						
Brothers/ Sisters						
Grandparents						
Other relatives						
Neighbors						
Teachers						
Friends in the classroom						
Friends outside of school						
Community						

PART B: In which language(s) do the following people speak to your child?

	Always in Mandarin	More often in Mandarin	Equal use of both languages	More often in Japanese	Always in Japanese	In another language (please specify)
Father						
Mother						
Brothers / Sisters						
Grandparents						
Other relatives						
Neighbors						
Teachers						
Friends in the classroom						
Friends outside of school						
Community						

PART C: Which language does your child use for the following activities?

	Always in Mandarin	More often in Mandarin	Equal use of both languages	More often in Japanese	Always in Japanese	In another language (please specify)
Watching TV						
Watching Videos						
Listening to CDs						
Listening to the radio						
Reading books by him/herself						
Listening to stories						
Shopping						
Phoning						
Clubs						

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日語中文雙語孩童日語塞音學習

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BFLA 小孩指的是幼兒時就開始接觸第二語言，或者從出生開始就在雙語環境成長兒童。本研究探討在南台灣成長的 3-6 歲中日 BFLA 孩童日語字首塞音發音嗓音起始時間(Voice Onset Time, VOT)。主要的研究結果有：1)日語無聲塞音常以中文吐氣塞音取代，日語有聲塞音常用中文的不吐氣塞音取代；2)有些孩童早在 3 歲時就可以發出日語有聲塞音；3)這些錯誤的型態指出在學習的過程，BFLA 兒童建立融合兩個語言的獨特語音系統。

關鍵詞：雙語、日語、中文、塞音、嗓音起始時間