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Stop consonant production of French immersion students in Western Canada: A study of voice onset time

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Abstract

Objectives/research questions: The present study investigates the development of French stop consonants among English-speaking children who are enrolled in an early French immersion program in Lethbridge, Alberta, Canada. Our goal is to observe the stop consonant production pattern, and to determine whether interactions between the two language systems occur, while examining student progression with increasing experience.

Methodology: Fifty-six students in grades 1, 3, and 5 participated in a speech production task administered in both English and French. For each language, they were asked to repeat a total of 54 words beginning with one of the six stop consonants, /p/, /t/, /k/, /b/, /d/, and /g/. In addition, 45 age-matched monolingual English-speaking children were tested to serve as a control group.

Data and analysis: Voice onset time (VOT) was the acoustic measure analyzed for each language and for children of each grade. An analysis of variance was conducted for language- and experience-related effects.

Conclusions: For the French voiceless stops, French immersion students display non-native-like VOT values in the intermediate range between monolingual English voiced and voiceless stops. Their English voiceless stops exhibit higher VOT values than the monolinguals' and are separate from those of their French. For voiced stops, their English and French are indistinguishable, located within the range of voiced stops for monolingual English speakers.

Originality: Previous research on French–English bilingualism has generally been limited to adults. Furthermore, examination of French immersion students has rarely focused on their phonetic development, and acoustic analysis of this population is virtually non-existent.

Implications: Our results highlight the importance of input, as well as social, and educational context in second language learning.

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Keywords
French-English bilingualism, French immersion, stop production, voice onset time, cross-language influence

The present study investigates the phonetic development of French immersion (FI) children in Western Canada, a particular population of second language (L2) learners. These children are native speakers of English who are immersed in a French environment during school hours starting from kindergarten (age 5). The larger sociolinguistic environment, outside of school, however, is English speaking. Although much research has been undertaken on FI students, particularly in Eastern Canada, little has touched upon their phonetic learning experience. In this study, we describe the stop production pattern of FI students, as measured by voice onset time (VOT), to shed light on the effect of social and instructional contexts on L2 phonetic learning. The following section reviews current research regarding relevant factors for L2 phonetic development, as related to language learners in language immersion school programs.

Factors affecting phonetic development of second language learning

Factors found to contribute to the ease and proficiency at which a L2 is acquired include age of learning (Kang & Guion, 2006), the quality of the L2 input (Flege, 1998), the opportunity for L2 output (Cummins, 2000), length of exposure (Flege & Liu, 2001), daily first language (L1)/L2 use ratio (Piske, MacKay, & Flege, 2001), the social status of L1 and L2 (Mougeon & Beniak, 1991), the degree of phonetic similarity between L1 and L2 (Baker & Trofimovich, 2005), and speakers' motivation and attitudes (Oxford & Shearin, 1994). Research has demonstrated that the earlier in life speakers are exposed to a L2 environment, the more likely they are able to gain native-like proficiency (Kang & Guion, 2006; Lenneberg, 1967), and to establish two autonomous language systems (Flege, 1987; MacLeod & Stoel-Gammon, 2010). However, the majority of research that has demonstrated the age effect on L2 learning has sampled speakers who are exposed to authentic L2 input where the L2 is the dominant language in the society, as in the typical case of immigrants. Not much is known about how L2 acquisition unfolds when children are exposed to semi-authentic input while residing in a society where the L2 is a minority language. The present study aims to fill in this gap by describing the phonetic development of students enrolled in a FI elementary school in Lethbridge, Alberta, an Anglo-dominant region in Western Canada. The immersion environment is 'semi-naturalistic' and 'semi-authentic' in the sense that children are not surrounded by native Francophone peers, and their input is limited to formal situations from a restricted number of adults, who are a mix of native Francophone and advanced L2 French speakers.

French immersion in Canada

In the body of literature on FI education, it is commonly agreed upon that children display comprehension skills comparable to their French peers, but can be accented in their pronunciation and/or ungrammatical in their sentence production (Genesee, 1978; Wesche, 2002). This research, however, tends to pay more attention to higher level language functions such as syntax, semantics, reading and writing. Phonetic development is rarely the focus of investigation, and acoustic description is virtually non-existent. Phonological competence has generally been evaluated using

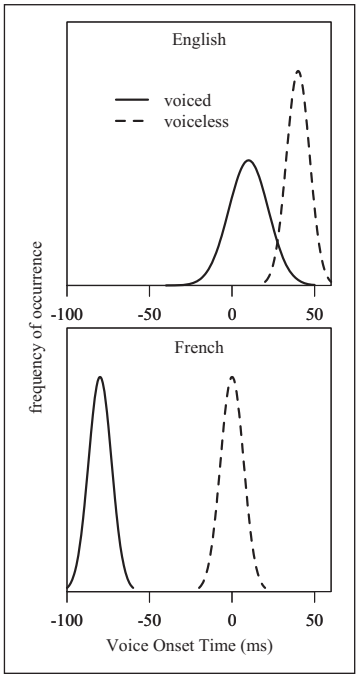

Figure 1. Hypothetical voice onset time ranges (in milliseconds) in the production of English and French voiced and voiceless stops based on previous research.

qualitative measures, in which native speakers are asked to judge L2 speakers' production to be language appropriate or not (e.g. Genesee, 1978). This type of perceptual evaluation provides a reasonable indication of accented speech, but does not capture fine-grained articulation details necessary for the identification of the degree of cross-language influence in L2 speakers.

Voice onset time in stop consonants of French and English

For the current study, we focused on stop consonants measured by VOT. Phonologically, both English and French have two sets of stop consonants that contrast in voicing: voiced /b/, /d/, and /g/; and voiceless /p/, /t/, and /k/. For both languages, this voicing contrast can be primarily distinguished through VOT, which acoustically measures the articulatory phasing difference between the release of a stop consonant and the onset of voicing in the following vowel (Lisker & Abramson, 1967). Despite such commonalities, the two languages differ in the specific ways that the voicing contrast is phonetically implemented in VOT: the English voiced stops occupy a 'short-lag' VOT range between 0 and 30 milliseconds (ms), while English voiceless stops usually fall into the 'long-lag' range (>30 ms) (Docherty, 1992). By contrast, French voiced stops are produced with glottal vibration occurring prior to consonantal release, which results in negative or 'lead' VOT (-150 to 0 ms) whereas French voiceless stops are short-lagged (0-30 ms) (Flege, 1987; Fowler, Sramko, Ostry, Rowland, & Hallé, 2008). As Figure 1 illustrates, English voiced stops overlap with French voiceless stops. This may present a challenge for French learning children, as this shared acoustic space is indexed as opposite phonological categories in the two languages, making it prone for erroneous L2 production.

The fact that French stops are not entirely new for English learners, as easily identifiable analogous sounds exist in English (but with language-specific features), makes it ideal to investigate how children learn to develop the French stop sound system in this shared acoustic space while examining how the two language systems interact. For example, Fowler et al. (2008) report a VOT study of voiceless stops produced by simultaneous French–English bilinguals in Canada who learned both languages before age 3. These speakers show clear distinction between their English and French stops, but the phonetic realizations do not equate to those of monolingual speakers: their English and French stops are pulled towards the intermediate range between the two monolingual norms, demonstrating a bidirectional cross-language influence. Unfortunately, the study of French-English bilingualism in the Canadian context has mostly been limited to adults (e.g. Fowler et al., 2008; MacLeod & Stoel-Gammon, 2009), while descriptions of VOT development in French-English bilingual children are scant.

In our investigation, voiceless and voiced stops (/p/, /t/, /k/, /b/, /d/, and /g/) were examined in the speech of FI students in grades 1, 3, and 5. At the school in question, 50% of the teachers are native speakers of French, the other 50% are native Anglophones, often themselves having learned French via a FI school and then taking Study Abroad programs and advanced French studies at university. Our research aimed to address the following questions. (1) Will FI students achieve native-like French proficiency? (2) Will FI students maintain two separate language systems? (3) Will children improve their French proficiency with accumulated experience? We included monolingual local English children to serve as our English control, but we relied on published studies on French-speaking children in France and Quebec for French control due to the dearth of monolingual French-speaking children in Southern Alberta.

Method

Participants

Fifty-six English-speaking children (38 female, 18 male) from an early FI elementary school in Lethbridge, Alberta, Canada, participated in the study: 18 children from grade 1 (M = 6.71 years; SD = 4.50; 13 females), 18 from grade 3 (M = 8.71 years; SD = 3.91; 13 females), and 20 from grade 5 (M = 10.54 years; SD = 3.72; 12 females). The FI students were tested inside the elementary school by the first author, who is a graduate of FI herself. In addition, 45 monolingual English children (25 female, 20 male) were recruited and tested in a research lab at the University of Lethbridge. These children included 15 six-year-olds (M = 6.56 years, SD = 3.57; 8 females), 20 eight-year-olds (M = 8.57 years, SD = 3.29; 13 females), and 10 nine-year-olds (M = 9.49 years, SD = 4.78; 5 females), serving as a monolingual English control group. All participants reported as having normal hearing with no known language, speech, learning, behavioral, or developmental delays, and they had never participated in any speech or language therapy programs. Parents filled out a detailed language demographic questionnaire prior to their child's participation and provided written informed consent.

Stimuli

The stimuli consisted of labial (/p/ and /b/), alveolar/apico-dental (/t/ and /d/), and velar (/k/ and /g/) voiced and voiceless stops in onset position immediately followed by one of three consistent vowel environments /i/, /u/, /æ/ (English) or /i/, /u/, /a/ (French). A total of 54 tokens were elicited, with nine tokens per stop. The French stimuli were produced by a female university instructor from France, and the English stimuli were produced by a monolingual English female university student

from Southern Alberta. The VOTs of the French stimuli had an average of 56 ms (SD = 21 ms) for voiceless stops and −132 ms (SD = 62 ms) for voiced stops. The average VOT for the English stimuli was 116 ms (SD = 24 ms) for voiceless stops and 24 ms (SD = 13 ms) for voiced stops.

Procedure

Children were engaged in a word-repetition task. This elicitation method has the advantage of easing the task demand for younger children who are limited in their French vocabulary, thus allowing for methodological consistency across grades. Participants were tested individually over two sessions, one for each language, performed on different days in order to minimize cross-language interference. During testing, participants sat at a desk in front of a computer in a quiet room. A series of images were displayed on the computer screen, presented one by one, paired with a matching audio prompt. Children were asked to repeat the word back into the microphone after it had finished playing. Children's speech productions were recorded into a Marantz flashcard recorder (PMD661) using a Shure SM87A microphone placed at distance of approximately 10–15 cm from the mouth. A practice trial was given prior to the commencement of the experiment. During testing, if a participant made an overt error, such as 'banane' instead of 'baleine', or 'caméléon' instead of 'camion', the researcher would play the audio prompt again and the child was asked to listen closely and then repeat the word back into the microphone. Mispronunciations and repetitions were excluded from the final analysis. A total of 2965 French stops and 2996 English stops from the FI group and 2348 tokens from the monolingual English control group remained for analysis.

VOT measurements. Speech events such as burst and voice onset were labeled using Praat (Version 5.3) (Boersma & Weenink, 2013). Both waveform and spectrograph were visually displayed to aid labeling. The burst was identified as the peak of an individual spike from a cluster of spikes that make up the transient noise of constriction release, and was recognizable by the first clear deviation from the zero crossing in the waveform. Voice onset was identified by locating the beginning of the first voicing cycle. After all labeling was finished, VOT was calculated by subtracting the time of voice onset from the burst time. In order to assess the reliability of temporal marking across six trained individual labelers, an Intraclass Correlation Coefficient test was conducted on 10% of the audio files. A high level of agreement was evidenced with a coefficient of 0.983.

Results

Grade 1 versus grade 3 versus grade 5: The effect of experience in French learning

Table 1 lists the summary statistics of the FI students' VOT production as well as the values of their age-matched monolingual English-speaking peers. The results can also be visually inspected in Figure 2. At first glance, no clear difference in FI students' French productions across grades can be identified. Our observation was statistically confirmed: a two-way repeated measures analysis of variance (ANOVA; within-subject variable: target stop consonant; cross-subject variable: grade) was carried out for FI students' production of French. No significant differences in grades (F (2, 42) = 0.046, p = 0.955) or interaction between target consonant and grades (F (10, 265) = 1.046, p = 0.405) were revealed. The lack of significant difference across grades indicates that FI students do not show a progression in their VOT patterns from grade 1 to grade 5. Similarly, no cross-grade difference was found for the English stop productions of FI students. Therefore, the data of all three

Table 1. Mean voice onset time values (in milliseconds) and standard deviations of the stops /p, t, k, b, d, g/ in word initial position produced by French immersion children and monolingual English children, segregated by grades as well as averaged across grades.

		Grade 1	Grade 3	Grade 5	Overall		Grade 1	Grade 3	Grade 5	Overall
French immersion French	/p/	63.8 (30.7)	60.7 (26.3)	57.7 (25.8)	60.7 (27.6)	/b/	0.4 (45.9)	−3.5 (51.5)	0.5 (45.6)	−0.9 (47.7)
	/t/	64.5 (28.5)	75.9 (34.6)	68.2 (20.9)	69.5 (28.0)	/d/	−13.9 (73.7)	−2.2 (64.5)	−0.1 (53.6)	−5.4 (63.9)
	/k/	86.3 (34.9)	84.1 (25.5)	81.1 (24.7)	83.8 (28.4)	/g/	16.7 (50.6)	14.1 (54.1)	13.9 (50.1)	14.9 (51.6)
French immersion: English	/p/	82.2 (31.7)	83.0 (28.9)	75.2 (21.3)	80.1 (27.3)	/b/	−2.7 (49.0)	−9.2 (55.5)	−0.1 (48.1)	−4.0 (50.9)
	/t/	91.8 (29.1)	92.3 (29.7)	84.2 (27.1)	89.4 (28.6)	/d/	−4.4 (59.3)	−9.0 (55.5)	−0.8 (57.9)	−4.07 (59.5)
	/k/	100.6 (30.4)	101.6 (29.4)	92.7 (26.6)	98.3 (28.8)	/g/	1.9 (63.2)	5.3 (57.0)	8.1 (60.4)	5.1 (60.2)
Monolingual English	/p/	73.4 (31.6)	75.1 (28.5)	73.9 (26.5)	74.1 (28.9)	/b/	−3.9 (49.5)	2.4 (33.2)	8.3 (30.4)	2.3 (37.7)
	/t/	83.7 (30.2)	82.1 (37.6)	80.6 (19.9)	82.1 (29.2)	/d/	−6.4 (65.3)	−11.9 (60.1)	−5.0 (60.3)	−7.8 (61.9)
	/k/	93.4 (33.2)	93.2 (31.3)	89.3 (24.9)	92.0 (29.8)	/g/	−0.1 (67.3)	5.1 (52.7)	15.7 (48.2)	6.9 (56.1)

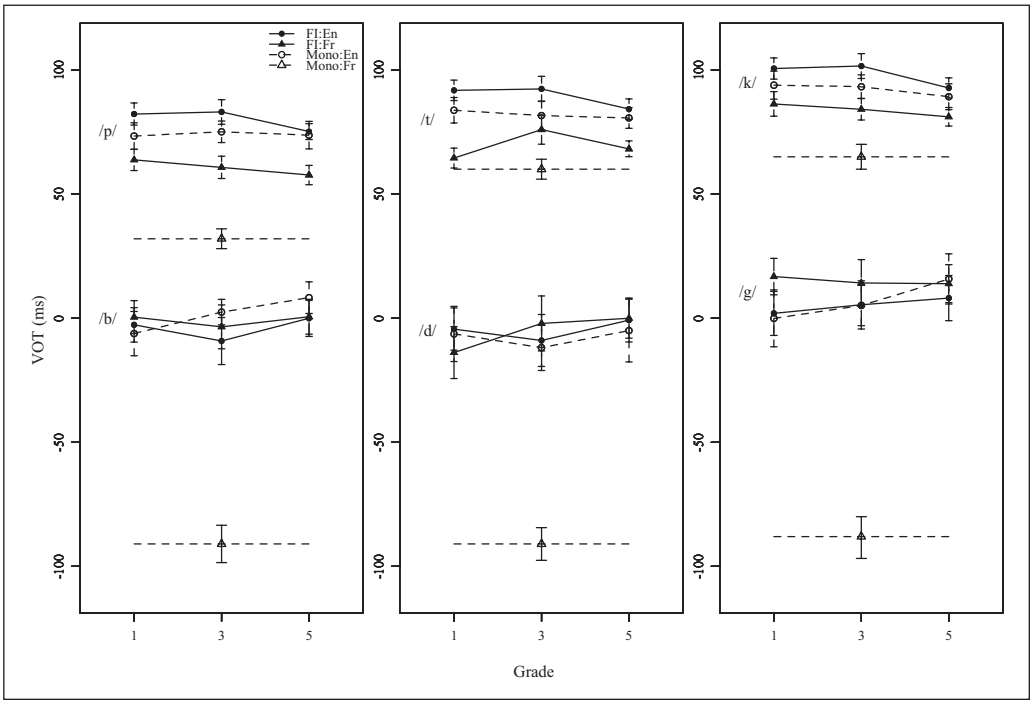

Figure 2. French immersion and monolingual English children's voice onset time (VOT) (in milliseconds) in the production of the stops /p, t, k, b, d, g/. Quebec French-speaking children's VOT values are also plotted as a control (Ryalls & Larouche, 1992). Plain lines are for French Immersion students and dashed lines are for monolingual children. Circles and triangles represent the mean VOT values in English and French, respectively. The bars indicate a 95% confidence interval.

grades were collapsed for the rest of the analysis. The implication of this finding is addressed in greater detail in the discussion.

FI French versus native French: The attainment of native-like French proficiency

The FI students' French was compared with previous studies of native French-speaking children in Quebec (Ryalls & Larouche, 1992) and France (Scarbel, Vilain, Lœvenbruck, & Schmerber, 2012; Scarbel, Vilain, & Lœvenbruck, 2013). The two studies are summarized in Table 2. Given that the VOT production patterns for the two studies are quite comparable, and that Alberta is closer geographically and culturally to Quebec, we plotted the values reported by Ryalls and Larouche (1992) of Quebec French-speaking children to serve as the native French control in Figure 2. The discrepancy between FI students' French and their Quebec French-speaking peers is quite obvious: while native French children produce voiced stops in the lead VOT range, FI students' French voiced stops are barely pre-voiced, and indistinguishable from their English voiced stops. For voiceless stops, FI students have distinctively higher VOT values than their Quebec peers.

FI English versus FI French: One system or two?

To address the question of whether FI students possess two sets of stop systems for English and French respectively, a two-way repeated measures ANOVA (within-subject variable: language;

Table 2. Mean voice onset time values (in milliseconds) and standard deviations of the stops /p, t, k, b, d, g/ in word initial position produced by native French-speaking children in Quebec (Ryalls & Larouche, 1992) and France (Scarbel, Vilain, Lœvenbruck, & Schmerber, 2012).

	French dialect	Subjects	Voice onset time					
			/p/	/t/	/k/	/b/	/d/	/g/
Ryalls & Larouche (1992)	Quebec French	7-9 years old	32 (12)	60 (22)	65 (15)	−91 (24)	−91 (21)	−88 (28)
Scarbel et al. (2012)	Hexagonal French	5-8 years old	39 (31)	45 (26)	61 (30)	−62 (56)	−49 (50)	−40 (53)

within-subject variable: target stop consonant) was conducted. An interaction between language and target (F (5, 275) = 22.28, $p < 0.001$, partial $\eta^2 = 0.03$) was found, suggesting that children are keeping their French and English stops separate, but such a separation is dependent on which stop consonant they produce. A post-hoc Tukey HSD (honest significant difference) test revealed that children systematically differentiate the voiceless stops ($p < 0.001$ for /p/, /t/, and /k/) as well as the voiced stop /g/ ($p = 0.018$) in English and French, but did not differentiate between English and French /d/ or /b/.

The separation of voiceless stops between the two languages of FI students can be clearly seen in Figure 2. Taking /p/ as an example, we see that the French of FI students occupies the VOT range of 50-65 ms, intermediate between the FI students' English productions and those of their native French peers. The same pattern holds for /t/ and /k/. The separation for /g/ is in the opposite direction of what would be expected, with FI student's French of longer VOT values than their English. Post-hoc examination of their French /g/ by the first author (an early English–French bilingual) through the transcription method suggests that several tokens were misarticulated as /k/. This result was somewhat surprising and is addressed in the discussion.

FI English versus monolingual English

Finally, we investigated whether FI students' English VOT productions differed from those of the monolingual English control group to look for signs of L2-to-L1 influence. A two-way repeated measures ANOVA (within-subject variable: target stop consonant; cross-subject variable: language) revealed a significant interaction term between stop consonant and language (F (10, 495) = 189.60, $p < 0.001$, partial $\eta^2 = 0.50$). Post-hoc t-tests indicated significant differences for all three voiceless stops (/p/: $t(891) = 3.06$, $p = 0.002$; /t/: $t(890) = 2.82$, $p < 0.002$; /k/: $t(889) = 3.54$, $p = 0.005$), but not for the three voiced stops. Important to note is that as Table 1 and Figure 2 demonstrate, FI students' English productions of the voiceless stops is about 2–10 ms longer than their monolingual English peers, which suggests an effort to make room to preserve cross-language distinctions.

Discussion

The present study served to explore the L2 phonetic development of native English-speaking children learning French through an immersion program. The first notable finding of our study is the stabilization of non-authentic VOT patterns across grades. Despite accumulated French experiences, early L2 learning onset, and many hours of French language immersion, FI students do not progress throughout the grades towards typical French VOT values. Such stability in production is

reminiscent of the so-called fossilization errors frequently reported in the FI literature regarding syntactic and lexical development. In a similar study on English-speaking students attending a Japanese immersion program in the USA, Harada (2007) reported the VOT values of /p/, /t/, and /k/ of children in grades 1, 3, and 5 to be similar across all age groups. Harada (2007) attributed the lack of VOT progress to the nature of the speech input these immersion students were receiving from teachers. It was revealed that immersion teachers were producing Japanese stops with VOT values falling in an intermediate range between monolingual Japanese (short-lagged) and monolingual English (long-lagged), despite the fact that teachers are native speakers of Japanese. In our study, as mentioned previously, approximately half of the FI teachers are native English speakers, suggesting that a considerable amount of teacher input is 'colored' by English. Of further consideration is the fact that teachers are just one source of linguistic input among all the individuals in the class and, in fact, they are likely not the most important input source for students. It is widely known that adolescents conform to the linguistic norm of the group, and that they adapt their speech under pressure from their peers (see, for example, Tagliamonte & Molfenter, 2007; and specific to FI, see Wesche, 2002). Given that these peers are Anglophones, it is not surprising that the FI students in this study do not attain native-like VOT values.

Despite distinct differences between Harada's study and ours (i.e. French versus Japanese, Canadian versus US context), the results of both studies show striking similarities with respect to voiceless stops, that is, the dissimilation between children's L1 and L2 through lengthening the L1's VOT values and the stabilization of the non-native production pattern across grades. These similarities indicate that our findings are not necessarily due to language specificity of the L2 that children acquire in school, but are more related to the type of education they receive, namely, immersion education. As pointed out by Cummins (1996, 2000), there is a lack of opportunity to practice speaking the L2 in the classroom. Furthermore, as children progress through grades, more emphasis is placed on high-level language functions, such as writing and reading, while articulation is less prioritized. Our study suggests the need to maintain attention to articulation proficiency in curriculum design, particularly for higher grades, and to create more authentic opportunities for students to practice oral French.

Another notable finding of the current research is the distinct pattern of L1-L2 interaction for voiced versus voiceless stops. For voiceless stops, although L1-to-L2 influence is still prominent, FI students have separate systems for each language. This finding is important, because it is indicative of the effectiveness of early FI schooling in facilitating sound system separation. For voiced stops (except in the case of /g/), however, children transferred their L1 system to their L2, and the two languages are merged in the VOT dimension. We speculate that the merge is due to one of two reasons. Firstly, English voiced stops are sometimes phonetically realized as pre-voiced (Kong, Beckman, & Edwards, 2012; also see Figure 2). Thus, it is possible that FI students may not recognize French voiced stops as a new category but, instead, equate them with their English voiced stops. Secondly, voiced stops are more inherently difficult to articulate than voiceless stops (Allen, 1985), as they require vocal fold vibration prior to stop burst, involving 'extra articulatory effort' (Westbury & Keating, 1986). Even for children whose native language has voiced stops, it is rare for them to fully master the skill of voicing before age 3 or maintain it in an English-dominant environment (Kong et al., 2012; Simon, 2010).

Children are also found to acquire voiced stops that involve different places of articulation at varying pace, but generally follow the sequence of /b/ being acquired earlier than /d/, and /d/ earlier than /g/ (Smit, Hand, Frieilinger, Bernthal, & Bird, 1990). In other words, /g/ is typically the last sound to be acquired for both monolingual English-speaking and French-speaking children. As aforementioned, our findings indicate that FI students demonstrate difficulty in acquiring French voiced stops, particularly in regard to the voiced stop /g/. Surprisingly, the FI students' mean

French realization of /g/ exhibited an even longer duration of VOT than the mean English realization of /g/. It has been noted that the /g/ sound has been associated with aspiration during French speech production in French-English bilingual children (Watson, 1990). When this is the case, the /g/ takes on more similar acoustic properties to /k/. As a result, when French /g/ is produced with aspiration and English /g/ is only slightly aspirated or not at all, then this facilitates phonetic spacing to emerge between the two language sound systems.

Finally, comparing FI students' English productions with monolingual English-speaking peers, FI students showed significant lengthening of their VOT values, beyond the corresponding monolingual range. The additional aspiration that FI students exhibited in the realization of the English voiceless stops when compared to the monolingual English control group may have assisted FI students to maintain a distinction between their L1 and L2. The overshooting of English VOT was also observed in a study conducted by Mack (1990) investigating the stops produced by an English-French bilingual child and in Flege and Eefting (1987) for Dutch-English bilinguals.

It is to be acknowledged that the current study has some inevitable limitations that need to be addressed in future research. Firstly, we were unable to obtain the actual input that FI students receive from their teachers. Our understanding of FI students' speech development will benefit from a more systematic evaluation of both the quality and quantity of different sources of input surrounding this group of children. Secondly, we relied on published data of native French-speaking children in Eastern Canada for a comparison. We are seeking opportunities to collaborate with colleagues in Eastern Canada to verify the reported pattern.

In sum, given the fact that age of learning has been ascribed as one of the leading factors facilitating authentic L2 acquisition, one might have expected that FI students would ultimately attain native-like speech production. However, the factors that influence the ease and proficiency at which an L2 is acquired do not operate in isolation. The dynamic interplay between age of learning, the nature of the L2 input, the opportunity for L2 output, length of exposure, daily uses of the L1 and L2, the status of the L1 and L2 in the society, all work together to influence L2 acquisition, as demonstrated in an immersion program such as that investigated in this study.

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