Bilingual Phonological Development in French Immersion Students

by

Aunya Weich

A thesis submitted in partial fulfillment of the requirements for the degree of

Master of Science

in

Rehabilitation Science

Faculty of Rehabilitation Medicine
University of Alberta

Abstract

The current research of French Immersion suggests that the education of a minority second language is complex, important to study and yet to be understood in the context of Western Canada (Walker, 2012). This thesis aims to better understand bilingual speech productions in French Immersion students in Alberta, by identifying children's emerging and accurately produced consonants. This thesis will focus on the following research questions: What is the overall percentage of consonants correct across grade levels and what are the patterns of accuracy for each consonant in initial and final position? What characteristics influence accuracy? This will be followed by an additional acoustic analysis of stop consonants that aims to highlight the variability identified in final position.

A total of 37 students participated in the study from grades 1, 3 and 5. These students are fluent bilinguals and the conditions in the community require the use of English in the majority of contexts outside of school and family circles. They completed French picture naming tasks that contained targeted consonants and probed spontaneous speech productions. Their speech productions were transcribed and analyzed acoustically. From the transcriptions, the student's accuracy of consonant production and error patterns were obtained. A descriptive analysis was used to highlight consonant accuracy in grade and word position. Finally, a mixed effects logistic regression model was used to measure the effect of word position, grade and unshared/shared consonants. From the acoustic transcriptions, the characteristics of their final consonants were measured, and a linear mixed effects model was used to analyze the acoustic measurements of stop consonants in word final position paired with a descriptive analysis of acoustic values.

The results reveal students in grade 1 were able to produce 90.3% accuracy, students in grade 3 produced 91.0% accuracy and students in grade 5 produced 95.8% accuracy across all consonants. Despite relatively high consonant accuracy, these results reveal accuracy that is lower than existing consonant accuracy in francophone children. Challenges emerged with the nasal palatal /ɲ/, the fricative alveolar /z/ and fricative alveolar /s/, specifically in final position. In addition, de-voicing was a common challenge with the bilabial stop /d/, velar stop /g/. These findings highlight specific developmental data of French Immersion students. In addition, the acoustic analysis documents an undefined grade progression in either duration measures.

This study focused on the phonological emergence of French Immersion students learning French in a minority sociolinguistic environment through two spontaneous speech tasks, PCC and acoustic analysis of stop consonants. The results of this study establish reference data for French Immersion students. The descriptions of children's emerging consonants provides insight on their phonetic and phonological systems and can be used to inform researchers, educators and policy makers in French Immersion education programs.

Preface

This thesis is an original work by Aunya Weich. This research project received ethics approval from the University of Lethbridge and University of Alberta Research Ethics Board for the project “SPEECH PRODUCTION IN CHILDREN ENROLLED IN SECOND LANGUAGE EDUCATION PROGRAMS”. A condensed version of the first manuscript was submitted to the *International Journal of Bilingualism* following the thesis defense. The second manuscript will be submitted as a research note to the *International Speech Language Journal.*

This research is part of a larger research collaboration studying Bilingual Language Development in Minority Contexts funded by the Social Science and Humanities Research Council.

Acknowledgments

I would like to express my appreciation to all the participants, parents and staff of Lethbridge district 51(École Agnes Davidson), the SSHRC funding agency and my supervisors Dr. Andrea MacLeod, Dr. Fangfang Li and supervisor committee who contributed and supported the present research project. In addition, I would like to thank the research assistants Aurora Gray, Taryn Glimpel and Graeme Donington who contributed to data collection and Scott Tobin who contributed to speech transcription. Finally, I would like to thank the Multilingual lab members, friends and family for their continuous support.

Table of Contents

List of Tables

List of Figures

Glossary of Terms

1. **French Immersion**: A bilingual French-English education program.
2. **Bilingual:** individuals speaking or learning two languages.
3. **L1:** First Language.
4. **L2:** Second Language.
5. **Phonology:** study of the sound patterns, production and description of speech sounds.
6. **Language Acquisition**: is the process by which humans acquire the capacity to perceive and comprehend language
7. **Simultaneous bilinguals:** individuals who are exposed to more than one language prior to age three. They develop two or more languages equally, or nearly equally, through exposure and frequent opportunities to use each language.
8. **Sequential bilinguals:** occurs when a person becomes bilingual by first learning one language and then another.
9. **Retention/Attrition:** student withdrawal from French language programs.
10. **At risk Students**: a label that encompasses a wide variety of learners including individuals with special needs, learning disabilities and those from low socio-economic background

General Introduction

French Immersion schools provide second language programming for students pursuing bilingualism in Canada's two official languages, English and French (Davis et al., 2021). The immersive pedagogy focuses on language immersion and the development of French as an additional language. There is limited literature exploring language acquisition of bilingual children who speak French outside of Quebec. This research gap highlights the need for more comprehensive research that documents regional variation, minority language acquisition and the impact of English on French Immersion students' language acquisition (Walker, 2012). Filling this research gap will allow parents, educators, clinicians, and curriculum designers to be better informed of how bilingual experiences affect the children's language skills. While the lexical, syntactic, and sociolinguistic development of immersion learners is documented, the phonological abilities of immersion students continue to be largely under-researched (Genesee, 1989; Netelenbos et al., 2015; Menke, 2010). Furthermore, even less research has examined phonological acquisition where the second language (L2) is a minority language (Netelenbos et al., 2015). The current research of French Immersion suggests that the education of a minority L2 is complex, important to study and yet to be understood in the context of Western Canada.

In this study, I aimed to fill these research gaps by examining the phonological development of students enrolled in a French Immersion in Alberta. The data collection of this project began in January 2020 in Lethbridge, Alberta and prior to the commencement of my master's program. I collected data alongside five undergraduate research assistants for 3 months until the COVID-19 pandemic began, and schools were closed at the end of March 2020. The question of how we can help to improve French Immersion speech when there is little documentation or research examining how French Immersion students acquire speech reappeared

through research an served as motivation to begin the investigation on phonology. This thesis is comprised of two related studies: the first focuses on the accuracy of consonants produced by children in French Immersion (Chapter 1), and the second focuses on the acoustic characteristics of word final consonants produced by these children (Chapter 2).

Chapter 1

French Immersion Consonant Accuracy

Introduction

French language acquisition and language immersion are the main goals of the immersive pedagogy of French Immersion (FI). There is little research on bilinguals' acquisition of French-speaking children outside of Quebec. This knowledge gap emphasises the need for more thorough studies that examine geographical variance, minority language acquisition, and the effects of English on the language acquisition of French Immersion speech (Walker, 2012). While immersion learners' lexical, syntactic, and sociolinguistic development has been studied, their phonological skills have not. A phonological study highlighting emerging patterns of French Immersion students will allow curriculum designers, clinicians, parents, and educators to understand how multilingual and bilingual experiences affect children's linguistic abilities.

The following sections will review the French Immersion program, models of L2 speech learning and existing consonant acquisition studies. This review of literature will be followed by research questions, methods, results, and a discussion.

French Immersion

The French Immersion (FI) program was originally initiated by the St. Lambert experiment where English-speaking parents developed a French language education system for their English-speaking children (Carey, 1984). Its primary mission was to address growing concerns about language barriers between French and English-speaking Canadians, particularly in Quebec. The program was developed through collaboration between educators, researchers, and parents to better equip Anglophone children to integrate themselves within the French community. French Immersion was later transformed to foster the development of bilingualism

by providing an adapted educational framework that can enable the majority language community (e.g., Anglophones in Western Canada) to become proficient in French (Dicks & Genesee, 2013).

Early, middle and late immersion programs have been developed through collaboration of teachers, researchers and administrators (Genessee, 1987; Turnball et al., 2001). Early immersion begins in kindergarten or grade 1, middle immersion offers an entry point in grade 4 and late immersion provides an opportunity for students to enter or re-enter French Immersion in Grade 7 (Cammarata et al., 2022). Although middle immersion programs offerings are no longer a popular option in Canada, late immersion programs are accessible in larger centers across Canada and provide an opportunity for those students who are motivated to benefit from French immersion education even if they have not started in early grades (Cammarata et al., 2022). The current study focuses on early immersion. Early FI programs are the most popular and the most effective program (e.g., Genesee, 1987; Lindholm Leary, 2001; Turnbull et al., 2001). Students in the program learn the majority of their subjects in French with an emphasis on fundamental literacy skills (Mady & Arnett, 2013). The integration of content and language is a core component of the curriculum in immersion programs, meaning that language is used to teach the subject content that makes up the local district's curriculum (Cammarata & Tedick, 2012).

The notable benefits of French Immersion include a greater functional L2 proficiency for students in immersion programs when compared to those learning the L2 in a more traditional educational context (Genesee, 1994; Lyster, 2007), students' L2 development is at no cost to their L1 (e.g., Lazaruk, 2007), students' academic achievement is similar to or greater than the achievement of their English counterparts (Bournot-Trites & Reeder, 2001; Genesee, 1987; Turnbull, Lapkin, & Hart, 2001). In addition, at risk students can succeed as well in these

programs as in monolingual English programs (e.g., Genesee, 2004; Genesee & Tedick, 2020). These benefits commonly associated with immersion/bilingual education lend clear support to the French Immersion educational alternative and can explain the appeal and continuous growth of FI schooling across Canada and into Anglo-dominant provinces of Western Canada. In Alberta specifically, the total student population has steadily increased over the last 20 years, from a total of 25,830 students in 1998 to 44, 982 students in 2019 (Cammarata et al., 2022; Roy & Galieva, 2011).

French Immersion Retention

Despite the increased enrollment and notable researched benefits of French Immersion programs, the program experiences significant attrition rates (Cammarata et al., 2022). The student population in French Immersion programs, originally designed to meet the needs of Anglo-dominant communities who wanted their children to be bilingual by the end of their schooling (Grade 12), have changed significantly in recent years to include a more diverse student body. French Immersion classrooms continue to transform from a mainly anglophone, typically developing student population to a multilingual, multicultural and diverse learning needs classrooms (Cammarata et al., 2018 & Roy, 2008). Its suitability and accessibility to all students have been a topic of debate since its inception and continues to pose challenges within the program (Willms, 2008). This major demographic transformation of the educational environment imposes new challenges as current curriculum, academic support and teacher training cannot adequately support the diversity of students (Cammarata et al., 2022). As a result, the program experiences significant retention issues where less than 50% of students who start in early immersion graduate from the program (Cammarata & Tedick, 2012). The main reasons for student withdrawal from French Immersion programs include a lack of course options, a lack of

opportunity to speak French outside of the classroom, difficulty with the program including a heavy workload, lack of adequate language skills to do well in the program teacher dissatisfaction and a lack of motivation (Beck 2004; Boudreaux & Olivier 2009; Cammarata et al., 2022; Leclerc, 2014;). In addition, parents often have concerns about university and beliefs that their children will be better prepared for post-secondary studies or achieve higher marks in an English program (Jansen & Beckmann, 2016).

Among these challenges, literacy and oral language difficulties have become the most prevalent issues that arise within French Immersion students and can be a significant factor that contributes to parents or students' decision to leave the program (Bournot-Trites, 2008; Cammarata et al., 2022). Additional research indicates that French and English word reading difficulties of Grade 1 French Immersion students persist into grades 2 and 3, pointing to the importance of early identification and intervention (Shakory et al., 2022). Reading and oral language difficulties are one of the most important factors influencing parents to withdraw their children from French Immersion and these withdrawals are typically made prior to the end of grade 3 (Shakory et al., 2022). Additional student withdrawal transition periods were identified where students leave the program at a higher rate at the end of grade 3, 6 and 9 (Cammarata et al., 2022). Of the students that graduate, French Immersion students are often noted to have the comprehension and reading skills of native speakers but are often accented in their speech and struggle to integrate themselves into French communities (Mady & Arnett, 2009). A number of interventions have been proposed to address this issue including oral literacy interventions and documenting how children learn French (Cavanagh 2007; Cavanagh & Blain, 2009). The lack of research and reference data examining how French Immersion students acquire the French language and how phonology emerges among students continues to contribute to the increasing

student withdrawal rates. Teachers, researchers, and curriculum designers understanding of how children acquire French in minority contexts is limited.

L2 Speech Acquisition Theoretical Models

Several theoretical speech models have explored second language acquisition. The Critical Period Hypothesis suggests that bilinguals after the age of 5 are developmentally less malleable and predicts decreased L2 proficiency after a certain age (Vanhove, 2013). This conclusion fails to provide insight into how L2 learning differs from L1 acquisition (Flege, 1995; Flege & Bohn, 2021). Studies further explore this discussion by differentiating L2 acquisition from L1. Several researchers, theories and models have described bilingual acquisition such as the Revised Speech Learning Model (SLM-r; Flege, 1995; Flege & Bohn, 2021)**,** Perceptual Assimilation Model (PAM; Best, McRoberts & Godell, 2001), Native Language Magnet Model (NLM; Kuhl, Tsuzaki, Tohkura & Meltzoff, 1994) and the Second Language Learning Model (L2PL; Van Leussen & Escudero, 2015).

Flege's revised speech learning model (SLM-r) proposed the continuation of speech sound acquisition beyond the critical period. The model suggests that the mechanisms for language learning are present throughout the lifespan which allows individuals to acquire an additional language at any age (Lefebvre, 2021; Flege, 1995). Flege's revised speech learning model (SLM-r) has suggested that some bilingual may develop a cross-linguistic merged category where the speakers produce the same phoneme in both their first and second language as L1 and L2 sounds exist in a "common phonological space" (Flege, 1995). This model further explains that the ability to perceive and classify L1 and L2 sounds into appropriate phonemic categories depends on the acquisition of a second language (Lefebvre, 2021). The SLM continues to adapt and describe the accuracy of shared and unshared phonemes. Higher accuracy

of shared sounds may be related to the frequency of word use, language exposure and other factors/characteristics. A final claim of SLM suggests that language learners may struggle with learning new phonemes that do not exist in their L1 but are similar across the two languages (i.e., ease of new category formation: identical >new > similar).

A similar proposal has been made recently in Second Language Phonetic Learning (L2PL) (Van Leussen & Escudero, 2015) proposes that when L2 learners are faced with a new phoneme, the learner must create a new category, but that this will be more challenging when phonemes that are dissimilar or new (identical> similar> new). This model focuses on the contrasts between the L1 and L2 rather than the phonemes themselves (Macleod & Meziane, 2020).

The Perceptual Assimilation Model of L2 speech describes how L1 influences L2 speech, the perception and production of L2 phonemes. The Perceptual Assimilation Model (PAM) starts with the observation that certain pairs or sounds from unknown language are easier to discriminate than other pairs (new>similar). The listener's perceptual assimilation of new phonemes depends on a number of factors: the phonetic contrasts that exist in the speaker's first language, the extent of similarity in the articulation of the new phonemes and the native phonemes, the native phonetic categories perceived by listeners (Best, 1994; Meziane & MacLeod, 2020). PAM proposes the assimilation of new phonemes to a native language. This model proposes the amount of language experience affects the ability to discriminate between acoustic features. Children acquiring their second language in school may struggle with learning phonemes that are similar across two languages, particularly those with the same articulatory organ (Meziane & MacLeod, 2020). As bilingual children begin learning the phonological systems of their two languages, it is hypothesized that they develop two distinct systems but that

these systems interact (Meziane & Macleod, 2020). Paradis and Genesee (1996) proposed that bilingual children acquire two language systems by declaration, acceleration and transfer. Bilingual children can show patterns of phonological development that are ahead of their monolingual peers (acceleration) or patterns of delayed phonological development (deceleration) (Lefebvre, 2021).

Building on speech perception research the Native Language Magnet (NLM) suggests that a critical phase is when languages are organized and acquired (Kuhl, Tsuzaki, Tohkura & Meltzoff, 1994). The NLM model states that early exposure to language enables children to develop sophisticated filters through which language is interpreted and classified. Bilingual children are able to identify sounds in both languages thanks to the magnetic effect and improved perceptual skills. In comparison to L2 adult learners, language learned in early childhood has highly accurate L2 consonant productions due to lower levels of interference (Lefebvre, 2021).

Finally, the broad Linguistic Interdependence Hypothesis proposed by Cummins (1978) suggests that both languages share concepts, abilities, and linguistic knowledge. As a result, L1 skills can be applied to L2 learning. This cross-linguistic influence or transfer often occurs in an educational context when the L1 is established prior to the L2 (Vrooman, 2000). Studies have suggested that even if a child has reduced language experience in one language, bootstrapping from the phonology of the other language may compensate for the reduced language experience (Kehoe et al., 2021). The phonological abilities in one language are often present in the other, according to Kehoe et al.'s (2021) study on the effects of language exposure on performance (2021). They also discovered that vocabulary and grammar, both within and between languages, had an impact on phonology. However, compared to other language domains, phonology may be less vulnerable to the impact of language experience.

In summary, the development of speech and phonology continues to be researched and theorized. Despite the divergence among these theories, they highlight the complexity of phonological emergence and accuracy of bilingual children. While no model can adequately describe or represent bilingual phonological acquisition, these models suggest key elements to consider in phonological learning that include the extent to which a phoneme is new, similar or identical across the two languages in both acoustic and articulatory characteristics.

Consonant Acquisition

Children's acquisition of speech involves mastery of the perception and production of consonants, vowels, tones, prosodic features and phonological rules of the languages they speak, with the outcome of intelligible speech (McLeod & Crowe, 2018). As described in the speech models, bilingual phonology systems and phonological accuracy can be influenced by language exposure, phoneme environment, phoneme position and shared and unshared phonemes (Lefebvre, 2021). Most children build on this knowledge when learning to read and begin to develop phonological awareness and the ability to distinguish between spoken sounds. This is also known as decoding. Thus, phonological development is important for oral language development, communicating effectively and for early literacy (Melby-Lervåg & Lervåg, 2011).

Consonant acquisition is one of the most widely used metrics of typical phonological acquisition (McLeod, 2008). Previous research has focused on consonant production because consonants are more reliably transcribed, in comparison to vowels. In addition, consonants are often correlated with intelligibility, validity and contribute to being understood. Studies examining consonant acquisition provide a rich description of how consonants are acquired and contribute key information regarding developmental trends for individual consonants as well as establishing language specific patterns (MacLeod et al., 2011). The Percentage of Consonants

Correct (PCC) has been used as a phonological evaluation tool to represent the percentage of consonants correct on an articulation test or other non-conversational tasks. It has also been used to document speech acquisition and error patterns of typically developing children (e.g. McLeod & Crowe, 2018). Error patterns, also known as phonological processes, are frequently used to describe a child's phonological system, and widely adopted in the field of child phonology (Preston et al., 2013). Since PCC's initial development, various approaches have been used by investigators researching child phonology (Shriberg, 1997).

French and English Consonants

French and English have relatively large consonant inventories, in comparison to other languages and share a number of them. French is typically said to have a phonetic inventory of 20 consonant sounds as displayed in Table 2, while English has 24 consonants. Some French consonants share the same place of articulation as English consonants and others differ. Place of articulation has been previously established as relevant to children's consonant development (Kehoe, 2021). The shared and unshared consonant inventory increases the complexity of consonant acquisition for bilingual children who have already acquired their first language as described in the speech learning models above (i.e., ease of new category formation: identical >new > similar SLM-r, identical> similar> new L2PL) (Flege & Bohn, 2021;Van Leussen & Escudero, 2015). In addition, given that the consonant articulation of French often results in non-native accent but does not impede understanding it may occur that a learner will not acquire different articulatory settings (Hannahs, 2007).

Table 1. French and English Consonants

			Bilabial	Labio-Dental	Dental	Alveolar	Post-Alveolar	Palatal	Velar	Uvular	Glottal
Place of Articulation											
Manner of Articulation	Stops	French	p b			t d			k g		
		English	p b			t d			k g		
	Nasal	French	m			n		ɲ			
		English	m			n			ŋ		
	Fricative	French		f v		s z l	ʃ ʒ			ʁ	
		English		f v	θ ð	s z l	ʃ ʒ				
	Affricate	French									
		English					tʃ dʒ				
	Approximant	French	w ɥ*					j ɥ*	w		
		English	w			ɹ		j	w		
	Lateral Approximant	French				l					
		English				l					

*some consonants have double place of articulation

French Consonant Studies

A number of studies have documented French consonants in adult speakers. Fewer studies in the existing literature have focused on the consonant acquisition of children. Majority of these studies focused on francophone children learning French as a first language or children learning French in a majority context. Of these studies, a small number of studies have reported on the phonological system of French-speaking children of pre-school and early school-age. MacLeod et al. (2011), investigated consonant accuracy in children 2 to 4 years old. This study established that emerging consonants were those that 75% of children could produce and mastered consonants were those that 90% of children produce correctly. This study found three patterns of consonant acquisition: consonants mastered by children at 3 years old were /t, m, n, z/, consonants mastered between 3 and 4 years old were /p, b, d, k, g, ŋ, f, v, l, w, ɥ/ and the consonants /s, ʒ, ʃ, j)/ were not mastered within the age range of the study. In addition, results revealed consonants emerge at an earlier age in initial position then final position (Macleod et al., 2011).

Rvachew et al. (2013), developed a picture naming task to investigate consonant accuracy of kindergarten and first grade students (Teste de Dépistage Francophonede Phonologie, TDFP). The probe words were intended to approximate the average words spoken in French, while targeting a full range of consonants in varied syllable positions and provide a representative sample of speech performance. This study examined emerging speech sounds of Kindergarten and Grade 1 Francophone students and found the Percent Consonants Correct was approximately 90% and did not change significantly with age or grade (2013). Rvachew et al. (2013), found the accuracy for the consonants /m, n, ɲ, p, t, d, k, f, v, r ɥ j ʁ/ were above 90% and the consonants /b, g, s, z, ʃ, ʒ, l, w/ fell below 90%.

MacLeod et al. (2014), developed a picture naming task to evaluate consonant accuracy and evaluated francophone children 2-5 years old (Évaluation sommaire de la phonologie chez les enfants d'âge préscolaire, ESPP). A similar approach was used when developing this task where all consonants were targeted. From this study they found the PCC was 97.7% in initial position and 88.8% in final position. However, the consonants /d, ɲ, v, s, z, ʒ, ʁ/ fell below the 90% accuracy and were not mastered within the age range of the study.

MacLeod and McCauley (2005) investigated speech sound production, through spontaneous speech tasks. They aimed to provide basic information about the phonological abilities of children with specific language impairment and four typically developing Québécois French speaking children ages 2-10. All consonants except the fricative /z/ were produced three or more times by the typically developing children, in initial, medial or final word positions.

Meziane & Macleod (2020) focused on shared and unshared consonants in French, English and Tagalog. They found that these children produced high accuracy with the shared consonants /p, b, t, d, k, g, m, n, s, l, w, j/ except for voiceless stops in word final position such as /p, t, k/. For unshared consonants that were similar they found a number of word medial and final errors. For new unshared consonants they found high and low variability across nasal palatals, fricatives and labio palatals (Meziane & Macleod, 2020).

Finally, one study examined the acquisition of French as a second language of students in Quebec, where French is the majority language (Meziane & Macleod, 2017). This study examined 49 multilingual kindergarten students and found consonant accuracy was 95% accuracy overall, 97% accuracy in initial position, and 88% accuracy in final position. They identified challenges with /s/ in initial position, consonants /ɲ/ and /ʁ / in medial position and /d, ɲ, v, z, ʒ, ʁ/ in final position. Overall, the consonants /ɲ, v, ʒ/ were not acquired. They

highlighted a variety of production patterns, such as substitution /valiz/ /valis/, omission, /tomat/ /toma/ epenthesis /kanaʁ/ /kaʁnaʁ/ and metathesis /zebʁ/ /zeʁb/. Substitution was the most common production pattern for the kindergarten students. This study highlights the importance of establishing bilingual norms specific to bilingual or multilingual children and documenting differences in their language acquisition in comparison to their monolingual and francophone peers.

In general, these studies highlight consonants with more complex manners of articulation such as fricatives, liquids and velars tend to be acquired later than those with less complex manner such as stops and nasals. Although consonant acquisition is extensively documented in English, these findings highlight the important role of language specific developmental data in understanding the course of consonant acquisition (MacLeod et al., 2011). In sum, this review of literature indicates that francophone and children learning French in a majority context acquire consonants relatively easily and at a young age (Kehoe, 2021).

Current Study

The goal of this study is to better understand bilingual speech productions in French Immersion students residing in Alberta. The conditions in the community require the use of English in the majority of contexts outside of school and family circles. The language demographics of Alberta continue to evolve but English is the most dominant language spoken by the majority of residents while French is spoken by only 6.7% of Alberta residents (Statistics Canada, 2016). However, the French-English bilingual population has seen a 19% increase in 10 years (Statistics Canada, 2016). This study aims to identify and describe children's emerging and accurately produced consonants and establish norms among bilingual children learning French in this minority context that is prevalent in Alberta.

Research Questions

Question 1:

What is the overall percentage of consonants correct across grade levels and what are the patterns of accuracy for each consonant in initial and final position?

Hypothesis 1: Based on the complexity of bilingual phonological acquisition we hypothesize high variability across grades and word positions and lower consonant accuracy based on the level of authentic input, language experience, and community context. In addition, we hypothesize lower accuracy in word-final position.

Question 2:

What characteristics influence accuracy?

Hypothesis 2:

We hypothesize greater accuracy in grade 5 students than in grade 1 and 3 based on children's prior knowledge of English and Flege's revised SLM model we hypothesize unshared consonants will have a lower PCC. In addition, we hypothesize that word position may pose some challenges in final position.

Methods

This study is part of a larger project examining minority language schools and bilingual language development of students across Alberta. The students in this study completed two articulation/picture naming tasks, one word repetition task, one sentence repetition task and one story-retelling task in French and a number of additional tasks and interviews in English.

Participants

Thirty-seven eligible students were sampled in a French Immersion school in Lethbridge, Alberta in order to observe speech progression and development within elementary schools. Children from grades 1-5 participated in this study: 9 students in grade 1, 13 in students grade 3 and 15 students in grade 5. Lethbridge, Alberta has a small French community and can provide insight of French learning in other French minority language environments across the country. Student eligibility was based on a speech-language background questionnaire filled out by parents. The questionnaire provided information on French input, their sociolinguistic environment, and daily uses of English and French outside of the school setting. From the questionnaire we gathered that all students spoke English as their first language, French as their second and three students spoke Spanish as an additional language at home. Within the group, 35 students attended French Immersion Kindergarten and 2 students attended English Kindergarten. A subset of children (30%) had at least one parent who spoke French. The results of the questionnaire indicated no severe hearing impairments or significant speech delays. One student indicated mild speech delay and three others reported receiving speech therapy at a younger age. A small number of questionnaires remained incomplete due to Covid-19 restraints but were found to not affect the course of the study. All participants and legal guardians provided written consent.

Five French speaking examiners conducted the screening tools and audio recordings. All five examiners learned French through French Immersion programming in Alberta. Participant data was transcribed by two French speakers trained in transcription. The French transcribers were both French Immersion graduates, one from Alberta and the other from Newfoundland.

Each transcription was transcribed and verified by both examiners, so we were able to provide interrater-reliability and validity for the entire transcribed data set.

Stimuli

This study focused on the two picture naming/articulation tasks: Test de dépistage francophone de la phonologie (TDFP) (Rvachew et al., 2013) and Évaluation sommaire de la phonologie chez les enfants d'âge préscolaire (ESPP) (MacLeod et al., 2014). The TDFP was created for francophone children between the ages of 3 and 7 years. The TDFP was guided by a non-linear framework and created to account for interaction between word structure and segmental acquisition. The ESPP, however, is guided by a linear phonological framework and primarily focuses on segmental acquisition, determining ages when specific consonants are acquired (Bérubé & Macleod, 2021). The screening tools are composed of numerous, varied and similar single consonants in word initial, medial and final positions. In addition, each task targeted all French consonants and probed spontaneous speech productions. This elicitation method aimed to target various speech production scenarios and phonemes. The ESPP tasks contained 40 words and the TDFP contained 30.

Procedure

Data was collected between January and April 2020. Each session took place in a quiet room and was recorded using a digital tape recorder and a head mounted microphone. These recordings were downloaded onto a computer and converted to digital wave files.

A standard procedure was used for both tools. For the ESPP, to elicit the word *block* (block) the experimenter showed an image of a block and asked an initial question *On peut jouer avec des….?* (We can play with….) In the case that the student was unable to produce the target word a delayed imitation was prompted by the experimenter saying, *Les blocs sont des couleurs*

différentes. Ce sont des…? (The blocks are different colors. They are….) If the student was unable to produce the word spontaneously after the speech prompts, the child would repeat the word after the experimenter (Macleod et al., 2014). This was noted as a repeated production. The TDFP followed a similar procedure probing 30 different target words. To elicit the word château (castle) the experimenter showed an image of a dragon in a castle and stated *Le dragon est dans le... ?* (The dragon is in the…?). In the case that the student was unable to respond, the experimenter provided two more additional hints before asking the student to repeat the word directly.

At the final stage of data collection, in March 2020, COVID-19 shut down all public schools and we were unable to fully complete our intended data collection goal of 60 students completing both tasks (20 from each grade). We were unable to continue data collection in the following school year because of continuing COVID-19 restrictions and students progressing to higher grade levels. However, significant data was collected, 3177 speech productions were included in the analysis and of the 37 students interviewed, 32 students completed the ESPP tasks, and 30 students completed the TDFP.

Analysis

Once data was collected and recorded, two phonetically trained French speakers transcribed children's speech production using Phon (Version 3.3: Hedlund, Gregory & Yvan Rose, 2020), a software developed for PhonBank/CHILDES database. Each word produced by children was phonetically transcribed to compare against the prescriptive transcription created by the authors of the two tasks. Transcribers judged the accuracy of sounds and used inter-rater reliability to verify each transcription. The inter-rater reliability was 92% and the remaining discrepancies were discussed and consulted by a third-party transcriber until it reached a

consensus. After each speech production was transcribed, Percent Consonants Correct (PCC) was used to calculate the accuracy of initial and final consonants using Phon expressions (Hedlund, Gregory & Yvan Rose, 2019).

These expressions highlighted errors in initial and final position of both tasks. The Percentage of Consonants Correct (PCC) expressed the percentage of intended consonant sounds in each speech sample that were articulated correctly. The total number of correct consonants in the speech tasks were divided by the total number of opportunities of consonant production and multiplied by 100. This metric measure allowed for an overview of production accuracy and reflects how accurately the child produced the consonant phonemes across two separate screening tools. Additionally, we included an unshared/shared consonant descriptive analysis to describe the effect of English and bilingualism.

Statistical Analysis

A descriptive analysis was done using Phon to evaluate each consonant per grade in initial and final position. Accuracy was scored as 0 or 1 for each consonant production. The mean accuracy was calculated for each consonant and the overall mean accuracy and standard deviation was calculated. To further examine the PCC accuracy and to examine if there was a significant effect of word position and grade a statistical analysis was run in R Studio (R version 4.1.2). Accuracy was modeled with a mixed effects logistic regression model using the *lme4* R package (R Core Team, 2013).

$$\text{Accuracy} \sim \text{Grade} * \text{Word Position} * \text{Consonant} + \text{Child ID} + \text{Test}$$

Fixed effects included Word Position, Consonant, and all possible interactions. Random effects included Child ID and Test.

Results

A descriptive analysis was conducted to describe consonants in initial and final positions across all three grade levels. Children produced an overall accuracy of 90.6% across all grades and consonants. The consonants /p, t, k, m, n, l, f, ʃ, ʒ, w/ had 90% accuracy across all grade levels and word positions. Despite relatively high consonant accuracy, these results reveal developmental data that differs from existing francophone consonant acquisition trends. The consonants /b, d, g, n, ɲ, v, s, z, ʁ, ɥ, j/fell below the 90% across positions and grade levels. All consonants were emerging (above 75% accuracy) by grade 5, except /ɥ/ and /s/. The consonant /ɲ/ shows significant accuracy growth from 57% accuracy in grade 3 to 90% accuracy in grade 5. As presented in Table 2, Children in grade 1 demonstrated the most difficulty, followed by grade 3 and grade 5. Despite lower accuracy in grade 1, most consonants in initial position were emerged by grade 5 except for the approximant palatal /ɥ/, the nasal palatal /ɲ/ and the fricative /s/. The consonant /ɥ/ posed the most difficulties to grade 5 students. Additional challenges emerged with the bilabial stop /d/, velar stop /g/ the fricative alveolar /z/ and fricative alveolar /s/, specifically in final position. Children produced lower accuracy in final position across all consonants and grades with an overall mean value of 89.6 % accuracy in comparison to word initial position 96.7% accuracy. Despite lower accuracy in final position in grade 1 and 3, consonants /d/, /g/ and /s/ were produced with higher accuracy in grade 5.

Table 2. Mean Accuracy by Word position and Grade

Consonant	**Grade 1**		**Grade 3**		**Grade 5**		**Mean**	**Std.**
	Initial	**Final**	**Initial**	**Final**	**Initial**	**Final**		
/p/	1	1	1	1	1	1	1.00	0.0163
/b/	0.875	0.807	0.99	0.862	0.987	1	0.929	0.227

/t/	0.933	0.9722	0.966	1	1	0.976	0.974	0.133
/d/	0.900	0.736	1	0.79	1	1	0.904	0.116
/k/	0.933	1	0.982	1	1	1	0.986	0.028
/g/	0.947	0.466	1	0.65	0.987	0.958	0.835	0.102
/m/	1	1	1	0.882	0.973	1	0.972	0.053
/n/	0.84	0.769	1	1	0.962	0.96	0.923	0.098
/l/	0.9375	0.9	0.965	1	1	1	0.961	0.041
/ɲ/		0.500		0.570		0.900	0.657	0.166
/f/	0.947	1.00	1	1	1	1	0.991	0.021
/v/	0.923	0.875	1	0.866	1	1	0.944	0.064
/s/	0.913	0.833	1	0.758	1	0.6538	0.859	0.1027
/z/	0.777	0.666	0.933	0.795	1	0.818	0.831	0.132
/ʃ/	0.947	1	1	1	0.982	1	0.988	0.021
/ʒ/	0.956	0.952	0.983	1	1	1	0.982	0.022
/ʁ/	0.866	0.800	0.866	0.945	0.987	1	0.911	0.073
/ɥ/	0.75		0.766		0.22		0.577	0.329
/j/	1	0.66	0.8	1	1	0.956	0.903	0.1398
/w/	1		1		1		1	0.011

*Accuracy values were calculated on a scale from 0-1

Characteristics that influence consonant accuracy

A mixed effects logistic regression was used to analyze the relationship between accuracy, consonant, grade and word position. This statistical test was used to determine the numerical relationship between one variable and others. Significant effects were for identified for grade and word position. It was found that word position had a significant effect as students produced higher accuracy across all consonants in initial position. A grade effect was identified between students in grade 3 and 5 as students in grade 5 produced higher accuracy across almost all consonants.

Table 3. Model Output from the Mixed effects logistic regression model

		Estimate	**Std. Error**	**Z value**	**Pr(> |z|)**
Grade	Grade 3	1.1003	0.2128	5.170	2.34e-07***
	Grade 5	1.7716	0.2523	7.021	2.21e-12***
Word Position	Initial	1.2258	0.2055	5.964	2.46e-09***
	Final	1.3895	0.3034	4.580	4.66e-06***

Consonant	**Estimate**	**Std. Error**	**Z value**	**Pr (> |z|)**
d	-0.3344	0.4156	-0.805	0.42101
f	1.6517	1.0500	1.573	0.11570
g	-0.8614	0.3634	-2.364	0.01806*
j	0.1486	0.4850	0.306	0.75935
k	1.4869	0.6446	2.307	0.02107*
l	0.8433	0.5810	1.451	0.14078
m	0.7673	0.5328	1.440	0.14978
n	0.2820	0.4784	0.5810	1.451

ɲ	-0.5304	0.4524	-1.172	0.24102
p	14.9776	491.1596	0.030	0.97567
ʁ	0.1756	0.3930	0.447	0.65502
s	-0.7139	0.3573	-2.048	0.04054*
ʃ	2.0626	0.7627	2.704	0.0684**
t	1.2145	0.4960	2.449	0.01434*
ɥ	-3.7147	0.4674	-7.948	1.90e-15 ***
v	0.3459	0.5835	0.593	0.55326
w	8.8392	74.3951	0.119	0.90542
z	-1.0449	0.35854	-2.914	0.00356**
ʒ	1.7490	0.6457	2.709	0.0676**

*=p<.05; **=p<.01; ***=p <.001

Figure 1. Significant consonant z-values and standard error bars.

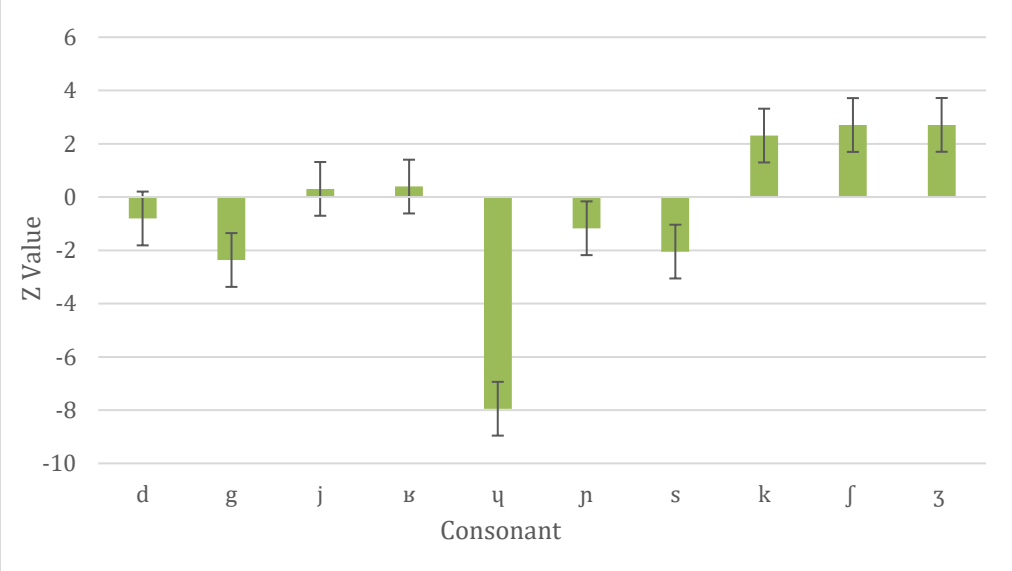

Figure 1 highlights the distribution of consonant values as well as the standard error bars compared against the mean accuracy value. The Z-score quantifies the discrepancy between the given value and the standard deviation. The Z-score, also known as the standard score, indicates how many standard deviations a specific data point deviates from the mean. These consonants were significant as indicated by the mixed effects logistic regression model. The differences in accuracy can be highlighted from consonants such as /ɥ/ with low accuracy and /k/ with high accuracy across grade and positions.

The accuracy of shared and unshared French and English consonants was analyzed as an additional descriptive variable. The following tables show the shared and unshared consonants targeted in the ESPP and TDFP tasks, followed by the overall mean and standard deviation of shared and unshared consonant accuracy.

Table 4. Shared and Unshared Sounds

Shared Sounds (French and English)	**Unshared Sounds (French)**
/p, b, t, d, k, g, m, n, f, v, s, z, ʃ, ʒ, j/	/ɲ, ɥ, ʁ/

Table 5. Mean and standard deviations of PCC for accuracy of shared and unshared sounds.

Shared	**Unshared**
0.941 (0.059)	0.712 (0.241)

As demonstrated in Table 5, shared consonants had a higher overall mean accuracy. Shared and Unshared consonants were further examined in initial and final position and the analysis showed that consonant accuracy of unshared consonants were the least accurate.

Table 6. The effect of position of shared and unshared consonants

	Shared		**Unshared**	
	Initial	Final	Initial	Final
Grade 1	0.931	0.852	0.808	0.726
Grade 3	0.977	0.912	0.870	0.809
Grade 5	0.993	0.966	0.733	0.909

Table 7. Consonant Production Opportunities

Consonant	**Attempts**
/p/	188
/b/	317
/t/	272
/d/	110
/k/	210
/g/	144
/m/	170
/n/	136
/ɲ/	62
/l/	136
/j/	102
/f/	102

Consonant	Attempts
/v/	102
/s/	203
/z/	134
/ʃ/	277
/ʒ/	240
/ʁ/	204
/ɥ/	34
/w/	34

Table 7 is the opportunities presented to children through the two spontaneous speech tasks. 1770 initial consonant opportunities were available in the TDFP and ESPP. The final consonant opportunities in the TDFP and the ESPP was 1407. The consonant opportunities showed no clear effect on consonant accuracy.

Discussion

The aim of this study was to establish French phonological acquisition data for French Immersion students. Students in grade 1, 3 and 5 learning French in a minority context completed two articulation tasks targeting consonants in initial and final position. The main measures evaluated in this study were as the overall percentage of consonants correct across grade levels, the patterns of accuracy in initial and final position and the characteristics that influence accuracy.

Consonant Specific Patterns

The results of the examination of FI consonant production demonstrate that accuracy varied by consonant, word position and grade. The tiered scoring enabled the researchers to yield conclusive information that highlights the differences of consonant production through their development of French as a second language. The consonants that emerged last and had lower accuracy across grades were /b, d, g, n, ɲ, v, s, z, ʁ, ɥ, j/. Overall errors decreased as the grades increased with all consonants except the consonants /ɥ/ and /s/.

Table 8. Types of Production Patterns

Consonant	**Target Word (s)**	**Error (s)**
/b/	garderobe /gaʁdʁob/	[gaʁdʁo]
/d/	glissade /glɪsad/ viande /vjɑ̃d/	[glɪsa][glɪsat] [vjɑ̃]
/g/	langue /lɑ̃g/ bague /bag/	[lɑ̃k] [lɑ̃] [la] [lag] [bak]
/s/	tournevis /tuʁnəvis/	[tunvi]
/z/	valise /valiz/ framboise /fʁɑ̃bwaz/	[vali] [valis] [fʁɑ̃bwas]
/ɥ/	huit /ɥit/	[wit]
/ɲ/	bain/bɛɲ/ arraignee /aʁɛɲe/	[bɛ] [aʁɛne]

Table 8 highlights a number of production patterns produced in certain words and positions. This table highlights the frequency of final consonant omission patterns as well as voicing errors particularly with the voiced consonants /g/ and /d/. The results of consonants /g/

and /d/ were surprising as students produced high initial position accuracy. Errors occurred in words where the final voiced consonant became voiceless /g/ to /k/. The /g/ sound has been noted to be connected to aspiration during French speech production in bilingual children who speak both French and English. In this situation, the /g/ acoustic characteristics are more similar to those of the /k/ (Netelenbos et al., 2016). Similar patterns emerged with the final voiced /d/ where voiced /d/ to /t/. Voicing errors were produced with several sounds which is a common phonological pattern in bilingual language. This can have an impact on comprehensibility.

Characteristics that influence accuracy/Factors that influence accuracy/acquisition

Unshared/shared consonants

The shared consonants /p, b, t, d, k, g, m, n, f, v, s, z, ʃ, ʒ, j/ posed minimal difficulty for the immersion students in this study. This can be explained by these consonants existing in similar contexts in English. As students in French Immersion enter in the program with an already developed L1, acquiring these shared consonants may be relatively easier for this population. French immersion students build on the transfers and commonalities that exist between English and French such as many similar phonemes and many identical or similar words. French may also be compared to other first languages to help students understand the commonalities or differences. These communication skills are transferable from one subject to another and from one language to the other, which reinforces the development of the first language as well as other languages of the students. As described in Flege's revised speech learning model (SLM-r) L1 and L2 sounds share a "same phonological space," and often produce the same phoneme in both their first and second languages. SLM-r makes one further assertion that shows language learners may have trouble, picking up new phonemes that are similar to those in their L1 but different from those in their L2 (identical >new >similar) (Flege, 1995).

The SLM-r can help understand the present data set where the unshared consonants /ɲ,ɥ,ʁ/ had significantly lower accuracy, specifically in final position in grade 1, 3 and 5. In final position, /ɲ/ errors occurred in the words such as /bɛɲ/ and /aʁɛɲe/ The most common error for this unshared consonant was consonant omission (e.g., /bɛ/). Similar but unshared phonemes also posed challenges for French Immersion students such as /ʁ/ and /ɥ/. The most notable error for /ʁ/ was its English equivalent /ɹ/. The English consonant /ɹ/ was produced in words such as /paʁaplɥi/, /akwaʁijɔm/ and /tʁɛ̃/. The negative aspect of cross-linguistic transfer is evident in the production of /ɹ/. In initial, position the most common /ɥ/ errors occurred in the word /ɥit/ where /wit/ was produced. Theses results can be related to the similar phonemes that exists in English. Anglophone second language learners the /ʁ/ is often difficult to produce but poses minimal comprehensibility challenges when the English equivalent is produced.

Number of Opportunities

Some characteristics of the consonants that had an impact on accuracy included the opportunities the student had to produce the consonant. Consonants such as /z/, /ɲ/ /ɥ/ had lower accuracy and lower opportunities. However, the opportunities presented in the ESPP speech task do not accurately reflect the occurrences of consonants in French speech, where the TDFP task is more frequency driven. In addition, students only had one opportunity to produce this consonant /ɥ/ which may explain its significantly lower accuracy.

Repeated/ spontaneous productions

When considering repeated or spontaneous productions, this study found that students produced higher accuracy on spontaneous productions. This result is different from previously identified studies looking at spontaneous or repeated productions. This result can be explained by the unfamiliarity of the repeated words and consonants and the structure of the tests itself. Words

such as *persil, langue, garderobe,* and *tournevis,* were the words most often coded as repeated and posed challenges when the tests were being administered. These words may be uncommon in the French Immersion classroom and the students were unable to produce these words spontaneously or repeated accurately.

Table 9. French Consonant Acquisition Studies

	Current Study Grade 1, 3 and 5 (FI) Alberta	**MacLeod et al. (2011) 36 months - 53 months Francophone Children**	**Rvachew et al. (2013) Kindergarten-Grade 1 Francophone Students**	**Meziane & MacLeod (2017) Kindergarten (FI) Québec**
Percent Consonants Correct	90.6%	95.3%	90.37%	95.1%
Consonants Mastered (above 90%)	/m, n, p, t, k, f, /v/ ʃ, ʒ/	/t, m, n, z/	/m, n, ɲ, p, t, d, k, f, v, j, ɥ, ʁ, ʃ/	/m, n, ɲ, p, t, k, f, v, j, ɥ, ʁ, ʃ/
Consonants Emerging (above 75%)	/g, d, z, ɥ, n, ɥ, j, ʁ/	/p, b, d, k, g, ν, f, v, l, w, ɥ/	/b, g, s, z, ʃ, ʒ, l, w/	/s, d, z, ʁ/
Consonants below 75%	/ɲ, s/	/s, ɜ, ʃ, j/		/ɲ, v, ʒ/

To highlight the significance of this study, Table 9 highlights the differences of developmental data and consonant emergence between school-aged French Immersion students

and Francophone students. The summary of results indicate that Francophone children acquire consonants relatively easily (Kehoe, 2021). A common progression identified in francophone studies was the early acquisition of stop consonants, voiceless consonants, nasals and fricatives (Macleod et al., 2011). In the current study, the emerging voiced consonants /b, d, g/ were produced with patterns of devoicing in final position, (voiced consonants becoming voiceless g>k, d>t). Students also produced low accuracy of /ɥ/ and /s/, and significant challenges across additional consonants in final position. In contrast, previous studies identified stop consonants as the earliest consonants to be mastered in French (MacLeod et al., 2016; MacLeod et al., 2011; Thordarottir & Trudeuau, 2011). This difference in developmental data follows the limited but previous research findings of stop consonants examining minority L2 French Immersion students, where difficulties acquiring the consonants /g/ and /d/ were identified (Netelenbos et al., 2015). Additional error patterns that emerged in the analysis of this study were inconsistent with previous francophone data such as documented early acquisition of /ɥ/ and /z/. These consonants were acquired last in this Immersion study. In contrast, Francophone data shows a later mastered acquisition of the post-alveolar fricatives /ʃ/, /ʒ/ where French Immersion students in this study acquired these consonants early and with high accuracy. In parallel with existing francophone data, some consonants were mastered early in one word position but not in another. The developmental differences further highlighted the need for separate norms of bilingual children learning French as a second language.

Significance

Impact on French Immersion education

This research can help teachers, parents, administrators, and curriculum designers understand how children in Immersion learn French and how their consonants are acquired. In

addition, this underlines the importance and the difference of context specific research and will motivate future research that focuses on French Immersion communication, literacy, and language development. In turn, the objectives of this research were to improve current understanding of French Immersion language development. This research can be transformed into infographics for parents and clinicians and can begin to establish developmental norms for this population. These results show how children's speech production errors begin to fossilize despite children's accumulated experience with the French language. Finally, this research can help inform early screening can identify at risk students and interventions that can be promptly initiated and reduce student withdrawal.

Limitations and Future Directions

A limitation of this study was the smaller sample size for statistical analysis. Despite a small sample size there are still 3177 speech productions that were included in the analysis. The smaller sample size may have helped highlight significant findings without over saturating the data. An additional limitation of the study was the inconsistent opportunities for students to produce consonants. This was a result of the available assessment tests for this population and age group. A standardized assessment tool would be beneficial to assess this population. Additionally, there was no information gathered regarding teacher language input or background information. Obtaining language information on teachers could provide a better understanding on developmental acquisition of the children they teach. Notwithstanding these limitations, this study provides reference data for future directions for several studies. This study provides data that focuses on children learning French in a smaller centre in a minority context. Future studies could build off this data and continue to examine and build understanding of French Immersion students learning French in a minority context. Future studies could examine the input of French

from Immersion teachers and parents to see if similar errors occur. Based on the high variability and de-voicing errors indicated by PCC, a final acoustic analysis can be conducted examining stop consonants in word final position. Additionally, future studies may wish to examine the amount of exposure to French as part of the statistical analysis to determine the quantity of exposure and how it influences the language development and accuracy. From this study's data, we can further examine what percentage of errors are accounted for by stop consonants, error patterns in detail for each consonant in initial and final position, and shared consonants across English and French. Finally, this population completed a number of other speech assessments tests including targeted spontaneous speech. Additional analysis can be done with these repeated and spontaneous speech tasks. This study can contribute to the pedagogical responses implemented to reduce the number of students who leave the program (e.g., developing appropriate assessment tools, enhancing research, understanding how French Immersion students acquire phonology and language).

Conclusion

This study shows that French Immersion children perform similarly to their monolingual peers on phonological assessment tasks but show variable characteristics, language patterns, types of errors and phonemes mastered. The data from this study could be useful to the various stakeholders working with French Immersion students across Canada and can provide a better understanding of the phonological profile of bilingual children learning French in a minority context.

Chapter 2

Acoustic Analysis of Stop Consonants in Final Position

Introduction

Across many languages that contrast voicing stops, most children first learn to produce voicing contrasts in word initial position and then final position (Li et al., 2009 & Millaseau et al., 2021), even though voicing contrasts in word final position are critical for distinguishing words. However, final consonant production often does not impede comprehensibility or understanding (Walker, 2012). In the initial study, *French Immersion Consonant Accuracy* (Chapter 1), we examined the development of all French consonants in grades 1, 3 and 5. After an accuracy consonant analysis we found significant stop consonant errors in word final position. To better understand this high variability pattern, we have undertaken an acoustic analysis of stop consonants in final position. The acoustic analysis of stop consonants of this demographic of students has been looked at in initial position and the outcomes contrasted with those of monolingual French students (Netelenbos et al., 2015). The overall absence of reference and data and variability in final position of French Immersion (FI) students, served as the impetus for this extended acoustic analysis on stop consonants. In these contexts, the current study examines children's stop consonant output through the acoustic analysis of two acoustic cues; release burst and closure duration.

The phonetic transcription of children's speech can provide insight into the presence of phonological categories, it is not sufficient to shed light on children's phonological knowledge because children may produce systematic acoustic distinctions such as voicing contrasts that adult listeners cannot hear through perceptual coding and cannot transcribe. (Li at al., 2009; MacLeod & Glaspey, 2014; Millaseau et al., 2021). Voicing errors have been found to be clinical

markers of speech sound disorders in English. The careful phonetic study of voicing contrasts across languages has shown that adult-like acoustic phonetic cues are acquired at a much slower rate and extend into school-age years (MacLeod, 2016).

Voicing contrasts in initial position have been distinguished through Voiced Onset Time (VOT), which acoustically measures the articulatory phasing difference between the release of a stop consonant and the onset of voicing in the following vowel (MacLeod, 2016; Millaseau et al., 2021). Acoustic investigations of the development of voicing contrasts and voicing errors have mostly focused on word-initial consonants in adult speakers. In final position, voicing contrasts are most often measured through closure duration and release bursts (Millaseau et al., 2021). Closure duration is defined as the interval between the last glottal pulse for the preceding vowel and the burst of the following stop (Stathopoulos & Weismer, 1983). Closure duration measurement findings are diverse across stop consonants. However, the data suggests that closure durations are longer for voiceless stops as compared to voiced stops. Release bursts are acoustically similar to fricatives. As the air accumulates for a relatively short period of time and intra-oral air pressure builds up and upon release the air produces a very short frication noise called the burst noise or release burst (Abrahamsen & Wallen, 2017). Similar to fricatives, the configuration of the burst's frequency spectrum is modulated by the size and shape of the vocal tract in front of the constriction, which allows the burst to serve as a secondary cue for place of articulation. These cues help distinguish voicing contrasts in final position.

Three stages of acquisition have been identified based in English speaking children producing consonants in final position (Macken & Barton, 1973; Eckman at al., 2015). The first showed that no stop consonants were voiced in the children's speech, and both voiced and voiceless consonant VOT values were within the short-lag range of adult speech. (Eckman et al.,

2015). However, all these values fell inside the adult perceptual categories of English voiced stop phonemes. In the second stage, the participants exhibited a statistically significant VOT differential between voiced and voiceless stops. Although the VOT distinction made by the students was statistically valid, it was not strong enough for adults to notice. Their use of VOT was not yet adult-like, the appearance of such a covert contrast stage demonstrated that the students were aware of the voicing disparity. In the last stage, the VOT contrasts created by the students matched those created by the adults (Eckman et al., 2015).

English and French have two sets of stop consonants that contrast in voicing, but use different acoustic cues: the voiced stops, /b/, /d/, and /g/ and the corresponding voiceless stops /p/, /t/ and /k/. In French, stages of acquisition of voicing contrasts have been identified in word initial position. MacLeod (2016) identified a clear progression of voicing contrasts as the children aged. Children produced significant voicing contrasts between homorganic stop using VOT, but at the phonetic level their productions were not yet within the adult range (MacLeod, 2016). Short lag voicing, which marks voiceless stops in French but voiced stops in English, requires that vocal fold vibration begin simultaneously with or shortly after the release of the stop closure in word initial position. The early stages of VOT development suggest that children produce stop mainly within the short-lag region prior to the age of 24 months and later expand into long-lag region (MacLeod, 2016). The protracted development is particularly the case in languages that contrasts stops using lead and short-lag VOT, such as French. An individual analysis was completed to assess whether each child was producing a phonological contrast and compared voiced and voiceless stops (MacLeod, 2016). This study found that children between the ages of 2 and 4 were found to produce significantly different VOT values for voiced and voiceless stops.

In final position, one study examined closure durations of adult French speakers. The study compared voiced and voiceless consonants in two speech tasks. They combined voiced consonants and found the average measure for closure duration was /b, d, g/ (M=53, SD=6) after /s/ and (M=59, SD=11) after /z/. For voiceless stops they found the average closure duration measurement was /p, t, k/ (*M*=74, *SD*=12) after /s/ and (*M*=63, *SD*=13) after /z/ (Abdelli-Beruh, 2004). The French speakers of this study produced longer voiceless closure durations than voiced. They also identified that voicing related closure durations are larger in French than English (Abdelli-Beruh, 2004).

Stop Consonants Studies

Previous research that has analyzed the acoustics of French Immersion students learning French in a minority context have studied the Voice Onset Time (VOT) of stop consonants. An initial study examined the VOT of students in grades 1, 3 and 5 in French Immersion, in Alberta who engaged in a word repetition task. In comparison to native French speakers, the French Immersion voiced stops were indistinguishable from their English voiced stops. In addition, the results indicated that French Immersion students demonstrate difficulty acquiring voiced stops, particularly /g/. For their voiceless stops, French Immersion students produced distinctly longer VOT values. Their findings showed that students were unable to differentiate between the English and French /d/ or /b/. Students were found to not change throughout the grades to VOT values of native French speakers (Netelenbos et al., 2015). This may reflect the acquisition of a different variety of French (e.g., Western Canadian French or Immersion French).

A second set of studies, examining the same population, found similar findings where results revealed no difference across three grade levels (Turner & Netelenbos, 2013). These studies compare French Immersion VOT values to native French speakers of Quebec and

illustrate the effects of the social as well as the educational context in bilingual children's speech production (Turner & Netelenbos, 2013). In general, these findings highlight the emergence of stop consonants of French Immersion students from repeated speech tasks. However, they do not provide error patterns and an acoustic analysis in final position. Limited research has examined consonants in final position as they are often omitted or variably produced in children's speech. This increases the complexity of final position analysis (Shattuck-Hufnagel et al., 2011). However, word final position is critical for distinguishing words in French (e.g., /langue/ and /lak/) and contributes to the comprehensibility of the child's speech.

Current Study

The purpose of this paper was to use two acoustic measures that would determine if students were able to produce differences between voiced and voiceless stop consonants in final position. In addition, these acoustic measures would highlight additional variability produced in final position. Based on previous findings from adult French speakers and previous VOT analyses on French Immersion students we hypothesize lengthening closure duration and release burst values, which would align with the targets from English children in final position. In addition, we hypothesize that by grade 5 students may be able to produce acoustic values that differ between voiced and voiceless stop consonants as a clear progression was found in their accuracy production. However, Netelenbos et al. (2015), did not find a grade progression in initial consonant productions.

Methods

Participants

Thirty-seven eligible students were sampled in grades 1, 3, and 5 in a French Immersion school in Lethbridge, Alberta to analyze acoustic production of this population.

Stimuli

In our investigation voiceless and voiced stops /p, t, k, b, d, g/ were examined in French Immersion students in grades 1, 3 and 5. This study used the two picture naming/articulation tasks: Test de dépistage francophone de la phonologie (TDFP) (Rvachew et al., 2013) and Évaluation sommaire de la phonologie chez les enfants d'âge préscolaire (ESPP) (MacLeod et al., 2014). These two tasks included a number of words of different lengths targeted stop consonants in final position.

Table 1. List of stimuli

Target Consonant	**Word List**	**Test**
/p/	envelope	TDFP
	jupe	ESPP
/g/	langue	TDFP
	bague	ESPP
/d/	glissade	TDFP
	viande	ESPP
/k/	bibliothèque	TDFP
/b/	garde-robe	TDFP
	robe	ESPP
/t/	marionette	TDFP
	fourchette	ESPP
	tomate	ESPP
	huit	ESPP

Transcription

A total of 37 files were inspected and annotated using Praat (Boersma & Weenink, 2019). 310 stop consonants were included in the initial analysis and 42 consonant omissions were excluded from further analysis. 268 stop consonants were included and annotated. These 268

stop consonants were reviewed and annotated in final position using Praat. Two acoustic cues were annotated 1) closure duration 2) release burst. Visual displays of the spectrogram and waveform helped with annotation. The closure duration was marked by the less intense noise in the spectrogram and the pause between the vowel and final consonant. The last glottal pulse after the vowel was used as the beginning marker of the closure duration measurement. The apex of a single spike from a group of spikes that make up the transient noise of construction release was identified as the release burst. Since the release burst was measured in its final position, higher intensity of noise across spectral values in the spectrogram were used to identify the release burst closing marker Each annotation was annotated with the same audio device and same visual window for consistent acoustic measurements. In the cases that students produced a final consonant error such as k in place of g, the production was still annotated and included in the analysis.

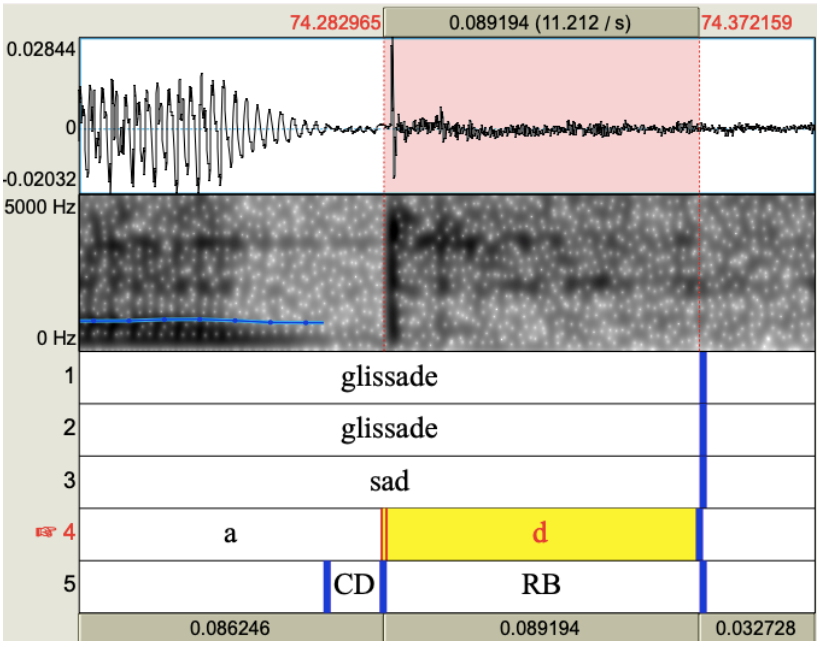

Figure 1. Representative waveform and spectrogram of the word “glissade” and the consonant /d/ as produced by a child in this study. The CD corresponds to the closure duration and the RB corresponds to the release burst.

Analysis

Following the completion of all labeling, Praat's closure duration and release bursts values were retrieved by extracting the acoustic measurements using the durations script (Lennes & Sauvageu, 2009). From the individual values for each target consonant in each word, the average values for each consonant and acoustics cue were calculated.

Statistical analysis

A linear mixed-effects model was used with the *lme4* package (Bates et al. 2015) in R (R Core Team, 2013) to measure each of the durational measures.

Closure duration ~ Grade* Consonant+ WordPosition
Release Bursts ~ Grade* Consonant + WordPosition

The fixed effects were grade, word and consonant and the random effects were the closure duration and release bursts. A number of stop consonants in final position were omitted where no consonant in final position was produced. Of these errors students produced consonant omission errors and devoicing errors. In the case when students produced an alternative consonant of the target consonants, these productions were still included in the analysis. The correlations among random effects were analyzed. Finally, a paired t-test was conducted for both acoustic cues to highlight the maintaining gap and contrast between voiced and voiceless consonants in final position. An additional paired t-test was conducted to further analyze the grade effect of release burst durations.

Results

Table 2. Mean release burst and closure duration in milliseconds by consonant and grade

Target Consonant	**Grade**	**Average of Release Burst**	**Average of Closure Duration**
p	1	167.8	79.37
	3	169.42	95.51
	5	136.5	86.14
t	1	182.2	61.87
	3	174.4	76.23
	5	73.65	95.56
k	1	157.9	88.46
	3	228.4	71.78
	5	142.6	86.14
b	1	183.3	115.4
	3	171.1	86.6
	5	137.7	87.42
d	1	161.6	87.44
	3	111.4	74.869
	5	135.0	95.61
g	1	160.5	88.31
	3	212.2	71.63
	5	183.7	55.61

*Final consonants that were omitted were not included in the average

** Consonants that were produced as the target consonant were included in the averages as the produced consonant.

Students produced shorter voiced closure durations (93.21 milliseconds) than voiceless (99.36 milliseconds). The results show high variability across all grades and no clear progression from the youngest to oldest children. These results align with previous Voiced Onset Time research done on this population where no grade difference was identified. The consonant /g/ was the most variably produced consonant with a substitution of /k/ or consonant deletion.

Table 3. Mean Averages across consonants.

Consonant	**Release Burst**	**Closure Duration**
p	156.4	87.80
t	157.1	89.7
k	171.7	120.6
b	161.3	104.6
d	138.6	103.8
g	185.3	71.23

Table 4. Results of the linear mixed-effects model for Closure Duration

	Estimate	**Std. Error**	***t* value**	Significance
(Intercept)	0.0864	0.0220	3.919	***
Grade	0.0030	0.0046	0.653	
b				
d	-0.0067	0.0208	-0.321	
g	-0.0205	0.0199	-1.030	
k	-0.0012	0.0221	-0.057	
p	-0.0080	0.0196	-0.407	
t	-0.0057	0.0171	-0.335	

*=p<.05; **=p<.01;***=p <.001
* b is included in the intercept

Table 5. Results of the linear mixed effects for Release Burst

	Estimate	**Std. Error**	***t* value**	Significance
(Intercept)	0.1812	0.0198	9.143	***
Grade	-0.0087	0.0040	-2.169	*
b				
d	-0.0115	0.0206	-0.556	
g	0.0315	0.0199	1.584	
k	0.0280	0.0220	1.271	
p	0.0018	0.0197	0.092	
t	0.0042	0.0171	0.247	

*=p<.05; **=p<.01;***=p <.001
* b is included in the intercept

The results from the linear mixed effects model for Closure Duration and Release Burst identify a grade effect in the production of release bursts.

Grade Effect

The results from the mixed effects analysis shows a grade effect for release burst but not for closure duration. To further investigate this effect, we conducted an additional t-test comparing each grade. Grade 1 vs Grade 3 (*M*= 168.9, *SD*= 0.0112, *p*=0.61) Grade 3 vs Grade 5 (*M*=177.91, *SD*=0.0407, *p*=0.079) and Grade 1 vs Grade 5 (*M*=134.89, *SD*=0.035, *p*=0.048). Grade 1 vs Grade 3 and Grade 3 vs Grade 5 showed no significant differences. However, Grade 1 productions were significantly different from Grade 5. Grade 1 was significantly different from grade 5.

Voicing Effect

An additional t-test was conducted to examine gap and contrast between voiced and voiceless consonants in final position. For release burst the value (*M*=161.7, *SD*=15.7, p =0.87) for closure duration (*M*=96.28, *SD* =17.09, p=0.83). There is no significant effect identified between the production of voiced and voiceless consonants for both consonant cues.

Discussion

This study investigated acoustic cues of stop consonants in final position. It measures durational information of closure and burst durations. This study suggests that children in French Immersion can make voicing contrasts, but their acoustic realizations remain less systematic, and they produce more variability than those of adults and other francophone children. Similar to acoustic studies done in initial position French Immersion speakers did not show a clear grade progression in either duration measure. This might suggest (a) insufficient input to guide learning, (b) influence of L1, (c) presence of another variation of French as the target, (d) that students are not using these cues to distinguish the words. The high frequency of deletion of these consonants supports this hypothesis and the identified pattern of Alberta phonology (Walker, 2012). The results of this study build on the previous study of bilingual consonant acquisition of French Immersion students. It presents acoustic understanding of children's ongoing phonological development. Contrary to previous studies, students produced longer closure durations in voiced consonants than those of voiceless consonants

Limitations and Future Directions

Two acoustic cues were measured in this study however, the vowel duration was not measured as the vowel environment varied unsystematically across the target words. A future study that had words that were balanced for word final vowel and consonant target would allow for including this cue. Although there were 268 stop consonants included in the analysis, a limitation of this study was that children, especially the youngest group omitted and variably produced acoustic cues in final position. This suggests that despite the variability across grade levels there was still 268 stop consonants included in the analysis. An additional limitation of the study was the inconsistent opportunities for students to produce consonants. This was a result

of the available assessment tests for this population and age group. A final limitation was that this study did not measure vowel duration or examine vowel influence on acoustic cues. This would be beneficial for future analysis and studies. Notwithstanding these limitations, this study provides reference data for future directions for several studies. Based on the high variability and de-voicing errors indicated by PCC, a final acoustic analysis documents acoustic cues in final position for stop consonants

Conclusion

This study provides resources for appropriate assessment tools, enhancing research and understanding how French Immersion students acquire phonology and language. Although no pattern of acoustic cues were identified, this study showcases the variability of production through three different grades.

General Conclusion

The present master's thesis highlights French Immersion consonant productions accuracy and acoustic measurements in final position. It begins to establish reference data which grounds initial insight of student's phonological acquisition. The key findings in the accuracy study include the consonants that emerged last and had lower accuracy across grades were /b, d, g, n, ɲ, v, s, z, ʁ, ɥ, j/. Overall errors decreased as the grades increased with all consonants except the consonants /ɥ/ and /s/. The key findings in the acoustic study of stop consonants in final position did not show a clear grade progression in either duration measures following previously established word-initial acoustic patterns.

Implications for Rehabilitation

Rehabilitation Science is an inherently multidisciplinary field designed to help individuals in a variety of sectors. This research was designed to help future French Immersion students and their bilingual language development - through the development of documented acoustic and accurate consonants. This was intended to optimize communication and education as learning in a minority context poses challenges and this creates barriers of second language research.

This initial description of French Immersion phonological development in a minority context can contribute to bilingual education research for this population and for bilingual education programs across Canada. In light of this research regarding phonological production, further research can focus on vowel quality and production of lateral/rhotic consonants in French Immersion student populations. The phonetic roadmaps will help educators develop appropriate assessment tools for bilingual children and inform teachers, curriculum designers and policy makers. Furthermore, these insights can be used as initial clinical markers and increase the data

set available to Speech language pathologists and clinicians who assess the phonological development of French Immersion students across Canada. Finally, this data begins to create norms for bilingual children and can be used to enhance diagnostic and education assessments. It increases French Immersion teachers and administrators' understanding on how consonants are acquired in this context. Improved clinician assessment, teacher understanding, and curriculum knowledge of phonological development can help improve students overall learning experience. This in turn can help reduce student attrition, oral literacy challenges and literacy issues. The evidence-based report demonstrates that French Immersion students develop French consonants but in a different pattern then their monolingual peers. French Immersion provides students with a unique learning environment and students produce different phonological norms and different patterns of second language acquisition that needs to be documented to continue to adapt and evolve the growing expansion of French Immersion programs across Canada.

References

Anderson, R. T. (2004). Phonological acquisition in preschoolers learning a second language via immersion: A longitudinal study. *Clinical Linguistics & Phonetics, 18*(3), 183-210.

Abrahamsson, N. & Hyltenstam, K. (2009). Age of onset and native likeness in a second language: listener perception versus linguistic scrutiny. *Language Learning*, *59*(2), 249-306.

Abramson, A. S. & Whalen, D. H. (2017). Voice Onset Time (VOT) at 50: Theoretical and practical issues in measuring voicing distinctions. *Journal of Phonetics, 63*, 75–86.

Arnett, K., & Mady, C. (Eds.). (2013). *Minority populations in Canadian second language education* (Vol. 32). Multilingual Matters.

Association canadienne des professionnels de l'immersion (2017). L'immersion en français au Canada : Guide pratique d'enseignement. Montréal, QC : Chenelière Éducation.

Baker, C. (2011). *Foundations of Bilingual Education and Bilingualism* (Vol. 79). Multilingual Matters.

Bérubé, D., Bernhardt, B. M., Stemberger, J. P., & Ciocca, V. (2020). Development of singleton consonants in French-speaking children with typical versus protracted phonological development: The influence of word length, word shape and stress. *International Journal of Speech-Language Pathology*, *22*(6), 637-647.

Bourgoin, R. C. (2014). Inclusionary practices in French immersion: A need to link research to practice. *Canadian Journal for New Scholars in Education/Revue canadienne des jeunes chercheures et chercheurs en éducation*, 5(1), 1–11.

Bialystok E. (2011). Reshaping the mind: the benefits of bilingualism. *Canadian journal of experimental psychology = Revue canadienne de psychologie experimentale*, *65*(4), 229–235. https://doi.org/10.1037/a0025406

Boudreaux, N., & Olivier, D. F. (2009, March). Student attrition in foreign language immersion programs. In *annual meeting of the Louisiana Education Research Association, Lafayette, LA*.

Bournot-Trites, M., & Reeder, K. (2001). Interdependence revisited: Mathematics achievement in an intensified French immersion program. Canadian Modern Language Review, 58(1), 27-43.

Bournot-Trites, M., & Reeder, K. (2005). French and English literacy in French immersion: Student performance and perceptions. In ISB4: Proceedings of the 4th International Symposium on Bilingualism (pp. 364-376). Cascadilla Press.

Brown, V. A. (2021). An introduction to linear mixed-effects modeling in R. *Advances in Methods and Practices in Psychological Science, 4*(1), 2515245920960351.

Cammarata, L., Cavanagh, M., Blain, S., & Sabatier, C. (2018). Enseigner en immersion française au Canada: Synthèse des connaissances sur les défis et leurs implications pour la formation des enseignants. *Canadian Modern Language Review/La Revue Canadienne Des Langues Vivantes*, 74(1), 101–127.

Cammarata, L., Marchak, K., Cavanagh., Elliot, S., Dickner, S., Fancey, R., & Weich, A. (2022). Etat des Lieux de l'enseignement du français en contexte immersif et francophone minoritaire. *L'Association des collèges et universités de la francophonie canadienne.*

FlCammarata, L., & Tedick, D. J. (2012). Balancing content and language in instruction: The experience of immersion teachers. *The Modern Language Journal*, 96(2), 251-269.

Carey, S. T. (1984). Reflections on a decade of French immersion. *Canadian Modern Language Review*, *41*(2), 246-359.

Cavanagh, M. (2007). Profil scriptural d'élèves du primaire en vue d'une intervention en milieu francophone minoritaire. *Canadian Journal of Education/Revue canadienne de l'éducation*, *30*(3), 691-724.

Cavanagh, M. & Blain. S. (2009). Relever quatre défis de l'enseignement de l'écrit en milieu francophone minoritaire. *Les Cahiers franco-canadiens de l'Ouest, 21*, 151-178.

Cho, T., Jun, S. A. & Ladefoged, P. (2002). Acoustic and aerodynamic correlates of Korean stops and fricatives. *Journal of Phonetics, 30*(2), 193–228.

Core, C., & Scarpelli, C. (2015). Phonological development in young bilinguals: clinical implications. *Seminars in speech and language, 36* (2), 100-8.

Dicks, J., & Genesee, F. (2017). Bilingual Education in Canada. Bilingual and Multilingual Education *Springer International Publishing Switzerland. (*pp.453-467). DOI:10.1007/978-3-319-02258-1_32

Eckman FR, Iverson GK, Song JY. (2015). Overt and covert contrast in L2 phonology. *J Second Lang Pronunciation.1*(2) 254-278. doi: 10.1075/jslp.1.2.06eck. PMID: 28090439; PMCID: PMC5228637.

Flege, J. E. (1987). The production of "new" and "similar" phones in a foreign language: Evidence for the effect of equivalence classification. *Journal of Phonetics, 15*(1), 47-65.

Flege, J. E. (1995). Second language speech learning: Theory, findings and problems. In W. Strange (Ed.), Speech perception and linguistic experience: Issues in cross-language research (pp. 233-277). Baltimore: York Press.

Flege, J. E. (2007). Language contact in bilingualism: Phonetic system interactions. *Laboratory phonology*, 9(353-381).

Flege, J. E., & Bohn, O. S. (2021). The revised speech learning model (SLM-r). *Second language speech learning: Theoretical and empirical progress*, 3-83.

Fowler, C., Sramko, V., Ostry, D., Rowland, S., & Hall., P. (2008). Cross language phonetic influences on the speech of French-English bilinguals. *Journal of Phonetics*, *36*, 649-663.

Genesee, F. (1989). Early bilingual development: One language or two?. *Journal of child language*, *16*(1), 161-179.

Guion, S.G., & Flege, J. (200)). An investigation of current models of second language speech perception: The case of Japanese adults' perception of English consonants. *The Journal of the Acoustical Society of America* 107, 2711. https://doi.org/10.1121/1.428657

Hodson, B. W., & Paden, E. P. (1981). Phonological processes which characterize unintelligible and intelligible speech in early childhood. *Journal of speech and Hearing Disorders*, *46*(4), 369-373.

Hannahs, S. J. (2007). French phonology and L2 acquisition. *French applied linguistics*, *16*, 50-74.

Imbrie, A.K.K. (2005). Acoustical study of the development of stop consonants in children. *Massachusetts Institute of Technology. Doctoral Theses*.

Kehoe, M. (2021). Coda consonant production in French-speaking children, *Clinical Linguistics & Phonetics, 35*(6), 509-533. DOI:10.1080/02699206.2020.1795723

Kehoe, M., Friend, M., & Poulin-Dubois, D. (2021). Relations between phonological production, grammar and the lexicon in bilingual French-English children. *International Journal of Bilingualism*, 25(6), 1576-1596.

Kehoe, M., Niederberger, N., & Bouchut, A. (2021). The development of a speech sound screening test for European French-speaking monolingual and bilingual children, *International Journal of Speech-Language Pathology*, *23*(2), 135-144. DOI: 10.1080/17549507.2020.1750699

Kuznetsova, A., Brockhoff, P. B., & Christensen, R. H. B. (2017). lmerTest Package: Tests in Linear Mixed Effects Models. J*ournal of Statistical Software, 82*(13), 1–26.

Leclerc, L. (2014). Reading comprehension and attrition in French immersion programs. [Doctoral dissertation]. Electronic version published by Vancouver Island University.

Lefebvre, E. (2021). Reframing Differences: The Dialect Variations in the Phonological Development of Canadian Bilingual Children who Speak French. [Master's Thesis]. University of Alberta.

Lindholm-Leary, K. (2001). Dual language education. *Multilingual Matters Ltd*.

Li, F., Edwards, J., & Beckman, M. E. (2009). Contrast and covert contrast: The phonetic development of voiceless sibilant fricatives in English and Japanese toddlers. *Journal of Phonetics, 37*(1), 111-124.

MacLeod, A.A.N (2016). Phonetic and phonological perspectives on the acquisition of voice onset time by French-speaking children. *Clinical linguistics & phonetic*s, 1-15.

MacLeod, A. A. N., & McCauley, R. J. (2002). The phonological abilities of bilingual children with specific language impairment: a descriptive analysis. *Journal of Speech Language Pathology and Audiology*, *27*(1), 29-44.

Macleod, A. A., Stoel-Gammon, C., & Wassink, A. B. (2009). Production of high vowels in Canadian English and Canadian French: A comparison of early bilingual and monolingual speakers. *Journal of Phonetics*, *37*(4), 374-387.

MacLeod, A.A.N., & Stoel-Gammon, C. (2009). Comparing bilingual and monolingual production of Voice Onset Time in Canadian English and Canadian French. *Applied Psycholinguistics*, *30*, 53-77.

Macleod, A.A.N., & Stoel-Gammon, C. (2009). The use of voice onset time by early bilinguals to distinguish homorganic stops in Canadian English and Canadian French: *Applied Psycholinguistics, 30,* 53-77.

MacLeod, A.A.N., & Stoel-Gammon, C. (2010). What is the impact of age of second language acquisition on the production of consonants and vowels among childhood bilinguals? *International Journal of Bilingualism*, *14*(4), 400-421.

MacLeod, A.A.N., Sutton, A., Trudeau, N., & Thordardottir, E. (2011). The acquisition of consonants in Quebecois French: A cross-sectional study of pre-school aged children. *International Journal of Speech-Language Pathology, 13*, 93–109. doi:10.3109/17549507.2011.487543

MacLeod, A. A., Sutton, A., Sylvestre, A., Thordardottir, E., & Trudeau, N. (2014). Outil de dépistage des troubles du développement des sons de la parole: bases théoriques et données préliminaires. *Canadian Journal of Speech-Language Pathology & Audiology, 38*(1).

MacLeod, A. A. N., & Glaspey, A. M. (2014). Gradient phonological change: A multidimensional view of speech sound disorder across children. *Clinical Linguistics and Phonetics*, early online, 1-18.

Mady, C., & Arnett, K. (2009). Inclusion in French immersion in Canada: One parent's perspective. *Exceptionality Education International*, *19*(2).

McLeod, S., & Crowe, K. (2018). Children's Consonant Acquisition in 27 Languages: A Cross-Linguistic Review. *American journal of speech-language pathology*, *27*(4), 1546–1571. https://doi.org/10.1044/2018_AJSLP-17-0100

Melby-Lervåg, M., & Lervåg, A. (2011). Cross-linguistic transfer of oral language, decoding, phonological awareness and reading comprehension: a meta-analysis of the correlational evidence. *Journal of Research in Reading*, *34*: 114-135. doi:10.1111/j.1467-9817.2010.01477.x

Meisel, J. (2008). Child second language acquisition or successive first language acquisition? In E. Gavruseva & B. Haznedar (Eds.), *Current trends in child second language acquisition: A generative perspective*, (pp. 55-80). Amsterdam: Benjamins.

Melby-Lervåg, M., & Lervåg, A. (2011). Cross-linguistic transfer of oral language, decoding, phonological awareness and reading comprehension: A meta-analysis of the correlational evidence. *Journal of Research in Reading, 34(1*), 114-135.

Menke, M. R. (2010). The acquisition of Spanish vowels by native English-speaking students in Spanish immersion programs. University of Minnesota.

Meziane, R. S., & MacLeod, A. A. (2017). L'acquisition de la phonologie en français langue seconde: le profil phonologique d'enfants allophones en maternelle. *Canadian Journal of Applied Linguistics/Revue canadienne de linguistique appliquée, 20(2*), 1-17.

Millasseau, J., Ivan, Y. U. E. N., Bruggeman, L., & Demuth, K. (2021). Acoustic cues to coda stop voicing contrasts in Australian English-speaking children. Journal of Child Language, 48(6), 1262-1280.

Netelenbos, N., Li, F., Rosen, N. (2016). Stop consonant production of French immersion children in Western Canada: A study of voice onset time. *International Journal of Bilingualism*, *20*(3), 346–357.

Preston, J. L., Hull, M., & Edwards, M. L. (2013). Preschool Speech Error Patterns Predict Articulation and Phonological Awareness Outcomes in Children With Histories of Speech Sound Disorders. *American journal of speech-language pathology*, *22*(2), 173-184.

Rose, Y., & Wauquier-Gravelines, S. (2007). French speech acquisition. In S. McLeod (Ed.), *The international guide to speech acquisition* (pp. 364–384). Clifton Park, NY: Thomson Delmar Learning.

Roy, S. (2008). French immersion studies: From second-language acquisition (SLA) to social issues. *Alberta Journal of Educational Research*, *54*(4), 396-406.

Rose, Y., & Wauquier-Gravelines, S. (2007). French speech acquisition. In S. McLeod (Ed.), *The international guide to speech acquisition* (pp. 364–384). Clifton Park, NY: Thomson Delmar Learning.

Rvachew, S., Leroux, E., & Brosseau-Lapre, F. (2014). Production of word-initial consonant sequences by Francophone preschoolers with a developmental phonological disorder. Canadian *Journal of Speech-Language Pathology & Audiology*, *37*, 252–267.

Rvachew, S., Marquis, A., Brosseau-Lapre, F., Paul, M., Royle, P., & Gonnerman, L.M. (2013). Speech articulation performance of francophone children in the early school years: Norming of the Test de depistage francophone de phonologie. *Clinical Linguistics & Phonetics*, 27, 950–968. doi:10.3109/ 02699206.2013.830149.

Silva, A. P. (2019,). The French Language in Alberta, 2001 to 2016: Facts and Figures.Ethnicity Language and Immigration Thematic Series. *Statistics Canada.* Retrieved October 4, 2021, from https://www150.statcan.gc.ca/n1/pub/89-657-x/89-657-x2019016-eng.htm.

Simon, E. (2010). Child L2 development: A longitudinal case study on Voice Onset Times in word-initial stops. *Journal of Child Language*, *37*(01), 159-173

Spencer, A. (1986). Towards a theory of phonological development. *Lingua*, *68*, 3–38. doi:10.1016/00243841(86)900215

Stathopoulos, E. T., & Weismer, G. (1983). Closure duration of stop consonants. *Journal of Phonetics*, *11*(4), 395-400.

Statistics Canada. (2016). French spoken at home (7), mother tongue (10) and sex (3) for the population of Canada. Retrieved from https://www12.statcan.gc.ca/census-recensement/2016/

Thomson, R. I., & Derwing, T. M. (2015). The effectiveness of L2 pronunciation instruction: A narrative review. *Applied Linguistics*, *36*(3), 326–344.

Turnbull, M., Lapkin, S., & Hart, D. (2001). Grade 3 immersion students' performance in literacy and mathematics: Province-wide results from Ontario (1998-99). *The Canadian Modern Language Review, 58*(1), 9-26.

Vanhove J. (2013). The critical period hypothesis in second language acquisition: a statistical critique and a reanalysis. PloS one, 8(7), e69172. https://doi.org/10.1371/journal.pone.0069172

Vrooman, M. D. (2000). *The Linguistic Interdependence Hypothesis and the language development of Yucatec Maya-Spanish bilingual children*. University of Massachusetts Amherst.

Willms, J. D. (2008). The case for universal French instruction. *Policy Options*, *29*(7), 91-96.

Appendix A- ESPP Task

ESPP word opportunities (Macleod et al., 2014)

bague /bag/

banane /banan/

beigne /bɛɲ/

bijoux /biʒu/

biscuit /biskɥi/

bloc /blʌk/

canard /kanɑʁ/

champignon /ʃãpiɲɔ̃/

chandail /ʃãdaj/

cheval /ʃœval/

chocolat /ʃʌkʌlʌ/

cochon /kʌʃɔ̃/

crayon /kʁɛjɔ̃/

douche /dʊʃ/

éléphant /elefã/

fève /faɪ͡v/

fleur /fla͡œʁ/

fourchette /fʊʁʃɛt/

framboise /fʁãbwɑz/

gant /gã/

girafe /ʒiʁaf/

huit /ɥɪt/

jupe /ʒʏp/

lapin /lapɛ̃/

mouton /mutɔ̃/

nid /ni/

oiseau /wazo/

persil /pɛʁsi/

poisson /pwasɔ̃/

pomme /pʌm/

robe /ʁʌb/

singe /sɛ̃ʒ/

tambour /tãbʊʁ/

tasse /tɑs/

tomate /tʌmat/

train /tʁɛ̃/

valise /valiz/

viande /vjãd/

yogourt /jʌguʁ/

zèbre /zɛbʁ/

Appendix B- TDFP Task

TDFP-word opportunities (Rvachew et al., 2013)

train /tʁɛ̃/

camion /kamjɔ̃/

avion /avjɔ̃/

enveloppe /ãvlɔp/

clown /klun/

cochon /kaʃɔ̃/

parapluie /paʁaplɛ̃

beigne /bɛɲ/

soleil /sɔlɛj/

château /ʃato/

niche /niʃ/

serpent /sɛʁpã/

géant /geã/

manger /mãʒe/

araignée /aʁɛɲe/

chapeau /ʃapo/

vaisselle /vɛsɛl/

garde-robe /gaʁdəʁɔb/

marionnettes /maʁjɔnɛt/

girafe /ʒiʁaf/

langue /lãg/

glissade /glisad/

nuage /nyaʒ/

hélicoptère /elikɔptɛʁ/

escalier /ɛskalje/

tournevis /tuʁnəvis/

singe /sɛ̃ʒ/

aquarium /akwaʁjɔm/

framboise /fʁãmbwaz/

bibliothèque /bibliɔtɛk/