THE PRODUCTION OF VOICE ONSET TIME AND ONSET F0 IN SECOND LANGUAGE LEARNERS OF FRENCH

by

Amy E. Hutchinson

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THE PURDUE UNIVERSITY GRADUATE SCHOOL
STATEMENT OF COMMITTEE APPROVAL

Dr. Olga Dmitrieva, Chair

School of Languages and Cultures

Dr. Daniel J. Olson

School of Languages and Cultures

Dr. Jessica L. Sturm

School of Languages and Cultures

Approved by:

Dr. Alejandro Cuza

Head of the Graduate Program

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LIST OF ABBREVIATIONS

adj: Adjective

AOA: Age of acquisition

f0: Fundamental frequency

L1: First language

L2: Second language

nf: Feminine noun

nm: Masculine noun

nmp: Masculine plural noun

SLM: Speech learning model

VOT: Voice Onset Time

vm: Modal verb

vtr: Transitive verb

[+voice]: voiced

[-voice]: voiceless

ABSTRACT

Author: Hutchinson, Amy, E. MA
Institution: Purdue University
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Committee Chair: Olga Dmitrieva

Voice Onset Time (VOT) and onset f0 are known correlates of voicing distinctions in stops and both contribute to the production and perception of voicing (House & Fairbanks, 1953; Abramson & Lisker, 1965; Ohde, 1984). As the values of VOT and onset f0, which correspond to voicing categories, vary cross-linguistically, a second language (L2) learner has to acquire a novel use of these acoustic cues to produce and perceive voicing in their L2. Although the acquisition of the primary voicing cue, VOT, has been studied extensively in L2 research (Flege & Eefting, 1988; Flege 1991; Birdsong et al. 2007), little is known about the acquisition of onset f0. The present study compares the use of VOT and onset f0 in French and English speech produced by American learners of French (23). The study also examines evidence for phonetic drift in L2 learners by comparing their English productions to a monolingual control group (33). Results indicate that although learners' VOT values in French were heavily influenced by English, their onset f0 production in both English and French were on target, showing that learners are able to manipulate the two cues independently of one another. Little evidence of the effect of learners' second language on the first language was found.

This study also examines the role of individual learning history on the realization of VOT and onset f0, determining that average number of hours speaking French and age of L2 acquisition (AOA) reported by learners shows the strongest correlation with the learner's acoustic productions.

CHAPTER 1: INTRODUCTION

1.1 Introduction and Goals

The purpose of this thesis is to investigate the production of Voice Onset Time (VOT, the interval of time between a consonant's release and the onset of vibration of the vocal chords) and onset f0 (the fundamental frequency at the onset of the vowel following a stop consonant) in native English-speaking students who are learning French as a second language (L2), with the intention to shed light onto the second language acquisition of a secondary acoustic cue to consonant voicing, onset f0. This work will examine the speech of L2 learners to determine whether they are realizing French voicing categories with appropriate combinations of VOT and onset f0 values, since the pairing of these correlates to signal voicing in English is different from that in French. Additionally, this thesis will examine the role of individual speaker characteristics, such as second language experience and age of acquisition, to determine whether they play a role in the acquisition of primary and secondary voicing cues. Finally, results will determine whether there is phonetic drift in the acoustic realization of voicing in the first language of these learners caused by exposure to the second language and if there is, whether or not these effects occur in both VOT and onset f0.

1.2 Outline of the Thesis

The following thesis is structured as follows: Chapter 2 provides a brief introduction to the topics at hand, while also surveying relevant literature on both VOT and onset f0, as well as literature on the L2 acquisition of these acoustic cues. It also examines literature on phonetic drift and concludes with the study's proposed research questions and hypotheses. Chapter 3 discusses the methodology of the study, specifically outlining information regarding the participants (in both the experimental and control groups), the speech materials, and the production task completed by each participant. This chapter concludes with a section on the statistical analysis performed on the elicited production data. Chapter 4 discusses the results of the study, which look at the overall productions of the experimental and control groups, as well as individual variation found in the data. This chapter also presents the results of a correlation analysis completed in order to determine how production of both VOT and onset f0 were affected by speaker background characteristics. Finally, Chapter 5 presents a discussion of the results as well as conclusions drawn by the study.

CHAPTER 2: BACKGROUND

2.1 On Voice Onset Time and Onset f0

Previous research demonstrates that Voice Onset Time (VOT) and onset f0 are important correlates of voicing distinctions in stops, and both contribute to the production and perception of voicing (House & Fairbanks, 1953; Abramson & Lisker, 1965; Ohde, 1984). Implementation of voicing categories via VOT and onset f0 vary cross-linguistically, and L2 learners must acquire a novel use of these acoustic cues necessary for correct production and perception in their L2. Although the primary acoustic cue, VOT, has been studied extensively in the acquisition of L2 speech (Flege & Eefting, 1988; Flege 1991; Birdsong et al. 2007), there is a gap in the research in regard to the acquisition of secondary cues, such as onset f0. Since onset f0 has been shown to aid in distinguishing between [+voice] and [-voice] consonants, especially when other cues, like VOT, are ambiguous or inhibited (Abramson & Lisker, 1965; Whalen et al., 1990), there is a need to understand how L2 learners acquire and use this cue in their speech.

2.1.1 Voice Onset Time

VOT is defined as the period time between a consonant's release and the onset of the vibration of the vocal chords. The languages used in this study (English and French), distinguish between three types of VOT across voicing categories: negative VOT (also known as prevoicing), short lag VOT and long lag VOT (Cho & Ladegoged, 1999). Prevoiced stops have a negative VOT (<0 ms) due to the fact that voicing occurs before the stop is released, during closure (Figure 1). In short lag stops, little time (< 40 ms) elapses between the release of the stop and the onset of vocal cord vibration (Figure 2). These stops are also known as voiceless unaspirated. In long lag stops, the period of time between the release of the stop and the onset of vocal cord vibration is longer (>40 ms) and its duration is typically filled with aspiration (Figure 3).

The use of VOT to implement phonological voicing varies cross-linguistically, which will be discussed in a later part of this chapter, but it is important to note that English behaves like a typical aspiration language in utterance-initial position, with short lag mostly representing the [+voice] category and long lag representing the [-voice] category. French is a typical voice language with prevoiced [+voice] stops and short lag [-voice] stops. That is, while both English and French have a two-way phonological voicing distinction, they differ in the phonetic realization of the voicing categories. In the present study, only utterance-initial stops will be examined.

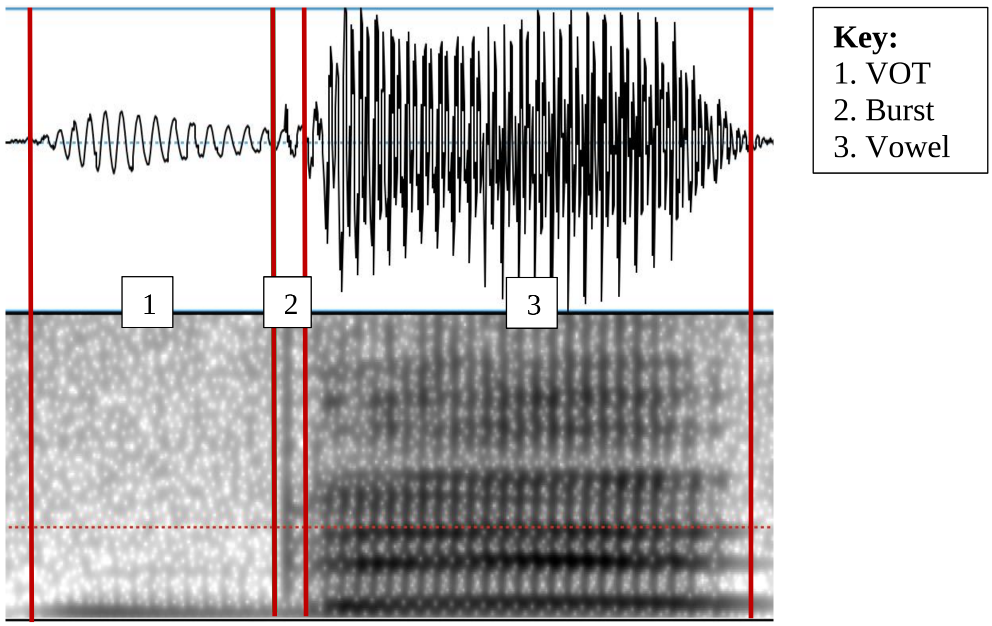

Figure 1. Prevoiced VOT in English *bat*

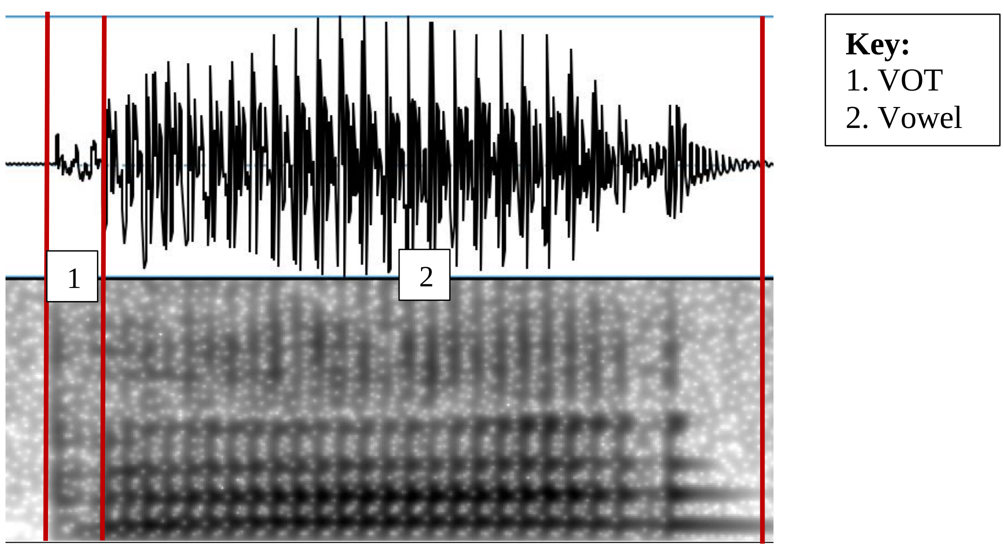

Figure 2. Short lag VOT in English *bet*

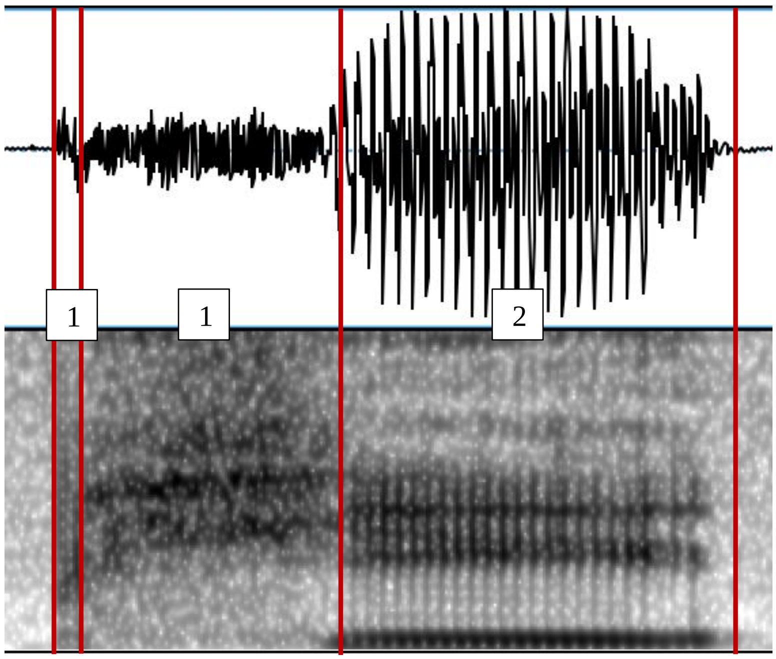

Figure 3. Long lag VOT in English *pat*

2.1.2 Onset f0

Onset f0 is defined as the fundamental frequency at the onset of the vowel following the target consonant (Figure 4). Across languages, onset f0 tends to be correlated with voicing (House & Fairbanks, 1953; Abramson & Lisker, 1965). Both types of languages with a two-way voicing distinction, voice languages and aspiration languages, demonstrate this property (Ohde 1984; Hombert, 1976). The literature shows that higher onset f0 co-occurs with [-voice] stops and lower onset f0 co-occurs with [+voice] stops across languages (Kingston & Diehl, 1994).

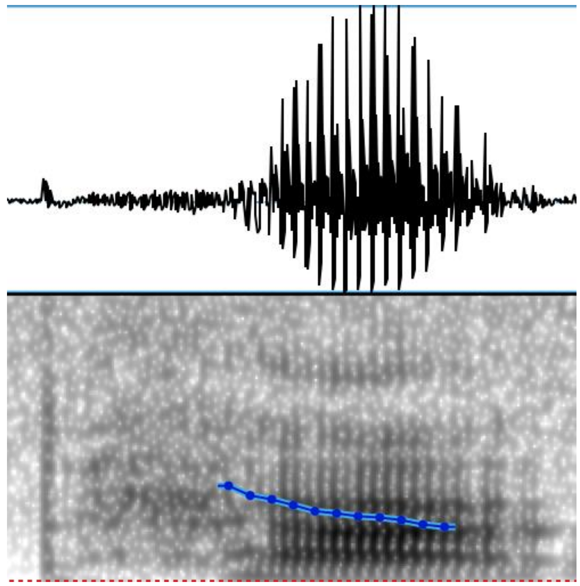

Figure 4. f0 in the word *pat* as indicated by the Praat pitch tracker (blue)

Onset f0 is considered a secondary cue to voicing in both aspiration and voice languages (Ohde, 1984), as VOT has been shown to dominate the perception of voicing distinctions (Abramson & Lisker, 1985). Despite its secondary nature, literature shows (Idemaru et al., 2012; Whalen et al., 1993) that when VOT is ambiguous, onset f0 can affect voicing decisions. Since research (Flege & Eefting 1988; Flege, 199; Flege et al., 1995) shows that beginner learners often have difficulties realizing L2 VOT in a target-like manner, it is important to investigate their use of secondary cues, such as onset f0.

2.1.3 Voicing in English and French

As mentioned above, French is a typical voice language: [+voice] stops are produced with negative VOT (prevoicing) and lower onset f0, [-voice] stops are produced with short lag VOT and higher onset f0 (for VOT: Caramazza, 1974; for onset f0: Kirby & Ladd, 2015). English, at least in word-initial position, behaves largely as an aspiration language would: [+voice] stops are produced predominantly with short lag VOT and lower onset f0, while [-voice] stops are produced with long lag VOT and higher onset f0. Prevoiced realization of English [+voice] stops is also possible in word-initial position as a sub-phonemic variant of the [+voice] category (for VOT: Lisker & Abramson, 1964; for onset f0 Kingston & Diehl, 1994). Prevoiced stops are realized with lowered onset f0, just as other [-voice] stops. These observations are summarized in Table 1 below.

Table 1. Voicing in English and French

	[+voice]	[-voice]
French	Prevoiced, lower f0	**Short lag, higher f0**
English	**Short lag/prevoiced, lower f0**	Long lag, higher f0

Importantly, as Table 1 demonstrates, the two languages use both VOT and onset f0 to contrast [+voice] and [-voice] stops, but they combine the two parameters differently. Specifically, both languages make use of short lag stops, but as their phonological categories differ, corresponding onset f0 levels also differ accordingly. English short lag is characterized by a lowered onset f0, in accordance with its [+voice] status, while French short lag has a raised onset f0, in accordance with its [-voice] status. American learners of French, aiming for French-like phonetic realization of voicing categories, should seek to produce their [+voice] stops as exclusively prevoiced and their [-voice] stops as short lags instead of long lags. In the latter case, the target realization of French [-voice] stops is indistinguishable from the English [+voice] category in terms of VOT. If learners simply rely on using English short lag stops when producing the French [-voice] category, the onset f0 of these realizations is expected to be lowered, reflecting the pairing of these two cues in English word-initial stops. In order to correctly represent the French [-voice] category, learners need to use short lag VOT in conjunction with heightened onset f0, a combination not found in English word-initial stops. Given that VOT is considered to be the primary correlate of voicing and the most important determinant of voicing identification in perceptual decisions, it is possible that L2 learners acquire VOT realization first and add onset f0 later. It is not known, however, whether and when L2 learners can produce both primary and secondary cues to the voicing contrast in their second language in a target-like manner. Therefore, one of the main questions this study addresses is whether beginner to intermediate American learners of French can shorten the VOT of their French [-voice] stops without simultaneously lowering the f0.

2.2 Second Language Acquisition of Acoustic Cues to Voicing

2.1.1 Theoretical Models of Transfer

For the sake of this research, the Speech Learning Model (SLM) proposed by Flege (1995) will be used as the primary theoretical model of transfer, which will ultimately guide the discussion around the difficulties learners might face while attempting to acquire VOT and onset f0 in their second language. The SLM was proposed to account for how language learning varies with L1-L2 language combinations and why learners are able to accurately produce and perceive some phonetic segments but not others at various stages of acquisition. Flege (1995) defines the aspect of a phonological space and states that in L2 learners, the L1 and L2 phonetic subsystems exist within the same space. L1 and L2 phonetic segments can be related on a continuum from "identical" (the L2 sound is phonetically identical to a L1 sound), "similar" (the L2 sound is phonetically similar but not identical to a L1 sound), and "new" (the L2 sound is fundamentally different phonetically from a L1 sound). Depending on the degree of phonetic similarity, the learners will assimilate L2 sounds into existing L1 phonetic categories. That is, identical/similar sounds will be assimilated to the corresponding L1 sounds and new sounds will form a separate L2 phonetic category. With this in mind, it was proposed that because similar L2 sounds are assimilated to the L1 category, they will be the most difficult to perceive and produce by L2 learners in a native-like fashion. On the other hand, dissimilar and unique sounds present less difficulty because they are not confusable with similar L1 categories.

This model of transfer has been chosen because it accounts for the challenges learners might face when attempting to acquire L2 categories that are subtly different from similar L1 categories.

2.2.2 L2 Acquisition of VOT

As the use of VOT and onset f0 to contrast voicing in stops varies cross-linguistically, a L2 learner must acquire a novel use of the acoustic cues necessary for correct production and perception of their L2. Despite the scarcity of research examining secondary acoustic cues in L2 speech, many studies have examined the acquisition of VOT as it the primary acoustic cue to voicing in many languages. Across the literature, when analyzing L2 learners' VOT production, variability occurs based on various individual learner differences. Variability has been revealed as a function of L2 input (Flege & Eefting 1988) and age of acquisition (AOA; Flege, 1991; Flege et al., 1995; Flege et al., 1999; Tsukada et al., 2005), among other things. When analyzing VOT duration as a function of L2 input, the general consensus is that L2 learners who receive more input are more successful at producing native-like VOT values than those who receive less. In terms of AOA, the literature suggests that learners with a lower AOA will produce VOT more native-like than those who acquire the L2 older. This is often attributed to the effect of the critical period hypothesis (Singleton & Lengal, 1995; Birdsong, 1999), which states that age is a crucial factor in the acquisition of both the first and second language and that learners are more successful at acquiring a language if they begin learning before the proposed "critical period" (often defined as the age around puberty.) Although this hypothesis is often debated among SLA scholars (Ioup et al., 2008; Scovel, 2000; Robertson, 2002), age is consistently seen as a robust factor in the acquisition of L2 pronunciation (Flege, 1991; Flege et al., 1995; Flege et al., 1999; Tsukada et al., 2005). Both L2 input and AOA are factors of interest in the context of this study, because recruited participants appear to vary quite drastically in the amount of L2 input and AOA, despite coming from similar classroom settings.

2.2.3 L2 Acquisition of Onset f0

In regard to the second language acquisition of onset f0, many studies have been done with Korean-English bilinguals (Kang and Guion, 2006; Lee & Iverson, 2011) and second language learners of Korean (Chang, 2009), as onset f0 is one of the primary acoustic cues to a three-way laryngeal distinction Korean. Although none of these studies appear to consider L2 input as a factor of native-like onset f0 distinction, Kang and Guion (2006) examine the effect of AOA on onset f0 production. Similar to the AOA results in L2 production of VOT, this study found that early Korean-English bilinguals out-performed late Korean-English bilinguals in their ability to distinguish and produce stops with native-like onset f0 values. Ultimately showing that the earlier the learner begins acquiring the language, the more success they will have with onset f0 production. However, although the previous research is helpful in regard to the L2 acquisition of onset f0 as a whole, as all of the literature is on Korean, it is challenging to make comparisons to the present study's population. It is not anticipated that the experimental group of this study will perform the same as those in the Korean studies because of the difference of onset f0's cue status in Korean vs. English/French (primary vs. secondary, respectively).

2.3.4 Phonetic Drift in the L1

In Weinreich (1953), transfer was defined as "… those instances of deviation from the norms of either language which occur in the speech of bilinguals as a result of their familiarity with more than one language." Although many considered transfer to be unidirectional due to the widespread belief that the L1 could not be altered due to the maturation of the brain, the definition itself suggests that transfer is in fact bidirectional. That is, while the L1 can affect the L2, the L2 can also have an effect on the L1. In the literature, many terms have been used to refer to the phenomena of the L2 influencing the learners L1, including but not limited to, "back transfer", "attrition", and "reverse interference." For the sake of this study, Chang (2012)'s term "phonetic drift" will be used for the effect of L2 phonetic features on L1. The idea of phonetic drift was discussed in Selishchev (1925), but significant work on the topic has been done since, especially in regard to L2 learners of advanced proficiency (Flege 1987; Flege 2002; Flege 2007). Flege (1987), for example, analyzed English-French and French-English bilinguals' production of VOT and compared it to monolingual norms. The study found that for both experimental groups, French [-voice] VOT was longer than the monolingual French controls, and English [-voice] VOT was shorter than the monolingual English controls, ultimately showing that in both experimental groups the L2 had begun to interfere with the production of [-voice] VOT in the L1. Although most studies on phonetic drift have examined relatively advanced L2 learners, recently it has been suggested that beginner learners might also experience phonetic drift, especially when in a complete immersion environment (Chang 2012; Chang 2013). With this in mind, this study aims to explore the possibility of phonetic drift in native speakers of English acquiring French in classroom setting.

2.4 Research Questions

With the previously mentioned literature and background in mind, the following study aims to explore the following four questions:

1. How do American learners of French use VOT to realize French voicing categories?
2. How do American learners of French use onset f0 to realize French voicing categories?
3. What role do individual differences in terms of AOA and L2 input play in the acquisition of acoustic cues to voicing?

4. Is there a phonetic drift occurring in American learners of French and if so, does it apply to both VOT and onset f0?

2.5 Hypotheses

Based on the previous literature, the following hypotheses were proposed:

1. Learners' French [-voice] stops will be produced with shorter VOTs than their English [-voice] stops.
2. Learners' French [+voice] stops will occur with higher frequency as well as longer duration of prevoicing than English [+voice] stops.
3. Learners' French [+voice] stops will be produced with lowered onset.
4. Learners' French [-voice] stops will be produced with raised onset f0 if incorrectly realized with long lag VOT. If correctly realized with short lag VOT, a lower onset f0 may be observed, under the effect of English.
5. Learners of French will vary in their production of both VOT and onset f0, with those with a lower age of acquisition and those with larger amounts of L2 input producing more "French-like" acoustic values.
6. Learners who were more successful in realizing one phonological voicing category (e.g. [+voice] in French will also be more successful in realizing another category (e.g. [-voice])
7. When comparing the Learners (English) production with the monolingual English speakers, their VOT duration or their onset f0 values will be significantly different, showing evidence of phonetic drift.

CHAPTER 3: METHODOLOGY

3.1 Participants

3.1.1 Experimental Group

The experimental group consisted of 23 native speakers of Midwestern American English (16 female, 7 males, mean age of 19.96, ranging from 18 to 26 years of age) who at the time of the experiment were learning French as a second language. Participants ranged in proficiency, as determined by level of course they were enrolled in at the time of research. Only students enrolled in FRE 201 (third semester French) or a higher level French course were recruited. The average length of French study across all participants was 7.11 years (ranging from 2 years to 11 years) and a majority of the participants indicated that they learned French primarily through classroom instruction. The average age of onset of L2 study was 12.3 years old, with the youngest being 2 years old (this participant did not indicate that they were a simultaneous bilingual, they were exposed to French as a second language at a young age) and the oldest was 18 years old. Eighteen of the participants indicated that they had visited and/or resided in a French speaking country for an average of 6.54 months (ranging from 5 days to 5 years), with Paris, France being the most common location. Participants were also asked to self-rate their speaking, listening, writing, reading, and grammar fluency in French, in addition to their “strength of foreign accent” as indicator of pronunciation accuracy. Proficiency in these areas was rated on a 7-step Likert scale (1 indicating “very poor” and 7 “native-like” proficiency). Foreign accent was scored on a 6-point Likert scale (1 indicating “very strong” and 6 indicating “no accent”). The mean, median, and range of self-rated proficiency and accentedness across participants is presented in Table 2. Majority of the values are around 5 (“very good”), with reading fluency as the highest value and speaking fluency as the lowest one. A relatively high value of accentendness (> 3) confirms that these learners estimated their pronunciation and general speaking ability in French lower than their reading and writing abilities.

Table 2. Self-rated judgement scores as indicated in the Language background questionnaire

	Mean	Median	Range
Speaking fluency	4.41	5	4
Listening fluency	5.11	5	4
Writing fluency	5	5	2
Reading fluency	5.22	6	5
Grammar fluency	4.52	5	4
Strength of foreign accent[1]	3.43	4	4

Participants were also asked to estimate, in terms of hours per week, how often they used French in the following contexts: speaking to a spouse/partner, speaking to other family members, speaking to friends, speaking to classmates, speaking to co-workers, listening to the radio/watching TV, reading for fun, reading for work, reading on the internet, writing emails to friends, and writing articles/papers. The mean, median, and range of these values for these categories are presented in Table 3 (speaking) and Table 4 (non-speaking oriented activities.)

Table 3. Estimations of time spent speaking French with others as indicated in the language background questionnaire (hrs/week).

	Mean	Median	Range
Speaking to a spouse/partner	0.04	0	1
Speaking to other family members	0.24	0	2
Speaking to friends	0.43	0	2
Speaking to classmates	2.92	3	5.26
Speaking to co-workers	0	0	0
Total hours speaking	3.64	3	7

[1] Strength of foreign accent was rated on a Likert scale from 1-6, differing from fluency scores, which were rated on a Likert scale from 1-7.

Table 4. Estimations of time spent engaging in non-speaking-oriented activities in French as indicated in the language background questionnaire (hrs/week)

	Mean	Median	Range
Listening to the radio/watching TV	0.70	0.5	0.5
Reading for fun	0.26	0	0
Reading for work	0.96	0	0
Reading on the internet	0.72	0.5	0.5
Writing emails to friends	0.33	0	0
Writing articles/papers	0.76	0	0
Total hours working	3.72	3	10

Based on this relatively low distribution of average French use outside of the classroom, in addition to the self-indicated judgements that the majority of their French learning took place in the classroom, it is reasonable to conclude that the majority of French language acquisition was limited to a formal classroom setting.

All participants identified English as their first language, and all spent the majority of their lives in Midwestern American towns. Out of the 23 participants, four participants had at least one parent who was a non-native speaker of English, but only one participant reported speaking a language other than English at home (Swiss German). Twelve participants indicated that they had studied an additional language besides French. The majority of the additional languages studied were Indo-European languages (Spanish and German, mostly) and the average length of study was 4.83 years, ranging from 4 months to 26 years. Three of the participants were recruited in a French phonetics class and one of the participants indicated that they studied linguistics. Participants did not report any history of speech, hearing, or language disability. All participants were recorded in the Phonetics and Phonology Lab at Purdue University in West Lafayette, Indiana. All participants received either monetary payment or extra course credit for their time.

3.1.2 Control Group

The control group[2] consisted of 32 monolingual speakers of American English (16 males, 16 females, mean age of 24.94 years, with a range of ages from 20 to 32 years). All participants indicated that English was their first language, and all spent the majority of their lives in America. None of the control group participants indicated a history of speech, hearing, or language disability.

3.2 Materials

3.2.1 French Speech Materials

As frequency and familiarity have been shown to affect the outcome of speech production tasks (Connine et al, 1990; Pluymaekers et al, 2005), French words (stimuli and fillers) were compiled based on the frequency score and the familiarity score for each word, as determined by the Université Savoie Mont Blanc *Lexique* frequency database (135,000 words), and estimations provided by one native French speaker, respectively. An additional familiarity ranking was completed post hoc, provided by an L2 speaker of French with American English L1 background. All familiarity scores were provided on a 5-point Likert scale (1 being "I never use this word" and 5 being "I use this word very frequently") The words (ortho), their IPA transcription (IPA), translation (trans), average frequency[3] (freq), familiarity by an L2 learner (famL2), and familiarity by a native French speaker (famL1) are presented in Table 5.

[2] Control group data was collected in a previous study. See Shultz (2011) for complete details.
[3] Lexique frequency database pulls frequency from films and books, Table 5 averages the two corpus categories.

Table 5. Frequency and familiarity scores of French speech materials

Target Words

Ortho	*IPA*	*Trans*	*Freq*	*FamL2*	*FamL1*	*Ortho*	*IPA*	*Trans*	*Freq*	*FamL2*	*FamL1*
pile	/pil/	battery (nf)	22.88	4	4	bile	/bil/	bile (nf)	3.67	1	2
piller	/pijɛ/	to plunder (vtr)	5.22	1	1	billet	/bijɛ/	ticket (nm)	55.29	5	5
pêche	/pɛʃ/	peach (nf)	25.67	5	4	bêche	/bɛʃ/	spade (nf)	2.03	2	3
poisson	/pwasɔ̃/	fish (nm)	54.93	5	5	boisson	/bwasɔ̃/	drink (nf)	12.72	5	5
Avg.			21.175	3.75	3.5	Avg.			18.22	3.25	3.75

Non-target Words

Ortho	*IPA*	*Trans*	*Freq*	*FamL2*	*Ortho*	*IPA*	*Trans*	*Freq*	*FamL2*
faire	/fɛʁ/	to do (vtr)	4608.39	5	guerre	/gɛʁ/	war (nf)	281.93	4
chaud	/ʃo/	hot (adj)	73.52	5	faux	/fo/	false (adj)	97.34	5
quoi	/kwa/	what (pron)	331.29	5	doit	/dwa/	must (vm)	1357.55	5
corps	/kɔʁ/	body (nm)	365.25	5	fort	/fɔʁ/	strong (adj)	192.34	5
donne	/dɔn/	give (vtr)	664	5	tonne	/tɔn/	metric ton (nf)	9.4	3
queue	/kø/	line (nf)	47.46	4	feux	/fø/	lights (nmp)	131.24	3
goutte	/gut/	drop (nf)	33.82	2	doute	/dut/	doubt (nm)	121.91	3
doter	/dɔte/	provide (vtr)	3.56	3	coté	/kɔte/	popular (adj)	3.97	2

French stimuli consisted of four monomorphemic minimal pairs that differed in the voicing of bilabial stop word-initially (/b/ or /p/). Minimal pairs were used to control for the phonetic environment. Three different vowels, /i/, /ɛ/ and /a/ were used across minimal pairs. These vowels were chosen due to their similarity to the vowels used in the English stimuli of the control group: /æ/, /ɛ/, /i/, and /ɪ/. (Vowels /æ/ and /ɪ/ are not found in French vowel inventory and the closest vowels are /a/ and /i/). The majority of the presented stimuli were judged to be highly familiar by both a native speaker of French and an L2 speaker of French. The stimuli were also examined in terms of their frequency. The mean familiarity for all 8 stimuli (on a scale from 1 to 5, 1 being completely unrecognizable and 5 representing a word that is used very frequently) was 3.6, with the lowest familiarity ranking of a 1 for the word *piller* (to pillage/loot). Additionally, the mean frequency of the stimuli was 22.8 words per million, ranging from 2.02 (*bêche*) to 55.28 (*billet*). Voiceless and voiced stimuli were on average of comparable frequency and familiarity (Table 6). Despite the low frequency and familiarity of some of the chosen stimuli, participants were not anticipated to have difficulties with their pronunciation given their straightforward orthography.

Table 6. Frequency and familiarity difference between /p/ and /b/ stimuli[4]

Minimal pair	Freq Diff	FamL2 Diff	FamL1 Diff
pile/bile	19.21	3	2
piller/billet	-50.07	-4	-4
pêche/bêche	23.64	3	1
poisson/boisson	42.21	0	0

The list of French stimuli also contained 16 distractor items. These words were also minimal pairs and had a similar structure to the stimulus words. Fillers words were chosen because they did not contain bilabial stops in word-initial position. Segments included [+voice] and [-voice] velar/dental stops and fricatives. The distractor items were not checked for familiarity, but the average frequency was considerably higher (520 words/million) than that of the stimuli words due in part to a pair of extremely frequency words: *faire* (4608 words/million) and *doit* (1357 words/million). The remaining filler items (without *faire* and *doit*) had an average frequency of 168 words/million.

3.2.2 English Stimuli Materials

English words were chosen based on frequency and familiarity scores (stimuli taken from Shultz, 2011). Both frequency and familiarity scores for each word were compiled from the Washington University Speech and Hearing Lab Neighborhood Database. Table 7 (modified from Shultz, 2011), shows the words (ortho), IPA transcription (IPA), frequency (freq), lexical frequency (LFreq), and familiarity (fam) of the stimuli and filler words.

Table 7. Frequency and familiarity scores of English speech materials

Target Words

Ortho	*IPA*	*Freq*	*LFreq*	*Fam*	*Ortho*	*IPA*	*Freq*	*LFreq*	*Fam*
beat	/bit/	18	2.26	7	peat	/pit/	35	2.54	7
bit	/bɪt/	20	2.30	7	pit	/pɪt/	8	1.90	7
bet	/bɛt/	68	2.83	7	pet	/pɛt/	23	2.36	7
bat	/bæt/	101	3.00	7	pat	/pæt/	14	2.15	7

Non-target Words

Ortho	*IPA*	*Freq*	*LFreq*	*Fam*	*Ortho*	*IPA*	*Freq*	*LFreq*	*Fam*
fig	/fɪg/	72	2.88	6.75	dig	/dɪg/	10	2	6.92
fit	/fɪt/	75	2.88	7	kit	/kɪt/	2	1.30	6.75
heap	/hip/	14	2.15	6.92	keep	/kip/	264	3.42	7
feed	/fid/	123	3.09	7	deed	/did/	8	1.90	7
fat	/fæt/	60	2.78	7	cat	/kæt/	23	2.36	7
head	/hɛd/	424	3.63	7	dead	/dɛd/	174	3.24	7
hay	/heɪ/	19	2.28	7	day	/deɪ/	686	3.84	7
hot	/het/	130	3.11	7	cot	/cet/	1	1	7

The English stimuli was identical in structure to that of the French stimuli (monomorphemic, minimal pairs which contrasted in the word-initial bilabial stop, /b/ or /p/). All target words were of similar frequency to the French stimuli (36 words per million) and high familiarity. English stimuli contained four vowels, /æ/, /ɛ/, /i/, and /ɪ/, all front vowels. Additionally, eight filler minimal pairs were also included. The words differed from the English stimuli in that they were either fricative initial or non-bilabial stop initial. The distractor words were of comparable frequency to the target words.

3.3 Production Task

Data elicitation was performed in a sound-proof room located in the Phonetics and Phonology lab at Purdue University using written stimuli. Data collection was conducted in one-hour sessions with optional breaks to avoid fatigue effects. After receiving general instructions, participants entered the sound-proof room and were instructed to read a priming text (Little Red Riding Hood/Le petit chaperon rouge) in either English or French depending on which language they were randomly assigned to start with. The order in which English and French reading tasks were completed was counterbalanced across participants. Following the priming text, a computer screen (Dell/Windows XP computer) presented each word (stimulus or filler), one at a time using an E-Prime interface (Scneider, Eschman, & Zuccolotto, 2002). Words were shown in 48-point, Times New Roman font and stayed on the screen for 2 sec. After each word disappeared, a blank screen was presented for 500 ms. Participants were asked to read the words into the microphone in their normal speaking voice. The set of 8 stimuli and 16 distractor items were presented three times to each participant randomized for every presentation, resulting in a total of 24 experimental items elicited from each participant. Between blocks, participants were presented with the option to take a short break. After completing the first part of the experiment, participants were given a break and then repeated the task in the other language (starting with the priming text).

As speaking rate has been shown to influence VOT duration (Volaitis & Miller, 1992), the timing of the presentation was chosen in order to control and normalize the speaking rate of each participant's speech, creating more uniform experimental conditions. Additionally, presentation of individual words aided in controlling the participant's intonation, encouraging participants to pronounce each word with the same falling pitch contour. Presentation of the stimuli in isolation also forced a complete intonational phrase, with the prosodic boundary before and after each stimulus.

Participants were recorded using an ART Tube MP Project Series preamplifier and an Audio-Technica (AE4100) unidirectional cardioid dynamic microphone. Audio was captured using Audacity at a 44.1 kHz sampling rate and saved in .wav format. Recording sessions lasted approximately 10-15 minutes per language session, and 20-30 minutes total per participant. Following the completion of data elicitation, participants were instructed to fill in a language background questionnaire. A language background questionnaire created by the researchers was used rather than a pre-existing questionnaire so that certain qualities and characteristics could be pinpointed when analyzing the production data. The questionnaire addressed biological characteristics including age, disability, and sex, as well as various language characteristics that could affect speech production like age of L2 acquisition, time spent in a French-speaking country, self-rated accent, etc. The questionnaire in its entirety is reproduced in Appendix A.

The control group of monolingual native speakers of English completed a comparable task (in English only) in similar experimental settings (see Shultz, 2011 for full details)[5].

3.4 Analysis

In order to analyze VOT and onset f0 of target words, data was annotated in Praat version 6.0.36. VOT was marked from the release of the stop to the onset of voicing. To measure onset f0, pitch measurements were taken using a Praat autocorrelation pitch tracking algorithm. Pitch was measured at the first point where the algorithm detected periodicity, starting from the offset of VOT portion of the stop. Following the extraction of the data, all pitch values were examined for outliers and manually corrected if necessary. Onset f0 was then normalized using the formula, *12 ln(x/individual mean onset f0)ln 2* in order to allow comparisons across sexes. Normalized onset f0 is centered around each speaker's mean (0) on a log scale. Values above 0 indicated higher than average pitch, values below 0 indicated lower than average pitch. Statistical analysis was conducted in IBM SPSS Statistics Version 24. A linear mixed model was conducted to assess the effects of voicing and language (English or French) on VOT duration and onset f0 of L2 learners

[5] All data from Shultz (2011) was used with permission from the author.

of French and monolingual controls. In the model, either VOT duration or onset f0 were used as dependent variables. Hybrid voicing (four levels: prevoiced [+voice], short lag [+voice], short lag [-voice], and long lag [+voice]) and Language (two levels: English vs. French) or Learner status (two levels: monolingual speakers vs. learners of French) were used as fixed factors. Hybrid voicing is a factor which combines phonological voicing specification of the stop and its VOT type into a four-way distinction. Such an approach was chosen because onset f0 could potentially be affected by both the phonological voicing and the VOT category of the stop. However, this also means stops are divided into four levels based on VOT duration, and therefore a main effect of Hybrid voicing on VOT measurements is to be expected and the significance of this effect is uninformative. It is important to note that the interactions, not the main effect, are of interest in this study. For example, an interaction between Hybrid voicing and Language in the analysis of onset f0 would indicate that the four categories of stops were realized with different onset f0 depending on Language.

CHAPTER 4: RESULTS

4.1 Speech Production

4.1.1 Production Data

Figure 5 shows a plot of the VOT duration and onset f0 values for each stimulus in the production task with distinction between the experimental group, French learners speaking English and French learners speaking French, and the control group, monolingual English speakers speaking English. There was a total of 48 target words spoken by each of the 23 experiment participants (24 English and 24 French), and 40 words spoken by each of the 30 control participants. Four items across experimental and control groups were dropped due to incorrect pronunciation of the stimuli. In total, the data set contained 2,305 words. While the prevoiced and long lag productions appear to have a large range of VOT values, short lag productions are in a tight cluster.

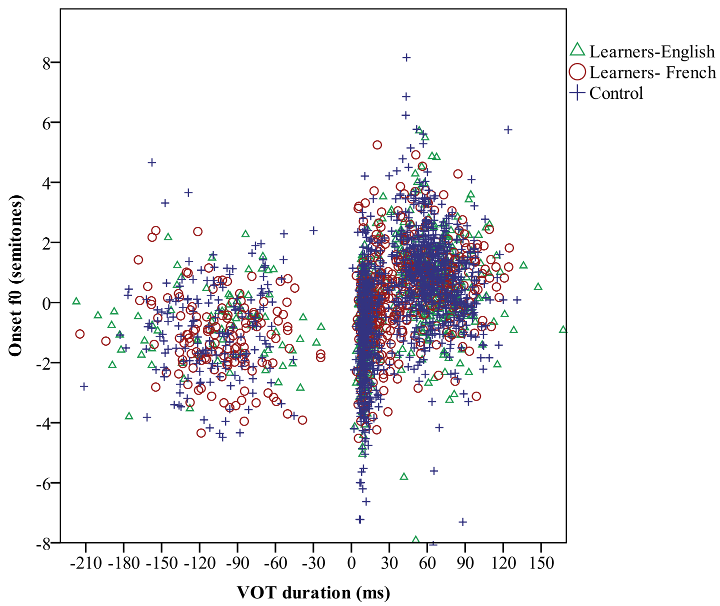

Figure 5. VOT duration (ms) vs. onset f0 (semitones)

4.1.2 VOT Production

Since ultimately the effects of both phonological voicing and VOT category on the realization of onset f0 were of interest, all stop productions were categorized into one of the four categories according to their phonological specification and VOT duration ('hybrid' voicing): prevoiced [+voice], short lag [+voice], short lag [-voice], and long lag [-voice]. In order to construct these categories, VOTs below 40 ms were considered 'short lag', those above 40 ms in duration were considered long lag. VOT below 0 ms indicated prevoicing. Table 8 shows the means and standard deviations for the control and experimental groups for each hybrid voicing category.

Table 8. VOT duration means (ms) across groups in a hybrid voicing context

	Prevoiced [+voice]		Short lag [+voice]		Short lag [-voice][6]		Long lag [-voice]	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Controls	-96.45	57.58	12.15	5.19	33.90	4.83	66.87	16.46
Learners (English)	-102.34	54.16	11.37	4.35	31.37	7.90	69.93	18.29
Learners (French)	-96.92	46.45	15.58	7.76	25.80	8.58	67.40	29.07

Figure 6 shows the percentage of prevoiced and short lag tokens across the [+voice] category in all groups. It is evident in this figure that learners (English) and the control group are using roughly the same amount of prevoiced and short lag stops when aiming for English /b/. Both the learners (English) and the control group use more short lag (more than 2/3) than prevoiced stops within the [+voice] category. The learners (French) demonstrate a slightly higher percentage of prevoiced stops than the learners (English) and the control group. Learners also produced approximately equal numbers of prevoiced stops and short lag stops when aiming for French /b/. Figure 7 shows the percentage of short lag and long lag tokens across the [-voice] category in all

[6] In English, [-voice] short lag only essentially 'undershoots' and occurred only 22 times across the Learner (English) data and 49 times across the Control data.

groups. This figure shows that, as expected, learners (English) and the control group both use predominately long lag stops when aiming for English /p/. But also use a small number of short lag stops (< 40 ms according to the present working definition). When speaking French, the learners demonstrate a considerably higher proportion of short lag stops than in their own and controls' English speech, but still favor long lag as a dominant type.

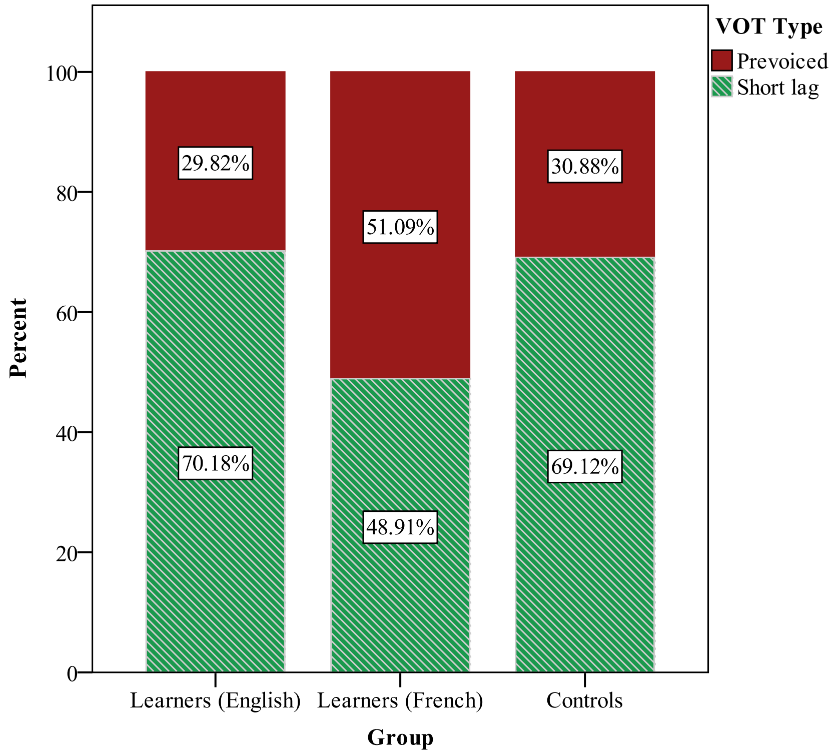

Figure 6. Percentage of prevoiced and short lag tokens across the [+voice] phonological category

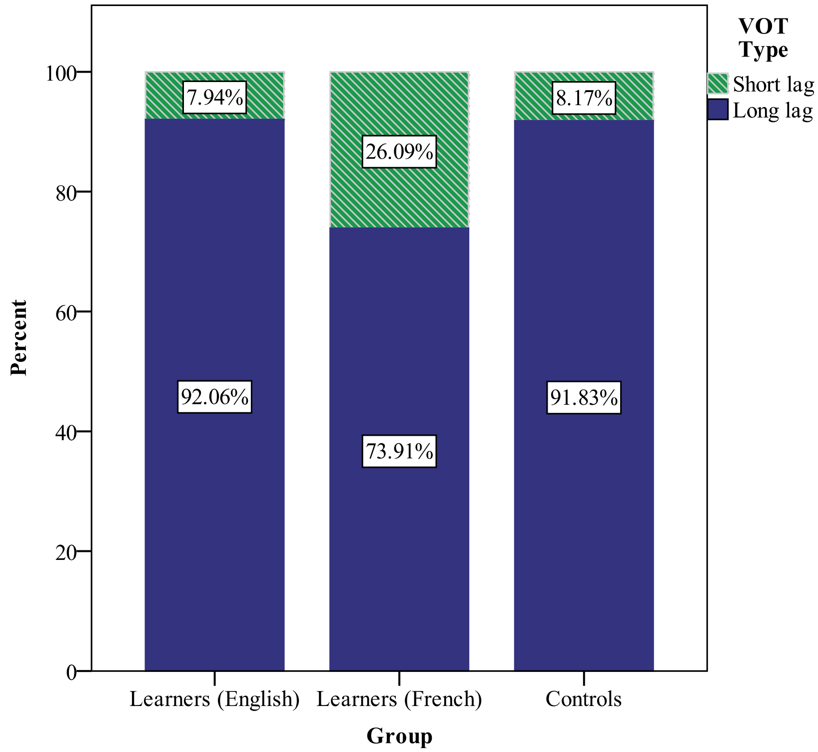

Figure 7. Percentage of short lag and long lag tokens across the [-voice] phonological category

4.1.2.1 Learners (English) vs. Learners (French)

To compare VOT production in learners speaking English vs. learners speaking French, a linear mixed model was conducted. VOT duration was used as a dependent variable. Hybrid voicing (four levels: prevoiced [+voice], short lag [+voice], short lag [-voice], and long lag [+voice]) and Language (two levels: English vs. French) were used as fixed factors. The random effect of subject was significant according to the Wald statistic ($p < 0.001$) and was included in the model as a random intercept (variance components covariance structure). The results showed a significant main effect of Hybrid voicing and a significant interaction between Language and Hybrid voicing: $F(3, 1087.156) = 1857.877$, $p < 0.001$, and $F(3, 1087.401) = 2.619$, $p = 0.05$, respectively. Pairwise comparisons with Sidak adjustment showed that VOT was significantly different across all four types of Hybrid voicing, in the following order: prevoiced [+voice] < short lag [+voice] < short lag [-voice] < long lag [+voice].

The significant interaction between Hybrid voicing and Language suggests that Hybrid voicing categories were not produced with the same VOT values across the two languages spoken by participants. To investigate the sources of this interaction further, four paired samples t-tests were conducted to compare mean VOT duration within each Hybrid voicing category as factor of Language. The results showed that only [+voice] short lag stops were produced with significantly different VOT values across the two languages: $t(133) = -4.377$, $p < 0.001$ (Figure 8). Specifically, [+voice] short lags had longer VOT in French than in English.

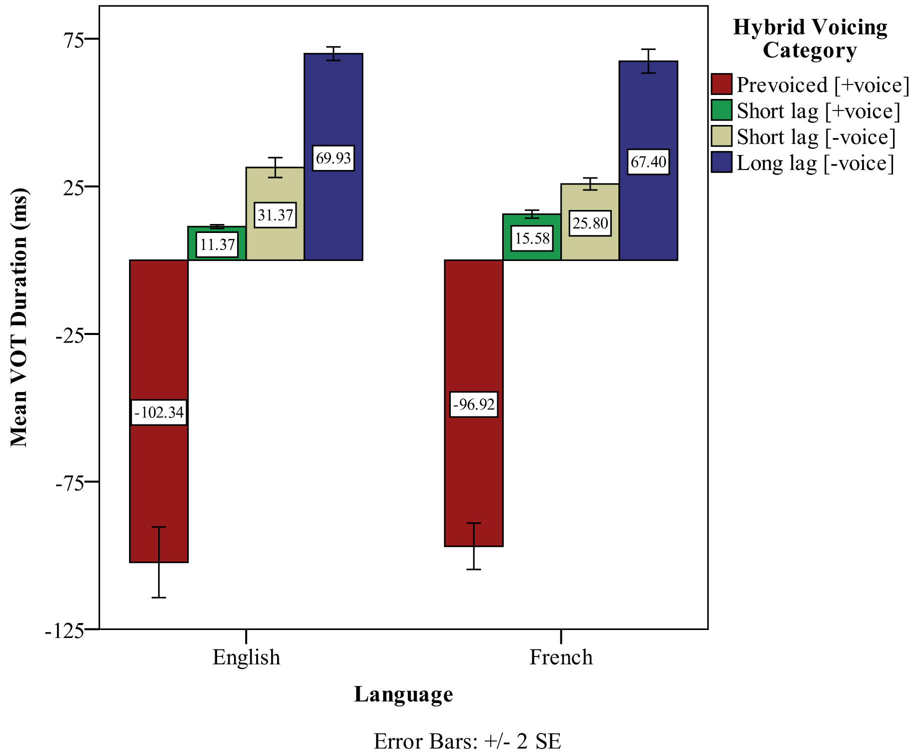

Figure 8. VOT duration in a hybrid voicing context across experimental groups

4.1.2.2 Controls vs. Learners (English)

To compare VOT production in monolingual English speakers to that of American learners of French, a linear mixed model was conducted. VOT duration was used as a dependent variable, Hybrid voicing (four levels: prevoiced [+voice], short lag [+voice], short lag [-voice], and long lag [+voice]) and Learner status (two levels: monolingual speakers vs. learners of French) were used as fixed factors. The random effect of subject was significant according to the Wald statistic ($p < 0.001$) and was included in the model as a random intercept (variance components covariance structure). The results showed a significant main effect of Hybrid voicing and a significant interaction between Learner status and Hybrid voicing: $F(3, 1737.681) = 2838.433$, $p < 0.001$ and $F(3, 1737.681) = 3.078$, $p < 0.05$, respectively. Pairwise comparisons with Sidak adjustment showed that VOT was significantly different across all four types of Hybrid voicing, in the following order: prevoiced [+voice] < short lag [+voice] < short lag [-voice] < long lag [+voice].

The significant interaction between Hybrid voicing and Learner status suggests Hybrid voicing categories were not produced with the same VOT values across the two groups of participants. To investigate the sources of this interaction further, four paired samples t-tests were conducted to compare mean VOT duration within each Hybrid voicing category as factor of Learner status. The results showed that only phonologically [-voice] long lag stops were significantly different between monolingual English speakers and learners of French: $t(245) = 2.056$, $p < 0.05$ (Figure 9). Specifically, [-voice] long lags were significantly longer when produced by learners of French than when produced by monolingual English speakers.

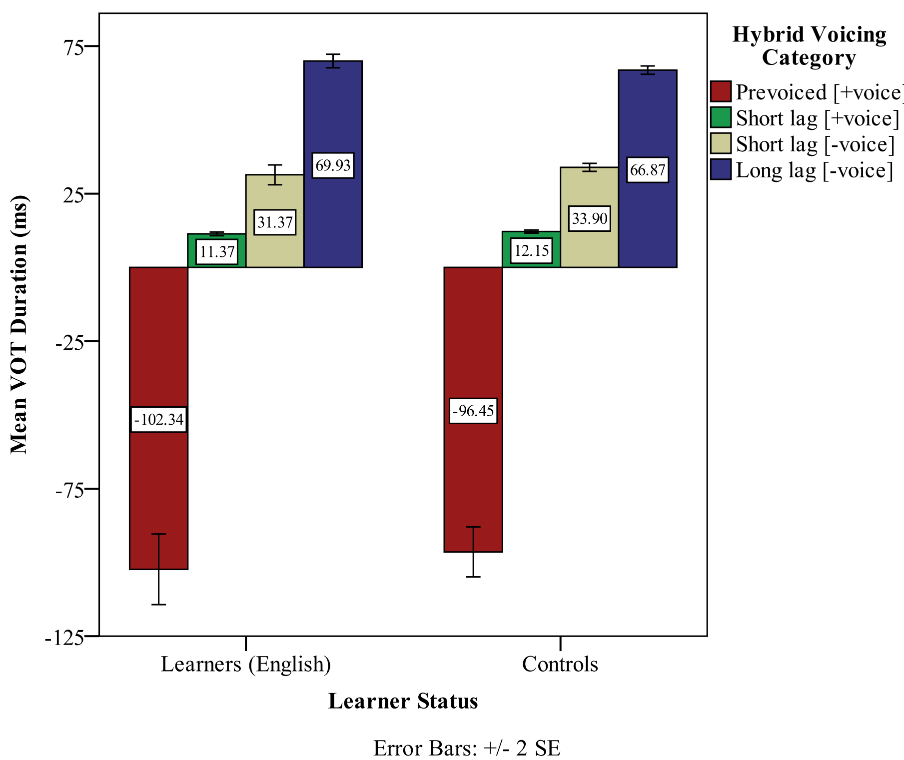

Figure 9. VOT duration in a hybrid voicing context across Learner status

4.1.3 Onset f0 Production

Table 9 depicts the means and standard deviations of onset f0 for the control and experimental groups in a hybrid voicing category (prevoiced [+voice], short lag [+voice], short lag [-voice], long lag [-voice]).

Table 9. Normalized onset f0 (semintones) across groups in a hybrid voicing context

	Prevoiced [+voice]		Short lag [+voice]		Short lag [-voice]		Long lag [-voice]	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Controls	-.99	1.81	-1.25	2.33	.97	1.65	-.83	2.25
Learners (English)	-.74	2.45	-1.09	1.77	1.37	1.51	.68	1.99
Learners (French)	-1.20	1.28	-.81	1.47	.70	1.49	.87	1.47

4.1.3.1 Learners (English) vs. Learners (French)

Onset f0 production in the English speech vs. French speech of American learners of French was examined via a linear mixed model with normalized onset f0 as the dependent variable. Language (French vs. English) and Hybrid voicing were used as fixed variables. The random effect of item was significant according to the Wald statistic ($p < 0.05$) and was included in the model as a random intercept (variance components covariance structure).

The results showed a significant main effect of Hybrid voicing, $F(3, 33.325) = 8.860$, $p < 0.001$, and a marginally significant interaction between Hybrid voicing and Language, $F(3, 33.325) = 2.877$, $p = 0.051$. Stops of contrasting phonological specification were significantly different from each other in terms of onset f0 (higher onset f0 after phonologically [-voice] stops than after the [+voice] ones) while different phonetic (VOT) realizations of the same phonological category were not distinguished via onset f0: prevoiced [+voice] = short lag [+voice] < short lag [-voice] = long lag [-voice].

A near-significant interaction between Hybrid voicing and Language indicates that participants tended to use onset f0 differently across the two languages they spoke to implement voicing distinctions. This was followed up with a series of paired-sample t-tests to examine the effect of Language on onset f0 within each Hybrid voicing category. The results demonstrated no significant differences (Figure 10).

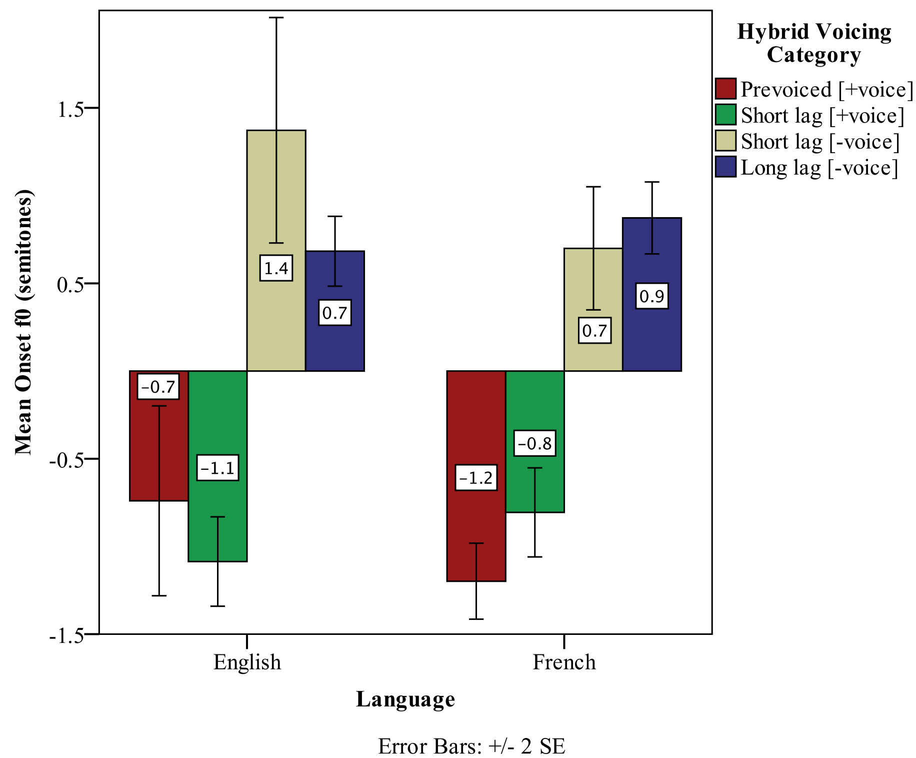

Figure 10. Onset f0 in a hybrid voicing context across experimental groups

4.1.3.2 Controls vs. Learners (English)

Onset f0 production in the English speech of monolingual speakers of English vs. learners of French was examined via a linear mixed model. Normalized onset f0 in semitones was used as a dependent variable in the model. Participants' Learner status and Hybrid voicing were used as fixed factors. The random effect of item was significant according to the Wald statistic ($p < 0.05$) and was included in the model as a random intercept (variance components covariance structure).

The results showed a significant main effect of Hybrid voicing, $F(3, 33.909) = 10.502$, $p < 0.001$. Pairwise comparisons with Sidak adjustment demonstrated that there were significant differences in onset f0 between [+voice] stops and [-voice] stops, but not between different VOT realizations of stops with the same phonological specification (e.g. prevoiced [+voice] and short lag [+voice] stops were not significantly different from each other). Onset f0 was significantly higher after [-voice] stop than after [+voice] stops. There was no significant interaction between Learner status and Hybrid voicing indicating that participants realized onset f0 the same way independently of their second language background (Figure 11).

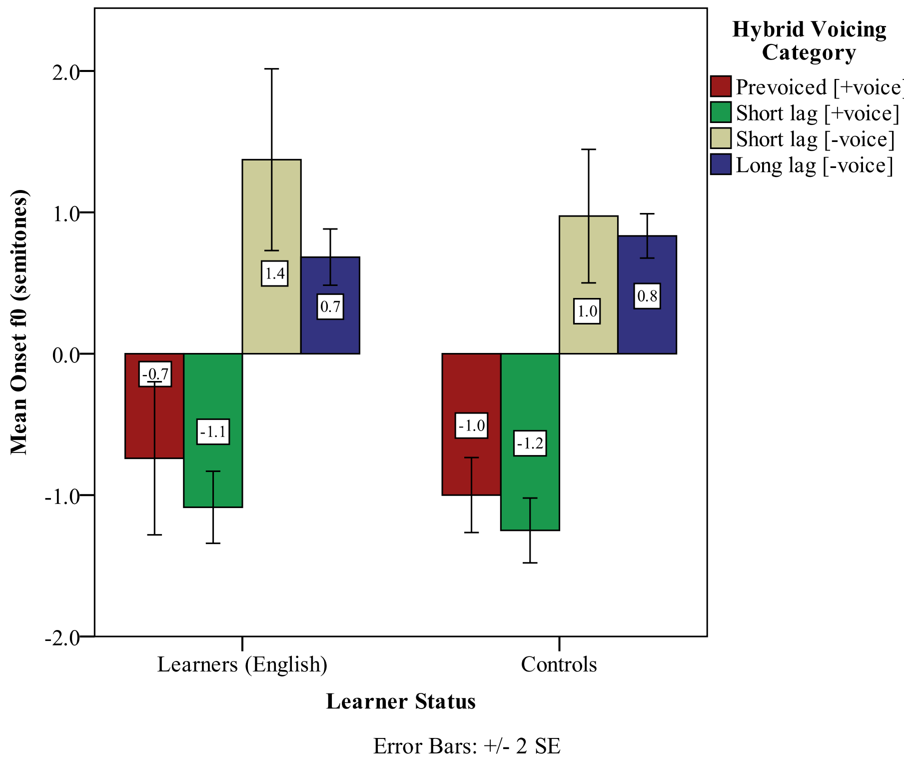

Figure 11. Onset f0 in a hybrid voicing context across Learner status

4.2 Individual Trends in Production

4.2.1 Trends in VOT Productions

The type of VOT produced by the learners speaking English and learners speaking French varied by individual participant. When analyzing the [+voice] category (Figure 12 and Figure 13), out of 23 total participants, 16 produced more prevoicing (69.57%) in French than in English, four produced less prevoicing (17.39%), and three produced approximately the same amount of prevoicing (13.04%) across their French and English productions. Out of 23 learners, only two produced no prevoicing whatsoever in their [+voice] French productions. One of them produced exclusively short lag in English, the other one produced prevoicing in English but not in French. This tendency to produce less prevoicing in French than in English was observed in four learners, each reducing their amount of prevoicing drastically in French compared to English. Another notable trend is that majority of participants who are most successful in prevoicing their French stops are the same ones who are producing a fair amount of prevoicing in their English speech (e.g. participant # 5, 8, 18, 22), although not without exception. Participant 9 presents the most drastic shift from English to French VOT type, producing all of their English [+voice] VOTs as short lag and all of their French VOTs as prevoiced.

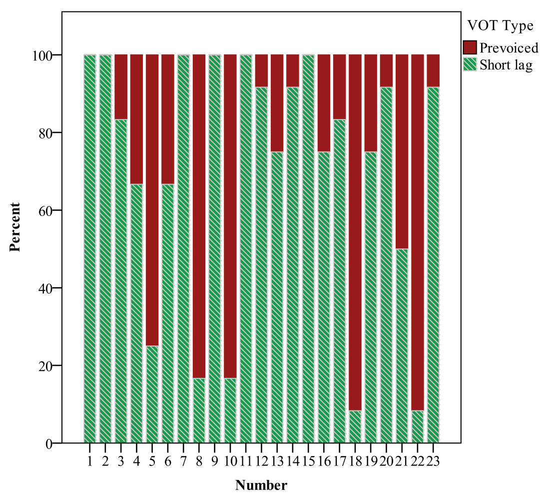

Figure 12. Percentage of prevoiced and short lag tokens across the [+voice] phonological category by Learners (English)

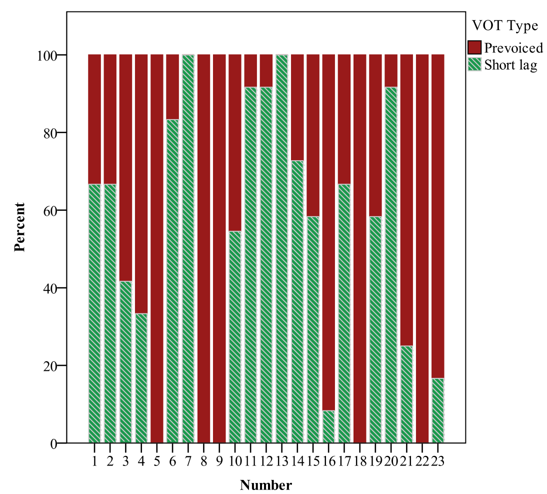

Figure 13. Percentage of prevoiced and short lag tokens across the [+voice] phonological category by Learners (French)

When looking at each learner's production of [-voice] VOT (Figure 14 and Figure 15) the most distinct difference from the [+voice] category is that no learner manages to produce only the target, short lag, in their French stops. Although 14/23 learners (60.87%) produce more short lag stops in their French than in their English, the highest percentage of short lag in a single learner is approximately 75%. Additionally, 2/23 (8.70%) produce fewer short lag stops in French than in English and 7/23 (30.43%) produce roughly the same amount of short lag stops in French and

English. The five learners who are able to completely produce prevoicing in their [+voice] French productions, do not appear to be any more or less successful than the other learners in [-voice] VOT production, suggesting that there isn't a correlation between success in [+voice] VOT and success in [-voice] VOT. In fact, the learner who appears to have the most success in their [-voice] (increasing their short lag production from 0% in English to 75% French), is one of the least successful at implementing the distinction between VOT types in their [+voice] stops (decreasing their prevoiced productions from 80% in English to 45% in French).

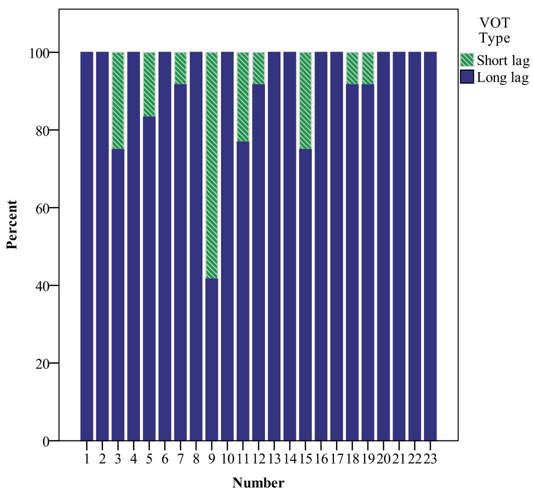

Figure 14. Percentage of prevoiced and short lag tokens across the [-voice] phonological category by Learners (English)

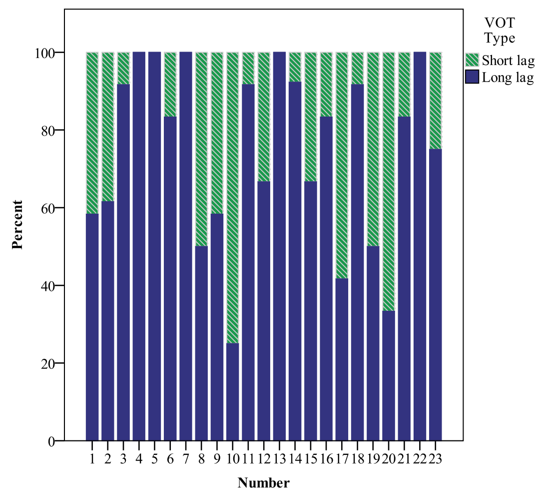

Figure 15. Percentage of prevoiced and short lag tokens across the [-voice] phonological category by Learners (French)

4.2.2 Trends in Onset f0 Production

As evident in Figure 10, learners clearly distinguish onset f0 across phonological voicing categories. That is, lower onset f0 for [+voice] and higher onset f0 for [-voice]. This is clear even in the learner's production of [+voice] and [-voice] short lags, despite belonging to the same VOT category. Figure 16 shows the individual variation in each learner's (French) [+voice] and [-voice] short lag onset f0 productions.

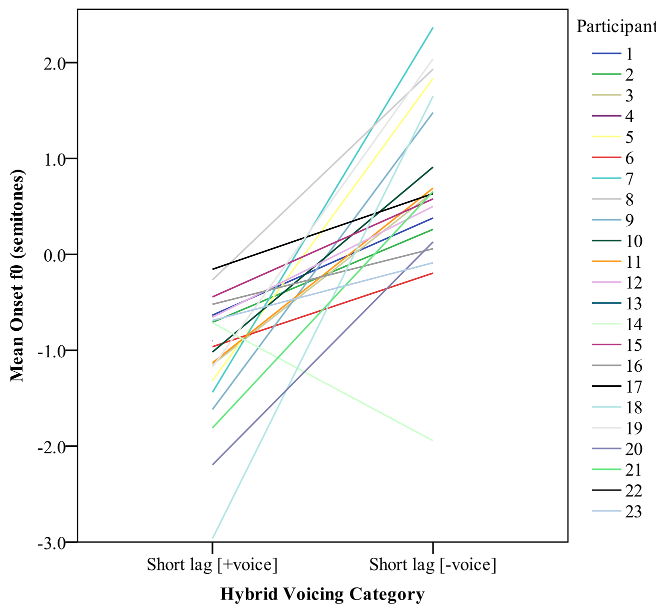

Figure 16. Individual variation in Learners (French) [+voice] and [-voice] short lag onset f0 production

As demonstrated in the figure above, when comparing French short lag productions across voicing categories, each learner varies. Although most of the learners raise their onset f0 in the [-voice] context, one learner (#14) appears to go the opposite way (higher [+voice] than [-voice]). There is also a great amount of variation in the slopes of each individual's onset f0 productions. While some appear to be making very large changes from [+voice] to [-voice] (this is especially seen in #18), others appear to make much more minor changes.

4.2.3 Individual Correlations Between VOT Duration and Speaker Background Characteristics

In order to explore the possible connection between speaker background characteristics, such as proficiency level in French, and the VOT production across the two languages, a number of Pearson correlations were performed. Average differences between learners' French and English VOTs (French - English) in each of the phonological voicing categories (hereafter referred to as VOT difference) were examined for correlations with various background characteristics reported by participants in the language background questionnaire. Significant correlations were found between Age of L2 Acquisition (AOA) and [+voice] VOT difference, as well as Total hours/week speaking French with others and VOT difference in [-voice] stops (marginal). There were no significant correlations between [+voice] VOT difference and Strength of accent, Length of time studying French, Length of time in a French-speaking country, Total proficiency score, Total hours/week speaking French with others, and Total hours/week engaging in non-speaking-oriented activities in French. Additionally, no significant correlations were found between [-voice] VOT difference and AOA, Strength of accent, Length of time studying French, Length of time in a French-speaking country, Total proficiency score, and Total hours/week engaging in non-speaking-oriented activities in French. Please see below for reports on the significant correlations found with VOT difference and Appendix D for the full report on all correlation analyses.

As shown in Figure 17, a significant positive correlation was found between AOA and [+voice] VOT difference: $r = .48$, $n = 23$, $p < 0.05$. As age of acquisition increases, so does the amount of VOT difference. Since the difference was calculated by subtracting English VOT from French, this trend demonstrates greater VOT values in French [+voice] stops than in English [+voice] stops for late learners. This result could be indicative of lower use of negative VOT and higher positive VOTs in French by late learners compared early learners. There was no significant correlation between AOA and [-voice] VOT difference.

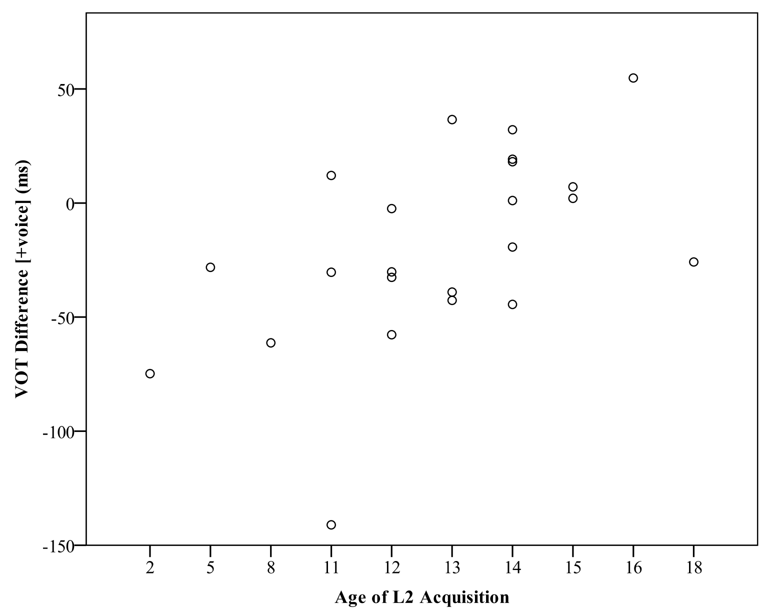

Figure 17. Pearson correlation between [+voice] VOT difference and AOA

As demonstrated in Figure 18, a marginal negative correlation was found between Total hours/week speaking French with others and VOT difference in [-voice] stops: $r = -.41$, $n = 23$, p

=.06. Participants who spent more time per week speaking French demonstrated lower VOT differences between French and English [-voice] stops, which suggests lower VOT values in French than in English for these speakers. This result is compatible with the interpretation that learners with more conversational practice produce shorter positive VOT in their French [-voice] stops. There was no significant correlation between hours speaking French in [+voice] VOT difference.

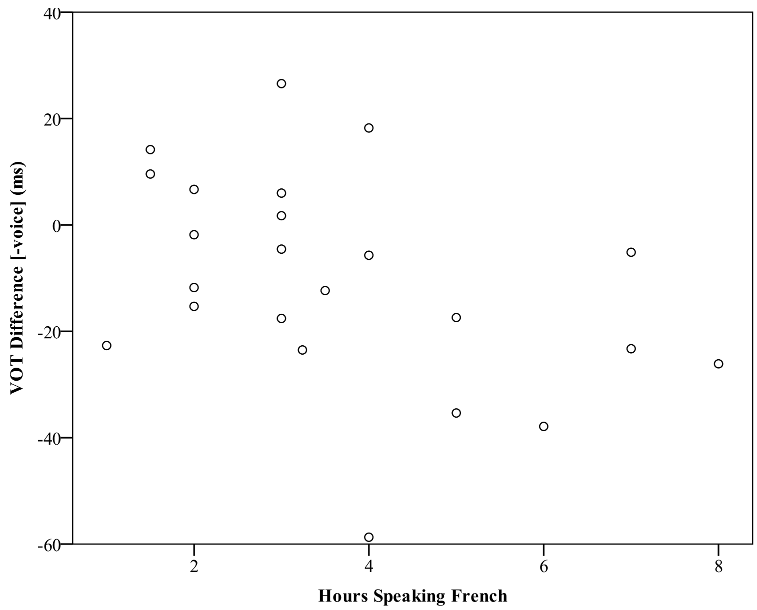

Figure 18. Pearson correlation between [-voice] VOT difference and Total hours/week speaking French with others

4.2.4 Individual Correlations Between Onset f0 and Speaker Background Characteristics

Like the individual learner trends in VOT production, effects of individual characteristics on f0 production were determined using Pearson Correlations that were conducted between the self-reported answers in the language background questionnaire and individual onset f0 results. The only significant correlations were detected for individual differences between French and English onset f0 ([+voice] and [-voice]) and Total hours/week speaking French. No significant correlations were found between both [+voice] and [-voice] onset difference and AOA, Strength of accent, Length of time studying French, Length of time in a French-speaking country, Total proficiency score, and Total hours/week engaging in non-speaking-oriented activities in French.

Please see below for reports on the significant correlations found with VOT difference and Appendix D for the full report on all correlations.

The correlation between Total hours/week speaking French and onset f0 difference was found in both [+voice] and [-voice] stops. Figure 19 shows the positive correlation between Total hours/week speaking French and the amount of difference between each learner's French and English onset f0 after [+voice] stops (French – English): $r = .59$, $n = 23$, $p < .01$. This result indicates that average onset f0 after [+voice] stops is higher in French compared to English for those learners who spend more time speaking French.

Figure 20 shows the significant negative correlation between Total hours/week speaking French with others and difference in onset f0 production in French vs. English after [-voice] stops: $r = -.62$, $n = 23$, $p < 0.01$. This trend suggests that in learners with more speaking practice, onset f0 after [-voice] stops in French is lower than in English. Given the disparate tendencies for onset f0 differences in [+voice] vs. [-voice] stops across French and English, these correlations cannot be explained by homogenous pitch raising or pitch lowering when speaking French for those with more speaking practice. Instead the trends seem to suggest that learners who speak more French produce less extreme f0 values as correlates of voicing in French compared to learners who speak French less frequently.

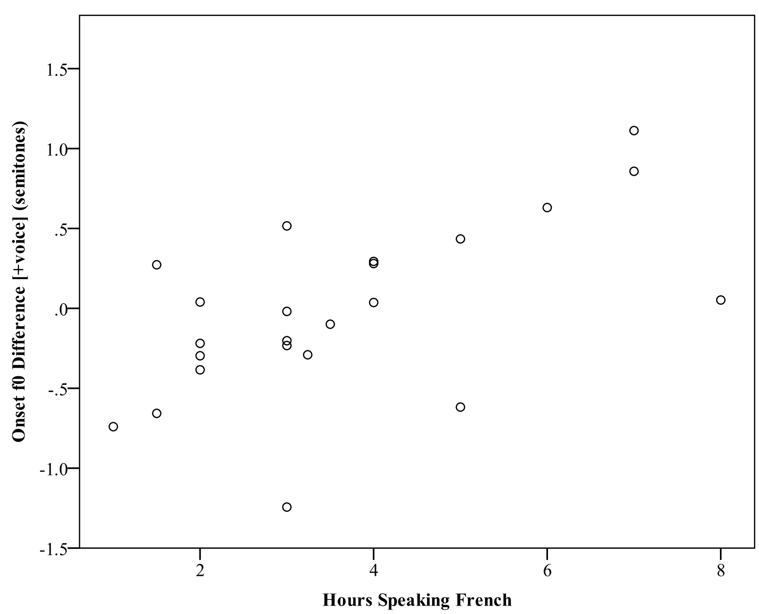

Figure 19. Pearson correlation between [+voice] onset f0 difference and Total hours/week speaking French with others

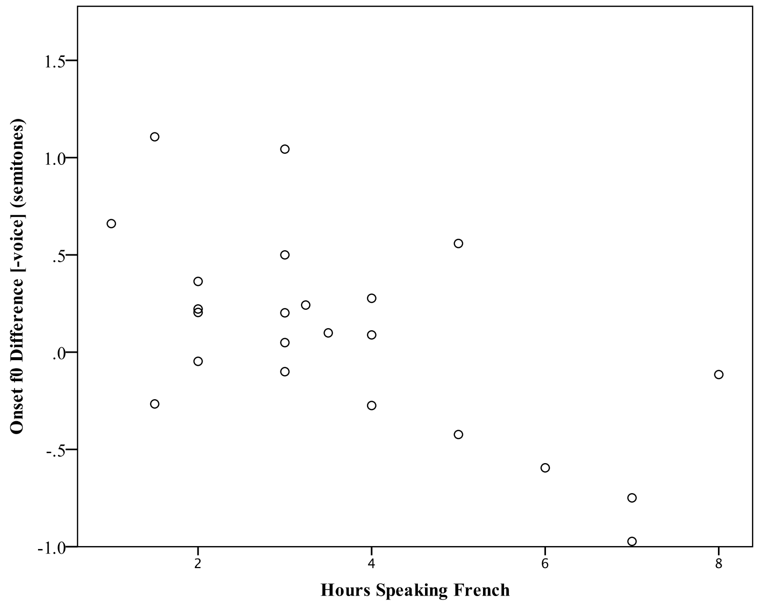

Figure 20. Pearson correlation between [-voice] onset f0 difference and Total hours/week speaking French with others

4.3 The Effect of Cognate Status on Learners' Production

As cognate status has been shown to effect L2 VOT production (Amengual, 2012), a post hoc analysis was done to determine if there was evidence of a cognate effect on French stimuli *pile* and *bile* (orthographic cognates with English). To investigate this potential effect, two separate paired samples t-tests were conducted to compare mean VOT duration of a cognate word with that of a non-cognate word. Since only two of the eight French stimuli words were considered cognates (138/552 tokens), cognate words were only compared to stimuli with the same voicing and following vowel to prevent a sample size issue when completing the t-test. That is, the mean VOT duration of *bile* (cognate) was compared to *billet* (non-cognate) and *pile* (cognate) was compared to *piller* (non-cognate). The results showed that both [+voice] and [-voice] VOT durations were significantly different between cognates and non-cognates ([+voice]: $t(137) = -8.432$, $p < .0001$; [-voice] $t(137) = -24.322$, $p < .0001$). Specifically, both the [+voice] and [-voice] cognates were significantly longer than their non-cognate counter parts (Figure 21).

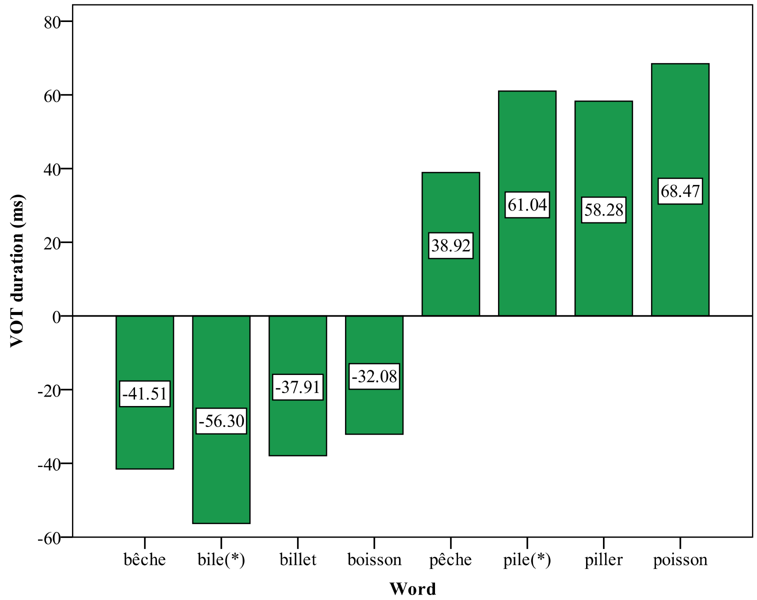

Figure 21. VOT duration across cognate status

Although there isn't any previous literature on how cognate status effects onset f0, two paired t-tests of a similar structure were completed. To investigate this potential effect, two separate paired samples t-tests were conducted to compare mean normalized onset f0 of cognate words with that of non-cognate words within stimuli of the same voicing and following vowel. The results showed that both [+voice] and [-voice], mean normalized onset f0 as significantly different between cognates and non-cognates ([+voice]: $t(137) = -19.436$, $p < .0001$; [-voice] $t(137) = 3.012$, $p < .001$). Specifically, both the [+voice] and [-voice] cognates were significantly lower than their non-cognate counterparts (Figure 22).

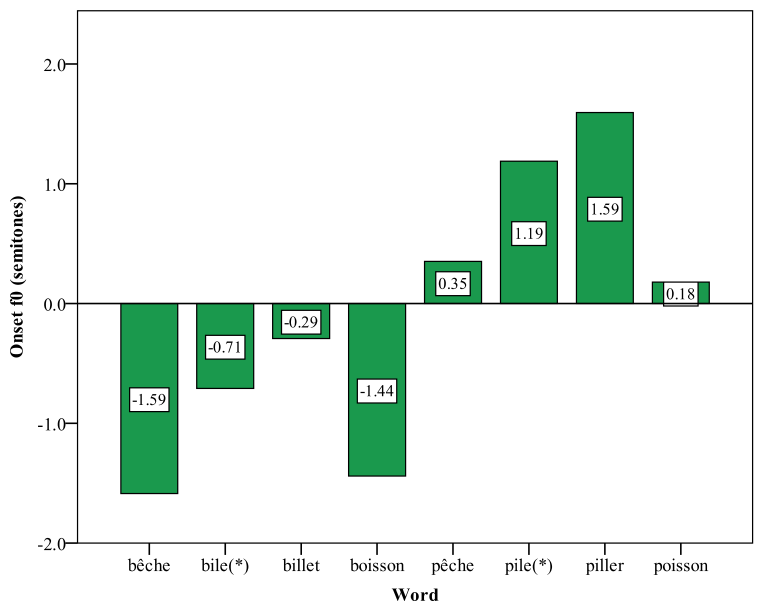

Figure 22. Onset f0 across cognate status

CHAPTER 5: DISCUSSION

5.1 Interpretations of VOT Production Results

5.1.1 Learners' VOT Production

With respect to the learners' VOT in English and French stops, it was predicted that French [-voice] stops would be produced with shorter VOTs than English [-voice] stops (Hypothesis 1). Additionally, it was predicted that French [+voice] stops would occur with higher frequency as well as longer duration of prevoicing than English [+voice] stops (Hypothesis 2). Frequency analysis indeed demonstrated that the number of short lag stops was higher in learners' French than English [-voice] productions, and prevoicing was also more frequent in learners' French speech. Additionally, analysis of VOT duration showed a significant interaction between Hybrid voicing and Language as predictors of VOT duration in learners of French. The interaction confirmed that voicing categories were not realized with equal VOT durations across the two languages. The prominent difference that likely contributed to this interaction is higher [+voice] short lag VOT in French compared to English.

In this case, French [+voice] stops erroneously produced as short lags by American learners are unexpectedly longer in terms of VOT than comparable English stops (that is, [+voice] short lags in English). It would be reasonable to expect that learners would strive to reduce positive VOT of French stops as much as possible even if prevoicing as such was not achieved, however the opposite is observed. The reason for this effect is unclear. To conclude, as a group, the learners are clearly making some attempt towards realizing French voicing categories with appropriate VOT values, but their productions are far from approaching native-like norms and are subject to strong influence of their first language.

Across individual participants, a fair amount of variability was observed in terms of modifying learners' VOT realization in French compared to English. Focusing on phonologically [+voice] stops, many learners were successful in increasing prevoicing in their French productions, especially those who demonstrated a tendency to prevoice in their English speech as well. A few reversals (less prevoicing in French than English) were also observed. With these results in mind, it is suggested the [+voice] VOT type distinction between English and French is relatively easy for learners to pick up on and implement in their speech. Although not all of the learners are producing the target VOT type exclusively in French, a large majority of them make noteworthy differences in their amount of prevoicing in English vs. French.

Comparing the individual patterns in the production of [+voice] stops with [-voice] stops, the differences are quite drastic. While majority of the participants were able to modify their [+voice] VOT in French in the target direction, success was less apparent in [-voice] stops. No participant was able to achieve 100% target productions in French [-voice] stops, and few achieved more than 50% success. On the other hand, reversals were rare too. Finally, comparing individual success in rendering French [-voice] and [+voice] stops, no consistency was observed. Ultimately, the data suggests that just because learners are able to produce the correct VOT distinction in a [+voice] context, does not mean that they are able to do so in the [-voice] context, and that these phonological categories are acquired separately by the learner, failing to support Hypothesis 6.

Individual results also suggest the [-voice] VOT category in French is more challenging for learners than the [+voice] VOT category. One possible explanation for this is that prevoiced and short lag stops are sufficiently different from each other acoustically for learners to be able to create a separate perceptual category for prevoiced stops as opposed short lag ones. Relating this assumption to the SLM (Flege, 1995), learners find the English/French [+voice] VOT difference more acoustically salient than the [-voice] VOT difference, which makes it easier for them to produce and perceive the non-native [+voice] category than the L2 [-voice] category. As the English and French [-voice] VOTs only differ their length (long lag and short lag, respectively), they are more likely to be assimilated to the same category, making them more challenging to perceive and produce. This explanation runs contrary to the fact that prevoicing-short lag difference is sub-phonemic in English word-initial [+voice] stops, while short lag-long lag difference spans a phonemic boundary. Thus, the results suggest that phonological structure of the L1 is not always fully determinative of the acquisition of L2 phonology.

An alternative, and more likely, explanation for this pattern is related to the familiarity of the VOT types as indicative of a particular phonological category to speakers of English. According to the present data, 17/23 learners (73.91%) produced some amount of prevoicing in their English word-initial [+voice] stops and 29.8% of all [+voice] English stops were prevoiced. [-voice] short lag [-voice] stops also occur in English but not in the word-initial position. Learners familiarity with prevoiced stops as instantiations of the [+voice] category in the word-initial position in English may have facilitated their acquisition in French.

5.2 Interpretations of Onset f0 Production Results

5.2.1 Learners' Onset f0 Production

As hypothesized (Hypothesis 3), onset f0 production was distributed as expected with lower onset f0 in [+voice] and higher onset f0 in [-voice] in both English and French, and phonological voicing categories were well distinguished via onset f0. This is evident in Figure 10, which demonstrates that in terms of onset f0, phonological division appears to matter more than phonetic division. These results are consistent with Kirby and Ladd (2015), which looked at the patterns of onset f0 in English, French, and Italian, and Dmitrieva et al. (2015), which found that when surveying Spanish and English, onset f0 was well-differentiated across phonological voicing categories. Thus, although learners' realization of VOT in French VOT was on average not very target-like, their onset f0 production in French was assigned as expected: lower onset f0 after [+voice] and higher onset f0 after [-voice]). These results are compatible with the possibility that learners are simply transferring both VOT and onset from their first language, English, into French, with VOT transfer being detrimental while f0 transfer is beneficial. However, since onset f0 was also realized correctly without VOT transfer, specifically on [-voice] French stops appropriately realized with short lag VOT, the results suggest that the learners were able to maintain the correct distribution of f0 values independently of VOT realization. That is, VOT and onset f0 as correlates of voicing are relatively independent of each other and appear to be manipulated separately by the learners. Moreover, the findings suggest that onset f0 is a more stable and reliable correlate of voicing in second language context, despite its status as a secondary voicing cue. Additionally, results of the correlation analysis are compatible with the possibility that less experienced learners may exaggerate onset f0 differences as a correlate of voicing in the second language compared to those with less speaking practice. This finding also suggests that when faced with not being able to use novel VOT categories to express voicing in their L2, learners may over-rely on onset f0. This observation is consistent with findings in Llanos et al (2013), which demonstrates that L2 learners rely on onset f0 in perception of voicing more than monolingual speakers do.

Additionally, it appears that when attempting to produce [+voice] in French and erroneously realizing it as short lag, learners raise their onset f0. This non-statistically significant tendency nevertheless suggests that learners are learning the association between high onset f0 and short lag VOT in French and this association emerges even when short lag is used as [+voice] instead of [-voice] category in French.

5.3 Correlation Results

5.3.1 Age of Acquisition

As demonstrated in Figure 17, there was a significant positive correlation between the learner's AOA and VOT difference. This result appears to show that the earlier the learner begins acquiring French, the greater the difference between their French and their English [+voice] VOT values, as partially hypothesized (Hypothesis 4). As French [+voice] is realized as prevoiced (a negative value) and English [+voice] is more commonly realized as short lag (a positive value) the greater French – English difference suggests that the learners are moving in the correct direction towards target French [+voice] VOT production. This finding is consistent with much of the previous L2 VOT research. For example, Flege (1991) proposed that the earlier the learner begins acquiring an L2, the more successful they were producing the correct VOT distinctions in their L2. Although an analogous correlation was not found for [-voice] in this study, this is likely due to the fact that learners were not as successful at realizing [-voice] French VOT.

5.3.2 Hours Speaking French

In both [-voice] VOT and onset f0, a correlation was found between the Hours/week speaking French with others and the difference learners made between their French and English acoustic productions. Similar to the correlation between [+voice] VOT differences and AOA, greater amount of speaking French per week correlated with smaller VOT differences between French and English [-voice] stops. (Figure 18). As English [-voice] VOT is realized as long lag and French is realized as short lag, the decrease in the French – English difference suggests that the learners are moving towards target French [-voice] production. Because the learners are speaking to others and therefore being spoken to in return, as hypothesized (Hypothesis 4) this finding is consistent with previous research (e.g., Flege & Eefting, 1988), demonstrating that more native-like L2 VOT productions are achieved as a function of the amount of L2 input. If French [-voice] stops are in in fact more challenging for learners, it makes sense that learners are more successful when they spend more time speaking the language.

For onset f0, a correlation between hours speaking French and differences between French and English f0 realization was found for both [+voice] and [-voice] stops. In [+voice] stops, speaking more French was correlated with a greater positive difference in French-English onset f0 (Figure 19). That is, average onset f0 after [+voice] stops is higher in French compared to English for those learners who spend more time speaking French. In [-voice] stops, Learners appear to be producing lower onset f0s in French than in English. As these correlations don't appear to be the cause of homogenous pitch raising or pitch lowering when those with more speaking practice produce French, it is suggested that learners who speak more frequently in the target language produce less extreme onset f0 values than those who speak French less frequently. This is compatible with the idea that beginners are more skilled at using onset f0, rather than VOT, at signaling voicing in their second language, and that they possibly exaggerate this property initially. However, as the learners use the language more frequently, and ultimately become more experienced, the exaggeration is toned down.

5.4 Phonetic Drift

5.4.1 Phonetic Drift in VOT and Onset f0 Production

When analyzing the effect of phonetic drift on the learner's English productions, no evidence of L2 to L1 transfer was found statistically, ultimately failing to support Hypothesis 7. Learners (English) and monolingual speakers had nearly identical distribution of VOT categories in both [+voice] and [-voice] stops. If phonetic drift had occurred, a higher percentage of prevoiced stops would be observed for French learners [+voice] productions as well as higher percentage of short lag stops in learners (English) [-voice] productions when compared to the monolingual controls. No evidence of gradient effects of French of VOT duration in English were found either. With those results in mind, it is concluded that no phonetic drift occurred in these data.

While the literature (Chang, 2013) suggests that beginner learners can experience phonetic drift, it was only found in learners who were in a complete immersion environment. Based on the self-reported answers to the background questionnaire, although some of the learners in this study had been in immersion environments, many of them were only completely immersed for short periods of time (like in study abroad). Additionally, if the learners had been in a complete immersion environment, they had all been back for at least a semester. The combination of the lack of immersion and the distance from return, does not make it surprising that there wasn't any evidence of phonetic drift.

In the current analysis, there actually appears to be a divergence effect, the act of shifting two similar sounds in the L1/L2 away from each other. In these data, this occurs specifically in [-voice] long lag stops, where learners use longer [-voice] long lags than the monolingual controls. Since in previous literature divergence seems to be found mostly in highly proficient bilinguals (Flege & Eefting, 1986; 1987), especially those who begin learning their L2 at a young age, this finding was unexpected, as the participants in this study were intermediate L2 learners.

5.5 Limitations of the Present Study

5.5.1 Participants

A relatively small sample size of 23 participants is one of the limitations of the current study. A larger number of participants could allow for the calculation of more reliable statistical measures. It is likely that with more participants the near-significant interaction between Hybrid voicing and Language in the Learner's onset f0 productions might reach significance.

5.5.2 Stimuli

One of the limitations of this study was that two of the eight French stimuli used are orthographic cognates with English. They are as follows: *pile* and *bile.* When looking at the effects of cognates on VOT production in Spanish-English bilinguals, Amengual (2012) found that there was a significant effect of cognate status on the bilingual's Spanish productions. That is, bilinguals produced English cognates with more English-like VOTs than non-English cognates. In order to determine if VOT duration was affected by cognate status, a paired samples t-test was completed on the learner (French) data. The statistical tests indicated that VOT duration was significantly different when comparing cognate and non-cognate words with the same voicing and vowel, with both cognates presenting with longer VOTs than their non-cognate counterpart. Despite the significant difference in VOT values, average [+voice] VOT duration in the cognate word appears to go in the opposite direction of what would be expected for a more “English-like” VOT. That is, [+voice] *bile* appears to use longer prevoicing on average than any other stimuli, ultimately presenting itself as the most “French-like” VOT. Thus for [+voice] VOT duration, the fact that the word is an English cognate doesn’t seem to negatively affect the leaners’ French VOT duration.

When comparing [-voice] cognate and non-cognate words with the same vowel, VOT duration appears to be longer (more “English-like”) in the cognate word, *pile*. Although this could be an effect of cognate status, an alternative explanation would be that the VOT durations differ due to syllable structure. As the VOT duration of [-voice] monosyllabic words have been shown to be longer than polysyllabic words (Klatt, 1975; Flege et al., 1998), this could account for the longer VOT duration in the monosyllabic cognate word, *pile*, when compared to bisyllabic non-cognate, *piller*.

Regarding cognate onset f0 results, there appears to be a significant effect on normalized onset f0 when comparing cognate and non-cognate words with the same voicing and following vowel. As onset f0 appears to lower in both voicing conditions among cognates, there doesn’t appear to be any obvious trend in the data. Additionally, since onset f0 targets as a function of voicing is similar in both languages, it is impossible to make assumptions as to whether the cognate status of the word is making the onset f0 more or less like English.

5.6 Conclusions

In summary, the purpose of this thesis was to examine the production of VOT and onset f0 in L2 learners of French who speak English as an L1. This thesis aimed to contribute to a better understanding of the acquisition of voicing, as well addressing a gap in the L2 acquisition literature by analyzing a secondary cue, onset f0. These inquiries may lead to a fuller understanding not only of the acquisition of acoustic cues in a second language, but also of the effect that individual trends play on the L2 acquisition of speech and may contribute to an enhanced understanding of second language phonetic acquisition in general.

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APPENDIX A: LANGUAGE BACKGROUND QUESTIONNAIRE

1. How old are you (in years)?
2. Are you a man or a woman (circle one)? Man / Woman
3. Have you ever had a vision problem, hearing impairment, language disability, or learning disability? (Circle all applicable).

   If yes, please explain (including any corrections):

   ____

4. Where were you born (country, town/state or region)? ______________________________
5. Where did you grow up? (give each location and # of years you lived there)

Location	*Years*

6. Was English the first language you spoke? Yes ___ No ___

   If "No", what age were you when you started speaking English _____

   If "No", what was the first language you spoke? ______________

7. Think of the adults who raised you. Was English their first language? (Write "Yes" or "No" for each person, and, if "no" write in their first language):

Person	*English?*	*Language*

8. How old were you when you started learning French? _________
9. How long have you studied French? _______ years/semesters
10. How did you learn French up to this point?

    (Mainly Mostly Occasionally) through formal classroom instruction

    (Mainly Mostly Occasionally) through interacting with people

    A mixture of both, but (More classroom More interaction Equally both)

    Other (specify: ____)

11. Have you lived in, or visited any French-speaking country? Yes___ No___

    If "Yes", indicate the place, the age you were when living/visiting, and the amount of time spent there (treat separate trips as distinct):

Location	*Language(s)*	*Age*	*How long there?*

12. Rate your proficiency in French using the following scale (write down the number in the table).

Very poor Poor Fair Functional Good Very good Native-like

___1_________2_______3_________4_________5__________6___________7_____

	French Proficiency
Speaking Fluency	
Listening Ability	
Writing proficiency	
Reading proficiency	
Grammar	

13. In your perception, how much of a foreign accent do you have when speaking French? Please rate the strength of your accent according to the following scale (circle appropriate):

Very strong   Strong   Moderate   Mild   Very mild   No Accent

___1______________2____________3__________4___________ 5____________ 6_____

14. Estimate in terms of hours per week, how often you speak (or used to speak) French.

    Spouse/partner: _____ (hrs)

    Other family members: ___ (hrs)

    Friends: ___ (hrs)

    Classmates: ___ (hrs)

    Co-workers: ___ (hrs)

15. Estimate, in terms of hours per week, how often you are engaged in the following activities in French.

    Listen to Radio/ Watching TV: ___ (hrs)

    Reading for fun: ___ (hrs)

    Reading for work: ___ (hrs)

    Reading on the Internet: ___ (hrs)

    Writing emails to friends: ___ (hrs)

    Writing articles/papers: ___ (hrs)

16. Have you studied any spoken language other than English and French?

    Yes ___ No___

    If "Yes", indicate each language, your age when you started studying it, and how long you have studied it, whether and how long you lived in any country where the language is spoken, and your overall proficiency rating for that language (use scale in 10 above).

Language	*Age started*	*No. years/semesters studied*	*No. years in country where spoken*	*Proficiency*

17. If there is anything else that you feel is interesting or important about your language background or language use, please comment below.

APPENDIX B: FRENCH FILLER WORDS

Word	**Translation**	**IPA**	**Frequency**
faire	to do (v)	/fɛʁ/	4608.3925
chaud	hot (adj)	/ʃo/	73.5225
quoi	what (pron)	/kwa/	331.2975
corps	body (nm)	/kɔʁ/	365.245
donne	give (verb)	/dɔn/	664
queue	line (nf)	/kø/	47.4625
goutte	drop (nf)	/gut/	33.82
doter	provide (vtr)	/dɔte/	3.555
guerre	war (nf)	/gɛʁ/	281.9275
faux	false (adj)	/fo/	97.34
doit	must (devoir v)	/dwa/	1357.545
fort	strong (adj)	/fɔʁ/	192.34
tonne	metric ton (nf)	/tɔn/	9.4
feux	lights (nmpl)	/fø/	131.2425
doute	doubt (nm)	/dut/	121.9075
coté	popular (adj)	/kɔte/	3.9675

APPENDIX C: ENGLISH FILLER WORDS

feed

keep

pit

cot

heap

fit

deed

head

dead

day

hot

fig

hay

fat

kit

cat

APPENDIX D: INDIVIDUAL CORRELATIONS (ALL)

		VOT Difference						**Onset f0 Difference**					
		[+voice]			*[-voice]*			*[+voice]*			*[-voice]*		
Category	**Q#**[7]	r=	n=	p=	r=	n=	p=	r=	n=	p=	r=	n=	p=
AOA	8	**.475**	**23**	**.022**	.225	23	.301	.276	23	.202	-.241	23	.267
Strength of accent	13	-.275	23	.205	-.021	23	.301	-.061	23	.781	.008	23	.972
Length of time studying French	9	-.397	23	.061	-.270	23	.212	-.161	23	.464	.204	23	.351
Length of time in a French-speaking country	11	-.250	23	.251	.125	23	.570	-.115	23	.602	.077	23	.727
Total proficiency score[8]	12	-.063	23	.775	-.170	23	.437	.072	23	.743	-.086	23	.693
Total hours/week speaking French with others	14	.069	23	.755	**-.406**	**23**	**.055**	**.558**	**23**	**.003**	**-.624**	**23**	**.001**
Total hours/week engaging in non-speaking oriented activities in French	15	.087	23	.693	.073	23	.739	.257	23	.237	-.334	23	.120

[7] Q# represents the question in the Language Background Questionnaire each category was pulled from
[8] Total of all categories out of 35.