SPANISH VOT PRODUCTION BY L1 NAHUAT SPEAKERS

A Thesis Submitted to the

College of Graduate and Postdoctoral Studies

In Partial Fulfillment of the Requirements

For the Degree of Master of Arts

In the Department of Linguistics

University of Saskatchewan

Saskatoon

By

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ABSTRACT

In the northern region of Puebla, Mexico, two languages have a long history of language contact: Nahuat and Spanish. The former is spoken as an L1 by most of the population, while the latter is typically learned as an L2. This study explores the production of voice onset time (VOT) an acoustic correlate used to identify and categorize stop consonants, among three types of Nahuat-Spanish bilingual speakers: simultaneous bilinguals (speakers who acquired Spanish alongside Nahuat), early bilinguals (speakers who acquired Spanish at around the age of 5), and late bilinguals (speakers who learned their second language after puberty). While Spanish has a stop voicing contrast (/p-b/, /t-d/ & /k-g/), Nahuat is a language with no voicing distinction (its inventory contains /p/, /t/, & /k/). Data to perform this research were collected from 30 bilingual speakers, ten from each bilingual group, and ten Spanish monolingual speakers used as a baseline for comparison. The data were analyzed in Praat and statistical analyses were run in R.

The results suggest that the age at which participants acquired Spanish is a crucial factor in how they produce the voiced stops present in Spanish. Simultaneous and early bilinguals presented slightly higher VOT values, while late bilinguals demonstrated a high degree of variation with positive VOTs, shorter VOT when produced as negative, and occasional weakening (in stops). This study represents one of a few studies looking at a diglossia situation with a clear prestige difference between the two languages under study.

ACKNOWLEDGMENTS

First and foremost, I am thankful for each one of my participants who are the life of the languages that were under study, they shared with me their heritage, and without that this research would have been not possible. Despite everything, Nahuat is still alive in Cuetzalan's streets.

I would also like to thank my supervisor Jesse Stewart who taught me one of the most important things in Canada, that science and technology should be used to preserve languages around the globe.Thank you for attending all my inquiries for sharing your knowledge with me and for your patience as well. I am also in appreciation with my committee members Dr. Olga Lovick, Dr. Martin Kohlberger as well as Dr. Hugo Cota Sanchez whose comments allowed me to improve my work.

I am also grateful to special people that life introduced me in the past few years. Ula, my dear Rusalka, thanks for all your words and your help during this journey. I loved your company especially during our endless walks in this opened zoo called Saskatoon. I am in appreciation with you my friend. Dina, you are such an example of being a strong woman and provide me with your invaluable friendship. Denis thank you for the support you gave me throughout my studies and for your words of encouragement that pushed me to complete this project. I appreciate all the time you cooked for me and all the efforts you made, I also appreciate that you were always there willing to provide me a good advice. George Hind, thanks for showing me the real meaning of friendship. I also want to thank to a few anonymous readers who provided me constructive and helpful advice and comments allowing me to do a better work. Fatemeh, gracias amiga por tu ayuda.

Así mismo, quiero agradecer a toda mi familia mis hermanos Angela, Isabel, Arturo, mi mamá y mi papá, mi abuelita gracias por todo los quiero mucho siempre están en mi mente, ustedes me han enseñado a no rendirse bajo ninguna circunstancia y a seguir siempre adelante. También quiero agradecer a diversas instituciones que me ayudaron cuando yo estaba recolectando mis datos tales como la Secretaria de Educación Publica, el Instituto Nacional de Antropología e Historia en donde conocí personas muy especiales en el sitio arqueológico de Yohualichan, siempre voy a llevar conmigo los recuerdos ahí creados y las personas que conocí. En San Miguel Tzincapan quiero agradecer a Radio Tzinaka por todo el apoyo que tuve. Y gracias Maribel (Yolotzin) por estar siempre ahí, respondiendo mis dudas.

A todas mis amigas también Natalia, Lili, Trini, Mirna que son mis amigas y hermanas, gracias por compartir la vida conmigo.

DEDICATION

To all my family back home

LIST OF ABBREVIATIONS

CI_{95} - 95% Confidence Intervals
CONAFE - Consejo Nacional de Fomento Educativo (National Council for Educational Development)
INALI - El Instituto Nacional de Lenguas Indígenas (National Institute of Indigenous Languages)
INAH - Instituto Nacional de Antropología e Historia (National Institute of Anthropology and History)
INEGI - Instituto Nacional de Estadística y Geografía (National Institute of Statistics and Geography)
NP - Northern Puebla
L1 - First language
L2 - Second language
SLA - Second Language Acquisition
SEP - Secretaría de Educación Pública (Secretariat of Public Education)
POA - Place of Articulation
VOT - Voice onset time
WAV - Waveform Audio File Format
B - Coefficient Estimate

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1. INTRODUCTION

In terms of linguistic diversity, Mexico is considered as one of the richest countries in Latin America with over 57 languages according to Ethnologue (2021). However, there is still a lack of studies that shed light on understanding bilingualism in the country. Moreover, there is not a lot of formal research in linguistics to understand how the age of L2 affects bilingual production in Spanish, especially when acquiring Spanish as their second language (L2 henceforth). The situation is critical given that the Indigenous languages are often found in an unfavorable social position with Spanish. Such is the case of Nahuat.

This research is aimed to provide empirical evidence on how age affects the acquisition of VOT, an acoustic correlate used to identify the acquisition of stop consonants in bilinguals. This study considers three different types of bilingual speakers: simultaneous bilinguals, early bilinguals, and late bilinguals whose first language is Nahuat[1]. Nahuatl is one of the most studied languages in Mexico because it is the most widely spoken language after Spanish (the official language of Mexico). Some of the studies in linguistics that are based on Nahuatl include: syntax (Robinson, 1966)**,** dictionaries (Key and de Key, 1953; de Pury-Toumi, 1980), textbooks (Wright 2016), and sociolinguistic studies (Flores 2007). Despite these studies, little has been written about Nahuatl bilinguals and only a limited number of studies shed light on its phonetic features. To help fill this gap, this research explores two primary areas related to bilingualism and phonetics in Nahuat and Spanish. As a first goal, this study intends to document VOT production in Nahuat L1 speech. A second purpose is to analyze Spanish stops produced by different groups of L1 Nahuat speakers based on their age of acquisition of Spanish.

This study was guided by the following research questions:

[1] Nahuat is a variation of Nahuatl spoken in the North of Puebla. Section 1.2.1 provides a broader explanation of this variation.

- How do simultaneous, early, and late bilinguals (L1 Nahuat) produce the voice onset time (VOT) of voiced stops when speaking Spanish? How do they differ from L1 monolingual Spanish speakers?
- What types of variation in VOT production, if any, can be found in the data?

1.1 Nahuatl

Nahuatl, also known as Mexicano by those that speak it, is the language of several Indigenous nations in North and Central America (henceforth Pueblos) including the Tlaxcalans and the Aztecs (Suárez, 1983). Nahuatl is a language native to the Americas and belongs to the Uto-Aztecan language family. It is the most widely spoken language in Mexico after Spanish (Cifuentes & Moctezuma, 2006). Canger (2001) points out that among Native American language families, Uto-Aztecan is seen as one of the largest regarding the number of languages in the family, number of speakers, and geographical extent. In terms of phonology, Nahuatl is a language with no stop voicing distinction in its plosive inventory, which contains /p/, /t/, and /k/.

1.2 Background information about the Nahuatl language

It is important to consider the periods in which historians have divided prehispanic Mesoamerica to understand how Nahuatl speakers had different displacements. Therefore, Mesoamerica has been divided into Paleo-Indian, Archaic, Preclassic, Classic, Postclassic. In the latter, the language became Central-Nahuatl ,Canger (1997). The data for this research was collected in that region.

As Canger (2011) states, Nahuatl speakers interacted with speakers of other languages (Cora and Huichol) that were also part of the same Uto-Aztecan family. The first contact between these languages took place in the western area of Mexico in the states of Nayarit, Jalisco, Michoacán, Durango, and Zacatecas, where Cora and Huichol were spoken at that time. Later, during the post-classic period (from 900 to 1521 CE), these Nahuat speakers migrated to the south and into central Mexico, including what is now known as Distrito Federal, Estado de Mexico, Queretaro, Hidalgo, Morelos, and Tlaxcala. After that migration, a second wave of contact took place with Eastern Nahuatl, a language that was already present in the region. Along with their counterparts, these migrants created a koine language that later became Central Nahuatl.

Additionally of being in contact with speakers of the Eastern region, Nahuatl speakers were in contact with many other languages in Western Mexico before the arrival of Europeans. These processes allow us to understand how historically Nahuatl has had an important status in Mexico before and after the conquest.

Finally, the western Nahuatl speakers relocated to new areas that include the Valley of Mexico, Texcoco, Morelos, Puebla, Mexico City, and Tlaxcala. Figure 1.1 illustrates the location of Puebla where the data for this study was collected.

Figure 1.1 Location of Puebla. Cuetzalan is located in the northern part of Puebla. This map is used under the permission of OpenStreetMap.

1.2.1 Nahuat - a variety of Nahuatl

According to Hasler (1975) there are three main varieties of Nahuatl, these are Nahuatl with tl at the end, Nahuat with t at the end and Nahual with l at the end. The main difference in Nahuatl and Nahuat is the word-ending. Whereas in the first one speakers tend to add tl at the end of the words, Nahuat speakers dropp out that ending (e.g., pajpata, pajpatatl). In addition, Whorf (1937) described Nahuatl and suggested that the one that ends with "t" is seen as conservative, whereas the Nahuatl the one that has "tl" at the end, is considered modern. In the northeast of Puebla in Cuetzalan where I collected the data for this study, Nahuat is spoken. Therefore, in the rest of this text I will refer to Nahuat for the variation of Nahuatl that is spoken in Cuetzalan and Nahuatl whenever I am describing general features of the language.

It is also worth mentioning that in Cuetzalan, speakers called themselves “Nahuas”. Today, according to INEGI (National Institute of Statistics and Geography) in Mexico Nahuatl is spoken by more than 1,500,000 people. Nahuat, on the other hand, the variety that was studied in this thesis is spoken by approximately 24,076 bilingual people. Nahuat language is used in smaller communities that are in the northern part of the State of Puebla along with Spanish. Neither Nahuatl nor Nahuat are formally taught in all public elementary public schools, however, there are some bilingual schools (Nahuatl-Spanish) that teach Nahuatl and therefore new generations can continue learning and using the language.

As for the media, there are specific radio stations whose announcers only speak either Nahuatl or Nahuat and the music they broadcast is also traditional Nahuatl music. In Catholic churches once a month the mass is provided in Nahuatl language and the people that sing in the church (choire) are L1 Nahuatl speakers. According to INALI (National Institute of Anthropology and History), most of the Amerindian languages have been preserved in Mexico orally rather than in their written form. Figure 1.2 presents a map of the Mexican State of Puebla and the town of Cuetzalan, from where I collected my data in several surrounding communities: San Miguel Tzinacapan, Yohualichan, Tecoltepec, Chicueyaco, Pepexta, Tzicuilan, Xiloxochico, Santiopan.

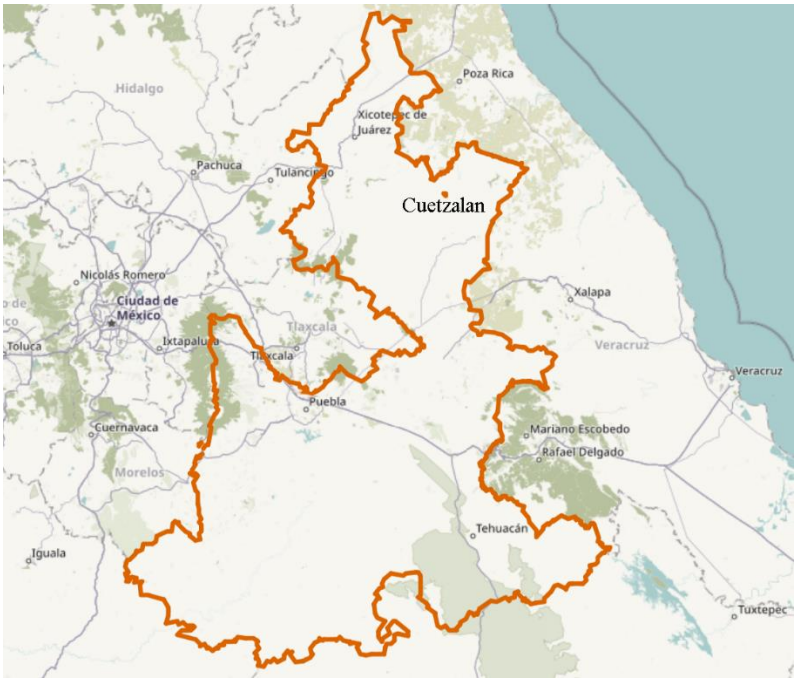

Figure 1.2 This map shows the state of Puebla, where the data of Nahuat language were collected. The map is freely licensed under the Open Data Commons Open Database License (ODbL) by the OpenStreetMap Foundation (OSMF). The globe is freely licensed under Creative Commons BY-SA 3.0

1.2.2 Diglossia

In terms of bilingualism, when two languages share the same geographical space, it is not uncommon to observe diglossia. Diglossia was originally proposed in 1959 by Ferguson where he described the use of two varieties of a single language are used in different facets of society. However, this term was broadened by Fishman in 1967 where he suggested two different languages instead of two different varieties. For decades authors such as Fishman (1980, 1986) and Hornberger (1998) have suggested that under this type of situation one of the two languages will inevitably obtain a more powerful status over the other and the lowest-status language will eventually be used less. The coexistence of Nahuatl and Spanish in the same geographical region constitutes an example of diglossia, where Spanish is regarded as the language with greater economic power, educational value, and social prestige, while Nahuatl, at times, is linked to historical disadvantage and oppression even among its speakers (Rolstad, 2001).

In the communities I visited, I noticed that people use Nahuat (their L1) in informal conversations. Subsequently, when talking with the members of the communities, some agreed that Spanish is seen as the 'more prestigious language' and it is also considered the language with greater economic power. Whereas it is common to find families whose new generation of children are learning Nahuat at home, and to see a few bilingual Nahuat-Spanish schools that foster Nahuat learning, it is also common to find bilingual speakers that are not proud of being bilingual given the negative attitudes at times associated with their L1. There are indeed some schools that formally teach Nahuatl, but Mexican government has not considered teaching Nahuatl in the public system of education.

Despite social pressure from some members of the society as well as from some institutions to adopt Spanish as the only official language, Nahuatl speakers across Mexico and Nahuat speakers in the communities that I visited are making constant efforts to preserve their mother tongue. It is clear that Nahuatl and the rest of Amerindian languages in Mexico have been greatly declining in use since the Spanish conquest. However, in 2003 a new law was created called the General Law of Linguistic Rights among the Indigenous Populations (*Ley General de Derechos Lingüísticos de Los Pueblos Indígenas*) and the National Institute of Indigenous Languages (*El Instituto Nacional de Lenguas Indígenas INALI*). Among other purposes, this law as well as the institute are aimed at recognizing that Spanish and all languages native to the Americas, specifically those in Mexico (endangered languages) are equally important.

1.2.3 Mexican Spanish

The Spanish language arrived in Mexico in 1519 when the Spanish colonizers, under Hernan Cortes' rule, encountered the Aztecan Empire. The Aztecan Empire had been ruling Tenochtitlan (pre-Columbian Mexico) for more than two centuries before the arrival of the Spanish invaders. To better understand this mix of cultures, it is necessary to mention a series of elements that took part in this process. The way that Indigenous civilizations acquired Spanish was multi-faceted. However, one widely accepted idea is that the Spanish colonizers taught their native language to the Indigenous people for religious purposes. Gomez (1942) states that Spanish was the language of conquest in Mexico.

Moreover, it has also been suggested that Spanish was an imposition from both the invading Spanish and the Catholic Church (Trueba, 2020). Catholic orders such as the Franciscans tried to evangelize through Amerindian languages, but later, according to Trueba (2020), decided to switch to Spanish. Therefore, many people argue that Spanish in Mexico was learned by people mainly through their conversion to Catholicism. Additionally, Spanish was used both in politics and administration in the post-conquest period of the history of Mexico. Regardless of which colonizing influence was most influential in spreading the Spanish language in Mexico, it is clear that Spanish was an imposed language (Paz, 1972) and was an important part of the colonial history in the region.

When the Spanish arrived in Tenochtitlan, they brought with them the interpreter *Malitzin*, an indigenous woman from the Gulf Coast region of modern Mexico. Better known as *La Malinche,* her interactions with the Spanish invaders served as a bridge between the two groups. According to Gomez (1953), she was a key factor in the Spanish colonial strategy. Initially given to the Spanish as one of over 20 slave women, she soon became valued by Gerónimo de Aguilar, one of the most influential Spaniards in the colonization of Mexico, for her knowledge in Nahuatl and Maya (Gomez, 1953). As a result, she, and Gerónimo made translations between Mayan, Nahuatl, and Spanish. Consequently, by using the work of the two interpreters and three different languages, the interaction between the Spanish and the Aztecs was carried out in what is now Mexico (Gómez, 1953).

While this description is not comprehensive in nature, it makes clear that there were multiple strategies that Spanish colonizers used to connect both Nahuatl and Spanish. It is not unsurprising to see that even today Nahuat communities have negative attitudes towards Spanish as Spanish is a language that have been displacing Nahuatl throughout history, as such, people in the communities believe that by losing Nahuatl, they also lose part of their identity.

Mexican Spanish across the country, therefore, has been influenced by a large number of borrowings that come from Nahuatl. This type of borrowing includes mainly nouns and it is common to name people after Nahuatl words such as *Xochitl* ‘Flower’, *Citlali* ‘Star’, *Yolotl* ‘Heart’, *Ejekatl* ‘Wind’, *Ameyal* ‘Spring’, *Asitali* ‘Starfish’, *Metsti* ‘Moon’, *Mixtli* ‘Cloud’, among many others. Moreover, many common words used on a daily basis in Mexican Spanish come from Nahuatl, such as *aguacate* ‘avocado’, *tomate* ‘tomato’, *cacahuate* ‘peanut’, *chocolate* ‘chocolate’,

comal ‘flat griddle’, *milpa* ‘cornfield’, and many more. When the Europeans arrived to now Mexican lands, these were concepts that were native to Mexico as such Spanish invaders did not have a word to name these concepts.

Even some of the state names in Mexico come originally from Nahuatl words such as *Oaxaca, Toluca, Tlaxcala, Jalisco,* and *Michoacán* to name a few. At present, Mexico has the highest population of Spanish native speakers in the world[2], and as Lipski (1994) indicates the majority of native Spanish speakers currently live on the American continent, where this language thrived through conquest.

1.2.4 Unguided learning

For decades, there has been an ongoing discussion about how effective guidance is on the process of second language acquisition (Mayer 2004). Hickey (2012) states that when speakers acquire or learn a second language under ‘unguided’ conditions, they tend to fill in ‘perceived’ gaps in their L2 with concepts and structures from their L1. However, Gadd (1998) states that all learners have the capability of taking information from the input language and organizing it within the framework of their current linguistic system, further adding that this reorganization modifies and restructures this system.

Simultaneous and early bilinguals acquire the language rather than actively learn it. In other words, these participants naturally acquired the language along with their relatives at home. Late bilinguals, on the other hand, typically learn Spanish under ‘guided’ circumstances. However, some of them, acquire the language naturally, in unguided learning conditions, for instance, by working with Spanish speakers. Late bilingual participants in my study acquired Spanish under ‘unguided’ circumstances. As a result of these different learning environments, each category of bilinguals showed different types of variations in Spanish stops production.

[2] Mexico has an estimated 121 million native Spanish speakers.

1.3 Spanish phonology

Compared to other languages and their dialects, Spanish has a relatively consistent phonological inventory across its dialects. This holds true for Mexican Spanish as well. Table 1.1 provides the consonant inventory for Mexican Spanish the IPA chart that contains the phonemes present in Standard Mexican Spanish showing that the language contains 18 consonants and a voicing contrast in the plosive series, which is the focus of this study. Mexican Spanish is also considered a *yeísta* dialect, which merges /ʎ/ <11> and /ʝ/ <y> into /j/. Like nearly all other dialects of Spanish, Mexican Spanish also contains the following five vowel phonemes /i, u, e, o, a/.

Table 1.1 Mexican Spanish Consonants

	LABIAL		CORONAL				DORSAL			RADICAL	LARYNGEAL
	Bilabial	Labio-dental	Dental	Alveolar	Palato-alveolar	Retroflex	Palatal	Velar	Uvular	Pharyngeal	Glottal
Nasal	m			n			ɲ				
Plosive	p b		t d					k g			
Fricative		f		s			ʝ	x			
Affricate					ʧ						
Approximant							j				
Tap				ɾ							
Trill				r							
Lateral Fricative											
Lateral Approximant				l							
Lateral Flap											

1.3.1 Voice Onset Time

Voice onset time (VOT henceforth) is defined as the temporal duration from the moment of release of a stop to the onset of voicing the following vowel (Lisker & Abramson, 1964), and VOT distinguishes plosives that have the same place of articulation (e.g., /b/ vs. /p/). In addition, this acoustic correlate has been the most common cue used to identify the acquisition of stop consonants in bilinguals as well as stop consonant production in comparative studies that focus on specific bilinguals such as French/ English or Spanish/ English speakers.

In phonetics, it is known that VOT production is language specific. For example, languages such as English distinguish between three different categories (voiceless aspirated in the initial position of the word /p^h/, /t^h/, /k^h/, voiceless unaspirated /p/, /t/, /k/, and voiced stop consonants (/b/, /d/, /g/) and Spanish distinguishes between voiced stop consonants /b/, /d/, /g/ (Figure 1.3) and voiceless unaspirated stop consonants /p/, /t/, /k/ (see Figure 1.4).

In linguistics research, studies have been carried out by using Voice onset time (VOT) to analyze how bilinguals acquire and produce stop consonants. As such, VOT can be used as an indicator of competence in second language. VOT has become a significant technique to explain phenomena that underly bilingualism. For example, Molfese & Hess (1978) used VOT cues to

understand Place of Articulation (PoA) in adults and as such obtain references to understand these abilities in infants. Figure 1.3 and Figure 1.4 show examples of negative VOT in Spanish words.

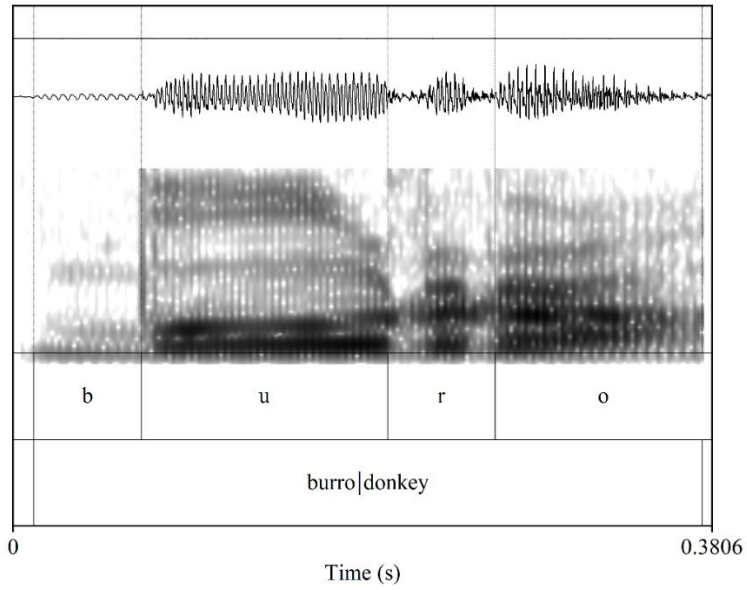

Figure 1.3 An example of the Spanish word burro 'donkey' with a negative VOT of -57 ms in the word-initial /b/. Consultant # 37.

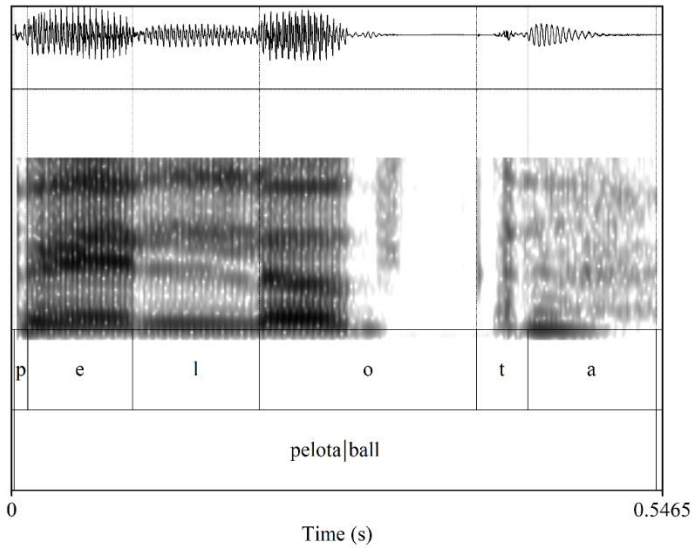

Figure 1.4 The Spanish word pelota 'ball'. We can see the VOT duration is 12 ms (short lag) (Consultant #36). This is known as a voiceless unaspirated stop consonant.

As seen in Figure 1.3, in a negative VOT voicing begins before the release of a stop (Lisker & Abramson, 1964). According to this study, the average values for monolingual Spanish speakers for Mexican dialect are displayed in Table 1.2.

1.5.1. Average of VOT durations across Spanish dialects

Table 1.3 displays the average VOT durations cross-dialectial variation. The shortest VOT values for the voiceless bilabial /p/ are found in Puerto Rican Spanish (4 ms), while L2 Ecuadorian Spanish speakers produced the longest VOT for /p/ (22 ms). A similar pattern is displayed for the dental voiceless /t/: Puerto Rican Spanish with the shortest VOT value of 9 ms and L2 Ecuadorian Spanish with the longest (25 ms). Interestingly, for the voiceless velar /k/, Mexico city dialect presents the longest VOT duration (49 ms) whereas Guatemalan dialect presents the shortest one (26 ms).

For the voiced series, Puerto Rican Spanish presents the longest duration (/b/: –138 ms; /d/: –110 (along with Peruvian); and /g/: –108 ms). The shortest VOT durarion for the bilabial voiced /b/ is found in Mexico city dialect (–65 ms). As for the dental voiced series /d/ (–73 ms) and velar voiced /g/ (–59 ms), the shortest values are seen in Urban Ecuadorian.

Although Spanish is spoken in all these regions, there are differences in VOT durations that are related to cross-dialectal variations.

Table 1.2 Average VOT values across nine Spanish dialects (Adapted from Stewart, 2018).

Dialect	/p/	/t/	/k/	/b/	/d/	/g/	Source
Puerto Rico	4	9	29	–138	–110	–108	(Lisker & Abramson 1964)
Guatemalan	9	10	26	–120	–109	–101	(Williams, 1977)
Venezuelan	14	20	33	–95	–79	–64	(Williams, 1977)
Peruvian	15	16	30	–102	–110	–98	(Williams, 1977)
Castilian	13	14	27	–92	–92	–74	(Rosner et al., 2000)
Urban Ecuadorian	19	19	33	–73	–73	–59	(Stewart, 2015)
Rural Ecuadorian	17	22	38	–89	–83	–86	(Stewart, 2015)
L2 Ecuadorian Spanish (L1 Quichua)	22	25	40	–87	–86	–87	(Stewart, 2015)
Mexico City	15	20	49	–65	–84	–73	(Avelino, 2018)

1.4 Nahuatl phonology

Nahuatl is an Aztecan language, part of the Uto-Aztecan language family. Nahuatl has a very conservative phonological inventory, which still contains most of the phonemes reconstructed in Proto-Uto-Aztecan (Campbell, 1976)[3] and has added affricates /tɬ/, /ʧ/ and the affricate offsets as single consonants (/l/ & /ʃ/) to the inventory. In addition, old documentation suggests a possible lengthening distinction in the sibilants /s/ and /ʃ/ and the lateral /l/ (de Molina, 1555). However, there are no recent studies that could show evidence about the current phonological features of the lengthening consonants. Both Nahuatl and Nahuat share the similar inventories and phonotactics, the main difference being the lack of affrication in word-final position.

Table 1.4 provides the consonant inventory for Nahuatl, which like Mexican Spanish also contains 18 consonants, but lacks a voicing contrast in the plosive series, which once again is the focus of this study. Nahuatl has a four-vowel system with a length contrast, which contains /i, e, a iː, eː, aː/ and a back vowel situated between /o/ and /u/ (~/o̜, o̜ː/).

Table 1.3 IPA chart with the phonemes present in Nahuatl.

/w/ - voiced lateral-velar approximant

	LABIAL		CORONAL				DORSAL			RADICAL	LARYNGEAL
	Bilabial	Labio-dental	Dental	Alveolar	Palato-alveolar	Retroflex	Palatal	Velar	Uvular	Pharyngeal	Glottal
Nasal	m			n							
Plosive	p		t					k kʷ			ʔ
Fricative				s sː	ʃ ʃː						
Affricate			ʦ				ʧ				
Approximant							j				
Tap											
Trill											
Lateral Fricative			ɬ	tɬ							
Lateral Approximant				l lː							

[3] Nahuatl contains most of the phonemes reconstructed in Proto-Uto Aztecan with the exception of of /ŋ/ and /r/.

1.4.1 Stop consonants and VOT in Nahuatl

Nahuatl's phonology contains unaspirated voiceless stops /p/, /t/, and /k/. Unlike Spanish, it does not contain a contrastive voiced series of stops consonants (/b/, /d/, & /g/) in its native lexicon.

See Figures 1.5-1.7 for examples of each VOT of the unaspirated voiceless stops.

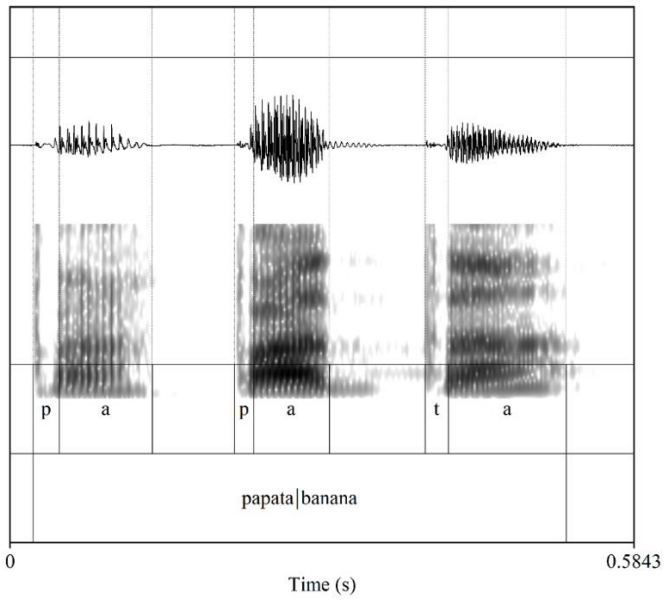

Figure 1.5 The word pajpata 'banana' produced by Consultant #23 presents a VOT duration of 23 ms inn the initial /p/.

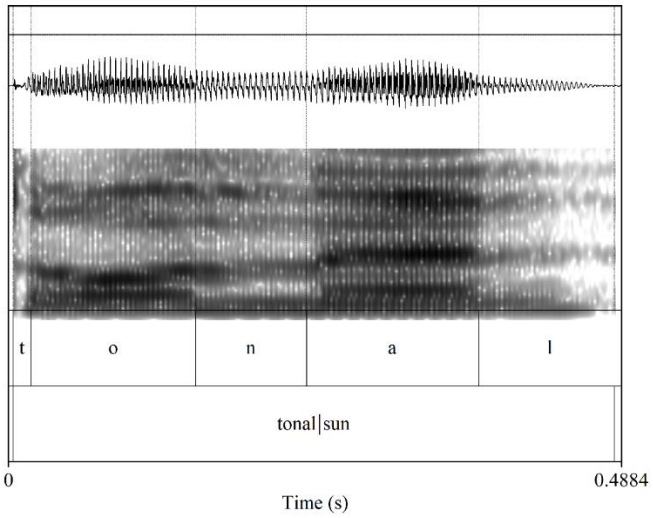

Figure 1.6 The word tonal 'sun' produced by Consultant #20 presents a VOT duration of 23 ms in the word-initial /t/.

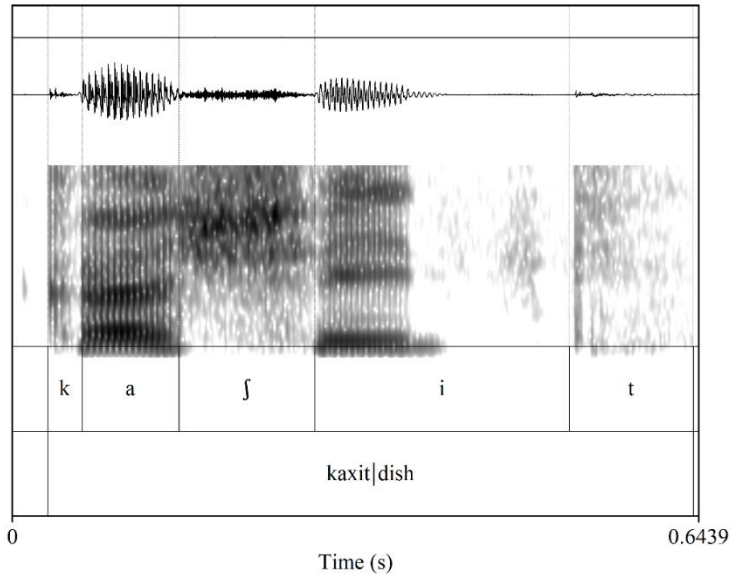

Figure 1.7 In the word kaxit 'dish', the voiceless velar /k/ is produced in word-initial position with a VOT value of 27 ms- Consultant #11.

1.5 VOT values according to age of L2 acquisition

This section presents past research that has shown that the age of L2 acquisition is correlated with VOT. Therefore, the age at which a person learns their second language can serve as an indicator as to how native-like their VOT values will be when compared to L1 monolingual speech.

1.5.1 Simultaneous and early bilinguals

Authors such as Flege (1995) suggest that language-specific VOT values must be learned to approximate pronunciation of a second language, and it is generally believed that the earlier a learner is exposed to a second language, the closer they will be to having native-like production in L2 (Bieber et al., 2018).

Moreover, studies conducted to identify the English voicing contrasts using VOT have suggested that children distinguish between voiced and voiceless stops by manipulating the onset phonation with respect to the release of the stop. When studying languages that have aspirated stop consonants like English, Fokes-Steinberg (1985) found that native Arabic children aged 2-11 years were able to produce voiceless bilabial /p/ and voiceless alveolar /t/ in their L2 (English) words with expected VOT values.

On the other hand, early and simultaneous bilinguals often present VOT production considered native-like given that they have been exposed to two languages for most of their lives. However, there are studies performed with early bilinguals that suggest that they can differentiate between voiced stops versus voiceless stops in their L1 and L2 accordingly. Such is the case in Antoniou et al. (2010), who studied Greek-English early bilinguals and compared them with Australian-English monolinguals. They found that for utterances where the stop consonant was in the initial position there was no difference to the monolingual control group. Instead, they showed slight differences where the stop consonants were present in medial position. As a result, these authors suggest that these differences rely rather on the position of the stop consonant in a word than in the phonetic categories (voiced-voiceless).

Likewise, a recent study performed by Face & Menke (2020) examined native English-speaking participants whose L2 acquisition took place in childhood (early speakers) and who had

been living in Spain for 11 to 36 years. Their findings suggest that there were differences for both the voiceless and the voiced stops. However, the most significant results were found in the voiced consonants. These authors, therefore, suggest that L1 English-L2 Spanish bilinguals are better at producing and recategorizing short lag voicing to indicate the required voiceless stops in Spanish than they are in producing the negative values for the voiced stop consonants. Spanish voiceless stops are characterized by short lag voicing, a phonetic feature that is present in English voiced stops, therefore, these authors suggest that English L1 bilinguals are able to produce these types of phonemes without learning a new way of production. While studies that measure VOT are increasingly used to examine bilinguals, there are few studies that compare Spanish dialects and late learning language acquisition data on Spanish dialect bilinguals. Similar studies have carried out studying vowel's acquisition.

Guion's study was based on discrepancy in the number of vowels between Spanish's five vowel system (/a/, /e/, /i/, /o/, /u/) and Quichua's three-vowel system (/ɪ/, /a/, /ʊ/). She showed that all of the simultaneous speakers and the majority of the early speakers were able to distinguish between Spanish and Quichua vowels in their production. She provided evidence that whereas early speakers were able to distinguish between Spanish mid and high vowels, the simultaneous group even had different categories for vowels of the same quality (e.g., /i/ & /ɪ/).

Caramazza et al. (1973), on the other hand, found that French Canadians who began learning English in school "no later" than the age of seven produced /p/, /t/, /k/ in English with VOT values that were significantly shorter (51 ms) than English monolinguals (74 ms). Despite these studies, some authors such as Bongaerts et al. (2000) suggest that there are positive effects of intensive training in pronunciation and stress the importance of phonetics exposure in successful L2 acquisition.

Moreover, studies conducted with simultaneous bilinguals suggest that they can produce virtually all the stop consonants categories within their languages with a few exceptions. For example, Macleod and Stoel (2005) described simultaneous bilinguals learning English and French. They showed that simultaneous bilinguals were able to produce native-like Canadian English and Canadian French stop consonants, except for the English voiced stops (/b/, /d/). In this case, VOT durations were similar to Canadian French. They also showed that simultaneous bilinguals had to 'exert effort' to attain the acceptable language-specific distinction.

Additionally, some VOT studies have provided evidence that it may be impossible, even for early bilinguals, to achieve native-like pronunciation when acquiring a second language (Kim, 1997). Williams (1979) identified that 8-10 and 14-16-year-old participants whose L1 was Spanish were producing English (their L2) with Spanish-like mean VOT values. These bilingual participants, originally from Puerto Rico, produced /p/ durations closer to Spanish expected values (their L1). As a result, he suggests that young children L2 learners may not be conscious of production differences in the shared stop phonemes.

1.5.2 Late bilinguals

Past evidence, for example, has shown that late bilinguals either tend to produce VOT values that are closer to their L1 than to the values expected for their L2, or that the average production of VOT values fall somewhere between those expected in the two languages. For instance, a study conducted by Simon (2009) compared Dutch, a language without aspirated stop consonants, with English, a language with aspirated stop consonants, in a group of late bilinguals enrolled at a university level, and this research showed that bilingual VOT values tended to overlap the sounds of their L1 to their L2.

Moreover, compromise values that are intermediate between monolingual L1 and monolingual L2 values are commonly reported for late learners, which explains different findings when compared with other bilingual groups. Length of residence, sound class (voiced or voiceless), and L1-L2 interactions are among the variables that differ across studies. However, Flege (1995) argues that outcomes for late bilinguals can depend on the relationship between L1 and L2 sounds.

As Face & Menke (2020) suggest, only a few studies have investigated voiced stop consonants in second language acquisition, and the findings in these studies indicate that voiced stop consonants may be more challenging to produce than their voiceless series. L2 studies have regularly reported variable outcomes, particularly for adult learners (over 18 years of age).

Previously, Guion (2003) showed evidence that a speaker's L1 vowel inventory can affect vowel production in L2. In her study, participants had Ecuadorian Quichua as their first language and Spanish as their second language. Guion's studied four different groups varying in age of Spanish acquisition (simultaneous bilinguals, early bilinguals, mid-bilinguals & late bilinguals),

and she demonstrated that these participants displayed different abilities in acquiring new second-language vowels. Guion defined simultaneous bilinguals as those speakers who were exposed to their second language at the same time as they learned their first language, or before the age of three (p. 10). In addition, she defines early bilinguals as those who learn their L2 once their schooling years start, which is usually after the age of five. The third group under study was 'mid' bilinguals, who acquired Spanish at around 9 and 13 years old. Finally, she describes late bilinguals as those who acquire their L2 after the critical period of language acquisition.

As for late bilinguals, only one was able to differentiate between Quichua and Spanish vowels, and the rest of the late speakers could not (Guion, 2004). Guion's study represents a precursor to the present research as it provides evidence that age is a crucial factor while acquiring a second language. Whereas Guion's presented four different types of criteria for a participant's L2 language acquisition, this study lacks mid bilingual participants given that it was difficult to find people who acquired Spanish between the ages of 9 and 12 according to Guion's criteron).

Furthermore, research carried out related to late bilinguals, however, suggests that these speakers have greater variation than early bilinguals and simultaneous bilinguals. For example, a study conducted by Flege (1991) demonstrated that late bilinguals with Spanish as their L1 and English as their L2 produced alveolar stops (/t/ and /d/) that were intermediate between English and Spanish VOT values.

2. METHODOLOGY

This study has three main purposes. The first one presents a phonetic analysis through VOT in Nahuat /p, t, k/ (see 3.1). The second is to identify the production of Spanish voiced stops in different types of bilingualism (see 3.3). The latter considers the following concepts: *Bilingualism* is understood as the use of two or more languages either by one speaker or by a group (Moradi, 2014). *Bilingual type*, on the other hand, is understood as the age in which participants acquired a second language, Spanish in this case. In other words, bilinguals were classified according to the age of Spanish acquisition.

This study considered three different types of bilingualism, simultaneous bilinguals, early bilinguals, and late bilinguals. Simultaneous bilingual participants are those whose second language learning experience was exposed from birth or at least before the age of 3 (Houwer, 1995; Mclaughlin, 1984). According to Beardsmore (1996), early bilingualism can be defined as the acquisition of more than one language in the preadolescent phase of life. Therefore, these learners were exposed to their L2 before the age of twelve at different sites such as schools or homes. In addition, as Fledge (1991) indicated, late bilinguals are those speakers that learned their L2 either in adulthood or adolescence. However, since participants did not specify the language of instruction of their formal education[4], I do not know whether Spanish was the language used in their formal education. Thus, participants were grouped according to the age they said they acquired the Spanish language at.

Consequently, simultaneous, early, and late bilinguals (bilingual type henceforth) were the types of participants that took part in this study. The third subsection has as a main goal to analyse VOTs variation across participants.

The data for this thesis were collected in two locations in Mexico under the University of Saskatchewan Ethics Board guidelines with approval number Beh-REB-1239. To obtain the VOT productions of Nahuat-Spanish bilingual speakers, I went to the Mexican state Puebla, specifically the northern part of Puebla called Cuetzalan, to speak with the communities that surround that area.

[4] In the visited communities, there exists schools that are bilinguals, that means that Nahuat and Spanish are spoken simultaneously. As such, some participants might have attended schools under the bilingual model. On the other hand, in some schools, only Nahuat is spoken. Therefore, some participants might received formal education in their L1.

Additionally, the data for monolingual speakers were collected in the metropolitan zone of Guadalajara, in the state of Jalisco. A total of 40 participants (10 simultaneous bilinguals, 10 early bilinguals, 10 late bilinguals and 10 monolingual Spanish speakers) made up a total of 7413 tokens.

To obtain the necessary data, first I constructed two word lists one in Nahuat and a second word list with Spanish words that covered all six stops (/p/, /t/, /k/, /b/, /d/, & /g/) at the beginning. After that, I created two power point presentations with images of the concepts with the words that I wanted to elicit. The first word list and power point presentation were created only for Nahuat-Spanish bilinguals and included 30 words in Nahuat (ten words for each of the voiceless unaspirated stop consonants /p/, /t/, /k/)(See

APPENDIX A)The second word list and power point presentation contained words 120 words in Spanish, 20 for each of the stop consonant. Spanish monolingual participants were only recorded with the second list, whereas bilingual speakers were recorded with both. In the power

point presentation, the slides contained a big picture of the needed word and in gray letters the written form. These words contained stops in word-initial and word-medial position.

2.1 Data collection

The data necessary for both Nahuat bilinguals and Spanish monolinguals were collected in different public locations such as museums, cafes, restaurants, libraries, radio stations, public schools, markets, little companies run by locals, archaeological sites, CONAFE (National Council for Educational Development), and SEP (Mexican Public Education System). Although in some spaces there were several participants gathering together, sessions were performed individually. Firstly, I introduced myself and explained the goal of the study, encouraging them to ask questions if they needed anything clarified. Then, I gathered socio-demographic information, including age at the time of the recording, place of origin, age of Spanish acquisition, and education. If some speakers needed special attention such as identifying the picture on the screen, they received help from me. Sessions took around 10 minutes with each of the participants. Participants were financially compensated for their time.

Each participant was asked to say the word as it is pronounced in Nahuat or Spanish, accordingly. That material was recorded with a portable digital recorder Zoom H4n Pro Handy Recorder and headset mic. The sessions with the participants were recorded in 16-bit Waveform Audio File Format (WAV) with a sample rate of 44.1 kHz. The figures below show examples of the pictures contained in the two lists. Figure 2.1 (Nahuat) and Figure 2.2 (Spanish) below show examples of the pictures that were used for collecting the data.

Figure 2.1 Three slides from the list of words in Nahuat. The left picture displays a picture of a pajpata ‘banana’. The middle slide displays a picture of the tonal, ‘sun’. The right image displays a picture of kosantsin, ‘rainbow’.

Figure 2.2 Six slides from the list of words in Spanish that contains both the voiceless series of stops consonants (/p/, /t/, /k/) and the voiced series of stops consonants (/b/, /d/, /g/). The top pictures show the words pera 'pera', and bandera, 'flag'. The middle pair of pictures contain the words tortilla, 'tortilla', and dulce, 'candy'. The bottom pair display the word cactus, 'cactus', and ganso 'goose'.

To collect my data, I mainly visited Cuetzalan and then the following communities: San Miguel Tzinacapan, Yohualichan, Xiloxochico, Tecoltepec. In Yohualichan, some participants that were originally from Tzicuilan took part of this study. In addition, when I was in Cuetzalan, some of the participants were originally from Santiopan, Pepexta or Ayotzinapa. All these communities are close to each other and they are located in the Northern part of Puebla in the East Central Mexico (See Figure 1.2).

To collect data from Spanish, I visited the cities of Guadalajara (the capital of the state) and Zapopan (part of its metropolitan zone), both located in the state of Jalisco, which is in the west side of Mexico. Figure 2.3 presents a map of Jalisco and the cities are represented by the dots colored accordingly.

Figure 2.3 This map shows the location where I collected the mononlingual Spanish speakers' data. This map is freely licensed under the Open Data Commons Open Database License (ODbL) by the OpenStreetMap Foundation (OSMF). The globe is freely licensed under Creative Commonns BY-SA 3.0.

Tables 2.1-2.4 provide the sociodemographic information of my participants (age, gender, community, and formal education). Table 2.1 describes the background information of simultaneous bilinguals. Table 2.2 provides the background information of early bilinguals and Table 2.3 provides the background information of late bilinguals. Table 2.4 describes the background information of Spanish monolingual speakers.

Table 2.1 Simultaneous bilinguals

Consultant	Age	Gender	Community	Formal education
# 1	26	Female	San Miguel Tzinacapan	High school
# 2	67	Male	Xiloxochico	Middle School
# 3	27	Male	Xiloxochico	Middle School
# 4	51	Female	San Miguel Tzinacapan	University

# 5	20	Female	Xiloxochico	Middle School
# 6	25	Female	Santiopan	Middle School
# 7	25	Female	Yohualichan	Middle School
# 8	23	Male	Yohualichan	Middle School
# 9	30	Female	San Miguel Tzinacapan	University
# 10	17	Female	San Miguel Tzinacapan	High school

Table 2.2 Early bilinguals

Consultant	Age	Gender	Age of Spanish acquisition	Community	Formal education
# 11	32	Male	7	San Miguel Tzinacapan	Highschool
# 12	35	Female	7	Pepexta	Highschool
# 13	44	Female	6	San Miguel Tzinacapan	Elementary school
# 14	24	Male	7	San Miguel Tzinacapan	Elementary school
# 15	33	Female	7	Cuetzalan	Middle school
# 16	44	Female	6	Tzicuilan	Middle school
# 17	37	Male	5	San Miguel Tzinacapan	Highschool
# 18	27	Female	7	Tecoltepec	University
# 19	40	Male	5	Cuetzalan	University
# 20	24	Female	5	San Miguel Tzinacapan	University

Table 2.3 Late bilinguals

Consultant	Age	Gender	Age of Spanish acquisition	Community	Formal education
# 21	78	Male	15	Yohualichan	Elementary school
# 22	45	Female	20	Ayotzinapa	Elementary school
# 23	75	Male	14	Cuetzalan	Elementary school
# 24	55	Female	14	Yohualichan	Elementary school
# 25	37	Female	15	Yohualichan	Elementary school
# 26	63	Female	14	Yohualichan	Elementary school
# 27	73	Female	14	Tecoltepec	Elementary school
# 28	47	Female	15	Xiloxochico	Middle school
# 29	65	Female	15	Yohualichan	Elementary school
# 30	41	Female	15	Yohualichan	Elementary school

Table 2.4 Monolingual Spanish speakers

Consultant	Age	Gender	City	Formal education
# 31	38	Male	Zapopan	University
# 32	20	Male	Guadalajara	University
# 33	43	Female	Guadalajara	Middle school
# 34	18	Female	Guadalajara	High school
# 35	31	Female	Guadalajara	High school

# 36	58	Female	Guadalajara	Middle school
# 37	35	Female	Guadalajara	University
# 38	31	Female	Guadalajara	University
# 39	59	Female	Guadalajara	University
# 40	67	Female	Guadalajara	University

2.2 Data analysis

After importing the sound files into the *Praat* software version 6.0.43 (Boersma & Weenink, 2020), I created a text Grid for each of the words. I marked a VOT as positive when there was no indication of pre-vocing in the wave form or spectrogram and if there was any degree of time lag between the release of the stop and onset of the following vowel; VOT was marked as such even when a voiced sound might have been expected as per orthographic conventions or based on common monolingual production. On the other hand, negative VOT was considered when participants produced voicing before the release of the stop consonants.

To measure VOT, I focused on the initial position of the stop before the vowel. Figures 2.4-2.6 display one example for each of the voiced stop consonants (/b/, /d/, /g/ respectively) of how participants voiced the first sound. For the voiceless series it was considered the exact moment of release of the stop consonant until the onset of the vowel, whereas for the voiced series the VOT was measured from the moment of phonation until release.

After measuring each stop consonant at the beginning of the word, a Praat script created by Stewart (2020) was used to extract all the data measurements to a textfile that was later imported into Excel. The data contained the following categories; annotation, stop type (positive or negative), ID for speaker (their initials), age of speakers at the time of the recording, bilingual type (simultaneous, early and late), community, language (Nahuat, Spanish), VOT duration the stop that was being measured, pre and post sound (this was to indicate which sounds were surrounding the stop consonant), gender (male, female), education (elementary, high school and university), syllables, and stress (stressed and non-stressed).

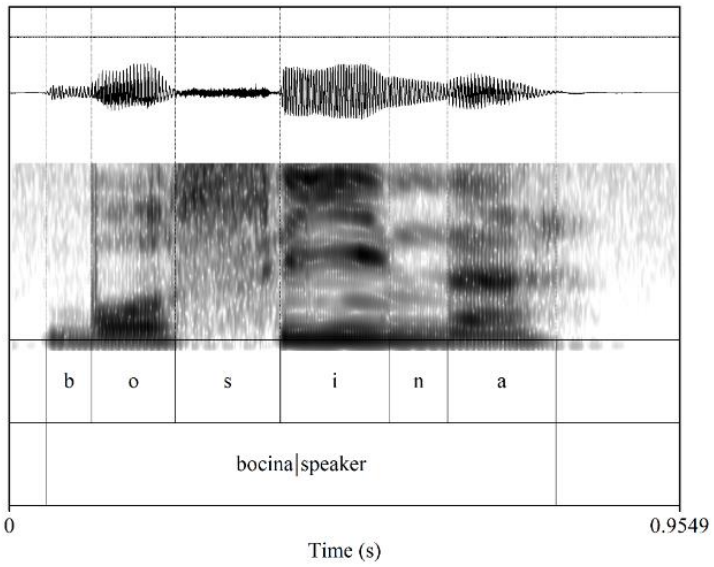

Figure 2.4 This word bocina 'speaker', shows an example of how a voiced stop was analyzed. The VOT duration for this word is -67 ms. This represents an example of a word whose VOT is slightly higher compared to Spanish monolingual speakers. Additionally to measuring the VOT in the spreadsheet, place of the stop (initial or medial), language, speaker, age, community, bilingual type, gender, education, and stress in words were identified.

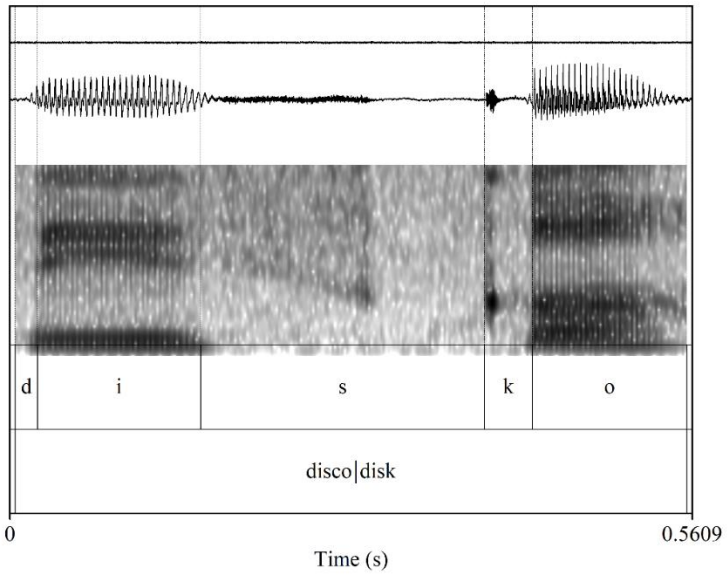

Figure 2.5 In this word disco 'disk', a late bilingual produces a Spanish origin voiced stop with a duration of -13 ms.

In the next example (Figure 2.6), the initial sound was expected to have a negative VOT because the word was expected to be /g/, however, the image shows how this participant devoiced the sound and displayed a positive VOT.

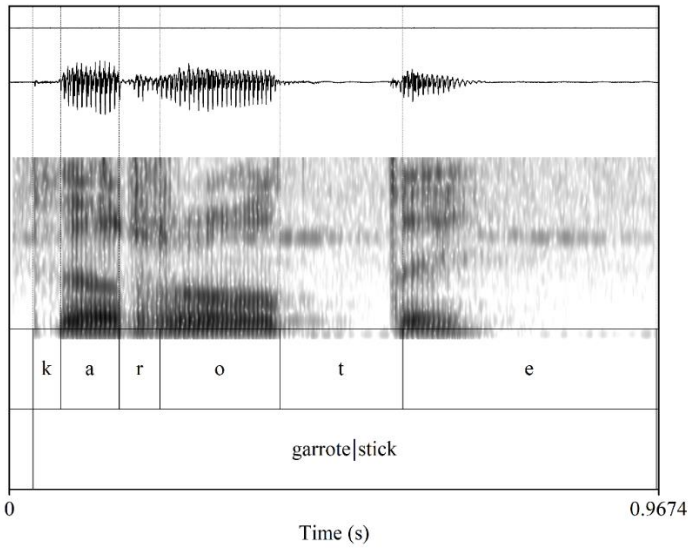

Figure 2.6 In this example, a late bilingual produces a Spanish origin voiced stops with a positive VOT of 52 ms consultant #27.

2.3 Statistical analysis

Once the Excel spreadsheet was complete, it was loaded into R for the statistical analysis. To analyze the VOT duration data, I created linear mixed effect models in R x 64 3.5.2 using the *lmer* function from the lme4 package (Kuznetsova, Brockhoff, & Bojesen, 2014), and 95% confidence intervals **(**CI95) are predicted by using the *confint* function of the *lmerTest* package (Kuznetsova et al., 2014). I considered *speaker* and *word* as random effects. During the model building phase, the non-significant predictors were removed from the model one-by-one, based on the closest t-value to zero, until the model only contained significant predictors. Predictors considered are described in each of the following subsections before the model output.

To describe the production variation of positive and negative VOTs in voiced series of Spanish stops based on bilingual type (see section 3.3), a logistic mixed-effect model was created, which helped, in addition to other sociolinguistic variables, to identify the differences in the production of /b, d, g/. The model was created under R 3.2.1 with the *glmer* function of the *lme4* package (Bates, 2012). Ninety-five percent confidence intervals (CI_{95}) were computed using *confint* function from the *lmerTest* package (Kuznetsova et al., 2014). Each model included *speaker* and *word* as random effects.

3. RESULTS

In each of the subsections below, I begin with a description of the raw data for visualization purposes, and then I follow it with a statistical analysis of the data. The first subsection (3.1) describes the voiceless unaspirated series of stops in Nahuat. The second subsection (3.1.2) described the Spanish voiceless VOT. The third subsection (3.1.3) presents Nahuat-Spanish comparison and 3.1.4 describes voiced VOT in Spanish.

3.1 Voiceless Stop Consonants

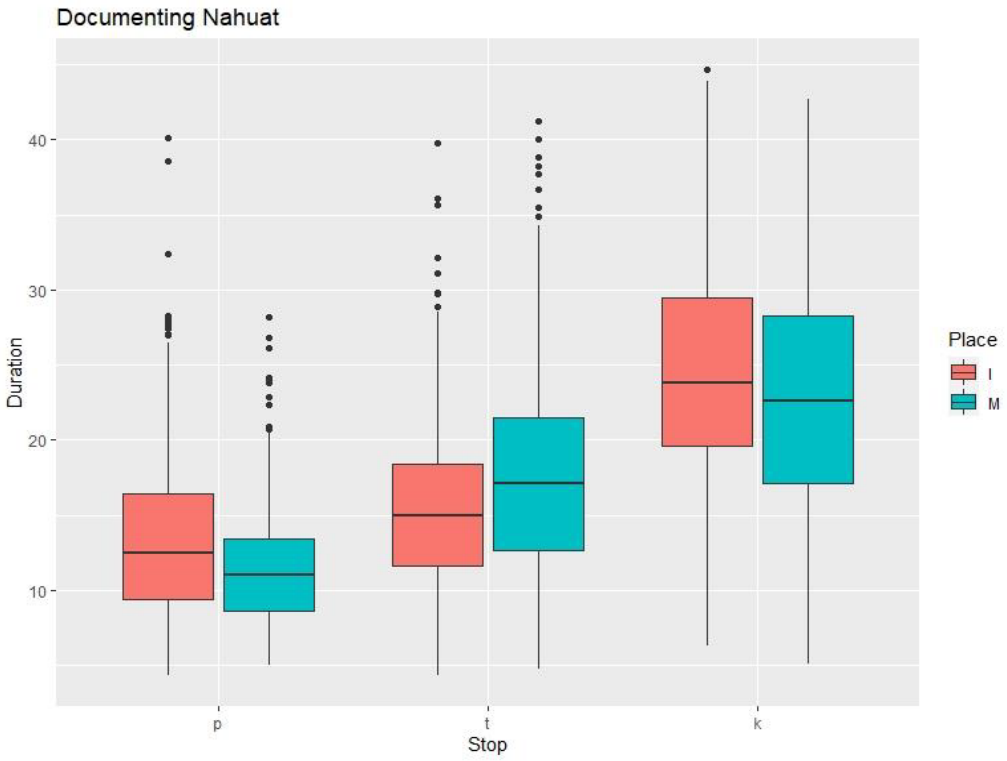

Figure 3.1 Voiceless series of stops in Nahuat. In this graph, "I" and "M" stand for initial and medial accordingly (the positions of the stops consonants in the words).

Figure 3.1 revealed that the longest VOT durations are concentrated in the voiceless velar stop /k/ in Nahuat (red for the initial position of the word and green for the medial position of the word), a phenomenon that required deeper investigation in this analysis. In the bilabial voiceless stop /p/, we can see that the initial position (red color) presents a longer duration than the medial

position (green color), whereas the VOT in the voiceless dental stop /t/ the medial position has longer VOTs than the initial position.

The following model was used to analyze voiceless unaspirated VOT in Nahuat a linear mixed effects model was created and the following variables were considered: **place** (the stops under analysis appear at the initial or medial position of the word), **age** (17-78,30 factors), **place of origin** (Ayotnizapa, Chicueyaco, Xiloxochico, Cuetzalan, Pepexta, San Miguel Tzinacapan, Santiopan, Tecoltepec, Yohualichan, as well as Zapopan city, and Guadalajara city), **education** (elementary, high school, and university), and the **stops voiceless series** /p/, /t/, and /k/.

Table 3.1 The linear mixed effects model results of voiceless stops in Nahuat.

	Estimate	**Std. Error**	**2.5%**	**97.5%**	**DF**	**t-value**	**Pr(>|t|)**
(Intercept)	13.8	0.8	12.0	15.5	88.0	15.6	< 2e-16 ***
/t/	4.1	0.6	2.8	5.4	790.1	6.3	4.38e-10 ***
/k/	13.2	0.8	11.6	14.8	374.0	16.1	< 2e-16 ***

When a result is significant, my focus is the coefficient estimate (β), which is an estimate of the mean (average) different durations measured in milliseconds between the segments under study. The intercept, on the other hand, can be considered as the base value in milliseconds where the predictor is considered as their baseline value, i.e., zero. The intercept, with a value of 13.8, predicts that (when all predictors are default levels), the average duration of the stop /p/ is 13.8 ms.

The model displays that the VOT of the dental stop /t/ is longer than /p/ by 4.1 ms on average, resulting in an average VOT of 18 ms for /t/ (14 (intercept) + 4 (/t/). There is a significant average difference in VOT between /p/ (the intercept) and the velar stop /k/ of 13.2 ms, resulting in an average VOT of 27 ms for /k/ (13.8 (intercept)+ 13.2 (/k/)).The results from the model reflect the information in Figure 3.1, in which according to the raw data, we can see that /k/ has a longer VOT with greater variation than /p/ and /t/. These results provide the first acoustic measurements of VOT in Nahuat and suggest there is little variation in the system beyond place of articulation, which, as stated before, is a common cross-linguistic effect.

3.1.1 Spanish Voiceless VOT

My goal for this section is to display a phonetic analysis of the Spanish voiceless stop consonants. Based on place of articulation, Figure 3.2 reveals the distribution of VOT duration in the voiceless series of stop consonants in Spanish. In the same vein as the Nahuat language the voiceless velar plosive /k/ presented longer VOT. This has been previously suggested, as more retracted places of articulation equate to longer VOTs in this voiceless series (Cho and Ladefoged, 1999).

The shortest VOT values were found in the initial position of /p/ sounds. Moreover, the /t/ initial position presented a slightly longer duration than /p/ medial position. Unlike the voiceless bilabial plosive where the initial position presents shorter duration than the duration of the medial position, the voiceless dental stop /t/ in the initial position presented longer duration than in the medial position. Same as in Nahuat language, the greatest variation and duration was found in the voiceless velar stop /k/ where the medial position shows longer duration than the initial position.

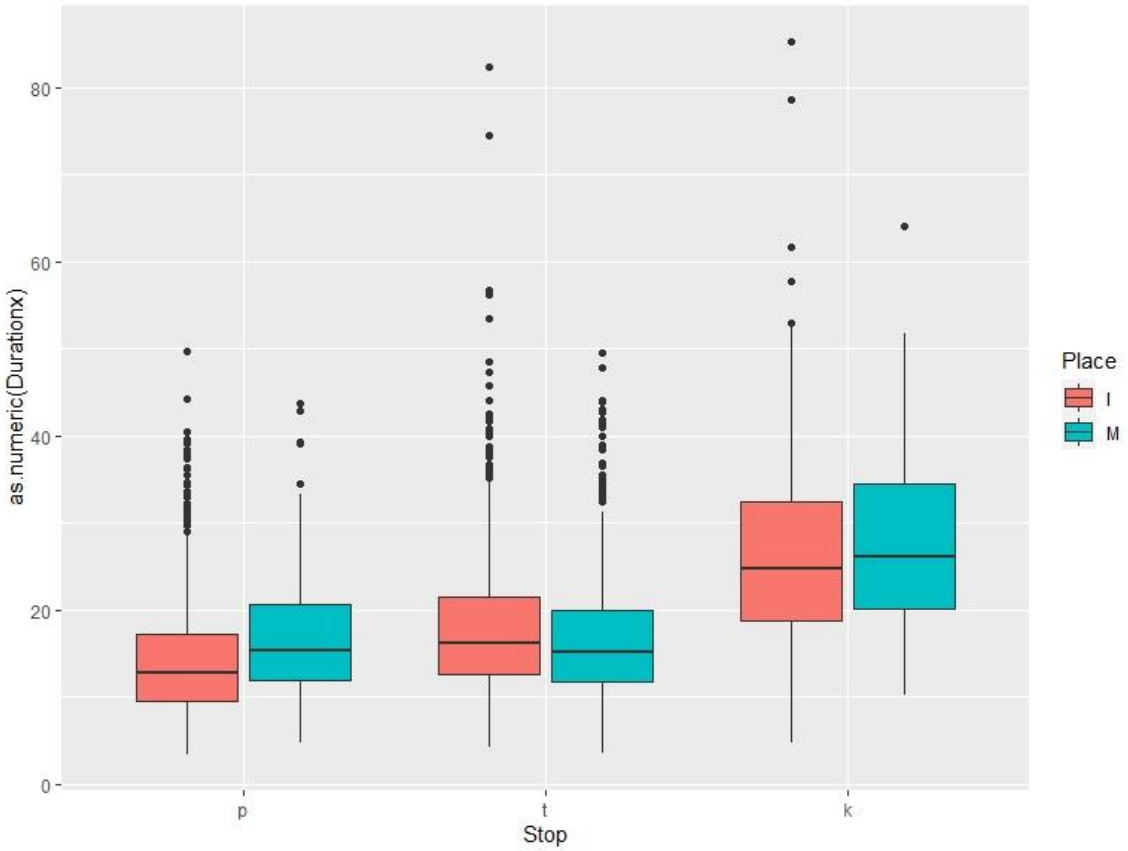

Figure 3.2 Spanish series of voiceless stop consonants

This model was used to analyze voiceless stop series VOT in Spanish. A linear mixed effects model was created and the following variables were considered: **place** (the position where a stop under analysis appears, initial or medial), **age** (17-78, 30 factors), **place of origin** (Ayotnizapa, Chicueyaco, Xiloxochico, Cuetzalan, Pepexta, San Miguel Tzinacapan, Santiopan, Tecoltepec, Yohualichan, as well as Zapopan city, and Guadalajara city), **education** (elementary, high school, and university), the **stops voiceless series** /p/, /t/, and /k/, and **stress** in words.

This model was used to analyze voiceless stop series of VOT in Spanish. Stop and stress are significant in this model.

Table 3.2 The linear mixed effects model results of stop and stressed stops in Nahuat.

	Estimate	Std. Error	t-value
(Intercept)	15.8	0.7	20.3
/t/	1.8	0.4	4.2
/k/	11.6	0.5	19.6
Stressed and non-stressed	-1.4	0.5	-2.8

Likewise, in the Nahuat voiceless model, my focus is the coefficient estimate (β), which is an estimate of the average different durations measured in milliseconds between the considered segments. Moreover, the intercept with the base value of 16, predicts that the VOT value of the stop /p/ is on average 16 ms.

The model provides evidence that the VOT of /t/ is longer than /p/ by 1.8 on average resulting in an average VOT of 20 ms for /t/ (16(intercept) + 2 (/t/)). There is a substantial average difference in VOT between /p/ (the intercept) and /k/ of 11.6 resulting in an average VOT of 28 ms for /k/ (16 (intercept)+ 12 /k/). The results from this model collaborates with the results of the boxplot where /k/ presents greater variation as well as longer duration.

3.1.2 Comparison in word-initial and word-medial combined

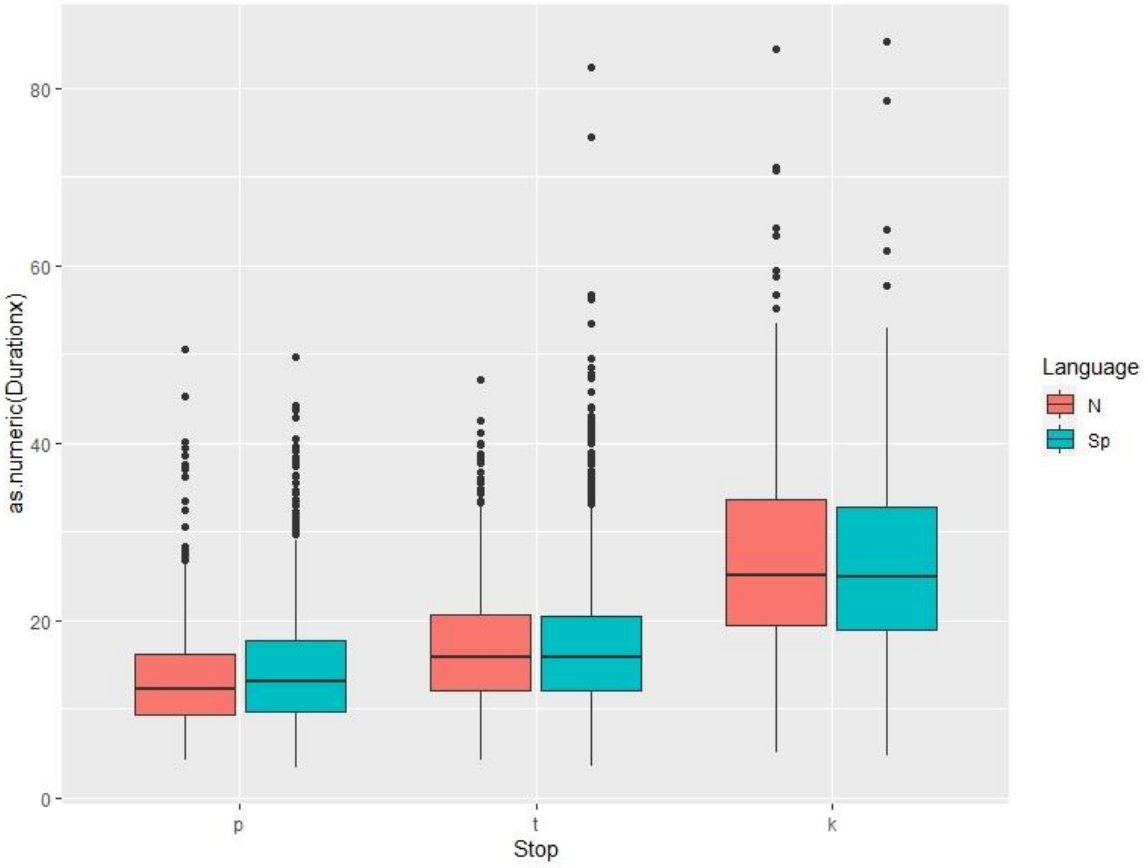

Figure 3.3 Comparison in word-initial and word-medial combined.

Figure 3.3 displays information of comparison of voiceless stops in word-initial and medial combined in both languages (red for Nahuat and green for Spanish). The shortest duration can be found in the initial position of /p/ of Nahuat. However, Spanish /p/ presents only a slight difference when compared with Nahuat. As for /t/ there is no differences between the two languages as the two of them present the same VOT values. On the other hand, for the voiceless velar /k/ Nahuat presents a non-significant higher VOT duration than Spanish VOT duration.

Table 3.3 The linear mixed effects model results of voiceless in Spanish

	Estimate	Std. Error	t-value
(Intercept)	13.4	0.8	16.0
/t/	4.0	0.6	6.5
/k/	13.3	0.7	17.7
Spanish	1.9	0.7	2.7
Spanish /t/	-2.4	0.7	-3.1
Spanish /k/	-2.0	0.9	-2.1

Both the stop /t/ and /k/ in Spanish are predicted to have slightly shorter duration by 2 than in Nahuat, resulting in an average VOT value of 14 ms (16 (intercept - 2 (/t/, /k/)). Whereas there exists a substantial difference between Spanish and Nahuat voiceless VOT values, the difference is not enough to postulate noticeable difference between Nahuat and Spanish. In the two languages the short lag unaspirated VOTs is present. As such, there is no reason for Nahuat speakers to accommodate to Spanish as this difference is not perceivable. Languages have different ranges within each category, therefore, there is no reason to think that languages should have the exact values given the fact that VOT categories are.

3.1.3 Stressed and non-stressed in Nahuat

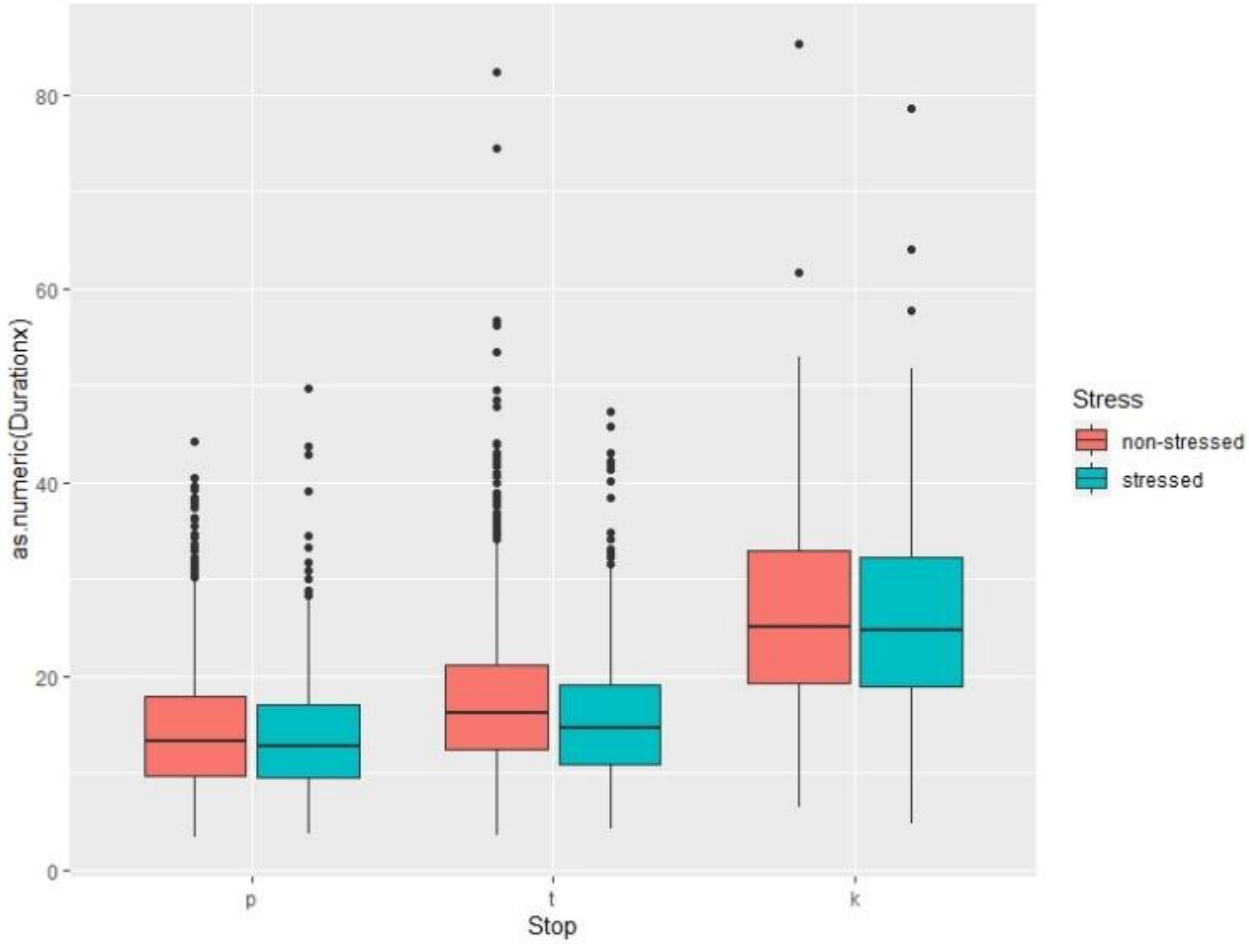

Figure 3.4 Stressed and non-stressed analysis in Nahuat.

Figure 3.4 provides comparison of stressed and non-stressed voiceless stops. For the stop /p/, the non-stressed (red color) presents a slightly longer VOT duration than the stressed (green color). Likewise, the non-stressed /t/ is showing higher VOT duration than the stressed one. For the voiceless velar /k/, the non-stressed series present a non-significant longer duration than the stressed.

Table 3.4 The linear mixed effects model results of stressed and non-stressed in Nahuat.

	Estimate	Std. Error	t-value
(Intercept)	15.8	0.7	20.3
/t/	1.8	0.4	4.2
/k/	11.6	0.5	19.6
Stressed and non-stressed	-1.4	0.5	-2.8

The intercept with a value of 15.8 predicts that the average VOT of the stop /p/ is 15.8 ms. The model displays that /t/ is produced longer than /p/ by 1.8 ms on average, resulting in an average duration of 17. 6 for /t/ (15.8 the intercept + 1.8 /t/). The difference between /p/ (the intercept) and the /k/ is approximately 11.6, resulting in an average VOT of 27.4 for /k/ (15.8(intercept)+11.6/k/). For the stop /p/, there is only a slight variation between the stressed series and non-stressed series, with only a difference of 1.45 ms on average. Likewise, the average VOT value for stressed /t/ shows a small difference from non-stressed one with the former being 16.1 ms (15.8 (intercept) +1.8 (/t/) – 1.5 (stressed)) while the latter being 17.6 ms (15.8 (intercept) +1.8 (/t/)). Also, the stressed stop /k/ presents slightly shorter duration than the non-stressed one, with an average VOT of 25.9 ms (15.8 (intercept) +11.6 (/t/) – 1.5 (stressed)). According to both the boxplot and the model, stressed /k/ is produced shorter but not longer than non-stressed /k/. When being stressed, all voiceless stops have a shorter duration than non-stressed series. However, /k/ is produced longer than both /p/ and /t/ regardless of being stressed or not. As previously stated, only little formal research in linguistics have been done to understand the features of this endangerous language, as such by identifying the stress in these consonants, this allows us to better understand another important factor in VOT production as well as in VOT variation.

3.2 VOT of Spanish stops based on bilingual type

The main objective of this section is to explore whether there is a difference in VOT production of voiced stops in L2 Spanish across the different types of bilingualism, and to compare the values with those from monolingual L1 Spanish speakers (our baseline) across bilingual type. The raw data suggests that early and simultaneous bilinguals show similar trends in VOT duration of voiced stops in Spanish. The data also suggest that late bilinguals, on the other hand, are displaying more variation in their VOT duration, which reaches into the positive range.

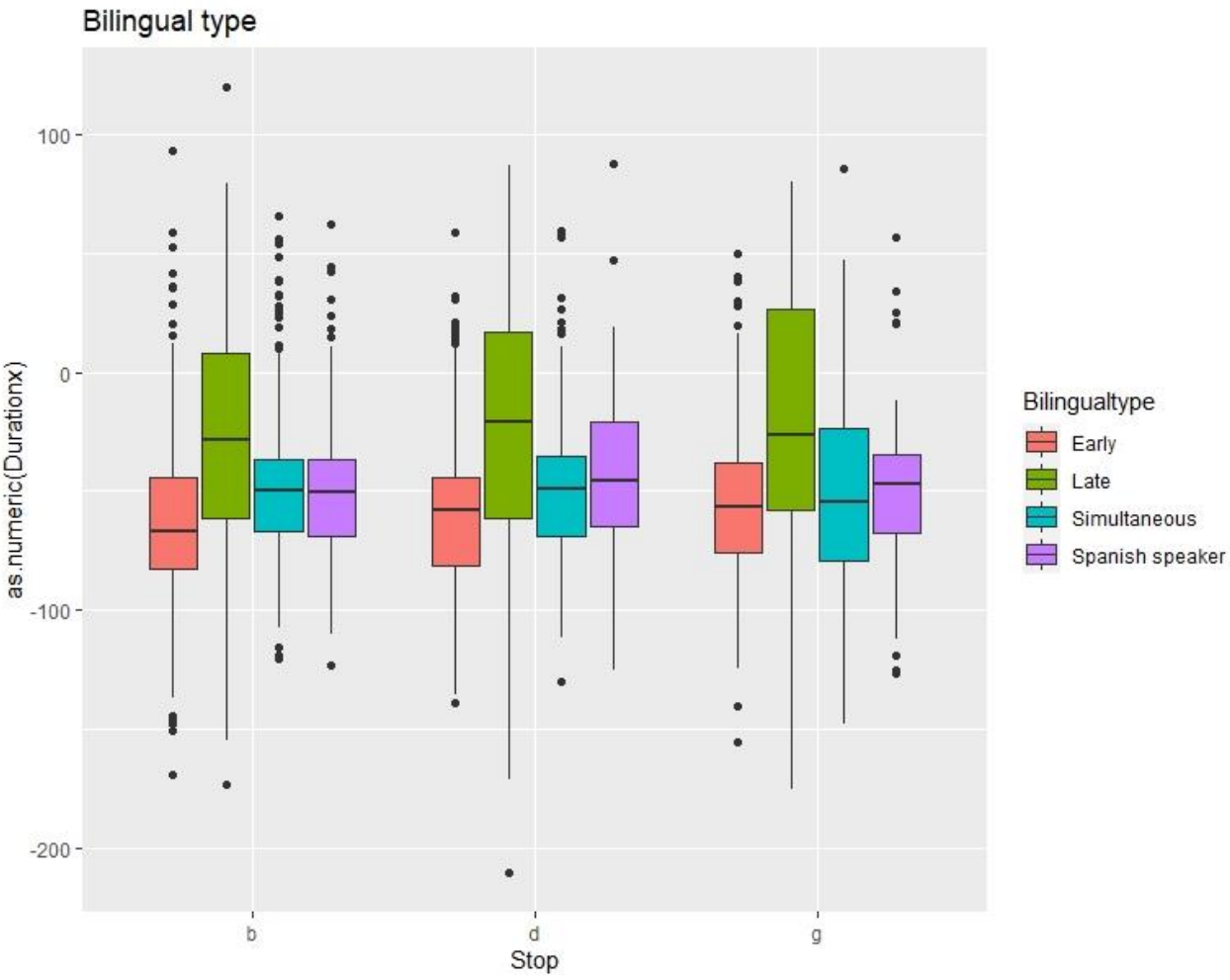

Figure 3.5 Analysis of bilingual type

The results reported here posit that both **place of articulation** and the **age of Spanish acquisition** play an important role. To identify specific differences among participants, the second linear mixed effects model was created and the following variables were considered: **bilingual type** (simultaneous, early, late, and L1 Spanish), **stop voiced series** (/b/, /d/, & /g/), **gender** (male and female), **age** (17-78 (with 30 factor levels)), **education** (elementary, high school, and university), and **community** (Ayotnizapa, Chicueyaco, Xiloxochico, Cuetzalan, Pepexta, San Miguel Tzinacapan, Santiopan, Tecoltepec, Yohualichan, Zapopan, and Guadalajara). I included **speaker** and **word** as random effects.

During the model building phase, there were non-significant differences between the groups who self-identified as simultaneous and early bilinguals; therefore, they were combined.

Combining them improved the overall model and allowed for the incorporation of 'gender', which accounts for significant variation.

Table 3.5 Voiced model results of voiced VOT duration

	Estimate	**Std. Error**	**2.5%**	**97.5%**	**DF**	**t-value**	**Pr(>|t|)**
(Intercept)	-51.2	5.8	-62.6	-39.9	54.1	-8.7	5.9
Simultaneous & Early	-17.1	5.1	-27.2	-6.4	361.9	-3.3	0.001
Late	38.3	6.1	25.4	50.4	6.2	6.2	1.4
Male	21.8	10.4	1.6	42.3	2.0	2.0	0.04

This model reveals that the production of voiced stops varies with the age of acquisition. The intercept predicts that (when all predictors are defaults) the average duration of the voiced stops produced by L1 Spanish speakers is -51.2 ms. Participants that acquired Spanish simultaneously or early in their life have an average VOT value of -68 ms (-51.2+(-17.1)), suggesting that the values are slightly higher.

There is also a significant difference between L1 Spanish speakers and late learners with the latter presenting a VOT value of -12.9 ms (-51.2+(-38.3)) on average. These results are interesting, but not surprising given late speakers may have not fully acquired an L1 Spanish-like VOT series and are relying on their native Nahuat system, which only contains voiceless unaspirated stops (see 3.1).

Additionally, gender has a significant impact on the production of voiced stops. The duration of the stops produced by males is, on average, -29.4 ms (-51.2 + 21.8) while females (the intercept) have an average VOT value of 51.2 ms shorter. More importantly, late bilingual males, compared to late bilinguals females (-29 ms), produced a positive VOT value of 8.9 ms (-51.2+38.3+21.8), which indicates that these participants are not producing negative VOTs like those produced by L1 Spanish speakers and early bilinguals, and instead are relying on their Nahuat series (/p/, /t/ and /k/) for both voiceless and voiced stops when speaking Spanish as can be seen in Figure 3.1.

Given that simultaneous and early bilinguals have been speaking Spanish for the majority of their lives and both sound like native Spanish speakers in informal conversation, it is unsurprising that their VOT values are non-significantly different. This has been shown before when Flege (1991) studied VOT production in Spanish-English bilinguals and his findings

suggested that both simultaneous and early bilinguals often produce L1 and L2 VOT values with only slight variation.

Moreover, there were non-significant differences found across place of articulation; therefore, they were treated as the same in the intercept as predicted in Figure 3.5. This has been studied before when Chodroff and Wilson (2017) showed VOT distribution data of stops /b d g p t k/ across American English speakers, which provided evidence of the nature of speaker variation. It was stated that while VOT values in absolute terms varied significantly among participants, participants showed similar linear relations between both voiced and voiceless stops and between different places of articulation (e.g., /p/ vs. /k/).

3.3 Variation in voiced stop production across bilingual type

Figure 3.6 displays variation in production in the voiced series of Spanish stops. On the x-axis, this graph focuses on different types of bilingualism (simultaneous, early, and late speakers) with monolingual L1 Spanish speakers used as a baseline for comparison.

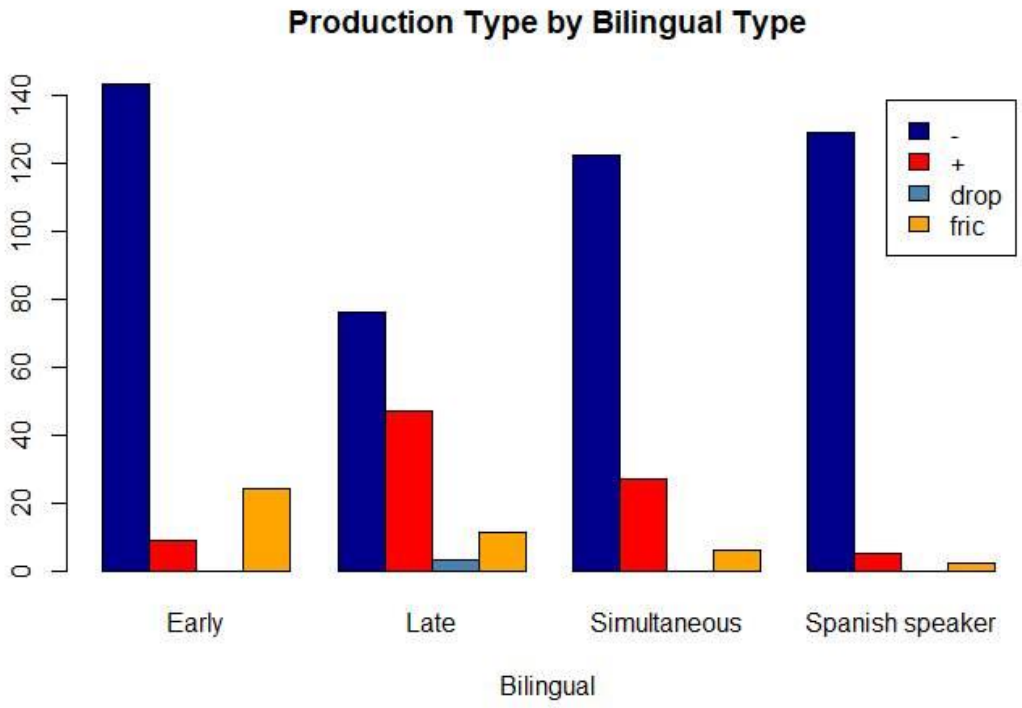

Figure 3.6 Voiced VOT variation according to bilingual type.

The trends from Figure 3.6 suggest that late speakers tend to produce a higher number of positive VOT in the voiced series of stops, followed by simultaneous bilinguals when compared to L1 Spanish speakers and early bilinguals. However, early bilinguals tend to produce greater number of fricatives compared to the other bilingual types. The results of the model are presented in Table 3.6.

Table 3.6 Voiced model results of voiced VOT variation

Variable	**Estimate (β)**	**Std. E**	**2.5%**	**97%**	**Z**	**Pr(>|z|)**
(Intercept)	-3.4	0.31	-4.15	-2.84	-10.92	< 2e-16 ***
Late	2.46	0.50	1.54	3.59	4.91	8.99e-07 ***
/g/	0.41	0.17	0.05	0.78	2.34	0.0191 *
Tecoltepec community	2.43	1.09	0.21	4.73	2.21	0.0265 *

The coefficient estimate (β) is the main focus when a result is significant. This can be defined as a conservative estimate of the average difference in log-odds (a measurement of probability) response between the factors that were analyzed.

The first significant factor found was related to *bilingual type*. Based on the model analysis, late bilinguals showed significant differences in the number of positive /b/, /d/, /g/ VOTs compared to the rest of the bilingual types under analysis. Therefore, in comparison to non-late bilinguals, it is predicted that late bilinguals will produce positive VOTs for /b/ and /d/, on average, 27% (i.e., -3.4 log-odds + 2.4 log-odds) of the time. Moreover, according to this model, late bilinguals tend to produce positive VOTs for the voiced velar plosive /g/, on average, 35% (i.e., -3.4 log-odds +2.4 log-odds +0.4 log-odds)) of the time. These results are in line with studies that show late bilinguals often do not fully acquire native-like VOTs in their L2 (see e.g., Flege & Eefting, 1986).

As for the results related to community, the model predicts that late bilinguals from Tecoltepec are expected to produce positive VOTs for /b, d/, on average, 80% (i.e., 1.4 log-odds (-3.4 log-odds + 2.4 log-odds + 2.4 log-odds)) of the time, and, on average, 86% of the time for /g/. (i.e., 1.8 log-odds (-3.4 log-odds + 2.4 log-odds + 0.4 log-odds + 2.4 log-odds)). Non-late bilinguals and late bilinguals differ considerably in the way they produce /g/. Tecoltepec was the most remote community visited, and it should be noted that speakers in this place have a more limited working knowledge of Spanish, which is typically used for commerce purposes. However, these results should be taken with reservation given the small participant pool from this group. This area provides an opportunity to study late learners' L2 acquisition.

4. DISCUSSION

This study has examined voice onset time production from simultaneous bilinguals, early bilinguals, and late bilinguals, which since the 1960s, has been used frequently to test the acquisition of stop consonants in bilinguals. The first goal of this study was to collect acoustic data on Nahuat (a variant of Nahuatl spoken in the Northern part of Puebla, specifically in Cuetzalan) for the first time.

After collecting this data, I conducted an acoustic analysis of VOT to document values for the voiceless stop consonants /p/, /t/, and /k/ in Nahuat. These results show that Nahuat speakers make use of short-lag or unaspirated VOT with an average range of 14 ms for /p/, 17 ms for /t/ and 28 for /k/, similar to that of Spanish. These results likely mean that acquiring Spanish /p/, /t/, and /k/ would not be a difficult task for most speakers no matter their age of acquisition or language ability.

For the simultaneous bilinguals, past studies (Fokes-Steinberg, 1985; Kim, 1997) have shown that even when their languages have similar phonemes, they are able to produce values similar to those of monolinguals. However, this study showed that early bilinguals along with simultaneous bilinguals, displayed a relatively large degree of difference in the production of thevoiced series of stops when compared to L1 Spanish monolingual values -68 ms compared to -51 ms, respectively. This may be the result of hypercorrection, but it is more likely that even though the speakers are early / simultaneous bilinguals, the Spanish language they acquired is likely influenced by the L1 of their parents or grandparents, which may contain hypercorrected VOT. Another possibility is that the monolingual Spanish in the state of Puebla, more specifically in Cuetzalan may simply have longer VOT values than monolingual Spanish from Guadalajara where my data were collected. Table 1.3 shows a great degree of variation in VOT duration cross-dialectally, so it would not come as a surprise if this was simply a feature of Spanish spoken in the region. It would be interesting to conduct future research on monolingual Spanish spoken in and around Cuetzalan.

An important factor to consider is that the majority of the simultaneous bilingual speakers were not older than 35 years of age and the use of their L2 (Spanish) more frequency because Spanish is encoaching more and more in people's daily lives through globalization. In addition,

most of their formal education has been provided in Spanish, many of them indicating that they learned Spanish as soon as they started elementary school. However, it must be noted that the differences in results between simultaneous and early VOT production are still not fully understood and require further investigation.

Another factor that requires further research involves the relationship between education and a bilingual type. Education was shown to be non-significant in the model results, which could mean one of two things (1) education is not a strong predictor of negative VOT production or (2) it might be confounded with bilingual type since there is a direct relationship between having a strong command of Spanish and access to higher education. This is apparent in Tables 2.1-2.4 where only one late bilingual had received a middle school level education while the other groups contained a substantial number of participants who had access to high school and university educations. This factor requires further exploration.

Furthermore, despite the vast diversity of languages in the world and the technological advancements that have allowed us to study language production in new ways, only a few studies have carefully analyzed phonological production in bilinguals. Moreover, it was found that late bilinguals had significantly shorter VOT durations when compared with Spanish monolinguals. This result most likely occurred because late bilinguals rely heavily on the phonological inventory of their L1 when producing their L2. In the specific case of the positive VOT measurements, the late bilinguals appear to be mapping Spanish VOT on to the closest native segments in their inventory; the voiceless stop series, which makes use of positive values.

Furthermore, gender was also a factor on the production of Spanish voiced stops in late bilinguals. Whereas late bilingual females displayed, on average, negative VOT values of -29 ms, late bilingual males showed a positive VOT value of 8.9 ms, on average. This suggests that, unlike other groups, late bilingual males are not producing negative VOTs and are relying on the phonemes present in their L1 inventory when speaking Spanish. This could be due to the fact that males spend more time in jobs related to agricultural process rather than dealing with people, as such, males might have less education opportunities. On the other hand, women are in charge of raising children and the type of jobs women perform are more related to dealing with people face to face such as selling goods or running small restaurants. Unlike males that displayed significant difference while producing Spanish negative VOT in their stop consonants, women did not show

such a marked difference suggesting that the type of activities that they performed may impact their language production.

Additionally, according to the statistical models, late bilinguals show a tendency to produce positive VOTs for the voiced velar plosive /g/, on average, 35% of the time. One of the reasons why non-late bilinguals and late bilinguals differ significantly in the frequency of devoicing in the production of /g/ likely has to do with the aerodynamics of velar stops. In non-velar prevoiced stop consonants, like those found in Spanish, air originating from the lungs enters the vocal tract through the glottis, where it encounters the vocal folds under tension as the artynoid cartilages are drawn together. This causes the vocal folds to vibrate as the air passes through the glottis and into the pharynx where it is subsequently deflected into the oral cavity, by the uvula, which is pressed against the pharyngeal wall. It then continues until it encounters an obstruction e.g., the tongue pressed against the back of the teeth for /d/, or the lips for /b/. This additional space in the oral tract allows more air to fill the cavity as pressure increases thus allowing additional time for phonation. This pressure will eventually reach a critical point where no more air will be allowed to pass though the glottis causing phonation to cease. Yet, this is typically enough time for speakers to release the obstruction and produce the stop before phonation is no longer possible. However, for prevoiced velar stops, the entry into the oral tract is blocked by the velar closure. This means pressure will increase quicker for /g/ and likely stop phonation sooner given the smaller pharyngeal cavity. For a native speaker of a language with prevoiced stops, this is not a problem because they are attuned to the timing gestures required to produce a prevoiced /g/ in their language. For non-native speakers, however, acquiring exact timing and fine tuned control for such a gesture can be difficult, which may lead to other strategies for dealing with pre-voiced /g/ e.g., pre-nasalization as the seal between the uvula and naso-pharengeal wall is broken to allow for depressurization or, in the case of the late learners in this study, to simply avoid phonation all together, which results in voiceless velar stop similar to [g̥]. Given that /k/ is Nahuat phoneme, it is unsurprising that this is the resulting sound.

Results from this study are in line with past research that shows place of articulation plays a role in voiceless VOT duration where cross-linguistically, greater retractedness equates to a long VOT. This can be seen in monolingual Spanish,where /k/ has an average duration of 28 ms whereas /t/ averages 17 ms, and the bilabial /p/ only averages 14 ms (See Table 2.3). Mexican Spanish

shares similar durations with Guatemalan Spanish dialect previously documented (Williams, 1977). Nahuat's stop inventory shows the same effect with /p/ having the shortest duration (14 ms), followed by /t/ (18 ms), /k/ being the longest at 31 ms.

This study found that other significant sociolinguistic variables such as place of origin also came into play when bilingual speakers produced VOT. The community of Tecoltepec was the most distant community from a major city centre visited during this research. Additionally, it was also shown to have a significant difference in how people from this community produce VOT. Results showed that speakers from Tecoltepec only had a negative VOT of, on average, -1 ms. This may be due to the fact that the community has less contact with Spanish speakers and only uses the language for business purposes. Unfortunately, not much data could be collected from Tecoltepec, so this is simply a working hypothesis. Table 4.1 summarizes the findings from this study.

Table 4.1 Average results from this study in milliseconds

Language Variety	**p**	**t**	**k**	**b**	**d**	**g**
L1 Mexican Spanish	14	18	23	-51	-42	-48
L1 Nahuatl	14	18	31	--	--	--
Simultaneous Bilinguals	14	17	27	-47	-49	-44
Early Bilinguals	13	16	27	-55	-53	-43
Late Bilinguals	17	20	27	-28	-21	-17

Whereas Mexico is considered a linguistically diverse country, there is still a lack of studies that provides evidence that the age of Spanish acquisition (the official language in the country) is an important factor to understand bilingualism in the country.

This study shed light that these participants indeed showed the greatest variation in language production among the rest of the groups. Late participants acquired Spanish after the critical period. As such, they rather learned the language than acquired it naturally. This is evidenced by the fact that some late bilinguals produced positive VOTs in the voiced stop series relying on their L1 for L2 production.

4.1 Limitations

Although this study provides evidence that late bilinguals showed more VOT variation than the either simultaneous or early bilinguals, the pool of participants in this study is considerably small in relation to the total number of bilingual people present in the communities. Due to the small number of participants for each of the bilingual categories, it is impossible to assume that all bilinguals with the same characteristics will present similar types of variation.

Moreover, there are other languages in the region that may limit this study's specificity to Nahuat speakers. Cuetzalan is located near a region where Totonaco is spoken, however, while collecting data and taking into consideration sociodemographic information, I made sure that participants had Nahuat as their L1 and Spanish as their L2. The population of Cuetzalan tend to be people who have arrived from different regions within Mexico, but people mainly come from the surrounding areas; therefore, I suggest that future studies that focus on participants originally from different communities in Mexico would help specify this research by discovering whether bilinguals from other communities show similar VOT variations.

In particular, I believe studies with participants from Tecoltepec the most remote community visited, where there are large numbers of late bilinguals, could help reveal whether this study's findings are specific to bilingual Nahuat speakers or whether they are significant across other bilingual Amerindian speakers.

Although studies that use VOT are increasing, little has been written about voiced stops acquisition using VOT studies, making it difficult for this study to compare its findings with previous research. This is especially true because it focuses on Nahuat and Nahuat phonetic features. Nahuatl is considered an endangered language, and while there are studies that have explored other languages that belong to the Uto-Aztecan family, there are virtually no studies that have focused on Nahuat phonetics. Given the lack of studies in Nahuat phonetic features and the existence of different varieties in Nahuatl, it cannot be concluded that bilingual speakers of Nahuat and Spanish will present similar tendencies to those found in this study.

Ideally, VOT data from L1 monolingual Spanish speakers would have been collected in a city/town centre closer to the communities where Nahuat is spoken e.g., Mexico City or Puebla or even Cuetzalan since Guadalajara is located quite far away. However, due to logistical and budgetary issues, this was not possible. Therefore, where possible VOT data on Mexico City Spanish from Avelino (2018), is also presented in the prose for comparison. Either way, there is

minor significant variation in the voiced VOT production of simultaneous/ early bilinguals when compared to Guadalajara Spanish, while the late bilingual results show the voiced VOT results are even more removed from Mexico City Spanish (Avelino, 2018). Therefore, when comparing voiced VOT with L1 Guadalajara Spanish, there is a slightly larger degree of uncertainty.

Finally, I was unable to document the labialized voiceless velar stop /kʷ/ in Nahuat as this project was primarily focused on VOT production in Spanish. Therefore, in order to complete the analysis of the Nahuat stop series, future research will want to focus on recording words containing /kʷ/.

5. CONCLUSION

In addition to the documentation of Spanish VOT production by L1 Nahuat speakers, this research also documents VOT in the Nahuat stop series (/p/, /t/, /k/) for the first time, with the exception of /k^{w}/. These results show Nahuat speakers use voiceless unaspirated stops. Through coincidence or not, these values are virtually indistinguishable for monolingual Mexican VOT values in voiceless stop consonants with the same place of articulation.

Additionally, this study reveals how age of language acquisition plays a role in the production of VOT in voiced stops in Spanish, with early and similtenous bilinguals acquiring slightly longer negative VOT values compared to the monolingual baseline group and late bilinguals producing substantially shorter values negative VOT values, and even at times reaching into the positive range. In the same vein, late bilinguals showed more variation than the rest of the groups, suggesting that they rely more on the phonemes present in their L1 to produce the sounds present in their L2.

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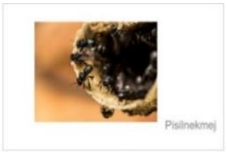
APPENDIX A

Pajpata



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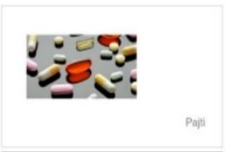

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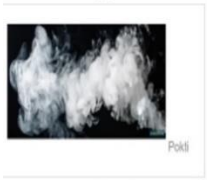

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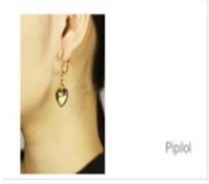
Pachti

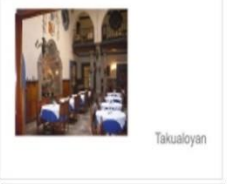
Pepeyoli

Pili



Pipilol

Piotet



Takualoyan

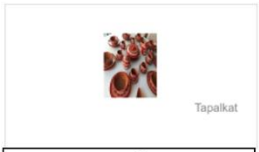
Tixti

Tentso

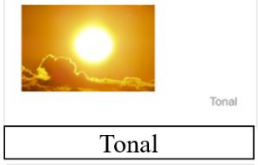
Taxkal

Taol

Tomin



Tapalkat



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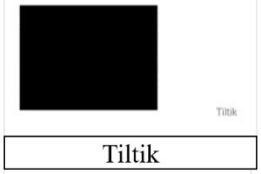

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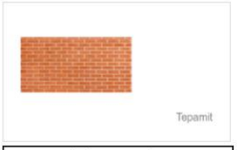


Tepamit

Kaxtol

Kali

Kimichi

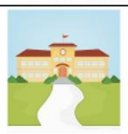
Kaxit

Kaltentatsacuil

Kouat

Kosantsin

Kiouit

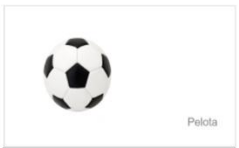


Kaltamaxtiloyan

Kilit

Pera

Pez



Pelota

Palmera

Payaso

Peine

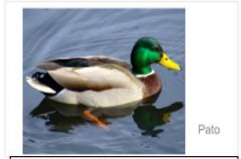
Pierna

Paleta

Pan

Paraguas

Paloma



Pato

Puerta

Pantera

Pájaro

Pantalón

Pijama

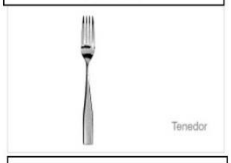
Pulpo

Pastel

Pandero

Taza

Tortilla



Tenedor

Teléfono

Tigre

Tortuga

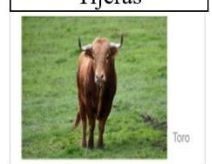
Televisión

Tijeras

Tiburón

Tina

Tierra



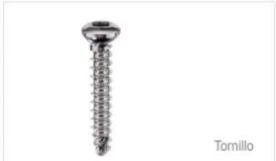
Toro

Tubo

Toronja

Tarro

Té



Tornillo

Tostada

Teja

Tabla

Cocina

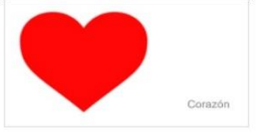
Casa

Cactus

Cabra

Comida

Carne

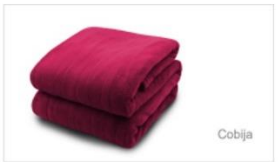


Corazón

Catre

Caja

Café



Cobija

Cotorro

Caballo

Conejo

Calabaza

Coco

Canasta

Cubo

Corona

Cara

Bata

Boca

Botella

Barba

Balón

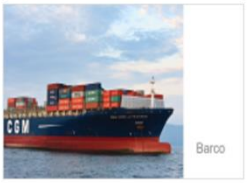
Barro

Botón

Burro

Bebé

Bandera



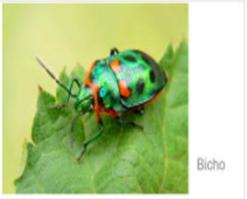
Barco

Banco

Bocina

Buzón

Butaca



Bicho

Botas

Bufanda

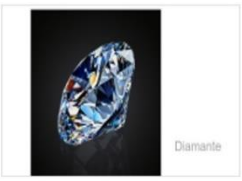
Bicicleta

Ballena

Dedo

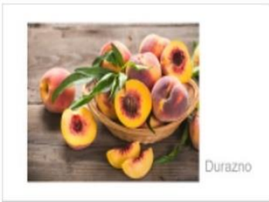
Dado

Diente



Diamante

Doctor



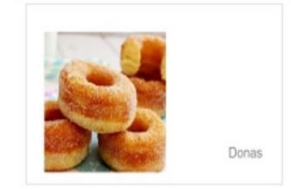
Durazno

Dinero

Dulce

Delfín

Dos



Donas

Dominó

Dinosaurio

Dólar

Dama

Deporte

Departamento

Dentista

Dibujante

Disco

Gato

Guitarra

Ganso

Guayaba

Gota

Gorra

Galleta

Gusano

Gallina

Guantes

Garra

Ganadero

Garrote

Gallo

Garrafón

Gancho

Garbanzo

Gafas

Goma

Gorro