

Acquisition of Spanish by Heritage Speakers of Ukrainian and Polish: a Phonetic and
Phonological Account

by

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

Doctor of Philosophy

(Spanish)

at the

UNIVERSITY OF WISCONSIN-MADISON

2018

Date of final oral examination: 04/05/2018

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Abstract

This study provides an acoustic analysis of vowels and voiceless and voiced stops in narrative, picture-naming, sentence-reading and nonce words reading tasks produced by heritage speakers (HSs) of Polish and Ukrainian residing in the Midwestern US who are beginning and intermediate-level learners of Spanish. The goal of this investigation was to examine if their production of Spanish segments relies more on their heritage language (HL) phonology, which, like Spanish, avoids unstressed vowel reduction, utilizes short-lag voice onset time (VOT) in the production voiceless stops and has true-voicing of voiced stops, or if they show evidence of transfer of unstressed vowel reduction, long-lag VOT, a lack of true-voicing, and a lack of intervocalic lenition from their dominant language, English.

Data from eleven Polish and six Ukrainian HS, with beginning or intermediate levels of Spanish proficiency were analyzed. Ten participants were recruited to serve as control groups: five L1 English L2 Spanish speakers (i.e., L2 acquisition baseline) and five L1 Spanish L2 English speakers (i.e., L1 Spanish baseline). All speakers watched a five-minute silent film and were recorded describing the events they observed. The HSs performed the task in Ukrainian or Polish, and English and Spanish, while the control groups only did it in the latter two languages. All speakers also completed three additional tasks in Spanish: a picture identification task with 33 items, a reading task with 64 contextualized sentences, and a reading elicitation with 44 nonce words embedded carrier phrases.

A subset of English, Polish, Spanish, and Ukrainian vowels and voiceless and voiced stops in different phonetic contexts were extracted and the following acoustic variables were analyzed in *Praat* (Boersma and Weenink 2016): the first two formants in vowels, VOT in voiceless stops, and VOT and relative intensity in voiced stops. The findings suggest reliance on

English in the production of unstressed vowels and intervocalic lenition and influence of the HLs in the production of true-voicing. The voiceless stops results suggest influence of both the HL and the dominant language.

This study fills research gaps in heritage and L3 phonetics/phonology through its focus on the effects of an HL on the acquisition of subsequent sound systems in adulthood. The results suggest that language contact, dominance, and typology, rather than order of acquisition are the most crucial factors in L3 phonological acquisition, which is insight that further supports existing theories of L3 acquisition.

Acknowledgments

I would like to take this opportunity to thank everyone who supported and guided me through my graduate studies. The life of a Ph.D. student is a challenging journey, with its ups and downs, and without these individuals and their continuous guidance it would have been more difficult and far less enjoyable.

First, I want to express my sincere gratitude and appreciation to my advisor, Professor Rajiv Rao. Thank you for introducing me to the marvelous world of phonetics and phonology, which not only formed the foundation of my research, but also became my life-long passion. I greatly thank you for spending countless hours reading and reviewing multiple versions of each chapter of this dissertation, giving valuable feedback and sharing invaluable ideas to improve and elevate this research. Your patience, guidance and continuous encouragement from the very beginning of my journey kept me on track and gave me reassurance when I most needed it. I truly thank you for being a wonderful advisor and mentor. Without you this dissertation would not have been possible.

I would like to extend my gratitude to Professor Catherine Stafford. Your wealth of knowledge and expertise in language acquisition is astounding. Thank you for continuously challenging me and encouraging me to look at my research from multiple lenses. Your insightful comments always reminded me to stay hungry for knowledge and never stop learning.

Professor Diana Frantzen, thank you for sharing with me your wisdom, numerous years of experience and inspiring passion for research and teaching. Since my undergraduate years you taught me the importance of fostering a connection between research and instructional practices, which made me deeply appreciate the practices of language teaching and learning.

Professor Fernando Tejado, I thank you for your high expectations of me to think critically. Your feedback challenged me to consider my research from multiple perspectives, helping me develop a deeper understanding of different research areas.

In addition to these individuals, I would like to give a special thanks to all my friends. You made this challenging experience pleasant and truly memorable. I also extend a special thank you to the administrative staff in the Department of Spanish and Portuguese who were always willing to help.

Finally, I want to thank my family. My parents, Viktoriya and Gennadiy Bondarenko, are the reason why I began this journey in the first place. Your unconditional love, support and tireless encouragement always reminded me what is truly important in life and allowed me to follow my dreams. Last, but certainly not least, I want to express my deep gratitude to my loving husband, Zifeng Zhao. Thank you for spending countless hours and your every free moment, of which you already had so few, teaching me to understand the statistics used in this dissertation. Your invaluable expertise in the area helped elevate this research and taught me to appreciate the importance of quantitative assessment. Above all, it is your love, friendship and unceasing support that I am most grateful for.

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Chapter 1

Introduction

1.1 Background and motivation

The field of language acquisition is a rapidly developing discipline, with each new wave of research enhancing our understanding of how languages are learned, whether they are first languages (L1s) learned from birth and "established up to a certain level in infancy," second languages (L2s) "encountered and acquired after infancy," third languages (L3s), or "non-native language[s] which [are] currently being used or acquired in a situation where the person already has knowledge of one or more L2s besides one or more L1s," (Hammarberg 2009, p. 5-6) or heritage languages (HLs), spoken by heritage speakers (HSs) who, according to Valdés (2000), are individuals "raised in a home where a non-English language is spoken, who speak or merely understand the heritage language and who are to some degree bilingual in English and the heritage language" (p. 1). Research to date has investigated certain languages more thoroughly than others due to various factors, such as the number of speakers around the world, the support and contributions of ruling administrations to the development of the field of linguistics with respect to different languages, and the economic and social status of languages that, in turn, contribute to their popularity among foreign language learners, just to name a few (Joseph 2006, May 2012, Norton and Toohey 2004, Pennycook 2001, Skutnabb-Kangas 2000).

Spanish, spoken by roughly 470 million native speakers or, as reported by the Instituto Cervantes, 559 million people worldwide (including L2 Spanish speakers), has definitely enjoyed a considerable amount of attention from the linguistics research community. The fact that it is the most commonly learned foreign language in the United States, studied by 72.06% of K-12 students and 50.6% of college and university students, has greatly promoted its inclusion in

studies on L2 acquisition, where some of the most investigated populations are L1 English L2 Spanish speakers (Goldberg et al. 2015). Furthermore, due to the growth of the Hispanic community in the United States, which now comprises 16.4% of the country's total population, and a corresponding increase in the number of Spanish speakers in the country, several new areas of research concerning the Spanish language have been steadily developing; one of which is the linguistic system of HSs.

Spanish, although certainly the most widely spoken foreign language in the United States, which, in turn, contributes to the wealth of works written on it, is definitely not the only non-English, minority language spoken in this country. The goal of the current research is to shed light on speakers of lesser-studied heritage languages (HLs) in the United States and to examine their experiences learning an L3. Specifically, this study investigates the speech of Slavic language HSs who are acquiring an L3. The particular focus is on the speech of Ukrainian and Polish HSs and their learning experiences with the most commonly taught and spoken foreign language in this country, Spanish. Focusing specifically on this unique group of speakers allows us to address several questions in one study.

One such question concerns the order of acquisition of languages during childhood and how it influences the acquisition of subsequent languages in adulthood. While the speakers under investigation are bilingual in their HL and English, their proficiency in their two languages most certainly shows variation. Many HSs are exposed to their HL first, which over time, may be either to some degree or nearly entirely replaced by the majority language or, on the contrary, may be maintained alongside it. This means that the HL may not necessarily be these speakers' least dominant language in adulthood and that it may play a strong role in influencing all other languages acquired by later in life. The lack of a clear connection between the sequence of

acquisition and the language dominance that the group of speakers in this study represents provides us with a very intriguing case that can help us more precisely understand the role of order of acquisition of an HL and a dominant language in the process of L3 acquisition, as well as help us identify the specific role of HLs in the acquisition of languages in adulthood (Gut 2010, Hammarberg and Hammarberg 1993, Llama, Cordoso and Collins 2010, Llama, Walcir and Collins 2007, Marx 2002, Tremblay 2007, Williams and Hammarberg 1998).

The study of heritage and L3 phonetics/phonology are two newly emerging fields that are still relatively understudied compared to other linguistics areas, such as morphosyntax. Although the number of studies is still limited in these areas, several works that have emerged in recent years certainly have enhanced our understanding of the sound systems of HSs and L3 speakers. For example, studies on Spanish HSs, such as Knightly et al. (2003), Au et al. (2008), Kim (2011), Boomersshine (2012, 2013), Ronquest (2012, 2013, 2016) and Rao (2014, 2015), all show that while HSs do not always perform like native speakers, their productions are often more native-like than those of L2 learners, with accuracy often correlating with the frequency of HL use. Several other studies on Spanish segmental and suprasegmental features (Carter and Wolford 2016, Kim 2014, O'Rourke and Potowski 2016), as well as those on Slavic HSs (Hrycyna 2011, Kochetov 2011, Łyskawa et al. 2016), also indicate that HSs are a heterogeneous group of speakers who exhibit intriguing cross-generational variation. In recent years, L3 acquisition has also gained wider recognition with researchers aiming to determine whether it is language typology (Rothman 2011, 2015), order of acquisition (Llama et al. 2007, 2010, Tremblay 2007) or language dominance (Hammarberg and Hammarberg 2005, Llama and López-Morelos 2016, Wrembel 2009) that is most influential in the production of L3 segments. Evidence of the traction L3 acquisition is gaining is that in 2017, *The International Journal of*

Bilingualism dedicated a special issue to L3 and Multilingual research, where Alonso et al. (2016), Slabakova (2016), Westergaard et al. (2016), Alonso and Rothman (2016), Cabrelli Amaro (2016), Green (2016), Wulff (2016), Schroeder and Marian (2016) comment on theoretical models, methodologies, and cognitive function in the field of L3 acquisition. In 2016, *The International Journal of Multilingualism* particularly focused on L3 phonological acquisition, where works by Cabrelli Amaro and Wrembel, Kopečková, Kopečková et al., Llama and López-Morelos, Onishi, and Sypiańska, examine the production of consonants and vowels in L3 learners of various linguistic backgrounds. Llama and López-Morelos's study is particularly intriguing with respect to this investigation, since it examines the speech of HSs in a trilingual social context. In sum, this collection of innovative studies demonstrates that trilingual learners' L3 sound systems, as compared to those of their L1 and L2, are gaining more interest and recognition in the fields of phonetics/phonology, multilingualism, and language acquisition.

Focusing particularly on Slavic HSs also allows us to look at a group of speakers whose HLs contain certain phonological features that do not directly overlap with English. This helps us paint a clearer picture as to what type of language transfer is taking place during L3 phonological acquisition, thus allowing us to understand the role of language typologies in L3 acquisition. The two Slavic languages in question - Ukrainian and Polish - are examined together in one category due to the fact that they belong to the same language family and relate very closely to each other in many phonological aspects, especially concerning the particular features investigated in this study. Moreover, although the two Slavic languages, English and Spanish all belong to different language families, the Slavic languages in question share several phonological features with Spanish that are not present in English. As will be shown in this study, these aspects may positively affect the experience of Slavic HSs when acquiring the L3 Spanish sound system,

especially in instances where language typology appears to exhibit the greatest influence on the acquisition of an L3 sound system (Cenoz 2011, Möhle 1989, Rossi 2006, Singleton 1987).

In this study we investigate the production of the Spanish vowels /i e a o u/, voiceless plosive segments /p t k/, and voiced stops /b d g/. Previous research on L2 acquisition has documented that these particular aspects of the Spanish sound system cause difficulties for L1 English learners of L2 Spanish due to the fact that they are produced differently in English. In the two Slavic languages that were selected for this study, these particular features are more similar to those of Spanish than the English realization of these segments is to that of Spanish, which in certain cases may help Slavic HSs avoid the same challenges that the L1 English learners face when acquiring L2 Spanish phonology. For example, Ukrainian and Polish have relatively small vocalic inventories like Spanish and do not feature unstressed vowel reduction, which is present in English (Bradlow 1995, Gussmann 2007, Hualde 2005, Jassem 2003, Korunets 2004, Menke 2010, Menke and Face 2010, Quilis 1999). The two Slavic languages, like Spanish, also belong to the short-lag language family where, /p t k/ are produced with VOT values that are around 30 ms or shorter. English, on the other hand, forms part of the long-lag language family, where voiceless stops (commonly referred to as aspirated stops) are produced with VOTs that are longer than 30 ms. (Castañeda Vicente 1986, Cho and Ladefoged 1999, Gonet 2001, Lisker and Abramson 1964, Nagy and Kochetov 2013, Newlin-Łukowicz 2014, Poch 1984, Ringen and Kulikov 2010, Rosner et al. 2010, Williams's 1977). While in Ukrainian and Polish, voiced stops do not undergo weakening in intervocalic position as they do in Spanish, they are produced as true-voice stops in nearly all syllabic positions, which is not usually the case in English, a language that lacks both intervocalic lenition and true-voicing (Carrasco et al. 2012, Colantoni and Marinescu 2010, Eddington 2011, Hualde 2005, Keating

1980, Newlin-Lukowicz 2014, Ringen and Kulikov 2012). Finally, Ukrainian and Polish are also similar to Spanish regarding the position of /t/ and /d/, which are produced as dental or dental/alveolar segments in the two Slavic languages, while they are alveolar in English (Danylenko and Valukenko 1995, Gussman 2007, Jassem 2003, Korunets 2004, Ponomariov 2001, Ročławski 1986).

Choosing to investigate Slavic HS learners of L3 Spanish helps us find answers to several inquiries in one investigation. First, it helps us understand how the order of language acquisition during childhood influences subsequent language learning in adulthood. Specifically, it helps us identify the potential influence of the HL, which may or may not be the weakest language of the speakers in this study, on the acquisition of L3 phonology. In addition, selecting HSs whose HLs have significantly different phonological systems from the dominant language, but share several aspects with the L3, allows us to search for evidence as to which language exhibits greater influence on the L3. In sum, focusing on this particular group of HSs/L3 learners helps us shed light on whether it is the order of acquisition, language dominance and/or language typology (in this case, similarities between the phonological features of the HL and the L3) that is/are the most influential during the acquisition of the L3 sound system, which, successively, helps us provide evidence for theoretical models, such as Flege's (1995) Speech Learning Model, Flynn et al.'s (2004) Cumulative-Enhancement Model, de Bot et al.'s (2007) Dynamic Systems Theory, Fernandes-Boëchat's (2007) Multilingual Role Model, Bardel and Falk's (2007, 2012) L2 Status Factor Model, Fernandes-Boëchat & Siebeneicher Brito's (2008) Cognitive Chain Reaction Theory, Cabrelli Amaro and Rothman's (2010) Phonological Permeability Hypothesis (PPH), Rothman's (2011, 2015) Typological Primary Model, and Westergaard et al.'s (2016) Linguistic Proximity Model. Finally, this investigation also provides us with a clearer understanding of the

linguistic system and experiences of a growing HS population in this country who is learning their L3 alongside other L2 students in a shared classroom space.

1.2 Slavic HS communities in the United States

Although Slavic HSs are not nearly as numerous as Spanish HSs, their population in this country is of a notable size. According to the American Community Survey (2011) conducted by the United States Census Bureau, Polish is the second most spoken Slavic language in this country with 607,500 speakers reporting using it at home (Russian is reported to be the first most spoken Slavic language, with 905,700 speakers; Ryan 2013). The survey, unfortunately, did not present data on the number of Ukrainian speakers; however, the American Community Survey (2006) stated that there are 961,113 people of Ukrainian ancestry in the United States. While this most certainly does not mean that every member of this group speaks Ukrainian, this number, nonetheless, shows that the Ukrainian presence in this country is significant. If we combine these two communities of Slavic language speakers, their presence in the United States becomes even more noteworthy and their multilingualism worthy of further investigation.

The community of Slavic language HSs becomes especially intriguing when one considers their foreign language education in the United States. The two Slavic languages under investigation are not nearly as studied as Spanish in higher education institutions, and hardly at all in grades K-12. According to Goldberg et al.'s report (2015), Russian is the most studied Slavic language in the United States, taken by 1.4% of college and university students and 0.14% of K-12 students. There is very limited data on Polish and Ukrainian enrollment numbers, but the same report mentions that for the one state that reported offering Polish in schools (out of 27 states that responded to the census), the enrollment consisted of 123 students in the years 2004-2005. We do, however, see an increase in enrollment in 2007-2008 to 285 students (a 131.71%

increase) in the two states that reported back, which indicates a promising growth of interest in the language, but certainly, an expansion that still has a long way to go to catch up with Spanish. To my knowledge, there is no available data on Ukrainian language enrollment in American schools and universities, but it can be safely assumed that they would be even lower than those presented on Polish. After looking at such reports, it should not come as a surprise that individuals who are HSs of Slavic languages begin learning another language - an L3 - in schools, and later, in universities. Spanish, being the most popular foreign language option in the United States, is often the favored choice among HSs whose HLs are not being offered and who are also motivated by the increase in career opportunities that knowledge of Spanish provides.

1.3 The current study

The central question posed by this study is: How do HSs of Ukrainian and Polish acquire and produce L3 Spanish vowels and voiceless and voiced stops? In order to address this extensive question, it was divided into several sub-questions:

1. When acquiring the sound system of L3 Spanish, will the HL (i.e., Ukrainian, Polish) or the dominant language (i.e., English) show evidence of exhibiting greater influence on Spanish phonology?
 - a) Will the Slavic HSs speakers of this study produce the dominant language's practice of unstressed vowel reduction into Spanish or will they be able to avoid it, potentially due to the influence of their HL knowledge?
 - b) Since Spanish and the two Slavic languages under investigation share the same short-lag feature for voiceless stops, will the Slavic HSs demonstrate evidence of influence from their HL sound system or from English's aspiration when producing the Spanish /p t k/?

- c) Will the participants of this study produce the voiced stops in Spanish with the pre-voicing that also exists in their HL or will they lack true-voicing like in English? Will the experience of Slavic HSs with the Spanish intervocalic lenition of voiced stops be similar to the experience of the L1 English L2 Spanish learner, since both the HLs and English do not have stop weakening in intervocalic position, or will it be different, and possibly influenced by the shared pre-voiced nature of /b d g/ in the HLs and Spanish?
2. What role does task type play in the production of vowels /i e a o u/, voiceless stops /p t k/, and voiced stops /b d g/?
3. Do the results of this investigation support any of the following theoretical models of L3 acquisition: the Cumulative-Enhancement Model, the Multilingual Role Model, the Dynamic Systems Theory, the Cognitive Chain Reaction Theory, the L2 Status Factor Model, the Typological Primacy Model or the Linguistic Proximity Model?

In order to answer these questions, the speech of Ukrainian and Polish HSs, as well as that of the L1 English L2 Spanish and L1 Spanish L2 English control groups was collected via narrative, picture-naming, sentence-reading, and nonce words reading tasks in Spanish. In addition, all speakers completed the narrative task in English, and the HSs also performed it in Ukrainian and Polish. Testing speakers in all their spoken languages was essential for this study, because as pointed out by Cabrelli Amaro (2013), it is problematic to assume that a participant will behave like a native speaker of a certain language, particularly in the case of HSs. The participants produced a total of 30,438 tokens, completing conversational, semi-spontaneous and highly controlled tasks. The results were analyzed both acoustically and statistically, and compared across the four groups of speakers in order to respond to questions concerning how the knowledge of an HL affects L3 acquisition in adulthood. The results point to an influence from

both the HL and the dominant language, in certain cases, suggesting that language contact and dominance are potentially playing a more significant role than order of acquisition, and in other instances, implying that language typology is the guiding mechanism in the acquisition of the L3 sound system. For instance, both Ukrainian and Polish HSs produced reduced unstressed Spanish vowels; however, vowel reduction was found in the speech of all four groups, including L1 Spanish speakers. While stress did not uniformly affect either tongue height or backness in the speech of Ukrainian HSs and L1 Spanish participants, it consistently affected either one axis or both axes in Polish HSs and L1 English speakers' productions. Ukrainian and Polish HSs, as well as L1 English speakers showed no clear link between task formality and rate of reduction, while L1 Spanish participants produced more reduced segments in the most controlled task and less reduced vowels in the least controlled elicitation. Like L1 Spanish speakers, Ukrainian HSs produced short-lag Spanish /p t k/ in all four tasks, while Polish HSs produced a mix of short-lag and long-lag stops. The L1 English control group produced long-lag segments in all tasks. Generally, Ukrainian HSs and L1 Spanish participants displayed longer VOTs in more formal tasks, while L1 English speakers and Polish HSs did so in less controlled tasks. In the production of voiced stops, Ukrainian HSs displayed the second most lenited segments after the L1 Spanish control group, while Polish HSs and L1 English participants showed less evidence of weakening than the other two groups. All participants produced more constricted segments in more formal tasks and more lenited stops in less controlled tasks. Almost all Ukrainian and Polish HSs as well as all L1 Spanish speakers produced true-voiced stops, while L1 English participants produced mixed results, displaying a greater frequency of short-lag productions in comparison to true-voiced realizations. All these results appear to support the Dynamic System Theory (DST) (de Bot et al. 2007, van Geert 2008), which highlights the complexity and volatility of the

multilingual brain. In comparison to other theories that mainly claim that either order of acquisition or language typology is the guiding mechanism in L3 acquisition, DST explains why the outcome is not easily predictable and describes the reasons behind both inter- and intra-group variability.

1.4 Significance of the current study

The unique speaker population investigated in this study presents us with a very fascinating, but at the same time, not yet fully examined research topic concerning speakers who grew up in an English language environment learning a Slavic language at home (and, at times, at religious institutions), and later studying Spanish in school and university classrooms. This interesting speaker profile also presents itself with certain challenges and advantages that these learners encounter when acquiring the Spanish phonological system (and surely, its linguistic system as a whole), both of which may differ from those experienced by L1 English learners enrolled in the same Spanish language courses. This investigation contributes to the study of HSs, language contact, and multilingualism by expanding our knowledge of the unique experiences of Slavic language HSs with the Spanish sound system and enhancing our understanding of L3 acquisition in general using a set of phonological features that are more similar in the Slavic versus Spanish comparison than in the English versus Spanish comparison. The findings of this research help enhance our understanding of the competing phonological systems of this speaker group in particular, and of this steadily growing L3 learner pool in general.

1.5 Overview

This section provides a roadmap of the remainder of this dissertation. Chapter 2 offers an overview of the features under investigation and reviews studies on the acquisition of these

specific features by L1 English L2 Spanish learners. It also introduces previous research on Spanish and Slavic language heritage phonetics/phonology and examines L3 phonology, commenting on theoretical frameworks and the unique methodological practices utilized when working with multilingual populations. Chapter 3 outlines the methodology implemented in this study. It describes the recruitment procedure and provides detailed background information about the participants. It also introduces the tasks used to elicit data, explaining the reasoning behind task designs, and discusses the acoustic and the statistical procedures implemented. Chapter 4 summarizes the acoustic and statistical findings, detailing the results for vowels and voiceless and voiced stops in Ukrainian, Polish, English and Spanish based on speaker group. The final chapter of this dissertation, Chapter 5, answers the research questions presented in the beginning of this study, discusses the implications of the findings in terms of previous, related empirical and theoretical works, and finally, overviews the study's limitations, which hope to inspire directions for future research.

Chapter 2

Literature Review

2.1 Introduction

The following chapter introduces the features under investigation – vowels, voiceless and voiced stops – in Ukrainian, Polish, Spanish and English and highlights similarities and differences between the production of these segments in the four languages. In the next section, I review the acquisition of these features by L1 English L2 Spanish learners, examining why these segments are challenging to acquire for this group of speakers and why they might also present a problem for HSs in this investigation. The third section introduces research on heritage phonetics, which informs of the unique language experiences of this group and different methods that have been implemented by researchers when working with HSs. The fourth section reviews previous research on L3 phonology, commenting on theoretical frameworks, as well as unique methodological practices that have been developed to work with this group of speakers. The last section presents my research questions, which are motivated by previous research on L2, heritage and L3 phonologies, and my hypotheses regarding the production of vowels and voiceless/voiced stops by Ukrainian and Polish HSs who are L3 Spanish learners.

2.2 Features under investigation

This section presents a description of the phonological features investigated in the speech of Slavic language HSs who are L3 Spanish learners. It discusses the characteristics of these segments in each of the languages in question: Spanish, Ukrainian and Polish.¹ As mentioned previously, the topics of this study will include the production of vowels /i e a o u/, voiceless stop segments /p t k/ and voiced stops /b d g/. These particular features have been chosen

¹ The production of these features in English will be presented in the "L2 phonology" section.

because in numerous studies they have been shown to cause pronunciation difficulties for L1 English learners of Spanish (Bradlow 1995, Cordero, Munson and Face 2006, Díaz-Campos and Lazar 2003, Díaz-Campos 2006, Elliott 1997, González-Bueno 1995, 1997, Hammerly 1982, Menke and Face 2009, 2010, Romanelli and Menegotto 2015, Stockwell and Bowel 1965, Zampini 1994, 1998). Thus, the objective is to see whether they present the same challenges for HSs of Slavic languages who grew up in an English environment, but were exposed to and are active users of HLs that differ typologically from the dominant language and have several phonological features that overlap with the L3.

2.2.1 Spanish sound system

2.2.1.1 Vowels /i e a o u/

The first topic examined are the Spanish vowels. The Spanish vocalic system consists of five phonemes /i e a o u/, which constitute almost half of the spoken (48%) and written speech (46%) of the language (Menke 2010). The Spanish vowels are traditionally classified in terms of height and backness, which are measured by an acoustic measurement called formants (i.e. frequencies at which sound waves resonate). Generally, three formant measurements are used to describe vowels across languages, but for Spanish, mainly two are utilized: the first formant (F1), which provides evidence of tongue height, and the second formant (F2), which gives acoustic cues to tongue backness. The tongue height and the F1 value demonstrate an inverse relationship, where higher vowels display lower F1 values and lower vowels have higher F1 values. In terms of backness and frontness, back vowels have a lower F2 value, while fronted vowels have a higher F2 value. Formants are measured in Hertz (Hz) and in a chart, F1 measurements are placed on the y-axis and F2 values are plotted on the x-axis (Menke 2010,

Menke and Face 2010). Figure 2.1 is an image of a spectrogram taken from Menke and Face (2010), which shows four formants as large concentrations of energy at different frequencies:

Figure 2. 1. Spectrogram image with the four formants (Menke and Face 2010, p. 183)

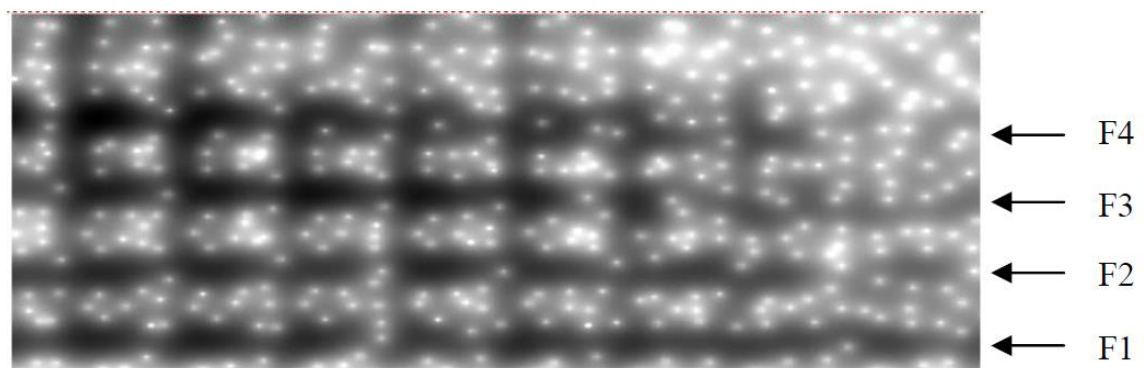
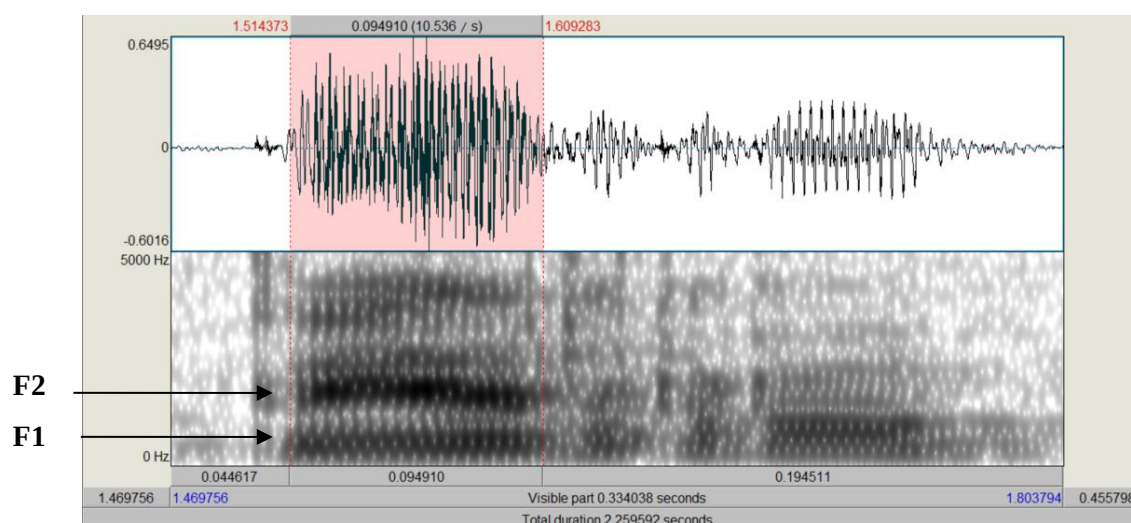


Figure 2.2 is a waveform and spectrogram image taken from *Praat* (Boersma and Weenink 2015) showing formants in a realization of [e] in the Spanish word *perro* ('dog'):

Figure 2. 2. Spectrogram image of the two formants (F1 and F2) in *perro* ['pe.ro] "dog"



Based on F1 and F2 measurements, the Spanish vowels are categorized in the following manner:

Height

high: /i u/

mid: /e o/

Backness

front: /i e/

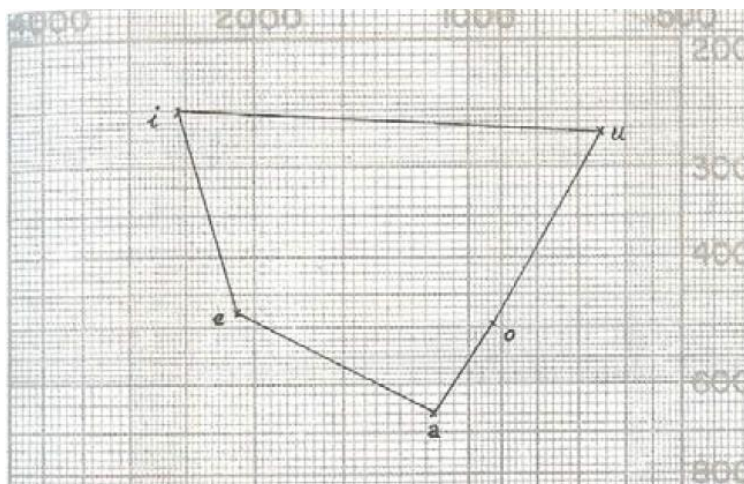
central: /a/

low: /a/

back: /o u/²

Figure 2.3 is an example of a prototypical triangular Spanish vowel space, taken from Quilis (1999):

Figure 2.3. Spanish vowel chart (Quilis 1999, p. 163)



The Spanish vowels of monolingual native speakers are regarded to be very stable, rarely showing dialectal or social class variation.³

2.2.1.2 Voiceless stops /p t k/

The next topic examined in this study is the voice onset time (VOT) of Spanish voiceless stops /p t k/. VOT is defined as an interval between the stop burst and the onset of vocal fold vibration and is used to establish a contrast between voiced and voiceless segments and to differentiate between simple unaspirated voiceless stops and aspirated stops. Lisker and

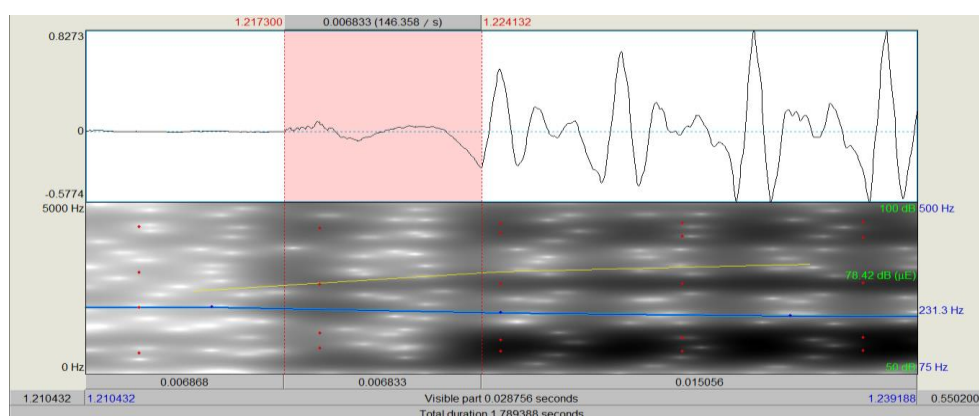
² Spanish back vowels are articulated with rounded lips, while the other front and central vowels are produced with unrounded articulation.

³ O'Rourke (2010) examines the vowel quality in Peruvian Spanish discovering that Cuzco speakers have a larger and more fronted vowel space than the speakers of Lima. The author contributes this difference to contact with Quechua and bilingualism of the Cuzco participants. Morrison and Escudero (2007) compared the vowel quality of Peruvian and Castilian dialects reporting lower frequencies, shorter durations and a presence of a creaky voice for the Castilian variety. These differences, however, were minimal and were not statistically significant. Only F2 value of /o/ showed a significant cross-dialectal difference.

Abramson (1964) showed that this feature differs significantly between languages. In Spanish, the voiceless stops /p t k/ are produced with a short-lag VOT of less than 30 milliseconds (ms) and in phonetic transcriptions, these realizations are annotated as unaspirated [p], [t] and [k]: *prisa* ['pri.sa] "hurry," *pulpo* ['pul.po] "octopus;" *tan* ['tan] "so, such," *tipo* ['ti.po] "type;" *coco* ['ko.ko] "coconut," *queso* ['ke.so] "cheese."

Figure 2.4 is a waveform and spectrogram image taken from *Praat* that shows a voiceless stop production in Spanish, the initial [p] of *papa* ("potato") with a very short VOT measurement of 6.8 ms:

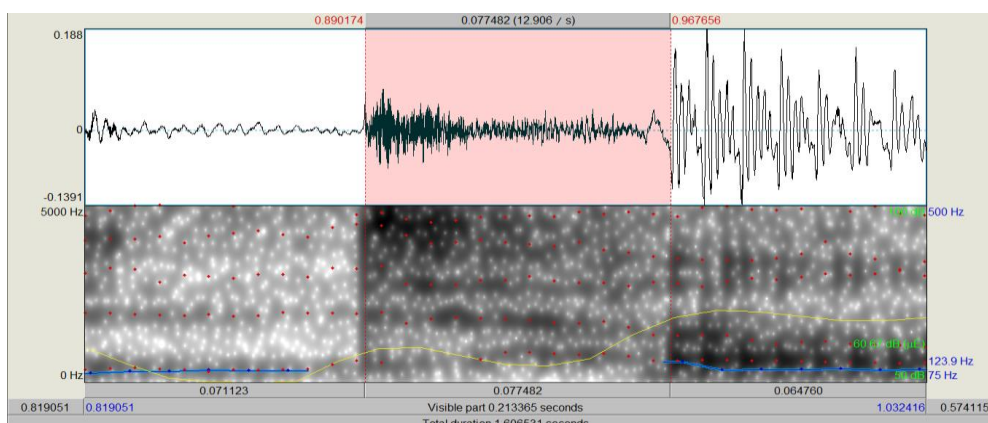
Figure 2.4. Spanish production of /p/ in *papa* ['pa.pa] "potato"



In languages that are classified as long-lag, such as English⁴, the segments /p t k/ have a VOT measurement of more than 30 ms and in transcriptions they are marked as aspirated [p^h], [t^h] and [k^h]: *pill* [p^hɪl], *pool* [p^hu:l]; *team* [t^hi:m], *till* [t^hɪl]; *cab* [k^hæb], *come* [k^hʌm] (Nagy and Kochetov 2013). Figure 2.5 is an example of a waveform and spectrogram image from *Praat* showing a voiceless stop production in English with a much longer VOT value than in Spanish, measuring 77.5 ms:

⁴ When a voiceless stop is preceded by the consonant /s/, such as in *spot*, *state*, and *skate*, its VOT is considerably reduced and end up being similar to that of voiced stops. Nonetheless, there is still a brief period of aspiration that is not seen during the production of voiced stops (Klatt 1975).

Figure 2.5. English production of /t/ in *television* [t^hɛl.ɪ.vɪ.ʒən]



Due to its considerable variation across languages, the topic of VOT has received much attention in the field of phonology. By examining spectrographic analyses of high-quality tape recordings of eleven languages, Lisker and Abramson (1964) were among the first to show how this single feature can serve to differentiate between the voiced and voiceless stops in initial position in languages that distinguish stop segments at the phonetic and/or phonological levels. The study demonstrated how languages such as English and Spanish contrast in their presence or absence of aspiration in the production of stops.

Acoustic and descriptive accounts of Spanish voiceless stops are one of the most studied topics in the field. After examining the results presented by Lisker and Abramson for Puerto Rican Spanish, Castañeda Vicente (1986) set out to test if they also apply to Castilian Spanish. The research analyzed ten Castilian speakers pronouncing disyllabic words containing stops in all possible combinations in both stressed and unstressed contexts. The VOT values that the author obtained were higher than the ones presented in Lisker and Abramson (but lower than the ones published in Poch 1984); however, the patterns in the two varieties were similar. The most posterior stops proved to have the highest VOT values. Castañeda Vicente pointed out that VOT values tend to increase if the following vowel also has a posterior position. Consonants that

appeared before /u/ demonstrated higher VOT measurements. In addition, stops that appeared in atonic position on average displayed VOT values that were 1.5 ms longer than those stops that appeared in tonic position, signaling that accent also plays a role.

After examining data from multiple speakers of 18 languages, Cho and Ladefoged (1999) revealed that consonants within the voiceless stops category can be differentiated not only based on the length of their VOT values, but also based on their place of articulation (e.g., bilabial, dental, alveolar, velar, etc.). In all of the languages studied that do not contrast between velar and uvular stops, the velar stops were shown to have the longest VOTs. In many languages the difference in VOT between bilabial and alveolar stops was not significant. The authors also concluded that the variation between languages is mostly predictable, if it is assumed that languages choose one of three options regarding the degree of aspiration of voiceless stops (i.e., voiced, voiceless unaspirated or voiceless aspirated) and that they can be categorized as having unaspirated stops, aspirated stops with VOT > 50 ms, aspirated stops with VOT > 90 ms or highly aspirated stops.

Rosner et al. (2010) also examined the Castilian variety, contributing further evidence that Spanish voiceless stops do not seem to vary greatly with dialect. Using Casteñada Vicente (1986) and Williams's (1977) studies as a starting point, both of which utilized different lists of spoken items and recorded measurements in different ways, Rosner et al. calculated the VOT of 32 Castilian speakers using the items presented in Williams's study. The results confirmed the main effects of voicing and place that were proven significant for Latin American Spanish dialects by Williams. The author also discovered that the post-consonantal vowel /o/ induced later voicing for /p/ and /k/ in Castilian speakers, while he did not report such results for Latin American varieties (also supported by Klatt 1975, Smith and Westbury 1975).

The results of these studies allow to better understand variation across languages in terms of VOT and inform of the particular characteristics of voiceless stops in Spanish. The findings presented in this section will help in interpreting data coming from Ukrainian and Polish HSs with greater precision and will establish clear points of comparison with L1 Spanish speakers.

2.2.1.3 Voiced stops /b d g/

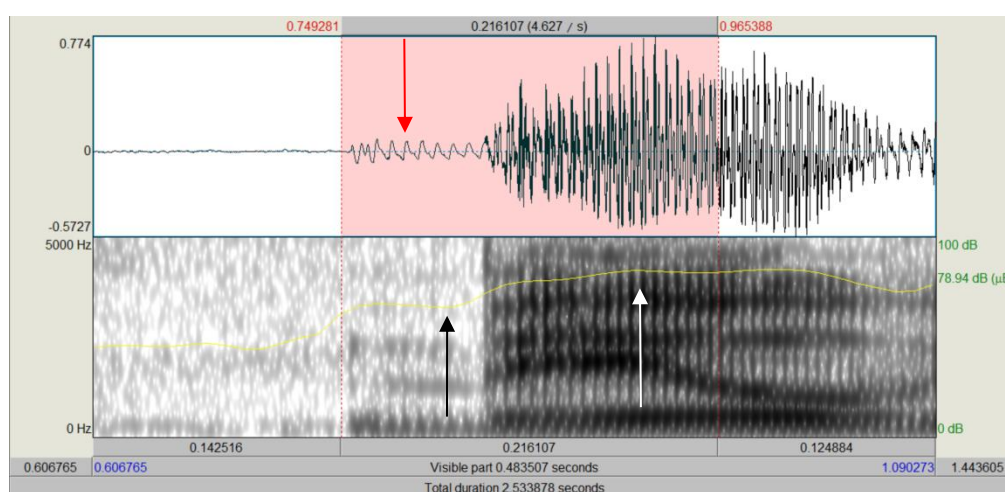
The voiced stops /b d g/ present an interesting phonological phenomenon due to their intervocalic lenition in Spanish. Lenition is a sound change during which consonants undergo articulatory weakening and are produced with less obstruction and less interruption of airflow, becoming sonorous or more vowel-like (Hualde 2005). When the three voiced segments appear after a pause, after a nasal segment or, in case of /d/ only, after the lateral /l/, they are produced as stops in Spanish: vaso - #['ba.so] "glass," ambos - ['am.bos] "both;" don - #['ðon] "gift," hondo - ['oŋ.ðo] "deep," aldea - [aɫ.'ðe.a] "village;" gato - #['ga.to] "cat," hongo - ['oŋ.go] "mushroom." In all other contexts, however, /b d g/ are lenited and are articulated as approximant segments [β ð ɣ]: haba - ['a.βa] "broad bean;" hada - ['a.ða] "fairy;" lago - ['la.ɣo] "lake" (Morgan 2010).

In this study, I focus particularly on lenition in intervocalic position because this context is known to be the most consistent environment of weakening (Carrasco et al. 2012, Eddington 2011). In order to determine the level of lenition of voiced stops the relative intensity (RI) difference between a consonant and the following vowel is used. Most varieties of Spanish, with some dialectal variation (Carrasco et al. 2012, Colantoni and Marinescu 2010), are known for their intervocalic weakening of the voiced stops /b d g/ and their production as [β ð ɣ]. In older literature, these weakened segments were described as fricatives, but with the development of new phonological software programs, such as *Praat*, which allow to examine the acoustic characteristics of segments with greater precision, [β ð ɣ] were reclassified as approximants,

meaning they lack the turbulence observed in fricative consonants. Hualde (2005) suggested that factors such as word stress, with segments after a stressed nucleus favoring weakening more than those before a stressed one, and word position, with certain segments, such as /g/, preferring lenition when surrounded by low vowels versus high vowels, can influence the amount of periodic energy (more periodic energy < more approximantized/less obstruction and turbulence) found in Spanish approximants.

Figure 2.6 shows a stop production of the voiced stop phoneme /b/ in initial position of *veo* ("I see"). There is an inactive waveform with a large RI measure and a complete absence of formants, all of which correlate with a moment of complete obstruction of airflow. The yellow line indicates intensity, the black arrow points to the intensity valley associated with the stop segment, and the white arrow indicates the intensity peak linked to the following vowel. The upper red arrow points to a waveform that shows pre-voicing, indicating that voicing began before the stop closure was released.

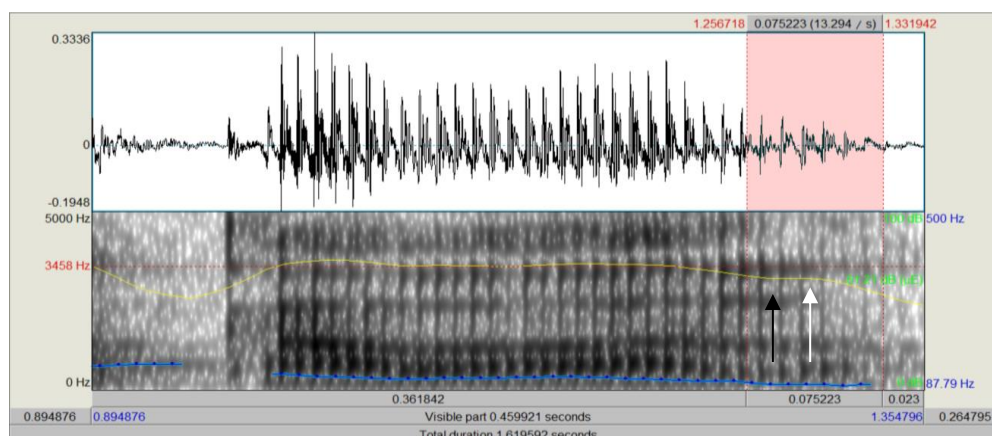
Figure 2.6. Spanish production of /b/ in *veo* ['be.o] "I see"



The image in Figure 2.7 shows an example of an approximant realization of /d/, where there is a periodic waveform, a low RI value with respect to the following vowel, and a constant

formant structure, all of which make the realization more closely resemble a vowel (i.e., minimal obstruction):

Figure 2.7. Spanish production of /d/ in *acabado* [a.ka.'βa.ðo]



Colantoni and Marinescu's (2010) study utilized an acoustic analysis of dialectological interviews in order to determine the degree of lenition in voiced and voiceless stops in Argentine Spanish. The authors made three hypotheses: the system-oriented hypothesis predicted a correlation between an increasing rate of approximation and deletion of voiced stops and voicing of voiceless stops; the effort-based hypothesis predicted that consonants that require more effortful pronunciation would lenite first and that voiceless stops should weaken first; finally, the perception-based hypothesis assumed that lenition would not be affected by the degree of constriction of the flanking vowels and predicted that voiced stops would lenite first. The results partially confirmed the third hypothesis and rejected the first two hypotheses. While lenition was not consistently promoted by more open flanking vowels, voiced stops did weaken the most. The authors determined that stress was the most significant cause of deletion. The highest rate of weakening and deletion occurred in post tonic syllables, specifically with /d/. Coronals (i.e., consonants articulated with the front part of the tongue, such as /d l n s t/) were shown to elide the most.

After examining informal telephone conversations of speakers from Argentina, Colombia, Ecuador, Nicaragua, Peru, Spain and Venezuela, Eddington (2011) found that the phonemes /b/ and /d/ showed a greater rate of constriction in comparison to /g/ and that these two phonemes appeared to be less lenited in word initial intervocalic positions in contrast to word internal intervocalic position, which did not hold true for /g/. All three segments exhibited lesser degrees of lenition when positioned between two stressed syllables, a finding that supports Hualde's (2005) claims.

Carrasco et al. (2012) study examined the production of /b d g/ in postvocalic /a/ context and after liquids, sibilants and glides in Costa Rican and Peninsular Spanish. The results obtained for the Madrid Spanish variety did not show a statistically significant difference between word initial and word medial tokens. The most weakening occurred after /a/, while the most restricted segments appeared after /s/, but overall, there was a continuum of constriction degrees. The results for Costa Rican Spanish differentiated between word initial and word medial positions and there was a significant difference between lenition after /a/ and all other contexts.

The studies presented in this section inform about voiced stop lenition in Spanish and describe its variation across dialects. The description of the contexts of lenition in L1 Spanish speech provide us with a baseline point of comparison when examining the production of Spanish voiced stops by Ukrainian and Polish HSs, and native speakers of Spanish.

2.2.1.4 Summary

Table 2.1 summarizes vowel, voiceless and voiced stop production in Spanish.

Table 2.1. Vowels, voiceless and voiced stops in Spanish

Relevant concept	Characterization in Spanish
Vowels	/i e a o u/
Vowel reduction	no

VOT of /p t k/	shot-lag (<30 ms)
True voicing of /b d g/	yes
Intervocalic weakening of /b d g/	yes

2.2.2 Ukrainian and Polish sound systems

Following an overview of the general characteristics of vowels, voiceless and voiced stops in Spanish, the current section outlines the general characteristics of these phonological features in Ukrainian and Polish to gather a better understanding of the aspects that might cause difficulties or, on the other hand, be beneficial for Slavic language HSs when acquiring the Spanish sound system. In this discussion, the two languages will be grouped together, since they belong to the same language family and, in the majority of cases, the specific features of interest are very similar. There are, however, some key differences in the phonological systems of Ukrainian and Polish that will be outlined as well.

2.2.2.1 Vowels

The Ukrainian vocalic system has six monophthongal vowels in its inventory: /i/ (дід ['dʲid] "grandfather"), /ɪ/ (кит ['kɪt] "whale"), /ɛ/ (мед ['mɛd] "honey"), /ɑ/ (мама ['mɑ.mɑ] "mother"), /ɔ/ (молоко [mɔ.lɔ.'kɔ] "milk") and /u/ (дух ['dʊx] "spirit"). In terms of tongue position, the vowels /i/, /ɪ/, /ɛ/ are classified as front segments and /ɑ/, /ɔ/, /u/ as back, with none of the vowels located in the central position. In terms of tongue height, /i/, /ɪ/, /u/ are high vowels, /ɛ/ and /ɔ/ are mid and /ɑ/ is a low segment. The back segments /ɔ/ and /u/ are rounded in Ukrainian. (Korunets 2004).

Figure 2.8 below is an image of the Ukrainian vowel space provided by Korunets (2004), which compares the position of the Ukrainian vowels to the position of English vowels in the

acoustic space. On the chart, the Ukrainian vowels are represented by capital letters, "I" standing for /i/, "И" for /ɪ/, "E" for /ɛ/, "A" for /ɑ/, "O" for /ɔ/ and "Y" for /u/.

Figure 2.8. Ukrainian vowel space (Korunets 2004, p. 37)

According to the height of the raised part of the tongue	According to the position of the bulk of the tongue According to the variation in the height of the raised part of the tongue	Front vowels	Front-retracted vowels	Central vowels	Back – advanced vowels	Back vowels
High (close) vowels	Narrow variation	I И i:				Y u:
	Broad variation		1		U	
Mid-open vowels	Narrow variation	E e		o ³ 3:		
	Broad variation	ε ¹		ə		ɔ: O u ⁴ ɔ
Low (open) vowels	Narrow variation			Λ		
	Broad variation	æ	a ²		A D ɑ:	

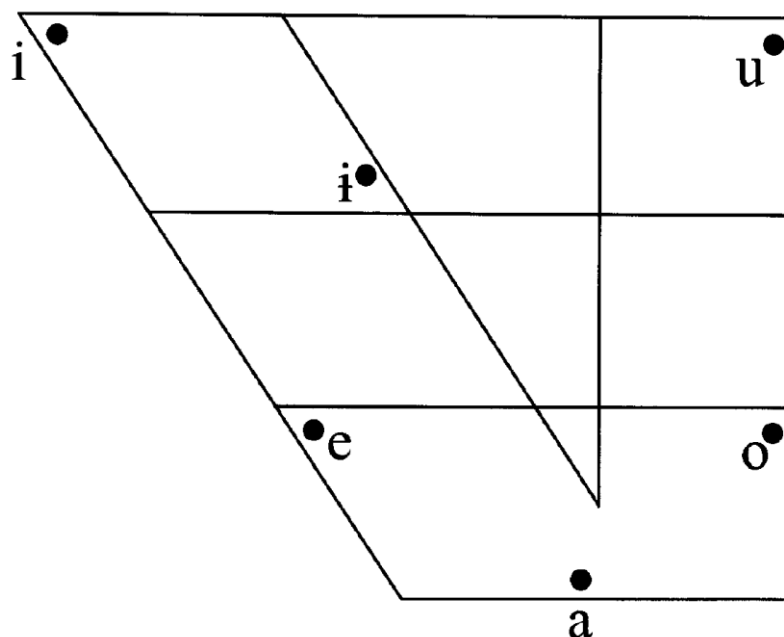
Ukrainian vowels do not undergo reduction in unstressed position, but they are produced with a shorter duration than stressed vowels, which leads to assimilation in certain unstressed vowels. Korunets (2004) reports that the high /i/ assimilates to high /ɪ/ in unstressed initial or final position due to the two vowels' already close proximity, with /ɪ/ being only slightly lower

and more retracted than /i/, which is further reduced when /i/'s duration is shortened in an unstressed context: іти [i'.tɪ] "to go by foot." The author also observes a glide feature in modern Ukrainian speech where the unstressed /ɪ/, /ɛ/, /ɔ/ turn into "something like slightly distinct diphthongs making other vowels pronounced like a sort of glide," leading to production of the monophthongal vowels as quasi diphthongs /ɪ^ɛ/, /ɛ^ɪ/, /ɔ^ʊ/, especially in colloquial speech (p. 40). This phenomenon may at times lead to ambiguity or misunderstanding of meaning of some different pairs of words, which may require speakers to check their spelling, as is shown in the following examples: мене [mɛ'.ne] "me," мине [mɪ^ɛ'.ne] "will pass," зозуля [zɔ^ʊ'.zu.lʲɑ] "cuckoo" (Korunets 2004).

The Polish vowel system also has six monophthongal vowels in its inventory: /i/ (igła [i'g.wa] "needle"), /i/ (my ['mi] "we"), /ɛ/ (wesele [vɛ.'sɛ.lɛ] "wedding"), /a/ (czas [tʃas] "time"), /ɔ/ (most ['mɔst] "bridge"), /u/ (stół ['stuw] "table"). It also includes two nasal diphthongs - /ɛ̃/ (gęsty ['gɛ̃.stɨ] "thick") and /ɔ̃/ (idą ['i.dɔ̃] "they go by foot") - a feature that is absent from Ukrainian. The position of the Polish vowels in the acoustic space differs slightly from Ukrainian. In terms of height, like in Ukrainian, Polish /i/, /i/, /u/ are high vowels, /ɛ/, /ɔ/ are middle vowels and /a/ is a low vowel. Unlike Ukrainian, Polish has central vowels. Segments /i/ and /ɛ/ are front, /i/ and /a/ are central and /u/ and /ɔ/ are back (Gussmann 2007).

Orthographically, "i" denotes not only the high front vowel /i/, but also marks palatalization of the preceding consonant. Figure 2.9 is an image of the Polish vowel space provided by Jassem (2003).

Figure 2.9. Polish vowel space (Jassem 2003, p. 105)



The nasals in Polish are not like the nasal vowels in French because they do not maintain the nasalization feature throughout the whole duration of the segment. Instead, they consist of a vowel that is followed by a nasalized palatal glide - [ɛ̃w], [ɔ̃w] - which better classifies them as diphthongs. The nasal segments only occur before a fricative and in word-final position. Besides the nasal diphthongs, Polish, like Ukrainian, does not have oral diphthongs. Also, similar to Ukrainian, Polish vowels do not reduce in unstressed syllables (Biedrzycki 1963, 1978, Gussman 2007, Wierzchowska 1971).

This brief overview of the vocalic systems in Ukrainian and Polish reveals that although the two languages are related and do have several aspects in common regarding vowel production, there are key differences that can influence each participant's performance in L3 Spanish depending on which HL they speak. Also, although the two languages have relatively small vocalic inventories like Spanish and do not practice unstressed vowel reduction, it is possible that Ukrainian and Polish HSs display some influence from the dominant language, such

as unstressed vowel reduction, in their HL. This is discussed in greater detail in the HS phonology section.

Table 2.2 provides an overview of vowel positions in English, Spanish, Ukrainian and Polish.

Table 2.2. Summary of vowel positions in English, Spanish, Ukrainian and Polish

		English	Spanish	Ukrainian	Polish
Tongue height	high	/i ɪ u ʊ/	/i u/	/i ɪ u/	/i i u/
	mid	/e ε ɔ o ə/	/e o/	/ε ɔ/	/ε ɔ/
	low	/æ ʌ ɑ a/	/a/	/ɑ/	/a/
Tongue frontness/backness	front	/i ɪ e ε æ a/	/i e/	/i ɪ ε/	/i ε/
	central	/ʌ ə/	/a/	none	/i a/
	back	/u ʊ o ɔ ɑ/	/o u/	/ɑ ɔ u/	/ɔ u/

2.2.2.2 Voiceless stops /p t k/

The two Slavic languages, like Spanish, belong to the shot-lag language family where /p t k/ are produced with VOT values that are around 30 ms or shorter. In the two languages, the voiceless stops can appear in various syllabic positions:

- In a simple onset: Ukrainian - пити ['pɪ.tɪ] "to drink," так ['tak] "yes," кава ['ka.wa] "coffee;" Polish - pan ['pan] "mister," to ['tɔ] "this, that," kawa ['ka.va] "coffee"
- In a complex onset: Ukrainian - прати ['pra.tɪ] "to laundry," стати ['sta.tɪ] "to become," кров ['krɔw] "blood;" Polish - spać ['spatɕ] "to sleep," trochę ['trɔ.xɛ[̥]] "a little bit," kraj [kraj] "country"
- In a simple coda: Ukrainian - пуп ['pup] "bellybutton," кіт ['kʲit] "cat," ток ['tɔk] "current;" Polish - map ['map] "maps" (gen. pl.), lot ['lot] "flight," sok ['sɔk] "juice"

- In a complex coda: Ukrainian - *кари* ['karp] "carp," *метр* ['mɛtr] "meter," *вовк* ['wɔʊk] "wolf;" Polish - *Cypr* ['tʂipr] "Cyprus," *żart* ['zart] "joke," *park* ['park] "park"

It is difficult to find concrete VOT measurements for the Slavic voiceless stops and to my knowledge, there are no available data on concrete estimated VOT values for Polish and Ukrainian voiceless stops. A study by Gonet (2001) that sought to facilitate pronunciation acquisition of voiceless stops by L1 Polish learners of English looked at the contrast between fully voiced and fully voiceless obstruents in Polish and English, and provided only one value for /p/, which measured at 25 ms. Newlin-Łukowicz (2014), who examined the differences between generations of Polish heritage speakers in New York, provided only a value for /t/ of 20 ms. Therefore, this study will refer to the data provided by Ringen and Kulikov (2010), who worked with a group of Russian monolinguals from St. Petersburg and reported the following VOT values: /p/ - 18 ms, /t/ - 20 ms, /k/ - 38 ms. Since Ukrainian, Polish and Russian all belong to a Slavic language family that is known for short-lag VOT values, it is reasonable to assume that the VOT values of /p t k/ in Ukrainian and Polish would be in a comparable range.

In terms of the articulatory position of voiceless stops, Ukrainian and Polish are similar to Spanish regarding the position of /t/, which is produced close to or exactly in the same position. In Polish, the segment /t/ is dental and in Ukrainian, while the phoneme /t/ is dental/alveolar, its phonetic realization is dental as well [t̪] (Danylenko and Valukenko 1995, Gussman 2007, Jassem 2003, Ročławski 1986). The Polish phoneme /t/, however, also has an alveolar allophone [t], which appears before /t͡ɕ/ and /d͡z/ (Ročławski 1986).

It is important to note that the Polish /p/, /t/ and /k/ segments and the Ukrainian /t/ undergo palatalization, while the Ukrainian bilabial /p/ is realized with partial palatalization and the velar /k/ with very weak palatalization, during which the tongue is raised toward the hard

palate and is slightly pushed forward when followed by the front vowel /i/, a feature that can be transferred to L3 Spanish where palatalization between /i/ is not practiced (Gussmann 2007, Korunets 2004, Ponomariv 2001, Ročławski 1986). The difference between the hard and soft (i.e., palatalized) segments is phonemic in the two languages⁵; however, there are no separate graphemes that represent hard and soft consonants. Instead, palatalization is indicated by the letter that follows the consonant; for example, in Ukrainian - a language that utilizes the Cyrillic alphabet - palatal indicating vowels є, ю, я - /jɛ, ju, ja/, the front vowel /i/, as well as the strong yer ь, signal that the preceding consonant is palatalized: Ukrainian - лент [lɛnt] "lent," потяг [pɔ.tɛɦ] "train," кіно [kʲi.nɔ] "cinema." Meanwhile, in Polish, which uses the Latin alphabet, palatalization is indicated by the letter "i" and the vowel clusters ia, ie and iu: piano [pʲja.nɔ] "piano," tik [tʲik] "twitch," kiedy [kʲɛ.di] "when."

2.2.2.3 Voiced stops /b d g/

The next three stop phonemes that are described - the voiced /b d g/ - do not have an abundance of literature discussing their production, since in Ukrainian and Polish they do not undergo weakening in intervocalic position as they do in Spanish and are produced as voiced stops in nearly all syllabic positions⁶:

⁵ There is no complete agreement regarding the nature of Ukrainian velars, with some linguists considering palatalized segments allophones of the hard counterparts and others as separate phonemes (Korunets 2004). Generally, linguists divide in their treatment of palatal segments in Eastern Slavic languages, following either the Moscow phonology school or the Saint Petersburg phonology school. The Moscow phonology school argues that the palatalized velars are actually allophones of the non-palatalized consonants and are in complementary distribution with palatalized segments appearing before front non-low vowels /i/ and /e/ and non-palatalized segments appearing in all other contexts. The Saint Petersburg phonology school, however, argues that the difference is phonemic (Chew 2003).

⁶ Polish voiced obstruents (which include stops, fricatives and affricates) undergo devoicing before pauses, voiceless consonants and in certain dialects before sonorants (mainly vowels): ząb [zɔ̥mp] "tooth," płód [pwut] "fetus," drug [druk] "friend" (Gonet 2001, Gussman 2007, Słowiacek and Dinnsen 1985, Urbańczyk 1984). Voicing is retained in Polish before voiced obstruents (Łyskawa et al. 2016). Ukrainian maintains voicing of the stops in all syllable final positions (before a pause, at word boundaries and in consonant clusters word medially), which makes it the most conservative Slavic language in this aspect (Tieszen 1997).

- In a simple onset: Ukrainian - баба ['ba.ba] "grandmother," день ['denʲ] "day," гава ['ga.wa] "crow;" Polish - obok ['ɔ.bɔk] "nearby," dywan ['di.van] "carpet," багаж ['ba.gaʃ] "luggage"
- In a complex onset: Ukrainian - брати ['bra.tɪ] "to take," здерти ['zder.tɪ] "to scratch off," ґрунт ['grunt] "soil;" Polish - brak ['brak] "deficiency," dramat ['dra.mat] "drama," grób ['grub] "grave"
- In a simple coda: Ukrainian⁷ - лоб ['lob] "forehead," лід ['lid] "ice;" Polish - obmierzły [ɔb.'mʲɛr.zwɨ] "loathsome," ognisko [ɔg.'nʲi.sko] "bonfire," ładny ['wad.ni]
- In a complex coda: Ukrainian - ромб ['rɔmb] "rhombus," бард ['bard] "singer;" Polish - garb na ['garb.'na] "hump on;" kadr ['kadr] "frame," mózg ma ['muzg.'ma] "brain has"

Polish has the segment [ɣ] in its inventory, which is the voiced allophone of the phoneme /x/ when it is followed by a voiced obstruent. It occurs both word medially and across word boundaries: dach /'dax/ "roof;" dach domu ['day 'do.mu] "roof of the house" (Rocławski 1986). In Ukrainian there are no approximant segments [β ɟ ɣ] on either the phonemic or the allophonic levels.

In addition, it is known that both Ukrainian and Polish, like most Slavic languages, are true voice languages, meaning the segments /b d g/ are pre-voiced stops, with voicing beginning before the stop closure is released, which is evident from their negative VOT values (Newlin-Łukowicz 2014, Ringen and Kulikov 2012). Keating (1980) demonstrated that Polish voiced stops are consistently pre-voiced, with word initial stops in isolated words displaying the highest

⁷ Ukrainian voiced velar /g/ only appears in an onset position. Around the thirteenth century, the voiced velar stop lenited to /ɣ/ and around the sixteenth century it debuccalized to a voiced glottal fricative /ɦ/, which in modern Ukrainian replaced nearly all instances of the voiced stop /g/. The voiced /g/ mainly appears in loan words (Shevelov 1977).

amount of pre-voicing. Ringen and Kulikov demonstrated in their study of voiceless and voiced stops in the speech of monolingual Russian speakers that the voiced stops were produced with pre-voicing 97.4% of the time by both female and male speakers, showing that this is the typical production of the segments in Russian by speakers of both genders. To my knowledge, there are no studies that examine pre-voicing in Ukrainian, therefore, in this investigation I will rely on the findings from Polish and Russian in predicting that L1 Ukrainian speakers would also demonstrate consistent pre-voicing of voiced stops. This feature of pre-voicing differs from English, where these segments are realized with shorter VOTs and without true voicing, which adds another layer of complexity for a L1 English speaking learner of Spanish, since the difference in the voiced stop pronunciation between the two languages is present on a phonemic level and not only in the phonetic realization (Newlin-Łukowicz 2014).

While sharing the true voice feature with Spanish can aid HSs of Slavic languages with the acquisition of intervocalic lenition of Spanish, it is important to consider that the participants in the study might not always produce the voiced stops in their HLs with pre-voicing due to contact with a language that differs with respect to this feature. Van Alphen and Smith (2004) reported that in Dutch voiced stops were pre-voiced 75% of the time, Ringen and Suomi (2012) found that Finno-Swedish (i.e., a variety of Swedish dialects spoken in Finland by the Swedish immigrants) lenis stops were produced with pre-voicing 87% of time, and Caramazza and Yeni-Komshian (1974) discovered that Canadian French speakers pre-voiced /b d g/ only 42% of the time. The languages mentioned in these studies, like Ukrainian and Polish, are also true voice languages, which makes the finding of the three studies surprising. The authors of these studies concluded that their findings were caused by the influence from another language that lacks true voicing. In the case of Dutch, it was due to the contact with English, which is used at schools and

in the media. The Finno-Swedish speakers were also speakers of Finnish, a language that has no pre-voiced or aspirated stops, and the Canadian French speakers also experienced strong contact with English. Given these findings, it is possible that increased contact with English could influence the Slavic HSs in this study by way of lower frequencies of true voicing of /b d g/ in the HL.

Finally, just like the voiceless stops, the voiced stops /b d g/ palatalize in Polish (biuro ['bʲu.rɔ] "office," diwa ['dʲi.wa] "diva," gigant ['gʲi.gant] "giant"), while in Ukrainian, /d/ undergoes full palatalization (дім [dʲim] "house"), /b/ partial palatalization, and velar /g/ minimal palatalization when followed by the high front vowel /i/ - a feature that needs to be considered in Spanish tokens that position voiced stops before /i/ (Gussmann 2007, Korunets 2004, Ponomarev 2001, Ročlawski 1986).

2.2.2.4 Summary

Table 2.3 outlines the main similarities and differences between Ukrainian and Polish regarding the production of vowels, voiceless stops and voiced stops. They both belong to the group of short-lag and true voice languages and do not practice intervocalic weakening of the voiced stops. They also have the same number of phonemes in their vocalic inventories and, although in the two languages the segments are positioned differently in the acoustic space, they do not reduce in unstressed position. Ukrainian and Polish differ slightly in terms of stops' palatalization. While in Polish the voiced and voiceless stops are completely palatalized before the front vowel /i/, in Ukrainian only /d/ becomes palatalized, while /p/ is partially palatalized and /k/ undergoes weak palatalization. The same holds true for the voiced stops in the two languages.

Table 2.3. Vowels, voiceless stops and voiced stops in Ukrainian and Polish

	Ukrainian	Polish
Vowels	/i, ɪ, ε, a, ɔ, u/	/i, i, e, a, ɔ, u/
Vowel reduction	no	no
VOT of /p t k/	short-lag (<30 ms)	short-lag (<30 ms)
Palatalization of /p t k/ before /i/	/t/- yes, /p/ - partial, /k/ - weak	yes
True voicing of /b d g/	yes	yes
Intervocalic weakening of /b d g/	no	no
Palatalization of /b d g/ before /i/	/d/ - yes, /b/ - partial, /g/ - weak	yes

2.3 Background on the acquisition of L2 phonology

2.3.1 Speech Learning Model

When reviewing L2 phonology, it is important to keep in mind Flege's (1995) Speech Learning Model (SLM), which helps explain individual differences between learners and why certain L2 segments are more difficult to acquire than others. The SLM considers both perception and production and proposes that the accuracy with which an L2 learner will be able to produce a sound depends on how well he or she is able to perceive it. Since the processes and mechanisms that allow for the acquisition of an L1 sound system remain with speakers throughout their lifetime, they can also be applied to L2 speech learning. Provided that a learner receives reasonable and sufficient input, he or she will be able to perceive L2 segments accurately.

According to the SLM, the phonetic elements acquired in an L2 interact with L1 elements in a shared phonological space, with both systems influencing one another. If a sound is perceived as "different" in an L2 when compared to an L1, it is likely that a new category will be

created for that particular segment. Flege (1987) demonstrated that L1 English L2 French speakers produced the French vowel /u/ similarly to the English /u/, differentiating it from the L1 French speakers' production. However, when producing the French vowel /y/, the learners' results did not differ significantly from the L1 French monolingual standard, possibly signaling a creation of a new category that was not influenced by L1 English. On the other hand, if a sound is perceived to be very similar to an already existing one in the L1, then a new category will not be formed and L1 and L2 categories will assimilate. Flege (1987) illustrated how L1 English L2 French and L1 French L2 English speakers perceived /t/ as a similar phoneme in the two languages. This perceived similarity prevented the creation of a new category, even though in English /t/ is a long-lag alveolar segment and in French it is a short-lag dental stop. Not only was the L2 segment produced with VOT values that were different from the monolingual standard, but the L1 production was also unlike the standard, signaling that the two segments existed in a common space and mutually influenced one another.

2.3.2 L2 acquisition of Spanish features by L1 English learners

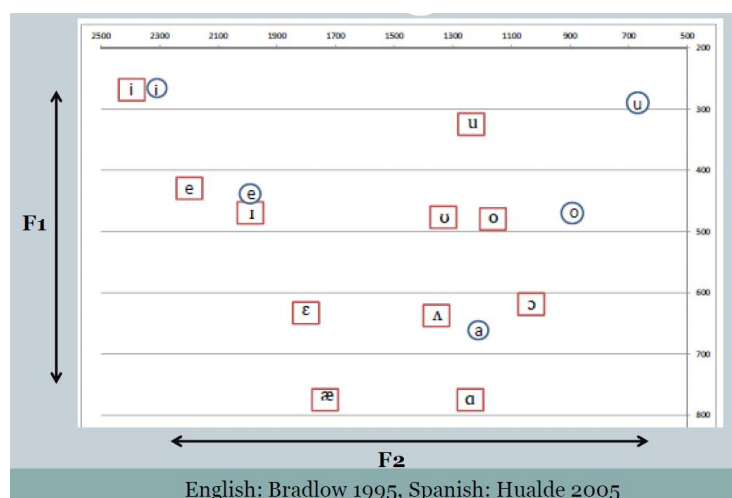
L1 English L2 Spanish speakers are one of the most investigated learner groups in the fields of linguistics and language acquisition. Thanks to an abundance of works available on this speaker profile, the specific challenges faced by English speaking learners of Spanish in language classrooms can be understood in greater detail. The following section outlines previous research that has investigated the production of /i e a o u/, /p t k/ and /b d g/ by L1 English L2 Spanish learners, highlighting possible similarities and differences in the difficulties that might be expected in the production of Slavic HSs learners.

2.3.2.1 Vowels /i e a o u/

The first topic - Spanish vowels - demonstrates how even an uncrowded acoustic inventory without great dialectal variation does not automatically eliminate any production challenges faced by learners. Presenting only 5 vocalic phonemes /i e a o u/, Spanish vowels are not easily mastered even by learners who are native speakers of languages that have twice as many vowels in their inventories, such as English, which is reported to have from 9 to 14 phonemes. That is, having more vowels in the English acoustic space does not mean that any of them directly corresponds to the ones in Spanish (Bradlow 1995, Menke and Face 2010).

Figure 2.10 is an image taken from Boomershine (2012) who utilized data from Bradlow (1995) and Hualde (2005) that compared the position of the Spanish vowels to the position of the English vowels in the acoustic space:

Figure 2.10. Spanish and English vowels



Bradlow (1995) described the English vowel space as more fronted than Spanish's and provided evidence of a higher articulation of /i/ and /e/ in English than in Spanish. Menke and Face (2010) showed that although English vowel counterparts have some similarities to Spanish segments, they are not identical, with the main differences being the diphthongization of /e/ and

/o/ to [eɪ] and [oʊ], mid vowels in Spanish being higher and tenser, Spanish /a/ being more fronted, and its /o/ and /u/ produced with more lip rounding than English's.

Another difference between vowels in English and Spanish is the presence of unstressed vowel reduction in English, which does not exist in most dialects of Spanish. Delattre's (1969) study investigated English, French, German and Spanish vowels. Through an acoustic analysis of spectrographic representations, as well as through an articulatory analysis of motion picture X-rays, he demonstrated that English had the largest degree of vowel reduction among all the languages tested. It occurred 17.78% of the time in English, while in Spanish, it was the smallest, taking place only 3.65% of the time⁸. Unstressed vowels in English reduce through the process of centralization to a mid-central vowel [ə], also known as schwa, which was shown by Delattre to be English's most pronounced allophone, appearing 22.99% of the time. The difficulties in Spanish vowel production by native English speakers were noted very early on, with Stockwell and Bowen (1965) pointing out the challenges faced by learners in the pronunciation of unstressed segments. Studies that followed, such as Hammerly (1982), provided additional evidence for the difficulties that learners face by examining vowel pronunciation in first semester university Spanish course students, who transferred the diphthongs /eɪ/ and /oʊ/ from English and regularly demonstrated vowel centralization.

Elliott (1997) provided promising results showing that vowel production in L1 English speakers can be improved through the use of explicit pronunciation instruction, specifically with the production of /o/ and /u/, as shown by his participants registered in a third semester university class. The study, however, revealed that the improvement in vowel production

⁸ While some studies (Canellada de Zamora and Zamora Vicente 1960, Delforge 2008, Gordon 1980, Hundley 1983, Lipski 1990) reported reduction through devoicing and elision in Mexican and Andean dialects of Spanish, generally, it is not observed in other varieties of Spanish.

required more time than with other classes of sounds and demanded consistent explicit instruction.

A trend towards improvement in vowel production as the linguistic competence of learners increases has also been reported by Cordero et al. (2006). The researchers analyzed the speech of 9 speech language pathologists who are L1 English speakers with an advanced knowledge of L2 Spanish and did not find many differences in formant values in the two languages. The F1 value tended to be a bit higher and the F2 was slightly lower in Spanish vowels than in English, but the difference only reached significance for /u/. Such results demonstrate that as speakers advance in their language acquisition, certain features from English are retained in the production of Spanish vowels, but there is a general trend for improvement.

Looking for vowel production trends across various levels, Menke and Face (2010) tested native English speakers enrolled in a fourth semester course, graduating Spanish majors and PhD students in Spanish. Graduating majors and PhD students performed similarly, producing formants with comparable frequencies and demonstrating a larger vowel space in comparison to the lower level learners, where the front vowels and the central vowel were more fronted, while high and back vowels had a more back production. Overall, the advanced groups' formant frequency values more closely resembled the native speakers' measurements than the novice group's; however, even high level students showed evidence of English transfer, specifically in atonic syllables.

Romanelli and Menegotto (2015) found that positive development over time in the vocalic system of Spanish by L1 English speakers was seen not only in production, but also in perception. The authors tested perceptual abilities with regard to the Spanish vowels /a e o/ in word final position after 90 hours of exposure to Spanish lessons in a three-week course in Mar

del Plata, Argentina. The test consisted of 42 triplets of nonce words that differed only in the final vowel and/or stress and learners were asked to mark the word they heard (e.g. semapa, semapá, semapo) (p. 33). The post-test results revealed that English learners were able to identify the vowels with the same accuracy as native Spanish speakers, concluding that vowel perception does not constitute a problem for L1 English learners of Spanish, especially when presented with extensive exposure to the language.

The studies reviewed thus far in this section have demonstrated challenges experienced by L1 English learners when acquiring the Spanish vocalic system due to differences in the acoustic spaces of the two languages. The difficulties encountered, however, are shown to lessen with time and increased exposure to the language. The question that needs to be addressed in the present study is whether the HSs under investigation will have the same experiences as the L1 English learner or if their production will differ given that vowel quality in Ukrainian and Polish is closer to that of Spanish, with all three languages lacking vowel reduction in unstressed contexts.

2.3.2.2 Voiceless stops /p t k/

Multiple studies have been done on VOT values in English speaking learners of Spanish, investigating transfer from the L1 as well as pedagogical implications. Since English is a long-lag language that has aspirated stops that are produced with a VOT longer than 30 ms, learners tend to transfer this L1 English feature into L2 Spanish, a short-lag language whose voiceless stop VOT measurements are typically shorter than 30 ms. González-Bueno (1997), who studied L1 English L2 Spanish students registered in fourth semester language classes, was one of the first researchers to examine stop pronunciation in learners. The author tested an experimental and a control group at the beginning and at the end of a semester. The experimental group received

instruction on the pronunciation of the stop segments throughout the semester, but the control group did not. The results from the pre- and post-tests showed that the experimental group significantly improved in their pronunciation of /p/ and /g/ in Spanish and there was evidence of a tendency towards improvement in other stops' pronunciation. Meanwhile, the control group did not demonstrate any significant progress in the articulation of these segments.

Zampini (1998) conducted a study of a similar nature by examining VOT production in L1 English learners of Spanish registered in an advanced undergraduate Spanish phonetics course. Learners were tested for production and perception three times: three weeks prior to instruction, six weeks later (right after training) and 15 weeks later. The analysis of the data revealed that students' production of /p/ in Spanish was significantly shorter than that of monolingual L1 English speakers. However, these VOT measurements were still longer than those of monolingual Spanish speakers. Also, even though the production of this segment improved after instruction, the decrease in VOT did not prove to be statistically significant.

The two studies discussed, as well as other research on this subject, particularly those studies that compared learners in a classroom setting in their home country with those registered in Spanish classes while studying abroad (Díaz-Campos and Lazar 2003, Díaz-Campos 2006), have shown that the difference between long-lag and short-lag VOT presents a special challenge for L1 English learners of Spanish, which possibly might not be experienced at all or to the same degree by HSs of Slavic languages whose HLs, like Spanish, are short-lag.

2.3.2.3 Voiced stops /b d g/

As stated previously, lenition presents a special challenge for language learners of Spanish whose native tongue is English. While in English there is a phoneme that resembles a Spanish lenited allophone of /d/ - the phoneme /ð/ ("that" - /ðæt/), which corresponds to the

Spanish allophone [ð] - for which learners can try to reset articulatory parameters when using the sound, there is no equivalent sound for the segments [β] and [ɣ], neither on the phonemic nor allophonic levels.

Zampini (1994) examined the role of the native language in the acquisition of the Spanish voiced stops /b d g/ by L1 English speakers studying Spanish while taking into account the effect that task formality has on the pronunciation of these phonemes. The author discovered three main aspects in which language transfer from L1 English played a role in the L2 acquisition of the Spanish voiced stops and lenition: the absence of an obligatory allophonic rule of voiced stop weakening in English, the transfer of English /ð/ to Spanish, which caused a much slower acquisition of that particular allophone in comparison to [β] and [ɣ], and finally, the role of the orthographic "b" and "v," which led students to transfer their "v" pronunciation from English into Spanish. This last phenomenon was more common during the formal reading task than during the informal conversation task.

González-Bueno (1995) performed a similar study with low and intermediate level university students of Spanish. After analyzing interviews that were conducted at the beginning of the semester, the researcher discovered that students were weakening the voiced stops in only about half of the required contexts.

Menke and Face (2009) studied lenition in L1 English L2 Spanish language learners with different proficiency levels: university students enrolled in a fourth semester Spanish course, graduating Spanish majors and Ph.D. students in Spanish. The authors considered the effects of orthographic "v," syllable stress and word position. The results revealed that stops predominated in the production of fourth semester learners, while graduating majors and Ph.D. students demonstrated higher instances of weakening. When the phoneme /b/ was orthographically

represented as "v," both the fourth semester students and graduating Spanish majors produced it as a fricative labiodental [v] with greater frequency than the Ph.D. students. Stress and word position also affected the results. The two lower level groups produced more stops in stressed syllables than in unstressed syllables, while Ph.D. participants' speech did not appear to be affected by syllable stress. All three groups of learners produced more approximants when /b d g/ occurred word internally than word initially.

The studies mentioned in this section illustrate how intervocalic lenition presents a special challenge for L1 English learners of Spanish. It is possible that this same phonological phenomenon will also prove difficult to master for Slavic HSs, due to the absence of this feature from their HLs. However, it may also be possible that the HSs display a less challenging process of acquisition of [β ð γ] due to the shared nature of true voicing of /b d g/ in Spanish and their HLs.

2.3.2.4 Summary

In this section I reviewed several studies that describe the most common difficulties faced by L1 English learners of Spanish when acquiring vowels, and voiceless and voiced stops. Vowels are some of the most difficult segments for L2 Spanish learners to produce due to a significant difference in articulation from English, as well as the absence of unstressed vowel reduction, which is common in English. The voiceless stops present a challenge because in Spanish they are produced with a short-lag VOT, but oftentimes the long-lag feature is transferred from English. The voiced stops are challenging due to the absence of the systematic voiced stop weakening in English that is present in Spanish. Additionally, while in Spanish voiced stops are true voiced segments, in English there is no true voicing of stops. Based on the difficulties L1 English L2 Spanish learners encounter with regard to the sound types outlined in

this section, I am motivated to examine whether the HSs of Ukrainian and Polish will face the same challenges. Considering that my participants are speakers of languages that do not have vowel reduction, have short-lag VOTs and are true voice languages, it is possible that they will not have the same difficulty in acquiring vowels, and voiceless and voiced stops when compared to L1 English L2 Spanish speakers.

2.4 Relevant research on heritage language phonology

The following section presents previous research on HSs of Spanish and HSs of Slavic languages. The Spanish HS studies present the unique linguistic experiences of this type of speaker and describe the methodologies utilized by authors when working with this community. The Slavic HS literature describe these speakers in English speaking environments, which directly relates to the present study. It also provides a list of segments that were previously investigated, pointing out the commonly studied aspects of heritage Slavic phonology.

2.4.1 Previous research on heritage Spanish phonetics and phonology

Considering that the study of HLs is an emerging field, it is not surprising that not much is known about HS phonetics and phonology. Polinsky and Kagan (2007) pointed out one of the reasons for the lack of investigation on HL sound systems is that many HSs "generally sound so native like," especially to an untrained ear (p. 378). However, there are several works that have investigated the HS' sound system, especially concerning those whose HL is Spanish. Although I will not work with HSs of Spanish, the results and implications in the studies that follow are very important to properly contextualizing the current study. Since heritage phonology is still an emerging field and there is still much to be learned about this type of speaker, the investigations mentioned in this section provide crucial information regarding HSs' linguistic experiences, as

well as various methodologies that authors have implemented when working with this unique language profile⁹.

2.4.1.1 Voiceless and voiced stops /p t k b d g/

Knightly et al. (2003) examined the speech of childhood overhearers of Spanish, or speakers who overheard Spanish during childhood but did not actively speak it, and compared their production to that of native speakers and typical late L2 learners. The study looked at the production of voiced and voiceless stops /p t k b d g/, as well as prosodic factors such as speech rate, phrasing and stress placement. The results revealed that the overhearers' production was more native-like than that of the late L2 learners, displaying shorter VOTs in /p t k/ word initially and more lenited /b d g/. The authors did not find a significant advantage on the prosodic level, where the three groups of speakers were comparable, explaining that the unreliable differences were most likely caused by the task design (short and simple sentences). The native-like production was also confirmed by the native speaker rater group, who assessed the overhearers' speech as more native sounding than that of the L2 learners. In addition, it was found that the advantages displayed by overhearers in Spanish did not negatively affect their production of English segments. These results confirmed the findings in a similar study by Au et al. (2002) that served as an interim report for this investigation and also provided additional support for Flege's (1995) Speech Learning model.

A study by Au et al. (2008) looked at two different groups of Spanish HSs: those who only overheard the language during childhood and those who also spoke the language for at least

⁹ In this section I will limit my discussion to previous heritage works on vowels and stops, but there are studies on other segmental issues, such as rhotics (Amengual 2016, Henriksen 2015). There are also studies on Spanish HSs' sound system that examine suprasegmental features (i.e., stress, rhythm and intonation), demonstrating that HSs differentiate themselves from native speakers not only in production of segmental features, but also in the realization of suprasegmental aspects. (e.g., Carter and Wolford 2016, Colantoni et al. 2016, Mazzaro et al. 2016, Rao 2016, Robles-Puente 2014).

three years in early life. The authors looked at the same phonemes described in the previous study and also included a native speaker rater group that assessed the presence of an accent in reading and narrative tasks. The results revealed that both HS groups produced samples that are more native-like than those of the speech of typical late L2 learners, with the speakers group performing in a more native-like manner than the overhearing-only group. These findings supported the previous studies by the authors regarding overhearing benefits and suggested that, in addition to overhearing, a regular use of the language through speaking can present HSs with further phonological advantages.

Kim (2011) set out to examine not only the production, but also the perception of voiced and voiceless stops of Spanish HSs who were more dominant in English than in the HL. The author found that during the production task the HSs displayed measurements that were significantly different from those of the native Spanish speakers, but did not differ significantly from the native English speakers. The perception task, however, showed that HSs differed significantly from the native English speakers, while there was no significant difference from the native Spanish speakers. Considering that perception in the native language stabilizes earlier than production, the author concluded that it is necessary to differentiate between production and perception and investigate both aspects in order to have a clearer understanding of L1 and L2 phonetic interference.

Amengual's (2012) study investigated the production of /t/ in cognates by Spanish HSs, English HSs, advanced L2 Spanish learners and advanced L2 English learners. The findings showed that there was a significant effect of cognate status, with speakers producing longer VOT values in cognate items, especially in word initial unstressed position. The Spanish HSs had slightly lower VOT values than the English HSs in cognate items; however, the study discovered

no significant difference in VOT values between Spanish HSs and late learners of Spanish. The researcher concluded that highly proficient L2 learners are capable of producing values that are not significantly different from those of simultaneous bilinguals, a statement that supports an earlier study by MacLeod and Stoel-Gammoon (2010) that investigated simultaneous and sequential English/French bilinguals and found no significant differences between the two groups in the pronunciation of labial and coronal stops and high vowels. Amengual suggested that this finding was likely due to the nature of the feature being investigated. Kessinger and Blumstein (1997) and Beckman et al. (2011) suggested that reducing the aspiration attributed to longer VOT values is a less effortful task than increasing the VOT value, which can possibly explain why the bilingual speakers tested in this study had no trouble producing Spanish short-lag VOTs.

Rao's study (2015) looked at the production of intervocalic voiced stops /b d g/ in four different groups of Spanish HSs: regular speakers (i.e., those who continue to actively use the language in adulthood), childhood speakers (i.e., those who spoke the language at a young age, but are not regularly using it in adulthood), childhood addressees (i.e., those who were addressed in Spanish during childhood, but did not speak the language) and speakers that had minimal exposure to Spanish (i.e., those who were not addressed in Spanish during childhood and did not speak the language, but occasionally heard it). He examined the effects of syllable stress, task, word position and the graphemes "b" and "v" on the allophonic realization of voiced stops. The results showed that the regular speakers performed in the most native-like manner and the childhood speakers were less native-like in their production than the regular speakers. Most interestingly, the childhood overhearers in this investigation were more comparable to adult L2 learners, contrasting with the findings in Knightly et al. (2003) and Au et al. (2008), possibly due

to a difference in experimental tasks, as well as the length of exposure to Spanish as adults. Finally, when looking at the task types, the reading task produced a higher number of non native-like segments in comparison to the spontaneous task, which could be due to a greater focus on form as well as an interference from English caused by orthography, as evident in the items that utilized "b"/"v" graphemes. Overall, the results supported the author's previous work, Rao (2014), which looked at the production of the phoneme /b/ by HSs, finding that decreased use of the language, word boundary position, stressed syllables and reading tasks all significantly affected the native-like production of the segment, promoting a less lenited production and a differentiation between "b" and "v" graphemes.

2.4.1.2 Vowels /i e a o u/

Research on Spanish HSs' phonology also includes several studies of the vowel system. Willis (2005) investigated the vowel production of Southwest Spanish HSs in stressed syllables (and unstressed for /a/), revealing that the speakers did not preserve a symmetrical triangular shape of the Spanish vocalic space. Instead, the participants demonstrated a lowering and fronting of /u/, a lowering of /o/ and a fronting of /a/, assimilating it to the English /ae/. The author, however, did not observe reduction of unstressed /a/ to schwa. With these findings the author demonstrated how the vowel space is not always stable across dialects of Spanish, especially in heritage varieties.

Ronquest (2012) supported Willis' findings that HS vowel systems differ significantly from the monolingual speakers'. The researcher found that Spanish HSs from Chicago produced /e/ further back and /u/ more fronted. Stressed vowels were centralized and produced with a shorter duration than unstressed vowels. The author also reported that as speech became more formal, vowels became longer in duration and were more spread out in the acoustic space.

Finally, Ronquest found that travel abroad and use of Spanish outside of the classroom affected the results; speakers who reported participating in these two activities displayed results that were closer to the native speaker norms.

Boomershine (2012), who studied HSs of Mexican, Colombian and Peruvian backgrounds from North Carolina observed that HSs produced both stressed and unstressed vowels that were more fronted and lower than those of bilingual native Spanish speakers, demonstrating an overall more crowded back vowel space and a greater dispersion of the front vowels in heritage speech. The author found that unstressed vowels were more condensed and produced higher than stressed vowels, which were lower and more spread out in the acoustic space. Finally, Boomershine also found evidence of word-final /a/ reduction.

In a subsequent study on vowels, Ronquest (2013) discovered the presence of unstressed vowel reduction in HSs of Spanish who tended to centralize atonic vowels (especially /e/, /a/ and /o/) in the Spanish vocalic space and produce them with shorter duration in comparison to tonic vowels. None of the vowels, however, were reduced to a schwa.

A study done by Boomershine (2013) focused on HSs' perception of the phonological features of English. The author compared HSs' perception of English vowels to that of native Spanish bilinguals and monolingual Spanish speakers and discovered that L2 learners were able to perceive L2 vowels more accurately as their proficiency in the L2 increases. The HSs differed significantly from the monolingual Spanish speakers in the perception of four vowels, while the native Spanish bilingual group differed significantly from monolinguals in the perception of two vowels. Although the researcher discovered similarities in the perception of heritage and bilingual speakers, the evidence for correlation between age and L2 exposure were considerable, especially for segments that are not present in the L1. These findings also seem to support Au et

al. (2002) finding (although the two studies looked at different segments and tasks) that knowledge of the HL sound system does not come at the cost of phonological understanding of the dominant language.

Ronquest (2016) demonstrated that vowels produced by HSs of Spanish differ systematically based on speech style: conversational, semi-spontaneous or highly controlled. During the semi-controlled picture identification and highly-controlled carrier phrase tasks, vowels were longer in duration in comparison to the conversational narrative retelling task. In terms of vowel space expansion, the most controlled task produced the greatest dispersion, possibly implying that speakers wished to maintain a clear separation of categories when there was no conversational context. When speech was more natural and contextual factors helped construct meaning, vowel categories were more likely to overlap. These findings reveal that HSs behave similarly to monolingual speakers when it comes to speech style and vowel space expansion, as well as vowel duration.

2.4.1.3 Summary

In sum, although the present study does not investigate the speech of Spanish HSs, the findings reviewed in this section demonstrate that HSs are a unique group of speakers who linguistically do not perform like monolingual speakers, late immigrants or L2 learners. Their distinct language experiences with their heritage language and their dominant language, as well as their distinct performance in the heritage language, demonstrate that these speakers should not be lumped together with either of the groups; rather, studying their linguistic repertoire requires distinct analytical approaches and methodological practices.

2.4.2 Previous research on heritage Slavic phonetics and phonology

Fortunately, there is a small body of studies that describe the sound systems of Slavic HSs. Hrycyna (2011) and Nagy and Kochetov (2013) examined the speech of Ukrainian and Russian HSs in an English-speaking environment. The two teams assessed the VOTs of voiceless stops in the conversational speech of three generations of Russian and Ukrainian bilingual HSs whose L1 was English. The researchers found that the Russian community showed the biggest drift from short-lag to long-lag VOT between generations 2 and 3, attributing this shift to an absence of an organized Russian community in Toronto, which prevents its speakers from using the Russian language in a casual environment outside of the household setting. In contrast, there is a large and active Ukrainian speaking community where members of all generations have a chance to casually interact with each other. This social factor contributed to a greater drift in VOT values between generations 1 and 2, where the second generation tends to quickly adjust to the norms of the already established community.

Łyskawa et al. (2016) compared the patterns of word-final obstruent devoicing in first (Gen 1) and second generation (Gen 2) Polish HSs living in Toronto, L1 Polish speakers living in Poland, and English monolinguals living in Toronto. The authors discovered that the HSs had a significantly higher number of instances of devoicing than both the homeland Polish speakers and the monolingual English speakers. Within the HSs group, Gen 2 speakers produced significantly more devoiced segments than Gen 1 speakers. When looking at the context of devoicing, the Gen 2 and L1 English speakers overlapped in their preference of word-final devoicing before a pause and the devoicing of fricatives and affricates over stops, which was the opposite of the Gen 1 and homeland Polish speakers' results. In sum, the HSs were affected by the majority language, which caused a merger of their two grammars in which the rules from

both Polish and English were applied to word-final obstruent devoicing. Gen 2 speakers were particularly affected by the two grammars, demonstrating the most instances of devoicing. This study is unique because, unlike many of the previous studies, it considers cross-generational immigrant variation and compares it with the variety from which these immigrant speakers originated, giving us a glimpse of change over time.

Asherov et al. (2016) investigated the vowel reduction patterns of Russian HSs living in Israel. While in Russian, the vowels /o/, /a/ and /e/ reduce in unstressed syllables, yielding differences in both quantity and quality when compared to unreduced articulations, in Modern Hebrew, there is mainly a quantitative distinction in which the two counterparts differ in duration, but not in quality. The authors found that the HSs produced native-like patterns of reduction in Russian real words. However, they discovered that in nonce words, when fronting vowels, the speakers consistently avoided vowel raising. This finding indicates that vowel fronting is not part of the productive grammar of the HSs and that the vowel reduction produced in real words was a result of role-learning (lexicalization), meaning the reduced vowels were stored forms rather than derived forms. This study presents a significant methodological contribution, showing the value of using nonce words and their advantage over real words. While nonce words are treated similarly to real words in speakers' grammars, they are unaffected by lexical factors, which allows researchers to see whether a certain phonological process is productive or the result of lexicalization. Following Asherov et al.'s example, the present study also incorporates nonce words in the data elicitation to allow for a clearer distinction between lexicalization versus productive grammar.

2.4.3 Summary

The various studies overviewed in this section on Spanish and Slavic HS segmental phonetics and phonology have clearly demonstrated that the HS profile is unique when it comes to the perception and production of segments, sometimes overlapping with monolingual and L2 learner groups, but more often displaying a distinctive behavior. While the majority of studies have looked at the bilingual profile of these speakers, based on the evidence provided, one could surmise that the distinctive phonetic and phonological abilities of HSs will manifest themselves in L3 acquisition as well, thus differentiating this group of learners not only from the typical late L2, but also from other L3 learners. Considering what previous research has shown about the acquisition of L3 and HL phonology, the goal of the current investigation is to combine the two research areas and examine the interaction between three typologically different languages (i.e., the dominant language – English, the HL – Ukrainian or Polish, and the L3 – Spanish), thus enhancing our understanding of the multilingual mind.

2.5 L3 phonology

After having reviewed several studies regarding L2 and HS phonology, I now turn my focus to the newly emerging field of L3 phonology and examine some key studies that highlight special processes and challenges faced by L3 learners when acquiring sound systems.

2.5.1 L3 acquisition theory

When working with L3 phonology, there are several theoretical frameworks that should be considered, all of which were specifically developed to account for the learning of multiple languages. In this section, I will examine the following models, several of which were summarized in Kopečková et al. (2016): Fernandes-Boëchat's (2007) Multilingual Role Model (MRM), Fernandes-Boëchat and Siebeneicher Brito's (2008) Cognitive Chain Reaction Theory

(CCRT), Flynn et al.'s (2004) Cumulative-Enhancement Model (CEM), Bardel and Falk's (2007, 2012) L2 Status Factor Model, de Bot (2012), de Bot et al. (2007) and van Geert's (2008) Dynamic Systems Theory (DST), Rothman's (2011, 2015) Typological Primacy Model (TPM) and Westergaard et al.'s (2016) Linguistic Proximity Model (LPM). While not all of these theories are applicable to the present study, they are very important to consider in order to understand the development of the relatively new field of L3 acquisition and the great degree of variability that researchers encounter when working with L3 learners.

Fernandes-Boëchat (2007) noted in her MRM that there is "a strong tendency for just the preceding foreign language to predominate in the role of the external supplier during initial target language production" after examining syllable stress produced by L3 French learners in cognate words inserted in a target language text in a reading task. She emphasizes that in order to witness such influence from the L2, the level in the non-native language must be at least at an intermediate stage (p. 203). The author's model is based on the CCRT, which states that "each new foreign learning experience is linked, involuntarily or unconsciously, by the learner to one's preceding foreign-language learning experience in a chain-like domino-effect fashion" explaining why it is the L2 that exerts the biggest influence on L3 (Fernandes-Boëchat and Siebeneicher Brito 2008, p. 204). It will be interesting to observe how this theory applies to the present study, considering that for HSs under investigation, neither English nor the HL are completely foreign and determining which of the two languages is the L1 and which one is the L2 will depend on whether we consider the order of acquisition as our guiding point or whether we rely on language dominance, which also can change over the lifetime of a speaker. Alternatively, it is possible that the speakers of the current study have two L1s and that neither of them is considered to be foreign. Fernandes-Boëchat also states that as a learner's competency in

the target language increases beyond the intermediate level, the involuntary process of transfer will be reduced. The speakers of the present study are beginning and intermediate-level learners of Spanish. Therefore, if their HL is classified as the L2, it is very likely that there will be transfer mainly from the HL, displayed as short-lag VOTs, lack of unstressed vowel reduction and avoidance of voiced stop weakening in intervocalic position.

The CEM postulates that neither the L1 nor any other language known by a speaker has a special role when it comes to the acquisition of additional languages. In a learner's mind, all languages share the same level of importance and all of them have an equal chance of influencing subsequent language learning. Prior languages can either be neutral or play a facilitative role, otherwise, non-facilitative transfer will be blocked. This model proves that neither the L1 nor the L2 acts as a default (Onishi 2016). Therefore, if L3 acquisition is guided by the CEM, the speakers in this study will only transfer the features from their HLs that facilitate their learning, such as short-lag VOT, lack of unstressed vowel reduction and true voicing of voiced stops. The non-facilitative features from the dominant language, such as long-lag VOT, unstressed vowel reduction, lack of true voicing of /b d g/ and a shared lack of voiced stop weakening in intervocalic position with the HLs will be neutralized. However, the studies reviewed in the section that follows showed that non-facilitative transfer does take place and is not always blocked or neutralized (Hammarberg and Hammarberg 2005, Kopečková 2016, Llama et al. 2007, Llama et al. 2010, Llama and López-Morelos 2016, Sypiańska 2016, Wrembel 2009).

The L2 Status Factor Model, inspired by Hammarberg (2001) and Hammarberg and Williams (1998), as well as Meisel (1983), posits that during L3 acquisition, the L2 plays a more significant role than the L1 due to association with a foreignness factor. Since the L2 and the L3

are classified as foreign languages, we are more likely to observe interactions between them due to their cognitive similarity, while L1 is suppressed as a non-foreign supplier. While this model supports the MRM and CCRT, and is evidenced in several studies (DeAngelis 2007, Llama et al. 2007, 2010, Tremblay 2007), there is evidence that the L1 is not completely suppressed (Kopečková 2016, Onishi 2016, Sypiańska 2016) and that the speakers witness even stronger influence from the L1 as they gain proficiency in the L3 (Wrembel 2009). As with the MRM and CCRT, the application of this model will depend on whether the dominant language or the HL is classified as the L2. As discussed previously, it is possible that both languages could be treated as L1s, which makes the L2 Status Factor Model challenging to apply to present investigation.

De Bot (2012) defines the DST as “the science of the development of complex systems over time” (p. 82). In this context, the multilingual brain is a complex system, where languages form interconnected networks that constantly interact with each other and continuously change over time. It is not easy to predict which changes will take place due to the changing nature of interactions between external and internal factors. However, even the subtlest changes will influence the acquisition of all languages in a learner’s mind, proving that language development is a dynamic process (see Kopečková et al. 2016 in section 2.5.3 of this chapter). If my speakers’ L3 acquisition is guided by the DST, it will not be easy to predict the outcome since interacting variables are constantly changing over time. However, I can expect great individual variability, guided by each speaker’s environment that will affect his or her language development in all three languages. Specifically, the results will depend on where and how each speaker acquired his or her HL, as well as on how much he or she uses it. These factors will influence the production of vowels, and voiced and voiceless stops in all three languages.

The TPM argues that typology is the deciding element in language transfer, regardless of the order of acquisition. According to the TPM, the typological proximity or the perceived (i.e., psychotypological) proximity between the two languages is the main factor determining whether or not transfer from the L1 or the L2 takes place. Like the L2 Status Factor model, TPM argues for an exclusive transfer from only one of the languages previously acquired by a learner. Unlike the CEM, the TPM postulates that transfer is always possible, even when it is non-facilitative. If the TPM is guiding L3 acquisition, my group of speakers will transfer from only one of the languages, whichever they perceive to be typologically similar to Spanish. If the HL is perceived as typologically close to Spanish, then I will find evidence of short-lag VOT, lack of unstressed vowel reduction and pre-voicing of voiced stops in L3 Spanish. However, if English is perceived to be typologically similar to Spanish, then I will observe long-lag VOT, unstressed vowel reduction and lack of pre-voicing in voiced stops. As I will note in Section 2.5.3 of this chapter, the TPM does not account for all stages of acquisition, especially when considering acquisition over time (Hammarberg and Hammarberg 2005, Wrembel 2009).

The LPM states that during L3 acquisition, bilinguals rely on both the L1 and the L2, and that transfer is not dependent on the order of acquisition or language typologies. Instead, “acquisition occurs when a particular linguistic property receives strong supporting input from the involved languages,” meaning L3 input displays an abstract structural similarity to the structures of previously acquired languages (Mykhaylyk et al. 2015, p. 341). According to the LPM, it is possible to observe different learning patterns for different phenomena, where transfer from either the L1 or the L2 is directed by individual structural properties. If the results of this study are interpreted within the LPM, it will be possible to observe transfer from either the dominant or the HL, depending on how each speaker perceives the structures in question. For

example, if speakers see Spanish voiceless stops as structurally similar to their HL, then they are likely to be produced with short-lag VOT. However, if a speaker perceives them as structurally similar to the dominant language, then they are likely to be produced with long-lag VOT.

2.5.2 Methodological considerations in L3 research

In this section I would like to discuss several methodological issues in L3 phonology. With the study of L3 acquisition, sound methods become even more crucial since investigations involve at least three competing linguistic systems that all play different roles. In order to better understand which language performs which function during the process of acquisition, each aspect of a study needs to be highly controlled - an issue that is thoroughly described by Cabrelli Amaro (2013).

Cabrelli Amaro's (2013) suggestions regarding L3 methodology are motivated by the Phonological Permeability Hypothesis (PPH; Cabrelli Amaro and Rothman 2010), which aims to explain that phonological systems acquired after the critical (or sensitive) period are fundamentally different from those acquired natively, even if the L2 sound system appears to be native-like. In order to verify or falsify this claim, the PPH relies on evidence provided by L3 acquisition, specifically regarding how it affects the phonological systems of the L1 and the L2. According to the researchers, if the native and the L2 phonological systems are learned or acquired in the same way, then the L3 will have a similar effect on both of the languages and both sound systems will be equally resistant to L3 influence. On the other hand, if the phonological systems of the L1 and the L2 have different underlying mental representations, meaning the two phonological systems are constructed differently in a learner's mind, then it is expected that the L3 will exhibit quicker and more aggressive interference on the L2 - the successive system - as the learner becomes more proficient in L3. In order to have a clear

understanding and evidence of how the three languages interact in the learners' mind and be able to either support or refute the PPH, strict methodological practices need to be implemented.

Cabrelli Amaro suggests that the very first step to a good L3 study is reporting sufficient background information on the speakers recruited for the investigation. Researchers need to provide basic information regarding age of arrival, length of residence, education in the L2 and the L3, self-reported use of languages, as well as self-reported competency in reading, writing, speaking and aural comprehension in all languages. Besides self-reported information, phonological proficiency and global language proficiency levels need to be objectively tested in all three languages, especially in L2 and L3 phonology. Simply assuming that a participant is a native speaker of a certain language is also problematic. Each phonological issue under investigation needs to be tested in the L1 as well, to ensure that the speaker is producing or not producing it in their native language, which helps justify or deny any possibilities of transfer. Ideally, these participants should be tested longitudinally to compare their L3 initial state to later stages of acquisition, but it is understandable that such studies are challenging to carry out. Therefore, the author argues for an inclusion of a control group that does not consist solely of monolingual native speakers of the L3, quoting Hopp and Schmid (2011), who state that native speaker norms "by definition, [are] out of reach for most bilinguals" (p. 4). Instead, Cabrelli Amaro proposes, if possible, use native speakers of the L3 who are advanced speakers of the experimental group's L1 and L2, which should provide a better understanding of the cross-linguistic interaction in the phonological systems of these languages. Based on this recommendation, for the present study, it will be best to have a control group that consists of native speakers of Spanish who are also advanced speakers of Ukrainian and English or Polish and English. Such groups of speakers will provide better insight on the end state of L3 Spanish

acquisition of the experimental group. However, this suggestion is challenging to follow, such as the trio that is the focus of this investigation.

During the testing phase of the experiment, the author encourages to develop tests for all three languages under investigation, especially when studying successive bilinguals of the L1 and the L2 to assure that the phenomenon under investigation is already acquired in the L2. Cabrelli Amaro suggests creating a "master set" of tokens that consists of nonce words that will be tested in all three languages on different occasions. The property that is under study needs to be present or absent in only two of the languages. When analyzing the data, the author proposes to utilize both the acoustic analysis and the perceptual judgments by trained raters, which can provide insights of how perceivable the differences from a native-speaker standard actually are. Several of the suggestions proposed by the author will be implemented in the present research, described in greater detail in the methodology chapter.

As was shown throughout this section, even with a slower development of phonological accounts of L3 speech, there already exists a good base of research in the area that helps understand various aspects of L3 phonological development and highlights several gaps that need to be filled by further investigation. Based on the previous findings, the goal of this study is to continue investigating cross-linguistic influence in L3 phonology by analyzing typologically distant languages, an area that still remains to be fully explored.

2.5.3 Literature overview

In recent years, L3 acquisition has gained wider recognition, most notably in the areas of education and sociolinguistics, and in the linguistic subfields such as the lexicon and morphosyntax; however, the same advancement is not yet fully evident in phonology, an

observation highlighted by Cabrelli Amaro (2012), who states that "L3/Ln¹⁰ phonology is notably understudied" (p. 1). Missaglia (2010) argues that this development is due to the fact that adults tend to master morphology and syntax faster in foreign language acquisition, outperforming children in these areas (who experience a faster advancement in phonology), which has encouraged researchers to focus on the areas where adults are more successful. Regardless of such development and the reasons behind it, there is a growth of interest in L3 phonology, as evident in the works that are presented next.

Hammarberg and Hammarberg (2005) claim that the L2 has more powerful influence during the initial stages of L3 phonological acquisition, as supported by the evidence from a well-known longitudinal study of an adult learner who was a native speaker of British English with a high level of proficiency in L2 German and was also a L3 Swedish learner. Initially, the speaker demonstrated obvious reliance on her German knowledge in terms of pronunciation in Swedish, explicitly noting a desire not to sound English. This phenomenon was also explained by the recency¹¹ of use of the L2 and its "freshness" in the speaker's mind, which were factors that contributed to German serving as an "external supplier language" (p. 82). As the speaker became more familiar with the Swedish sound system, the reliance on German gradually reduced. The authors note, however, that the decreased reliance on the L2 was not replaced by an increased dependence on L1, which suggested that "articulatory patterns have a basis in neuro-motor routines that have been established according to L1 requirements and are difficult to control or modify at will" (p. 84). Hammarberg and Hammarberg call the L1's influence on articulatory settings a "basic constraint" and the reliance on the L2 a "coping strategy," that is

¹⁰ The notation Ln refers to 'additional languages acquired by a learner'.

¹¹ The concept of recency is important to consider for the participants in the present study who might not have a very recent experience with the HL.

utilized during the initial stages of L3 acquisition and overrides the basic constraint for a period of time. The findings from this study suggest that various variables such as psychotypology (i.e., perceived differences and similarities between two languages from a learner's perspective), recency and intensity of use of the L2 should be taken into account in L3 studies.

Llama et al. (2007) tested VOT production of L3 Spanish learners with the goal of establishing whether L2 status or typology would have a stronger influence on L3 pronunciation. The researchers used L1 Canadian English speakers with advanced knowledge of L2 Canadian French and L1 Canadian French speakers with advanced knowledge of L2 Canadian English who were intermediate learners of L3 Spanish. As with the 2010 study, if the classification of the language played a stronger role, it was expected that L1 French speakers would perform better in L3 Spanish, producing native-like VOTs, while L1 English speakers would produce long-lag durations; however, if the L2 was more significant, then the expected results would be the opposite. The results demonstrated that L2 status was more influential in the production of the L3 stops than the L1.

The results of this study, as well as the authors' later study (Llama et al. 2010), go along with the findings of Tremblay's (2007) work on L1 English L2 French speakers learning L3 Japanese. This study also looked at VOT values and found L2 influence to be stronger than L1 influence. De Angelis (2007) described this phenomenon as "association of foreignness," defining it as "the cognitive association that learners establish between non-native languages, which are assigned the common status of 'foreign languages'... [which] thus results in an increased acceptance level for non-native information into the target language" (p. 29). While the author made this statement based on empirical studies about lexis, the same observations have

been made regarding the sound system as well, specifically by Fernandes-Boëchat (2007), as discussed in Section 2.5.1 of this chapter.

Hammarberg and Hammarberg's (2005) results are strongly corroborated by Wrembel (2009) (as well as Fernandes-Böechat's (2007)) who investigated L1 Polish L2 German and L3 English speakers' perceived foreign accent in English. Expert judges (seven native English speakers and 20 near-native speakers of English) scored the participants' speech in various controlled and spontaneous tasks, grading speakers for an overall presence of a foreign accent and identifying the speakers' native language from a list presented by the investigator. The results revealed that determining foreign accent and language background depended greatly on the state of L3 proficiency; some learners' speech was categorized as more accented than others and some participants were identified as L1 Polish speakers while others as L1 German. Elementary and beginner speakers received higher foreign accent scores than the intermediate level learners, which showed that foreign accent can be used as a reliable measurement. When it came to L1 identification, participants at higher levels of the L3 were correctly identified as native Polish speakers, while elementary and beginner groups tended to be placed in the L1 German category. When participants were identified as L1 accented, there was no difference between the reading and the speaking tasks, but when they were placed in the L2 accented category, the foreign accent scores were higher for the speaking task, which demonstrated that this mode of communication was more vulnerable to phonological transfer.

Since L3 acquisition involves more than two languages, it becomes more complicated to determine which language has greater influence on the L3 or if such influence is present at all, as evident from Gut's (2010) study, which set out to examine cross-linguistic influence from the L1 in speakers' L2 and L3 phonological systems by reviewing vowel reduction, speech rhythm and

oral fluency in L2 German L3 English and L2 English L3 German learners with different L1s (Polish, Russian, Hungarian and Spanish). The results revealed a more native-like performance in the L2 by all speakers. However, although their performance was more successful in the L2 than in the L3, none of the speakers reached the monolingual level, which, as discussed in the methods chapters, perhaps should not be a standard to which L2/L3 speakers are compared (Hopp and Schmid 2011). These results demonstrated that fluency is an articulatory skill that differs from phonological operations like vowel reduction and speech rhythm because although all speakers spoke their L2 with native-like fluency, they did not demonstrate similar native-like performance in the phonological processes in question. In conclusion, the author did not find conclusive evidence of L1 or L2 influence on the L3, which he suggested might be due to participants' lack of awareness of the phonological concepts under investigation, which could have aided them in establishing connections between the three languages and facilitate positive transfer (see Jessner 2006). Gut claims that in order to see influence from the L1 or L2, learners need to have at least minimal language awareness.

When investigating L3 acquisition, researchers take into account many variables, two of which are the typological distance between languages and the L2 acquisition stage. Both were examined by Llama et al. (2010), who, inspired by the studies of those such as Möhle (1989), Rossi (2006) and Singleton (1987), claim that typological closeness is the most influential factor in the acquisition of an L3. On the other hand, Hammarberg and Hammarbergs (1993), Marx (2002), Tremblay (2007) and Williams and Hammarberg (1998) claim that the L2 status is more influential. Llama et al. set out to study the production of voiceless stops in L1 English L2 French and L1 French L2 English learners of L3 Spanish in search of more conclusive evidence about the nature of L3 phonology. Both participant groups revealed that the L2 exhibits greater

influence on the L3 than language typology. The L1 English group demonstrated transfer from the L2 of the newly acquired short-lag VOT, while the L1 French group showed the same L2 transfer from English, relying on long-lag VOT instead of transferring the corresponding L1 short-lag VOT feature into the short-lag L3.

The findings on the influence of the L2 on the L3 led Marx and Mehlhorn (2010) to suggest that language instructors actually need to encourage phonological transfer from the L2 to the L3. The authors argued that students of L3s generally possess greater knowledge of the L1 and the L2 sound systems and that they understand that the two sound systems differ from each other. This phonetic awareness helps students focus on the target language's unique sound system and if instructors incorporate explanations and activities that encourage the development of phonetic and meta-linguistic knowledge, students are very likely to succeed in the acquisition of L3 phonology. The authors exemplify their theory by demonstrating how positive phonological transfer can be beneficial to L2 English L3 German learners, who can have greater success with the German sound system if they practice transferring various phonological features from English to German. While the authors' suggestions do present several benefits, this practice will not be applicable to all L3 learners, especially for those who are learning languages that do not belong in the same language family and do not share as many identical phonological features that can be transferred. Also, students' previous educational experiences with language learning need to be considered in terms of how they might have affected learners' ability to have a heightened phonological awareness. Finally, as concluded by Fernandes-Boëchat (2007) and Wrembel (2009), as L3 proficiency increases, involuntary transfer from the L2 decreases, which means that students with a higher level of L3 proficiency might not necessarily benefit from a forced transfer of L2 phonological features.

Sypiańska (2016) set out to investigate cross-linguistic influence (CLI) patterns in bilingual L1 Polish L2 Danish speakers and multilingual L1 Polish L2 Danish L3 English speakers. The goal of the study was to determine whether the languages within the speakers' systems acted as component languages of a global language system in which each one differentiated itself from baseline monolingual speech. Looking at front vowels in all three languages, the authors discovered different CLI tendencies. The multilingual group produced higher and fronted Polish vowels, likely due to influence from L2 Danish and L3 English. L2 Danish vowels were produced further back, potentially due to influence from L1 Polish. L3 English did not differ from the baseline, possibly due to mixed CLI from both the L1 and the L2, which counterbalanced each other. No CLI was observed from the L3 to the L2. Most interestingly, L1 vowels from the bilingual group differed from L1 vowels of the multilingual group, likely due to the presence of an L3 in this group, which supported the argument in favor of the existence of a global language system.

The next study, done by Llama and López-Morelos (2016), is particularly intriguing for the purposes of the present study because it investigated the speech of HSs in a trilingual context. The authors studied VOT production in trilingual HSs to examine whether they created different categories for voiceless stops in the three languages in their systems: heritage/L1 Spanish, L1 dominant English and L3 French. The results revealed that this group of speakers had a distinct Spanish and English voiceless stop categories. However, there was no evidence of a separate category for L3 French, as evidenced by the production of longer VOT values in the L3 in comparison to the monolingual norm. This finding suggests that HSs were either transferring their VOT values from the dominant L1 or were imitating the values that they were hearing from

their classmates, who served as their main source of French input. Both explanations are crucial to consider when looking at the production of HSs in the present study.

Kopečková et al. (2016) examined the interaction between the German, English and Polish vocalic systems in multilingual speakers. Three groups of speakers were chosen: L1 German L2 English L3 Polish children and two groups of HSs of Polish who were German dominant learners of English, with the distinguishing factor between these two groups being whether one or both parents spoke Polish. The authors interpreted the results within the Dynamic System Theory framework (de Bot 2012, de Bot et al. 2007, van Geert 2008), discovering that the multilinguals' language systems demonstrated greater variation, even in the cases such as twin sisters with identical language backgrounds. This shows that in addition to language status, which can partly explain differences between multilingual learners at different stages of phonological acquisition, individual variability is another important element that shapes the phonological subsystems of multilinguals.

Kopečková (2016) examined the effect of bilingualism on L3 acquisition. The author compared productions of the Spanish trill and tap in L1 German L2 English L3 Spanish learners and in HSs of various languages who were German dominant L2 English L3 Spanish learners. The results demonstrated that active bilinguals were not automatically superior when compared to foreign language learners with respect to L3 phonological acquisition. Although two of the participants, a HS of Hebrew and a HS of Spanish, performed like active bilinguals when producing the tap, they were closer to foreign language users in the production of the trill. This finding supported Antoniou's et al. (2015) claim in order that to see a more accurate acquisition of a segment in the target language, a speaker needs to have had contact with languages that have that specific segment. Nonetheless, all of the active bilinguals in the study, other than, the HS of

Spanish, showed more accurate production of L2 and L3 sounds at the start and showed a bigger improvement over the span of three years than the foreign language users.

Onishi (2016) studied the influence of L2 knowledge on the perception of phonological contrasts in L3 learners by examining perceptual abilities of L1 Korean L2 English L3 Japanese speakers. The participants varied in their perceptual proficiency, but certain contrasts revealed that those who performed better in the L2 also performed better in the L3, even when certain contrasts did not appear in the L2. This finding suggests that having knowledge of an L2 provided L3 learners with an increased ability to differentiate between non-native speech sounds. L3 speakers who were more proficient in the L2 appeared to be more sensitive to sounds that were not part of their native speech and tended to differentiate between them more accurately. In addition to transfer from the L2, the author also found evidence of transfer from the L1, suggesting that there was a positive influence from both the L1 and the L2.

2.5.4 Summary

In this section I presented an overview of L3 acquisition theory, methodological considerations in L3 research, and discussed previous literature on the acquisition of L3s. At the moment, there is no agreement as to what guides L3 acquisition. Some theoretical models suggest transfer from both the L1 and the L2 (i.e., CEM, DST, LPM, MRM, CCRT), while others argue for transfer from only one previously learned language (i.e., L2 Status Factor Model, TPM). Also, while some studies argue that L2 status is the determining factor in L3 acquisition (Llama et al 2007, Llama et al 2010, Tremblay 2007), others consider typological proximity between languages to be the most influential aspect (Antoniou 2015, Kopečková 2016). Alternatively, there is also evidence that as speakers become more proficient in an L3, the external supplier language changes (Fernandes-Boëchat 2007, Fernandes-Boëchat and

Siebeneicher Brito 2008, Hammarberg and Hammarberg 2005, Wrembel 2009). Both the theoretical frameworks outlined, as well as previous research in the field of L3 acquisition help motivate the present study, which aims to discover what guides L3 acquisition in a context where one of the languages is a HL, which cannot be automatically classified as an L2 and which shares several phonological features with the L3.

2.6 Research questions

After having reviewed various phonological phenomena that have been shown by multiple researchers to be challenging for L1 English learners of Spanish to acquire, the main goal of this study is to investigate phonological experiences of Ukrainian and Polish HSs who grew up in the English-dominant environment of the United States learning the Spanish sound system, a topic that has not yet been studied. Taking into consideration all of the previous research done on HSs, L3 acquisition, production of vowels, voiceless stops and voiced stops in Spanish, English, Ukrainian and Polish, the specific questions that this study aims to answer are the following:

1. When acquiring the sound system of L3 Spanish, will the HL (Ukrainian, Polish) or the dominant language (English) exhibit greater influence on Spanish phonology?
 - a) Will the speakers of this study transfer the dominant language's practice of unstressed vowel reduction to Spanish or will these HSs of Ukrainian and Polish perform in a more native-like manner when pronouncing unstressed vowels, potentially due to the influence of their HL knowledge?
 - b) Since Spanish and the two languages under investigation share the same short-lag feature, will the participants in this study be influenced by their knowledge of the HL

sound system and produce the Spanish /p t k/ segments without aspiration or will they transfer the long-lag feature from English, their dominant language?

c) Will the participants transfer the palatalization feature from the HL when pronouncing voiceless and voiced stops followed by the front vowel /i/ in Spanish or will they avoid palatalization by relying on their knowledge of the dominant language, English, which does not have palatalization in this phonological environment?

d) Will the participants of this study produce the voiced stops in Spanish with the pre-voicing that also exists in their HL, or will English, a language that lacks true voicing, interfere with the production of /b d g/ in Spanish? Will the experience of the Slavic language HS with the Spanish intervocalic lenition of voiced stops be similar to the experience of the L1 English L2 Spanish learner, since both the HLs and English do not have stop weakening in intervocalic position, or will it be different, and possibly influenced by the shared pre-voiced nature of /b d g/ in the HLs and Spanish?

2. What role would task type play in production and possible reduction of vowels /i e a o u/, the rate of aspiration of voiceless stops /p t k/, and lenition of voiced stops /b d g/ in the speech of heritage Ukrainian and Polish speaking learners of Spanish?

3. Do the results of this investigation support one specific theoretical model of L3 acquisition: the Cumulative-Enhancement Model, the Multilingual Role Model, the Dynamic Systems Theory, the Cognitive Chain Reaction Theory, the L2 Status Factor Model, the Typological Primacy Model or the Linguistic Proximity Model?

2.7 Hypotheses

I hypothesize that in this study, language typology will be the most influential factor in L3 phonology acquisition. I predict that during the production of vowels and voiceless stops,

Ukrainian and Polish HSs will exhibit greater transfer from their heritage languages than the dominant language. As was shown by Kopečková (2016) and Antoniu et al. (2015), speakers need to have had contact with languages that have specific segments present in the target language in order to excel in L3 acquisition, and as was presented at the beginning of this chapter, the production of these particular segments in Ukrainian and Polish is very close to their production in Spanish. Based on this prediction, the production of voiced stops in intervocalic position will be the most challenging for the participants of this study because my speakers did not have direct experience with languages that weaken these phonemes between vowels. I believe that language typology is a better predictor in this study than L2 status factors because my speakers have a unique experience with their heritage (Slavic) and dominant (English) language, which does not allow for the classification of either of them as foreign, thus making it difficult to associate either of them with the foreignness of L3 Spanish.

Specifically, I predict the following outcomes in the L3 Spanish of Ukrainian and Polish HSs:

1. The Spanish vowels /i e a o u/ will not be reduced in unstressed syllables. Spanish, Ukrainian and Polish do not practice unstressed vowel reduction (Biedrzycki 1963, 1978, Cordero et al. 2006, Delattre 1969, Elliott 1997, Gussman 2007, Hammerly 1982, Korunets 2004, Stockwell and Bowen 1965, Wierzchowska 1971). Therefore, if the speakers of this study rely on their HL knowledge, as is predicted by the language typology factor, this practice will be avoided in L3 Spanish as well.
2. The voiceless stops /p t k/ will be produced with a short-lag VOT. Spanish, Ukrainian and Polish are all short-lag languages (Castañeda Vicente 1986, Gonet 2001, Lisker and Abramson 1964, Newlin-Lukowicz 2014, Ringen and Kulikov 2010, Rosner et al. 2010, Williams 1977).

Therefore, if language typology proves to be the determining factor in L3 acquisition, the speakers of this study will transfer the Ukrainian and Polish short-lag feature to L3 Spanish.

3. Finally, the Spanish voiced stops /b d g/ will be produced with pre-voicing; however, they will not be weakened in intervocalic position. Since Spanish, Ukrainian and Polish are true voice languages, the speakers of this study will be able to transfer the pre-voicing feature to L3 Spanish, provided that the language typology factor guides their acquisition (Keating 1980, Newlin-Lukowicz 2014, Ringen and Kulikov 2012). However, since Ukrainian and Polish, along with English, do not have stop weakening in intervocalic position, the participants of this study will not be able transfer this feature to the L3 from any of the languages they speak, thus producing stops in this phonological context.

Chapter 3

Methods

3.1 Introduction

The following chapter outlines the methodology implemented in this study. First, it describes the recruitment procedure and provides detailed background information about the participants in this study. Second, it presents the tasks that were utilized to elicit data and explains why certain task designs were chosen. Third, it describes the data collection procedure and the reasoning behind the order of task administration. Finally, it discusses the acoustic and the statistical analysis of the data.¹²

3.2 Participants

3.2.1 Recruitment procedures and selection criteria

The participants for this study were recruited from my personal circle of friends and through word of mouth. Initially, only speakers that were either born in this country or arrived in United States before the age of six were asked to participate. This particular age group was chosen so that I could focus exclusively on HSs who did not receive formal educational instruction in their HL in the homeland country. Only the most proficient speakers of the HLs, who had intense contact with it as children and are currently using it, were asked to participate. Also, only participants that were enrolled in low and intermediate-level Spanish courses were asked to participate in order to eliminate the amount-of-exposure factor's influence on the final results.

¹² The research is conducted under the UW-Madison approved IRB protocol 2015-0341.

However, due to low enrollment numbers, especially with the Ukrainian HSs group, the selection requirements were adjusted and speakers from a wider range of backgrounds were invited to participate. For example, two participants in this study, one Ukrainian HS (U3) and one Polish HS (P3), moved to the United States when they were 10 and 9 years old. Although their age of arrival is higher than the one set initially, Oyama (1975) showed that speakers who arrive to a foreign country before the age of 12 are likely to acquire native-like production in their L2 in comparison to individuals who arrive at a later age. Therefore, it is safe to assume that both U3 and P3 acquired native-like command of their DL's phonological system, which makes these two speakers comparable to the rest of the participants.

Another informant, a Ukrainian HS (U2), majored in Spanish, and therefore, her training in the L3 was at a higher level than intermediate. However, she reported rarely utilizing the language after graduation, which took place 10 years ago, possibly signaling that her proficiency level is not very different from the speakers who are currently at an intermediate stage of L3 acquisition.

Speaker U6 was born in Argentina and acquired Spanish as her L2 in a country where it is the dominant language. The participant began learning L3 English at 8 years old after moving to the United States. Although this speaker's childhood background differentiates from that of the other participants, she is still a HS of Ukrainian who learned the HL at home. In addition, this speaker spent most of her life in the United States, making L3 English her dominant language.

Finally, one Polish HS (P11), was a childhood overhearer of the HL and is not a proficient user. However, as shown by previous research (Knightly et al. 2003), the production of childhood overhearers in the HL is more native-like than that of L2 learners, meaning it is still

possible to see the effects of the HL on subsequent language learning, in contrast to speakers that were never exposed to an additional language during childhood.

Since these speakers did not fit the initial background requirement, their data was analyzed separately and later compared to the group of speakers that followed the initial background restrictions. This approach accounts for any similarities and discrepancies in production in all three languages that could potentially be attributed to variation in language acquisition background.

The selection of control group speakers for the present study had one main criterion: only speakers who acquired their L2 in adolescence or later, and not during childhood, were asked to participate.

3.2.2 Language background questionnaires

As emphasized by Cabrelli Amaro (2013), reporting sufficient background information on the speakers recruited for the study is the very first step to effective L3 research. For this purpose, two questionnaires were utilized. One was a language history questionnaire, adapted based on Marian et al. (2007) and Oh and Au (2005), requesting basic information about place of birth, place of birth of parents and grandparents, number of years residing in the United States (indicating age of arrival if applicable) and outside of the country, precise details about places of residence and periods of time in each place, as well as information about current language use and self-perceived dominance. The speakers were also asked to self-assess their speaking, understanding, reading and writing performance in Spanish on a Likert scale from 0-6, where "0" stood for "not well at all" and "6" for "very well". Finally, participants were asked whether they

have studied abroad in any country, and if so, where and for how long, as well as whether they have taken any phonology or phonetics course in any of the languages that they know.

The HS group was also administered a second questionnaire - the Bilingual Language Profile (BLP) (Birdsong et al. 2012) - in order to determine the nature of the relationship between the heritage and the dominant languages. The BLP was developed to assess language dominance through self-reports. Unlike interviews, proficiency tests and other tools used to evaluate bilingual language abilities, the BLP provides standardized assessment through systematic means. It inquires about a variety of factors that influence language dominance, such as age of acquisition and exposure, years of schooling, frequency and function of use, linguistic environment, language attitudes, proficiency and processing ability, which allows for a direct comparison between participants and the interpretation of results. The BLP makes a clear distinction between proficiency and dominance. Gertken et al. (2014) argue that proficiency does not require a bilingual context and is often utilized with monolingual speakers in assessing their language knowledge. Dominance, on the other hand, derives from bilingualism and while proficiency is part of it, it is not the only aspect that defines it. Harris et al. (2006: 264) contextualize this distinction: “for immigrants with many years of immersion in their second language, the second language can come to be the most dominant language, even if it remains the less proficient language, as measured by tests of grammar and vocabulary.”

Since determining the L1 and L2 of the HSs under investigation is quite complicated, language dominance can serve as a crucial aspect in guiding our understanding of the relationship between the two languages in speakers' minds. Recognizing which language is the most accessible, the most highly activated, and the default choice during speaking and thinking helps enhance our interpretation of its interaction with the L3.

The BLP questionnaire is scored numerically and each response is associated with a number on a scale. Generally, a higher number represents greater dominance in a language. The questionnaire is divided into four modules. The “Language History” module has six questions that are worth between 0 and 20 and each item is worth the number value given in the response. There are, however, exceptions; for example, responses “Since birth” and “For as long as I can remember” are worth 20 points and a response “Not yet” is worth 0 points. For the first two questions in the module, the items are scored in reverse fashion, where a response “20” is worth 0, a response “19” has a value of 1, and so on. The module “Language Use” has 5 questions, each worth between 0 and 10 and each item is worth the numerical value given in the response. Finally, the modules “Language Proficiency” and “Language Attitudes” have four questions each, with values between 0 and 6 and, as with the previous module, each item is worth the number value given in the response. After calculating the score for each module (separately in each language), the score is multiplied by the following factors: Language History – 0.454, Language Use – 1.09, Language Proficiency – 2.27, Language Attitudes – 2.27. After the multiplication process, the new scores are added together, representing a global score for each language. The total number of possible points is 218. Finally, to obtain a language dominance score, one language total is subtracted from the other, which will result in a range from -218 to +218. A score that is close to zero demonstrates that an individual is a balanced bilingual, while more positive or more negative scores reflect language dominance in the language for which an individual accrues more points. The BLP was not administered to either of the control groups since determining language dominance was not the main research goal concerning these groups of speakers.¹³

¹³ The full language history questionnaire and the BLP are available in an appendix at the end of this dissertation.

3.2.3 Ukrainian HSs

Six Ukrainian HSs were recruited for this study. The recruitment was done through word of mouth and although the participants knew some of my immediate friends and colleagues, they did not know me personally prior to the data collection meeting. All participants are female. They were between the ages of 20 and 64 at the time of recording, with a mean age of 29.7. Three of the participants were born in the Midwestern United States and have never lived in Ukraine. Two informants were born in Ukraine and one participant was born in Argentina. One individual (participant U5) moved to the United States when she was 5 years old and never attended school in Ukraine. Another speaker (participant U3) moved to the United States when she was 10, completing the first four grades of elementary school in Ukraine. Participant U6 moved to the United States when she was 8 years old. The participants' parents are all of western Ukrainian heritage, from the Lviv and Ternopil area, but their places of birth show variation. Four of the participants' parents were born in Ukraine, while the other two participants' parents were born outside of Ukraine. While the father of participant U4 was born in Ukraine, the mother was born in the United States. The father of participant U2 was born in Germany and the mother in Argentina, but the paternal and maternal grandparents were born in Ukraine.

When asked which language they considered their L1, four informants answered Ukrainian and two English. The speakers reported using their HL with family members and some friends, and English in all other circumstances. When asked which culture the speakers identified with the most, all participants said that they felt a stronger connection with the Ukrainian-speaking culture and reported that it was very important to them to use Ukrainian as native speakers and be perceived as native speakers of Ukrainian by others. Participants U1, U2 and U3 also indicated that they attended a Ukrainian Sunday school organized by their local

churches and reported taking 10, 13 and 11 years, respectively, of Ukrainian language and culture classes. The BLP scores show that one participant (U3) is more dominant in Ukrainian, while the other four (U2, U4, U5) are English dominant speakers. Two participants (U1 and U4) have BLP scores that are the closest to zero, indicating that they are the most balanced bilinguals of the group.

Five participants have been to Ukraine and one informant (U6) has never visited the country. Speaker U1 reported going to Ukraine once for an entire summer when she was 10 years old. Participant U2 also visited Ukraine one time for about a month when she was in high school. Speakers U3 and U5 reported going back to Ukraine most frequently, visiting the country every other year after moving to the United States for about a month at a time. Finally, speaker U4 visited Ukraine one time when she was 18 years old for a month.

All speakers identified Spanish as their L3 (except for speaker U6 who identified it as her L2). They began learning it between ages 5 and 14, with a mean age of 10.7. The reported language use per week was between 0 and 10 percent, with most activity occurring in a classroom setting during interactions with instructors and classmates. Some speakers reported using Spanish at work and with neighbors. Participants U2, U4 and U6 reported traveling to Spain: U2 studied abroad in Granada for 6 months, speaker U4 visited Spain on a 9-day language exchange trip and participant U6 spent a semester in Madrid. When asked to self-assess Spanish language reading, writing, listening comprehension and speaking abilities on a scale from 0 (none) to 6 (native speaker), the score for reading was the highest, averaging 4.75, followed by writing, with an average score of 4.5. Comprehension received an average score of 4.25 and speaking had the lowest average score of 3.7.

Finally, participant U4 reported taking an English education phonology course and speaker U5 has taken an introduction to Spanish phonology class.

Table 3.1 summarizes the Ukrainian HSs' background information.

Table 3.1. Ukrainian HSs' biodata

Speaker Code	Sex	Age	Place of birth	Language acquired first	Language acquired second	Reported L1	Reported L2	BLP score	Age of learning Spanish (L3)	Self-rated proficiency in Spanish
U1	F	20	IL	Ukrainian (since birth)	English (age 3)	Ukrainian	English	33.4 (English dominant)	12	speaking: 3 understanding: 4 reading: 5 writing: 5
U2	F	33	IL	Ukrainian (since birth)	English (age 4)	English	Ukrainian	86.8 (English dominant)	10	speaking: 4.5 understanding: 4.5 reading: 4.5 writing: 4.5
U3	F	21	Ukraine	Ukrainian (since birth)	English (age 9)	Ukrainian	English	-103.8 (Ukrainian dominant)	14	speaking: 2.5 understanding: 3 reading: 4 writing: 2.5
U4	F	19	IL	Ukrainian (since birth)	English (age 3)	Ukrainian	English	30.7 (English dominant)	12	speaking: 3 understanding: 4 reading: 4 writing: 5
U5	F	21	Ukraine	Ukrainian (since birth)	English (age 5)	English	Ukrainian	82.3 (English dominant)	11	speaking: 4 understanding: 4 reading: 5 writing: 4
U6	F	64	Argentina	Ukrainian (since birth)	Spanish (age 5)	Ukrainian	Spanish	77.37 (English dominant)	5	speaking: 5 understanding: 6 reading: 6 writing: 6

3.2.4 Polish HSs

Eleven Polish HSs were recruited for this study. As with the Ukrainian HSs, the recruitment was done through word of mouth and the participants did not know the researcher personally prior to their data collection meeting. They were between the ages of 18 and 22 at the time of recording, with a mean age of 20.2. Nine participants are female and two are male. Ten participants were born in the Midwestern United States and one was born in Poland. Nine of the informants had only lived in the United States, while one participant (P8) spent 4 years of her

childhood in Poland, but returned to the United States before entering school. Another participant (P3) was born in Poland and arrived in the United States when she was 9 years old, having attended three grades of elementary school in Poland. The participants' parents were born and grew up in Poland, except for one informant (P5), whose father was born in Russia. When asked which language participants considered their L1, six answered Polish and three English. One participant (P9) identified both Polish and English as his L1 and one participant (P5) reported Polish and Russian as her L1s. While ten of the participants can be classified as active speakers of the HL, participant P11 is better classified as a childhood overhearer of the language, meaning he overheard Polish while growing up and occasionally spoke it with his grandfather, but has not actively used the language at any point of his life.

The participants reported using Polish with family and certain friends. Three participants (P1, P8, P9) said that they also utilize Polish at work. Unlike the Ukrainian HSs, Polish HSs had a less unanimous response regarding the culture with which they feel a stronger connection. Three participants (P2, P3, P4) responded that they identify with the English-speaking culture and four participants (P1, P5, P9, P11) said that they feel an equal connection with both cultures. The rest of the participants (P6, P7, P8, P10) identified themselves more with the Polish-speaking culture. Seven participants (P1, P2, P3, P6, P8, P9, P10) indicated that it is very important to them to speak Polish like native speakers and to be identified by others as native speakers of Polish, while the rest of the informants do not feel very strongly about these issues. When looking at the BLP scores, one speaker (P10) is dominant in Polish, while the remaining ten participants show greater dominance in English. Four participants (P6, P7, P8, P9 and P10) attained scores that are the closest to zero, indicating that they are the most balanced bilinguals of the group.

Finally, all participants have been to Poland. Participants P1, P2, P4, P6, P8, P9, P10, P11 have visited the country with the greatest frequency. Informant P1 has gone to Poland every summer since turning 13 years old. Speaker P2 reported traveling to Poland every other year since she was young for 1 to 3 months at a time. Participant P4 traveled to Poland every 2 or 3 years after turning 5 years old and began visiting the country every year for about a month at a time after entering high school. Informant P6 traveled to Poland approximately every other year for 1 to 3 months at a time when she was younger. In the last 7 years, this speaker has visited the country 3 times for at least a month, with the last trip having taken place when she was 20 years old. Speaker P8 visited the country for a month at a time during the ages of 8, 11, 13, 16 and 20. Participant P9 traveled to Poland between the ages of 0 and 10 every year for several weeks and also visited in 2016 for a month. Speaker P10 spent a summer or a month in the country when she was 8, 10, 12, 13 and 16 years old. Finally, participant P11 traveled to Poland every other year until turning 12 and had his last two-month long trip when he was 17 years old. Participants P5 and P7 have been to Poland two and three times, respectively. Informant P5 was there for 2 to 3 weeks when she was 1 and 6 years old and speaker P6 visited for several weeks when she was 9, 17 and 18 years old. Speaker P3 has not been to Poland after moving to the United States.

All eleven informants identified Spanish as their L3. They began learning it between the ages of 10 and 15, with a mean age of 12.8. The participants estimated using Spanish from 0 to 20 percent of the time during an average week. Those who utilize Spanish reported using it in class with instructors and other students, and occasionally with friends outside of class. Only one informant reported traveling to Spain for 2 weeks for a vacation, while all others reported having never visited a Spanish-speaking country. On a scale from 0 (none) to 6 (native speaker), the participants gave the highest proficiency scores to reading and listening comprehension and the

lowest scores to speaking and writing. The mean score for comprehension was 3.8, reading 3.4, writing 3.4 and speaking 2.8.

Finally, two participants (P2 and P11) reported having taken an English phonology and phonetics course.

Table 3.2 provides a summary of the Polish HSs' background information.

Table 3.2. Polish HSs' biodata

Speaker Code	Sex	Age	Place of birth	Language acquired first	Language acquired second	L1	L2	BLP score	Age of learning Spanish	Self-rated proficiency in Spanish
P1	F	18	IL	Polish (since birth)	English (age 3)	Polish	English	52.6 (English dominant)	14	speaking: 3 understanding: 4 reading: 5 writing: 3
P2	F	21	WI	Polish and English (since birth)		English	Polish	62.8 (English dominant)	13	speaking: 3.5 understanding: 3.5 reading: 3.5 writing: 4
P3	F	22	Poland	Polish (since birth)	English (age 9)	Polish	English	59.6 (English dominant)	15	speaking: 1 understanding: 2 reading: 1 writing: 1
P4	F	20	IL	Polish and English (since birth)		Polish	English	100 (English dominant)	14	speaking: 0 understanding: 0 reading: 2 writing: 0
P5	F	19	IL	Polish (since birth)	English (age 4)	Polish, Russian	English	79.2 (English dominant)	12	speaking: 3 understanding: 4.5 reading: 6 writing: 4.5
P6	F	21	IL	Polish (since birth)	English (age 3)	Polish	English	15.1 (English dominant)	12	speaking: 3 understanding: 4 reading: 4 writing: 4
P7	F	19	IL	Polish (since birth)	English (age 3)	Polish	English	44.9 (English dominant)	12	speaking: 4 understanding: 5 reading: 5 writing: 4
P8	F	21	IL	Polish and English (since birth)		English	Polish	30.4 (English dominant)	12	speaking: 5 understanding: 6 reading: 5 writing: 5
P9	M	21	IL	Polish and English (since birth)		English, Polish		42.5 (English dominant)	10	speaking: 4 understanding: 4 reading: 5 writing: 3

P10	F	18	IL	Polish (since birth)	English (age 5)	Polish	English	-25.2 (Polish dominant)	15	speaking: 2 understanding: 4 reading: 5 writing: 5.6
P11	M	22	MN	Polish and English (since birth)		English	Polish	107.8 (English dominant)	12	speaking: 3 understanding: 5 reading: 4 writing: 3

3.2.5 Control group

Ten participants were recruited to serve as a control group: 5 L1 English L2 Spanish speakers and 5 L1 Spanish L2 English speakers. As discussed in Chapter 2, Section 2.5.2, in the introduction to L3 methodology, Cabrelli Amaro (2013) argues for the inclusion of control groups, strongly urging that such groups do not solely consist of monolingual native speakers; rather, the author suggests including native speakers of the L3 who are advanced speakers of the experimental group's L1 and L2. This type of linguistic profile allows for a better understanding of the cross-linguistic interaction in the phonological systems of these languages and provides a glimpse into the end state of L3 acquisition of the experimental group. For the current study, this meant finding a control group that consisting of native speakers of Spanish who are advanced speakers of Ukrainian and English or Polish and English. However, since this investigation deals with a rare language combination, it was difficult to find speakers with this particular background. Therefore, I include two control groups: L1 English L2 Spanish and L1 Spanish L2 English. While the individuals in these control groups are not trilingual and do not speak a Slavic language, they are also not monolingual speakers and two of the languages they speak are relevant to this study. The L2 Spanish group allows for a comparison with HS groups, helping determine whether the acquisition of the features under investigation presents the same level of difficulty for the two groups. The L1 Spanish group establishes a baseline to which the HS group can be compared. However, since these speakers are also bilingual in English, they represent a

phonological space where two sound systems interact and influence one another, allowing for a more accurate comparison with L3 learners who also have multiple sound systems interacting in a shared space.

3.2.5.1 L1 English L2 Spanish speakers

The L2 Spanish speakers are currently enrolled in an undergraduate program at a large university in the Midwest region of the United States. They were recruited from a fifth semester Spanish course taught by me, which focuses on intensive writing and conversation. They were between the ages of 18 and 21 at the time of recording, with a mean age of 19.4. Four of the participants are female and one is male. All speakers were born and grew up in the Midwestern United States and have never resided outside the country. All participants began to learn Spanish in middle school, when they were 12 or 13 years old, and indicated that they consider it their L2. Three of the speakers learned it continuously throughout school and university, while two had breaks between courses. Four speakers have never traveled to a Spanish-speaking country and one individual (participant E4) visited Spain for two weeks for a vacation. Similarly, four students have not taken any phonology or phonetics courses, while participant E3 took a phonetics course in English and Spanish in primary school, but reported not remembering anything from the class. All five speakers reported using Spanish only during class time when interacting with classmates and instructors. When asked to assess their proficiency in Spanish, all but one participant (E2) rated their comprehension of the language the highest, with a mean of 4.4 on a scale from 0 (not well at all) to 6 (very well). Reading was ranked second overall, with a mean of 3.9; writing was third, with a mean score of 3.7, and speaking was ranked lowest, with a mean of 3.6.

Table 3.3 summarizes the L1 English L2 Spanish speakers' background information.

Table 3.3. The L1 English L2 Spanish participants' biodata

Speaker code	Sex	Age	Place of birth	Age of learning Spanish	Self-rated proficiency in Spanish
E1	M	18	WI	12	speaking: 3.5 understanding: 5 reading: 4 writing: 4
E2	F	21	IL	13	speaking: 3 understanding: 3 reading: 3 writing: 3
E3	F	19	WI	12	speaking: 3 understanding: 4 reading: 3 writing: 3
E4	F	19	WI	13	speaking: 4.5 understanding: 5 reading: 4.5 writing: 4.5
E5	F	20	WI	13	speaking: 4 understanding: 5 reading: 5 writing: 3

3.2.5.2 L1 Spanish L2 English speakers

The L1 Spanish L2 English participants recruited for this study were graduate students in the Spanish Department of a large university in the Midwestern region of the United States. Four of the participants are female and one is male. Their ages ranged from 28 to 41 at the time of recording, with a mean of 32.6. All of the informants were born in Mexico and moved to the United States between the ages of 21 and 31, with a mean of 23.4. The age of the speakers when they began learning English varied from 3 to 21 years old, with a mean of 11. The speaker who reported learning English at the age of 21 (include which one) briefly learned the language in kindergarten, but had to re-learn it completely in adulthood. All speakers considered English their L2 and reported using it in their daily life about 50 to 90 percent of the time, with a mean of 63%. They reported utilizing it at work, in classes, with family, friends, coworkers, classmates,

students and during interactions with people who do not speak Spanish. When asked to assess their L2 proficiency on a scale from 0 (none) to 6 (native speaker), the average reported scores are as follows: for reading – 5.6, writing – 4.6, listening comprehension – 5, and speaking – 5. Finally, four of the speakers reported having never taken a phonology or phonetics course, while one speaker (S3) reported having taken a graduate-level phonology course.

Speakers of the Mexican variety of Spanish were chosen as controls because this is the variety that students are most likely to encounter in their state of residence in the Midwestern United States, where the Hispanic population is predominantly of Mexican heritage.

Table 3.4 presents a summary of the L1 Spanish L2 English speakers' background information.

Table 3.4. The L1 Spanish L2 English participants' biodata

Speaker code	Sex	Age	Place of birth	Age of learning English	Age of arrival to USA	Self-rated proficiency in English
S1	F	28	Mexico	kindergarten/21	21	speaking: 4 understanding: 5 reading: 5 writing: 4
S2	F	41	Mexico	7	31	speaking: 6 understanding: 5.5 reading: 6 writing: 6
S3	M	29	Mexico	9	20	speaking: 6 understanding: 5 reading: 6 writing: 5
S4	F	26	Mexico	15	17	speaking: 4 understanding: 5 reading: 5 writing: 4
S5	F	39	Mexico	3	28	speaking: 5 understanding: 5 reading: 6 writing: 4

3.3 Data collection tasks

Four tasks were completed by all participants: a video description, a picture-naming, a sentence-reading and a nonce words reading. Details about the design of each task are presented in this section.

3.3.1 Video description

Participants were shown a five-minute silent animation clip about a woman and a man running into each other at a bus stop and were asked to describe it in their HL, in English and in Spanish. The goal of this task is twofold. First, it elicits data in the most spontaneous speech style possible in a controlled setting, thus closely mimicking natural discourse. Based on the findings of those such as Ronquest (2016), speech style is an important variable to consider in studies on sound systems that involve HSs. By examining vowel production in Spanish HSs, Ronquest demonstrated a trend for vowel space expansion and lengthening in clear speech conditions, such as reading, and centralization of vowels in spontaneous, conversational speech. The same impact of speech style on vowel production was found to be significant for both monolingual (see Ferguson and Kewley-Port 2007, Moon and Lindblom 1994, Picheny et al. 1986 for English and Harmegnies and Poch-Olivé 1992, Poch-Olivé et al. 2008 for Spanish) and bilingual speakers (Alvord and Rogers 2014, Bradlow 2002, Willis 2005), demonstrating that both languages with a crowded vowel space (e.g., English) and languages with smaller vowel inventories (e.g., Spanish), are equally affected by speech style.

Speech style has also been shown to affect consonants in both monolingual and bilingual speakers. Warner and Tucker (2011) observed a gradient reduction in English stops and flaps, with conversational speech having the most reduction and isolated word reading showing the

least reduction. Lewis (2001) and Warner (2005) observed a lack of the characteristic period of silence and burst in intervocalic voiceless stops in conversation speech, with Lewis reporting a voiced approximant production of Colombian and Northern Peninsular Spanish intervocalic voiceless stops in spontaneous speech (see Hualde et al. 2011 for Majorcan Spanish and Torreira and Ernestus 2011 for Madrid Spanish). Likewise, speech formality has been found to affect L2 production (Beebe 1987, Dickerson and Dickerson 1977, Major 1986, 1987, Tarone 1972, 1982, 1983, Zampini 1994). However, in these cases, style effects were manifested in the form of accuracy during production. While some have argued that task formality increases accuracy (Major 1986, 1987, Tarone 1972, 1982, 1983), others have presented evidence showing that casual speech results in increased learner accuracy (Beebe 1987), with Zampini (1994) demonstrating evidence of more accurate productions of voiced intervocalic stops in L1 English L2 Spanish learners in conversational tasks than in reading tasks. Although there is no clear conclusion as to what speech style leads to higher accuracy in language learners, it is certain that this variable plays a significant role.

The second purpose of the video description task is to gather data on participants' HL and English performance, in addition to Spanish. The goal is to examine whether the features tested in Spanish are produced according to each language's standard or if speakers produce them in a manner that is different from the expected norm. As stated by Cabrelli Amaro (2013), it is problematic to assume that an individual is a native speaker of a certain language. Therefore, it is essential to elicit data in all languages spoken by participants to ensure that they are producing or not producing the features in question in their native language, which helps justify or deny any possibilities of transfer. This particular task design was chosen in order to avoid reading or writing, since the HSs recruited for this investigation are not proficient in these two areas of their

HL and have only used it in oral mode. In order to be consistent with the data collection procedure, participants performed the same re-telling task in English as well, even though they are able to read and write in the dominant language.

3.3.2 Picture-naming task

The picture-naming task was designed to obtain L3 Spanish data. It is administered through a PowerPoint presentation and consists of 33 slides, each containing a picture of an object that elicits at least one instance of a Spanish vowel, and a voiceless or voiced stop in various positions within a word (e.g., *abogado* ‘lawyer,’ *turista* ‘tourist,’ *calculadora* ‘calculator’). All target words come from the first nine chapters of a beginning-level text (i.e., Dorwick’s (2012) *Puntos de partida: An invitation to Spanish*), which are covered in the first-semester Spanish course of a large university in the Midwest. Each target word ranges from two to five syllables in length and contains both open and closed syllables. When performing the task, participants are asked to name an object that they see pictured using the carrier phrase *Yo digo ___ para ti* ‘I say ___ for you.’ This carrier phrase is utilized to embed the target words into sentences in order to reduce the effect of listing intonation and increase the naturalness of the pronunciation; that is, this task serves as a semi-spontaneous stimulus. Since the participants of this study range in their proficiency in Spanish, not all of them could produce the same amount and quality of spontaneous conversational speech in their L3 during the video description task. Therefore, the picture-naming task serves to supplement the previous conversational elicitation and prompt a comparable data sample size for all of the participants.

3.3.3 Sentence-reading task

The sentence-reading task consists of 64 short sentences in Spanish. Each phrase contains a target word that tests the phonological features under investigation in different phonetic environments (e.g., *Quiero comprar **ropa** nueva **para** vestir a la moda*. ‘I want to buy new clothing to dress fashionably’). The target tokens range in length from two to four syllables and include both open and closed syllables. Although the reading task does not provide the most natural data, the controlled aspect of the task makes it approachable, especially for beginning language learners, and also allows for the examination of a variety of segments in different environments, which may or may not show up in free speech tasks. It also allows me to compare productions in controlled speech versus those in (semi-)spontaneous speech. Testing target words within sentences rather than in isolation is implemented to reduce the formality of the task to some extent and to allow the speakers to immerse themselves in a coherent text (Tarone 1983). All the items in this task are randomized in order to prevent speakers from determining the research objective, but no distractor words are added since the list is already heterogeneous and does not present a clearly predictable pattern.

3.3.4 Nonce words reading list

A nonce words reading list is included as one of the data elicitation tasks based on Asherov et al.’s (2016) study design, which demonstrated the value and advantage of nonce words over real words. It was shown early on in generative phonology that nonce words are treated similarly to real words in speakers’ grammars and are usually not influenced by lexical factors (Halle 1978, Shademan 2007, Vitevitch and Luce, 1998, 1999). Therefore, they serve as a useful tool to test whether a certain phonological process is productive rather than lexicalized. Nonce words are particularly useful when working with HSs because they provide a more

complete image of the phonological systems of this speaker profile. As shown in Asherov et al., although the Russian HSs in the study implemented vowel reduction in real words, they did not do so in nonce words, signaling that vowel reduction was a lexicalized process for them and not a productive phonological process. In order to have a better understanding of the productive and lexicalized processes in Ukrainian and Polish HSs who are learning Spanish, a nonce words task is incorporated into the current study as well.

The nonce words used in this study are based on the rules governing Spanish phonology. To the best of my knowledge, there are no studies that utilize nonce words modeled after Ukrainian or Polish. By relying on the Spanish nonce words in this study, I am still able to witness whether the processes investigated in this study (i.e., lack of vowel reduction, short-lag VOT, true voicing) are productive or lexicalized. If these processes are productive in the speakers' HLs, they should also be productive in L3 Spanish. However, if said processes are lexicalized in the HL, they will not appear in nonce words modeled after Spanish because the speakers cannot transfer a lexicalized process.

The nonce words used in this study are taken from Hochberg (1988) and Face (2005). According to the authors, all items were designed and tested under strict guidelines. For example, every word begins with a consonant and all the vowel-final words end with /a/. None of the words end in -ara, -era, -ira and consonant-final items avoid the endings -ar, -er, -ir, -an, -en, -ron, -s. While the words were designed to be as Spanish-like as possible, any item that resembled an already existing word too closely, as judged by adult native speakers who Hochberg consulted, was discarded. In the current task, 44 nonce items are tested. They range in length from two to four syllables, contain both open and closed syllables, and vary in stress position (e.g., *noca*, *galefa*, *mitabusa*). The stressed syllables are marked with a written accent

mark and are also underlined. Like the picture-naming task items, the nonce words are imbedded in the carrier phrase *Yo digo ___ para ti* in order to avoid listing intonation.

3.4 Data collection procedure

Data collection was carried out in quiet locations on two large university campuses in the Midwestern United States. Participants met with me individually at times that were convenient for them. All of the participants, except the L1 Spanish control group, were greeted in English. The L1 Spanish speakers were spoken to in Spanish throughout the whole session because they are the researcher's close colleagues and Spanish is the language that is always used during daily interactions. After brief introductions between the researcher and the participant, the subjects were asked to fill out the language history questionnaire and the BLP. As stated previously, the L1 English and the L1 Spanish control groups did not fill out the BLP.

After completing the questionnaires, the participants did the video description task. Before watching the film, they were told that they would have to describe it in their HL (Ukrainian or Polish), in English and in Spanish. The control group subjects were asked to describe it in English and Spanish. They were instructed that the description would have to be approximately one to two minutes long and that it does not have to be exactly the same in all three languages. Prior to each description, the subjects were addressed in the language in which they were about to describe the film in order to trigger a specific language mode. Previous research has shown that it is possible to control for language mode and that language activation may affect the final results (Green et al. 1997, Grosjean 1998, Zampini and Green 2001). For instance, when bilingual speakers are in monolingual mode and only one language is activated, they are likely to produce more native-like utterances than if they were in a bilingual mode with both of their languages activated (Grosjean 1998, Zampini 2008). The goal with this task was to

place the participants in the competing heritage and English language modes prior to speaking Spanish. In this manner, with both of the languages activated, I was able to test which language showed evidence of a stronger effect once participants entered Spanish mode.

After completing the video descriptions, the participants were introduced to the picture-naming task. If a participant did not remember a certain word in Spanish, it was skipped over. After the picture-naming exercise, the participants were asked to complete the sentence-reading task. They were instructed to read at a speed they considered natural. Some participants read all 64 sentences in one time, while other speakers asked to take small breaks in between. Finally, the participants were asked to complete the nonce words reading task. They were instructed to read at a natural pace and were asked to stress the syllables that were underlined.

The recordings were conducted using a Lenovo Yoga 3 Pro laptop, a Blue Snowflake Compact USB microphone and *Praat* (Boersma and Weenink 2016).

3.5 Analysis

3.5.1 Acoustic analyses

The recorded data was analyzed with *Praat* v.5.4.12 signal-processing software. When examining vowels, F1 and F2 formant values were measured in order to determine vowel height and backness. As described in Chapter 2 Section 2.2.1.1, F1 provides evidence of tongue height, and F2 gives acoustic cues to tongue backness. First, I isolated and extracted vowel tokens from speech samples in each task. Next, in order to obtain formant values, I positioned the cursor at the mid-point of the segment I wished to measure, where the formants appeared to be stable and flat, and did not change much over time, an example of which is pointed out by the red arrow in Figure 3.1. It is important to measure at a spot where formants seem to be stable and flat, and

avoid the very beginning and the very end of vowels, where neighboring consonants can influence formant frequencies. Next, in the “Formant” tab, I selected the “Formant listing” option, which provides values for F1, F2, F3, F4, as well as the time point at which the measurements are taken. In Figure 3.2, the F1 measurement, pointed out by the black arrow, is 780 Hz and the F2 measurement, indicated by the blue arrow, is 1680.87 Hz, which was rounded up to the closest integer, 1681 Hz. The F1 and the F2 measurements were entered into an Excel file for each segment individually, while accounting for word position and stress. The measurements were taken only for vowels that appeared in open syllables.

Figure 3.1. Extraction of formant values for tonic /a/ in Spanish word *para* ['pa.ra] ‘for’

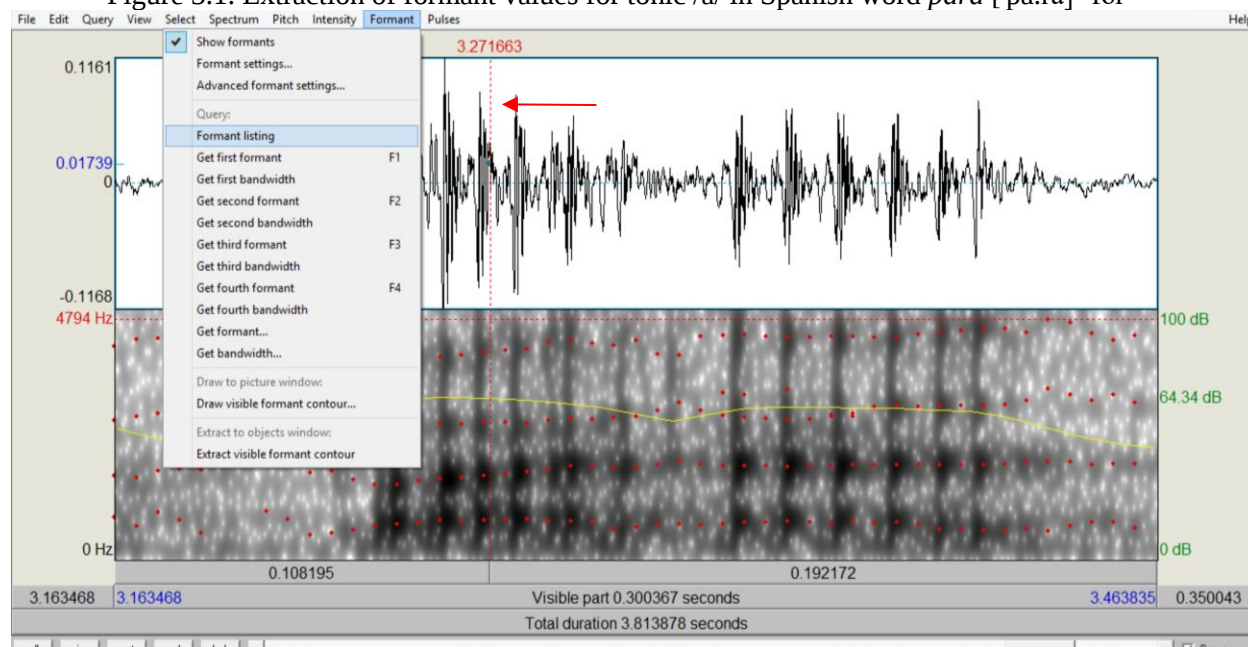
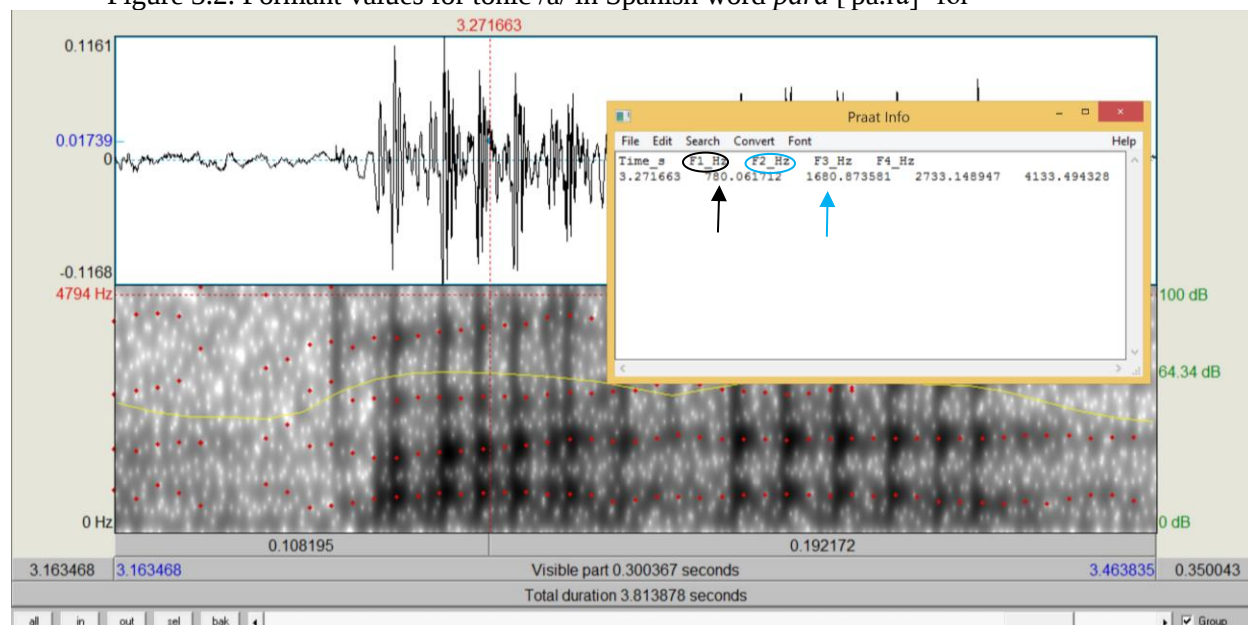
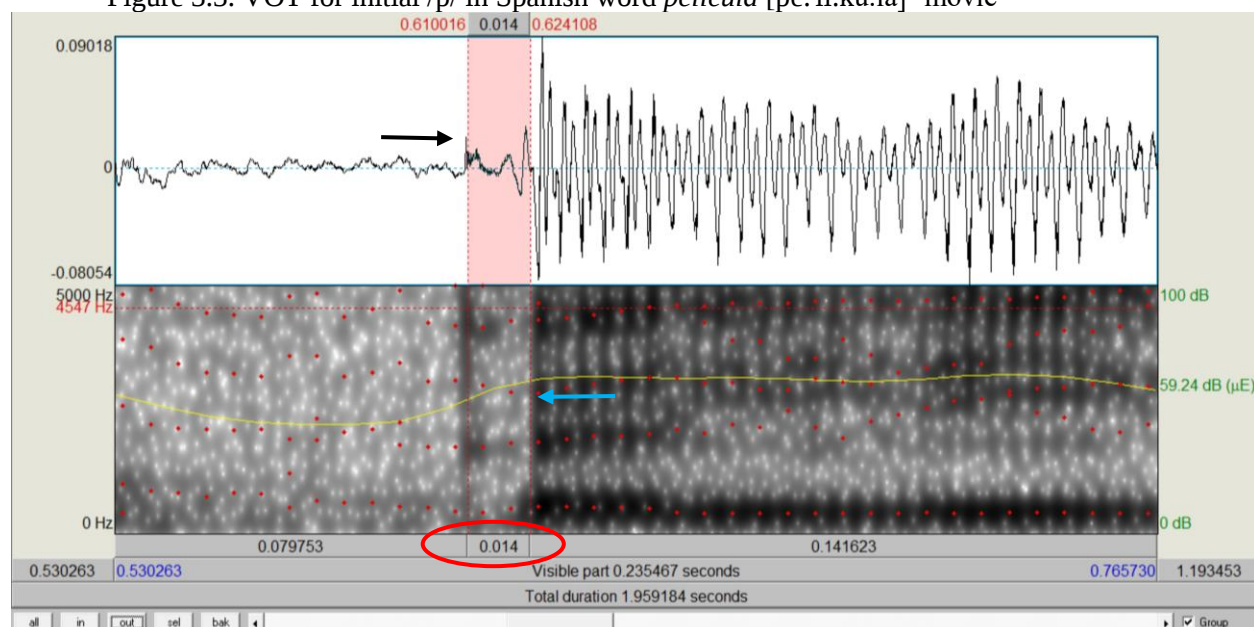


Figure 3.2. Formant values for tonic /a/ in Spanish word *para* ['pa.ra] ‘for’



A measurement of VOT, or the time that elapses between a stop burst and the onset of vocal fold vibration associated with the following vowel, was taken in ms for the voiceless stops /p t k/. In order to measure VOT in *Praat*, first, I identified a stop release point, indicated by the black arrow on Figure 3.3, and then the start of voicing, pointed out by the blue arrow in the figure. Next, I selected the span between the two points and recorded the duration of the selection displayed in the bar along the bottom of the analysis window, which is circled in red in Figure 3.3. In the example below, the VOT for initial /p/ in the Spanish word *película* [pe.'li.ku.la] ‘movie’ is a short-lag measurement of 14 ms. Measurements were taken for segments that appeared in a simple onset position in both open and closed syllables and were entered into an Excel file for each segment individually, while also taking into account word position and stress.

Figure 3.3. VOT for initial /p/ in Spanish word *película* [pe.'li.ku.la] ‘movie’



For the voiced stops /b d g/, a measurement of relative intensity was recorded, calculated as a difference in decibels (dB) between the intensity valley of the stop consonant and the following vowel. A smaller intensity difference corresponds with less obstruction, or a more vowel-like (i.e., approximant) articulation. First, I isolated the voiced stop token I wanted to measure and identified the lowest intensity point in the stop segment and the highest intensity point in the following vowel. In Figure 3.4, where the yellow line tracks intensity, the black arrow points to the intensity valley associated with the stop segment, and the white arrow indicates the intensity peak linked to the following vowel. Next, I placed my cursor at the stop segment's valley, which is pointed out by a black arrow in Figure 3.5, and selected the “Get intensity” option in the “Intensity” tab. The intensity measurement of the approximant [ð] in this example is 65 dB. The same procedure was repeated for the following vowel and the intensity measurement at the vowel peak is 70 dB. The difference between the two intensities is 5 dB, meaning that the segment was produced as a true approximant, a production that is typical for intervocalic voiced stops in Spanish. Relative intensity measurements were taken for voiced

stops that appeared in intervocalic position, and as with the voiceless stops, they were recorded for segments that appeared in simple onset position in open and closed syllables. The results were entered into an Excel file for each segment individually and each token was also coded for word position and stress.

Figure 3.4. Intensity of intervocalic [ð] in Spanish word *calculadora* [kal.ku.la.'ðo.ra] ‘calculator’

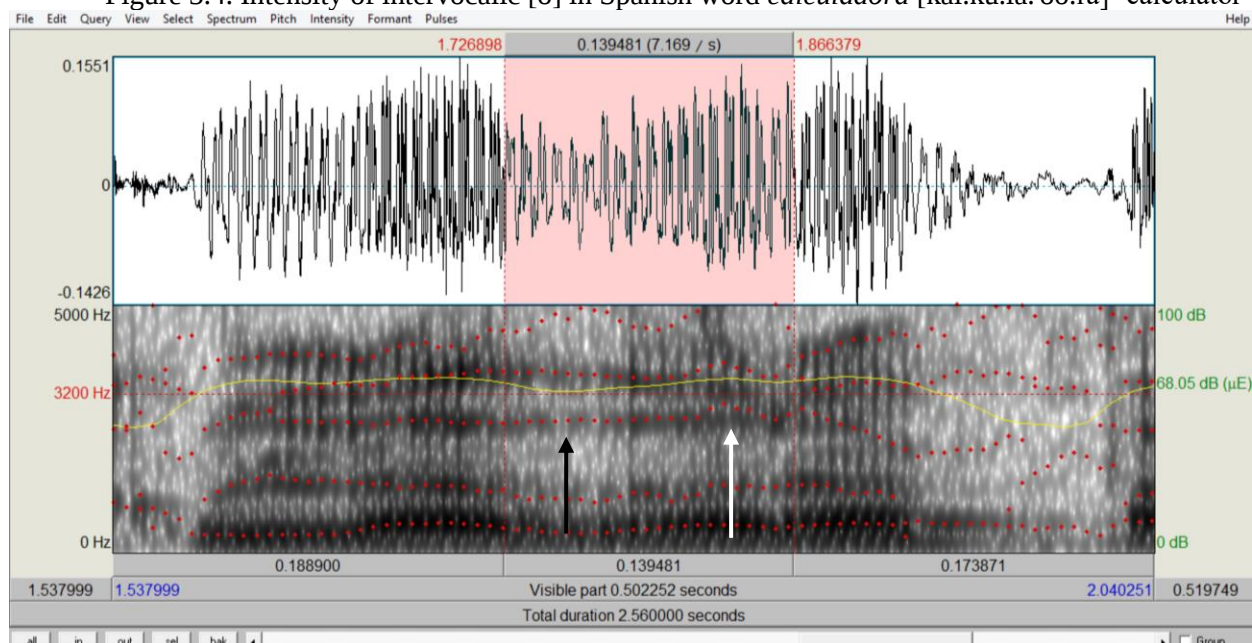
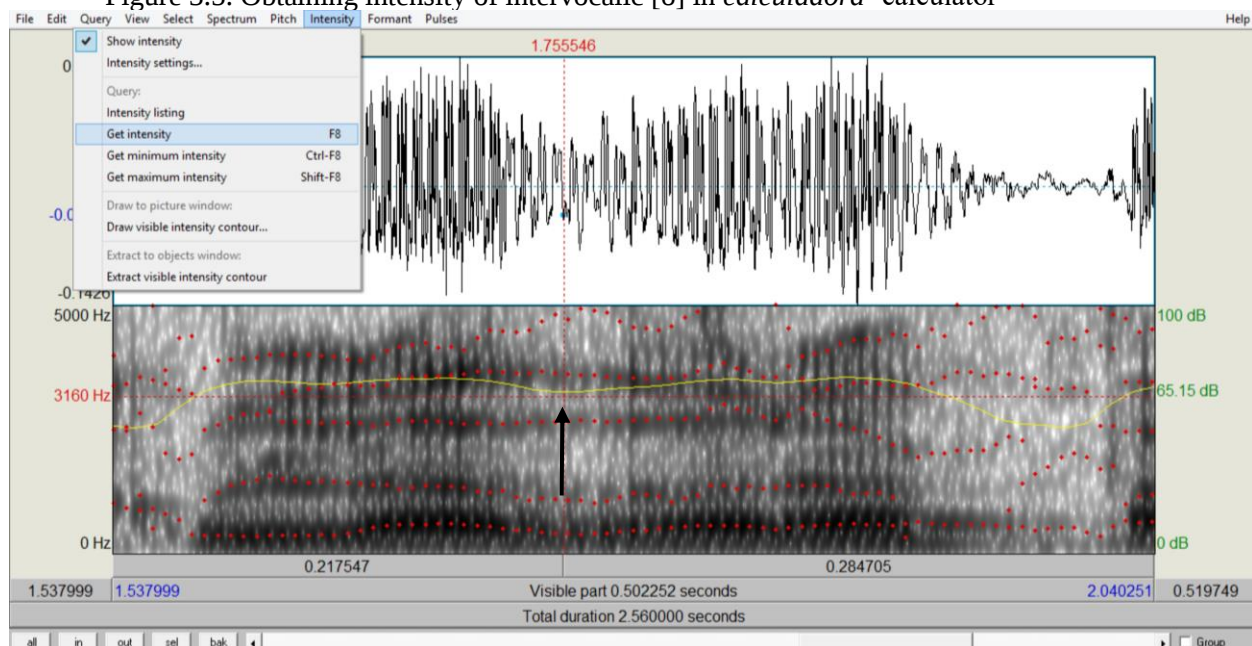
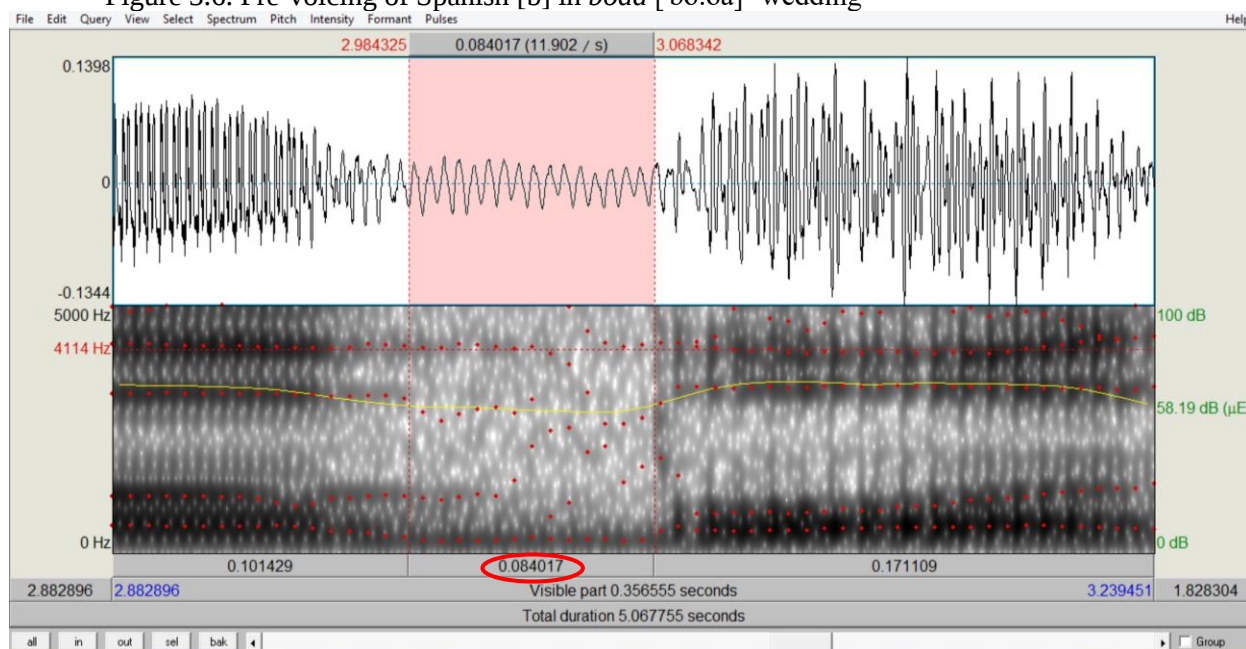


Figure 3.5. Obtaining intensity of intervocalic [ð] in *calculadora* ‘calculator’



In addition to measuring relative intensity, voiced stop (i.e., not weakened forms) productions were examined for evidence of pre-voicing, which is when the vocal folds begin vibrating during the occlusion, unlike voiceless stops, where voicing happens at or right after the release burst (Hualde 2005). As with the voiceless stops, pre-voicing is measured using VOT, but the values are negative, since they represent voicing before the release of the stop. On a spectrogram, pre-voicing is evident from a low amplitude and some periodic activity in the waveform right before the burst; the acoustic correlates are highlighted in Figure 3.6. In this particular example, an articulation of the Spanish word *boda* ['bo.ða] 'wedding,' there is clear pre-voicing of the initial [b] and the VOT measurement is -84 ms. The measurements were entered into an Excel file and were, once again, coded for word position and stress.

Figure 3.6. Pre-voicing of Spanish [b] in *boda* ['bo.ða] 'wedding'



3.5.2 Statistical analyses

The acoustic measures described above are described quantitatively, in terms of mean F1 and F2 values for vowels, mean VOT values for voiceless stops, and mean intensity values for voiced stops. The vowel frequency values, the voiceless stop VOT, as well as the relative

intensity measurements obtained for the L3 Spanish of the Ukrainian and the Polish HSs, as well as the L2 Spanish of the L1 English control group were compared to the values obtained in Spanish of the L1 Spanish group. The vowel frequencies, voiceless stop VOT, and voiced stop relative intensities produced in English by the Ukrainian and Polish HSs, as well as the L1 Spanish control group were compared to the English productions of the L1 English group. Finally, the HSs' Ukrainian and Polish vowel frequencies, voiceless stop VOT, and voiced stop relative intensities were compared to the values presented in previous research.

Mean and standard deviations were calculated using R statistical software (R Development Core Team 2008). In order to determine whether the HSs' L3 Spanish performance was closer to that of the L1 Spanish control group or to that of the L1 English L2 Spanish group, a Linear Mixed Effects Model was applied. This test is deemed appropriate because it allows us to determine whether there are any statistically significant differences between the acoustic means of the four groups of speakers (i.e., Ukrainian HSs, Polish HSs, L1 English, L1 Spanish), which act as independent variables, taking into consideration speaker variation. A Linear Mixed Effects Model was also utilized to compare the English productions (i.e., vowel frequencies, voiceless stop VOT and voiced stop intensity measurements) of the HSs and the L1 Spanish participants to those of the L1 English group to establish whether they fell within the native standard. When a Linear Mixed Effects Model showed significant effects, a post hoc Bonferroni test was carried out for further comparison between the main group and the two control groups. The post hoc Bonferroni test was conducted to compare all possible pairs of means, in order to determine which specific means were significantly different from each other.

A two-sample t-test was used to determine the statistical significant of independent variables (e.g., tonic/tonic position, open/closed syllable, word initial/internal position) on the

Spanish vowel frequency values, voiceless stop VOT and voiced stop intensity measurements produced by the four speaker groups. This test is deemed appropriate because it allows to compare the average difference between two groups (i.e., tonic vs. atonic) to determine whether it is statistically significant. Although it does not take into account speaker variation, it is used as a preliminary test to determine whether different phonological environments play a significant role on the values obtained in Spanish. The same test is utilized for the English, as well as Ukrainian and Polish vowel frequency values, voiceless stop VOT and voiced stop intensities.

Finally, the main groups' Ukrainian and Polish performance was compared to the native standards provided by previous researchers (Gonet 2001, Gussmann 2007, Jassem 2003, Keating 1980, Korunets 2004, Newlin-Lukowicz 2014, Ringen and Kulikov 2010). Since there is no concrete data available for every feature in the HLs investigated, no formal statistical test was conducted. Instead, a confidence interval of the mean values for each feature produced by the HS group was calculated and then compared to the standard range in the literature. In this comparison, the VOT of voiceless and voiced stops was tested. Since previous research did not provide specific vowel frequencies for Ukrainian and Polish, no formal statistical test was performed. Instead, the obtained vowel frequency values for the heritage Ukrainian and Polish productions were plotted and visually compared to the vowel charts provided for the monolingual norm by Korunets (2004) for Ukrainian and Jassem (2003) for Polish.

The statistical tests carried out for the vowel frequencies, the VOT values of the voiceless stops, and the relative intensity measurements of the voiced stops utilized raw data. However, the vowel graphs and Euclidean distance tables used normalized values. Normalization is a process through which talker-related variation, which includes anatomical, physiological, and sociolinguistic factors, is accounted for in the data. In this research, Lobanov's (1971) z-

transformation method was utilized, which was shown by Adank et al. (2004) to be the best procedure for vowel normalization. The transformed vowel measurements cannot be utilized in the statistical tests when comparing means across speaker groups, since all sample means of the transformed values are set to zero by the z-transformation. Therefore, only raw values can be utilized in all statistical tests.

3.6 Summary

In this chapter, I presented the methodology implemented in my study, which was inspired and motivated by the insights of the large body of previous research outlined in Chapter 2, as well as the research questions proposed in that chapter. I discussed the recruitment procedure and presented detailed background information about the participants in this study. I also explained the tasks implemented to elicit data and provided a thorough explanation of the data collection procedure. Finally, I discussed the acoustic and the statistical analysis of the data, which will facilitate the interpretation of the results for all participant groups and the comparisons between groups presented in the next chapter, both of which will have implications for the fields of HLs and L3 acquisition.

Chapter 4

Results

4.1 Introduction

A total of 30,438 tokens were analyzed as part of this study: 19,297 vowels, 6,398 voiceless stops and 4,743 voiced stops. In this chapter, the vowel results are presented first, followed by a description of voiceless stops. The chapter concludes with a discussion of voiced stops. The Ukrainian and Polish data are summarized in the beginning of each section. The English data are presented next, first describing the L1 English and L1 Spanish control groups' results, followed by a discussion of the Ukrainian and Polish HSs' productions. Finally, at the end of each section, Spanish data are presented. The Spanish data are divided into four parts in order to discuss the results of each speaker group separately. The L1 Spanish group's data are presented first to establish a base to which subsequent groups' results are compared. The L1 English speakers' results are outlined after the L1 Spanish control group. Finally, each section ends with a discussion of the Ukrainian and Polish HSs' results. Each section contains a short summary to outline the main findings on a global level.

4.2 Vowels

In each subsection of the vowels unit there are two sets of tables. The first table summarizes the group's overall mean frequencies and frequency means based on stress, and also provides standard deviations and token counts for each vowel. The second table presents three different Euclidean distance measurements. The first Euclidean distance measurement accounts for the distance between each stressed vowel and its unstressed counterpart (e.g., the distance between stressed and unstressed /i/). The second Euclidean distance measurement calculates the distance between each pair of vowels (e.g., the distance between /i/ and /ε/, /ε/ and /α/, /α/ and

/ɔ/, /ɔ/ and /u/, and /u/ and /i/). For this measurement, the stressed and unstressed vowels were combined into one category in order to provide a clear presentation of the outcome and allow for an easier interpretation of the results. Finally, the last Euclidean distance measurement calculates the distance between each vowel and the group's centroid, following the S-Centroid procedure described by Watt and Fabricius (2002). As with the previous Euclidian distance measurement, the stressed and unstressed vowels were also combined in this calculation to permit a comprehensible and unambiguous presentation and interpretation of the results. The first Euclidean distance measurement helps observe the degree of reduction between stressed and unstressed vowels. The second and third Euclidean distances help establish the overall dispersion of vowels in the acoustic space.

The figures presented in this unit summarize the speakers' stressed and unstressed vowel distributions. In addition, four figures that present the standard vowel distributions in Ukrainian, Polish, English and Spanish are included in this section to serve as a reference to compare the HSs' and the control groups' results to the monolingual standards described in the literature. Furthermore, in this section as a whole, tables containing raw data summarize means and standard deviations, while graphs and Euclidean distance tables utilize normalized values. Recall that normalization is a process through which talker-related variation, which includes anatomical, physiological, and sociolinguistic factors, is accounted for in the data. In this research, Lobanov's (1971) z-transformation method was utilized, which was shown by Adank et al. (2004) to be the best procedure for vowel normalization. As was described in greater detail in the Methods chapter, the statistical models utilized in this study are a two-sample t-test, a Linear Mixed Effects Model, and post-hoc pairwise comparisons with a Bonferroni adjustment. A two-sample t-test is used to determine the statistical significance of independent variables (i.e., stress,

word position, and syllable type). The other two tests are utilized to cross-compare the results of the four speaker groups to determine any statistically significant differences in the productions of the four groups, thus accounting for inter-speaker/language background variability.

4.2.1 Ukrainian vowels

A total of 887 vowel tokens were collected from the Ukrainian narrative task completed by the Ukrainian HSs. The Ukrainian HSs produced a well-distributed data set in their HL, with each vowel category containing a reasonable token count. The vowels /ɑ/ and /ɔ/ are the most represented segments, while /ɛ/ and /u/ have the smallest number of tokens. The vowel distribution graph shows that, generally, the Ukrainian HSs followed the native Ukrainian norm, with some exceptions (compare Figure 4.1 to Figure 4.2). The main difference between the HSs' data and the native Ukrainian standard is the position of /ɪ/. In Ukrainian, it is a high front vowel, but the Ukrainian HSs produced it as mid-central vowel. The segment /ɛ/ in Ukrainian is also a front vowel, but it was centralized and lowered by the participants of this study. The high vowel /u/ also experienced centralization in stressed position, but interestingly, was produced further back in the unstressed context.

When looking at the distribution of the stressed and unstressed vowels, the Ukrainian HSs' data reveals reduction in unstressed position, which is not the norm in Ukrainian, a language where stressed and unstressed vowels share the same quality. The most reduced segment was the low /ɑ/, followed by the mid /ɔ/. The vowels /ɛ/ and /ɪ/ also experienced reduction, but not to the same extent as the previous two segments. The high segment /i/ barely experienced any reduction in unstressed position. Finally, as mentioned before, /u/ was more reduced in stressed position than in unstressed context. A two-sample t-test confirmed stress to

be statistically significant for F1 ($p < 2 \cdot 10^{-16}$), which provides evidence of tongue height, but not for F2, which provides acoustic cues to tongue backness, at the $\alpha < 0.05$ level.

Table 4.1. Mean frequencies (Hz) in Ukrainian produced by the Ukrainian HSs

Phoneme	Mean / SD	Mean / SD stressed position	Stressed tokens	Mean / SD unstressed position	Unstressed tokens	Total tokens
/i/	F1: 402.4 / 44.4	F1: 395.8 / 27.7	53	F1: 409.2 / 56.2	51	104
	F2: 2397.2 / 416.5	F2: 2410.8 / 385.5		F2: 2383 / 449.8		
/ɪ/	F1: 529.9 / 76.7	F1: 568.5 / 69.9	41	F1: 509.4 / 72.5	77	118
	F2: 1845 / 415.7	F2: 1861 / 304		F2: 1836.4 / 233		
/ɛ/	F1: 552.4 / 118.8	F1: 620.5 / 151.1	22	F1: 525.6 / 92	56	78
	F2: 1933.6 / 248.3	F2: 1987.9 / 247.6		F2: 1912.2 / 247.9		
/ɑ/	F1: 688 / 141.4	F1: 770.2 / 106.5	122	F1: 627.9 / 129.3	144	266
	F2: 1629.2 / 297.3	F2: 1587 / 250.7		F2: 1652.6 / 347.2		
/ɔ/	F1: 526.9 / 106.2	F1: 619.1 / 101.5	56	F1: 498.4 / 90.4	181	237
	F2: 1535.2 / 347	F2: 1371.4 / 282.3		F2: 1577 / 359.2		
/u/	F1: 476.2 / 70.5	F1: 476.19 / 58.3	27	F1: 476.24 / 76.1	57	84
	F2: 1375 / 415.7	F2: 1452.1 / 370.8		F2: 1338.5 / 433.6		

Table 4.2. Euclidean distance measurements in Ukrainian vowels produced by the Ukrainian HSs

Phoneme	Distance between stressed and unstressed vowels	Distance from centroid	Phonemes	Distance between vowel pairs
/i/	0.1	1.7	/i/ - /ɪ/	1.6
/ɪ/	0.4	0.2	/ɪ/ - /ɛ/	0.2
/ɛ/	0.6	0.3	/ɛ/ - /ɑ/	1.2
/ɑ/	1.1	1.2	/ɑ/ - /ɔ/	1.2
/ɔ/	1	0.6	/ɔ/ - /u/	0.5
/u/	0.3	1	/u/ - /i/	2.4

Figure 4.1. Mean frequencies (Hz) in Ukrainian produced by the Ukrainian HSs

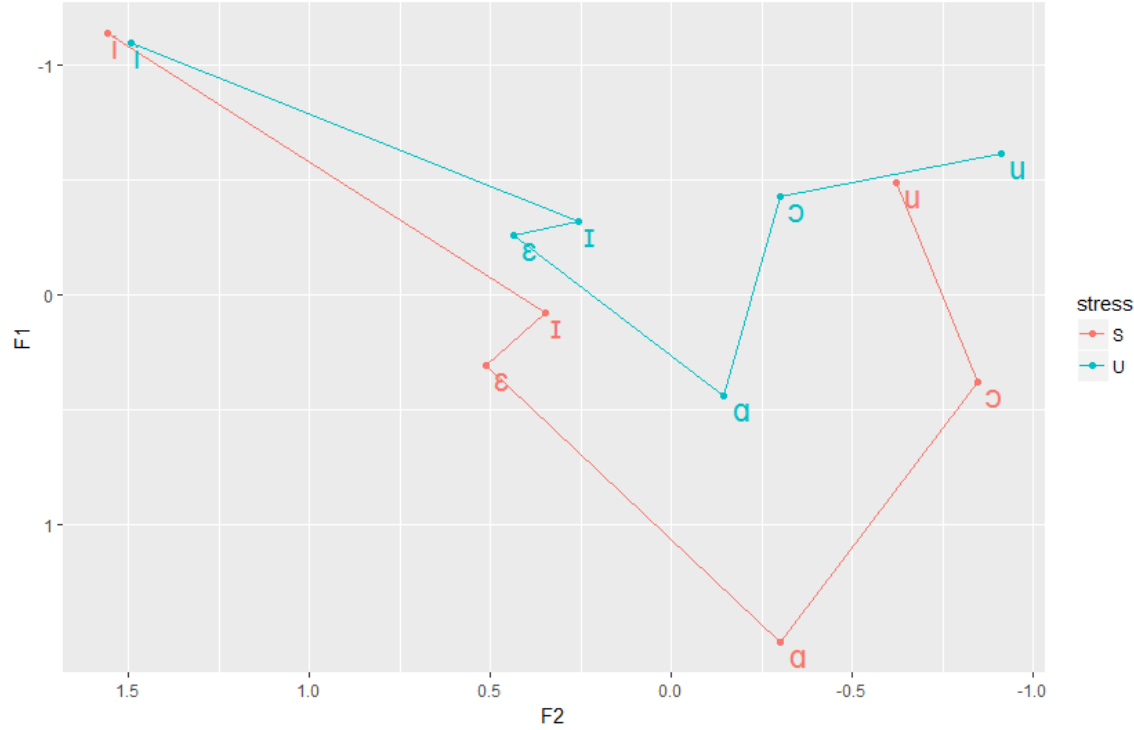


Figure 4.2. Ukrainian vowel space (Korunets 2004, p. 37)

According to the height of the raised part of the tongue	According to the position of the bulk of the tongue		Front vowels	Front-retracted vowels	Central vowels	Back – advanced vowels	Back vowels
	According to the variation in the height of the raised part of the tongue						
High (close) vowels	Narrow variation		ɪ И i:				ʏ u:
	Broad variation			ɪ		ʊ	
Mid-open vowels	Narrow variation		ɛ Е e		o ³ 3:		
	Broad variation		ɛ ¹		ə		ɔ: О u ⁴ ɔ
Low (open) vowels	Narrow variation				ʌ		ʊ ⁴ ɔ
	Broad variation		æ	a ²		ʌ D ɑ:	

4.2.2 Polish vowels

The Polish HSs produced a considerably large number of vowel tokens (a total of 1,134 tokens) in the Polish narrative task (Table 4.3). The segments /a/ and /ɔ/ have the largest number of tokens, while /u/ has the least. When looking at vowel distribution, the Polish HSs' data resembles very closely the native Polish vowel shape that is seen in Figure 4.4; in particular, the stressed vowels of Figure 4.3 are nearly identical to those of in Jassem (2003). One slight difference is the position of /i/, which in the HSs' data appears more centralized than in Jassem's plot. Figure 4.3 also reveals a small degree of reduction in unstressed position, but it is not as large as the reduction observed in the Ukrainian HSs speaker's Ukrainian data. The unstressed vowels /ε/ and /a/ appear slightly more centralized. However, the segments /i/, /i/, and /u/ are further dispersed than their stressed counterparts, displaying a similar pattern to that of the Ukrainian /u/ in the Ukrainian HSs' results. The middle vowel /ɔ/ did not experience centralization, but rather raising in the unstressed context. A two-sample t-test revealed stress to be statistically significant for both F1 ($p < 4.71 \cdot 10^{-11}$) and F2 ($p < 2.86 \cdot 10^{-5}$) values, meaning it affects both tongue height and backness.

Table 4.3. Mean frequencies (Hz) in Polish produced by the Polish HSs

Phoneme	Mean / SD	Mean / SD stressed position	Stressed tokens	Mean / SD unstressed position	Unstressed tokens	Total tokens
/i/	F1: 429.2 / 64.8	F1: 446.7 / 60.1	22	F1: 425.8 / 65.4	112	134
	F2: 2378.2 / 340.6	F2: 2305.3 / 336.9		F2: 2392.5 / 341		
/i/	F1: 550.8 / 83.6	F1: 501.6 / 58.7	49	F1: 502 / 95.6	84	133
	F2: 1808.9 / 331.3	F2: 1655.3 / 391.2		F2: 1898.4 / 253		
/ε/	F1: 550.8 / 93.1	F1: 567.8 / 92.5	68	F1: 541.8 / 92.5	123	191
	F2: 1909.8 / 263	F2: 1964 / 236.5		F2: 1879.8 / 272.9		
/a/	F1: 697.7 / 97	F1: 711.5 / 96.1	142	F1: 688.3 / 96.8	206	348
	F2: 1581.7 / 1581.7	F2: 1593.3 / 225		F2: 1573.7 / 244.7		
/ɔ/	F1: 5947 / 99.2	F1: 628 / 94.9	120	F1: 566.7 / 94.2	143	263
	F2: 1319.5 / 297.8	F2: 1331.9 / 301		F2: 1309 / 295.8		
/u/	F1: 443.1 / 80.5	F1: 392.3 / 70.4	20	F1: 465.8 / 74.7	45	65
	F2: 1246.7 / 358.3	F2: 1317.9 / 364.8		F2: 1214 / 355		

Table 4.4. Euclidean distance measurements in Polish vowels produced by the Polish HSs

Phoneme	Distance between stressed and unstressed vowels	Distance from centroid	Phonemes	Distance between vowel pairs
/i/	0.3	1.7	/i/ - /i/	1.4
/i/	0.6	0.4	/i/ - /ε/	0.4
/ε/	0.2	0.5	/ε/ - /a/	1.4
/a/	0.2	1.3	/a/ - /ɔ/	1
/ɔ/	0.5	1	/ɔ/ - /u/	1.1
/u/	0.4	1.3	/u/ - /i/	2.6

Figure 4.3. Mean frequencies (Hz) in Polish produced by the Polish HSs

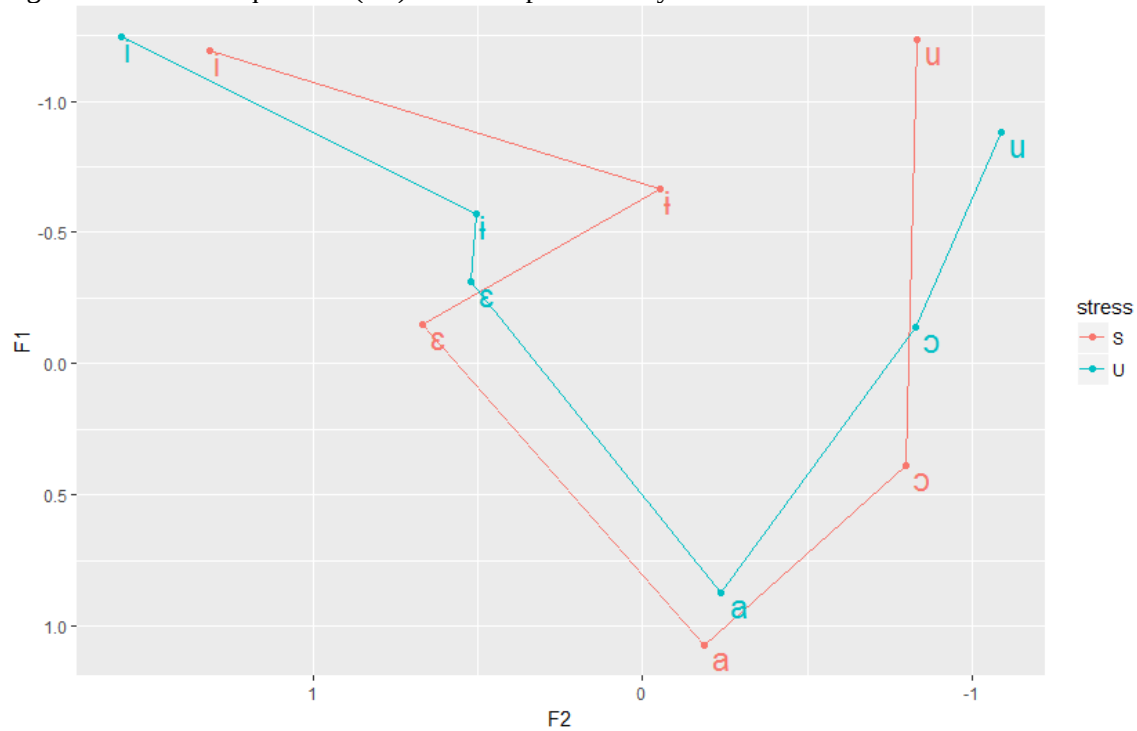
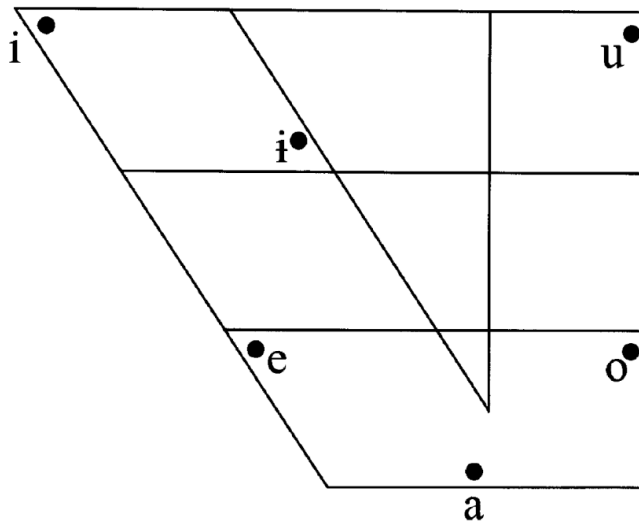


Figure 4.4. Polish vowel space (Jassem 2003, p. 105)



4.2.3 English vowels

4.2.3.1 L1 English control group

A total of 330 productions of English vowels were analyzed in the English narrative task completed by the L1 English control group. The segment [ə] was excluded from the calculation of the distance between vowel pairs, since it is an allophone that only appears in unstressed context. The English narrative task did not yield an even number of tokens for all vowels and there are cases where certain phonemes are underrepresented (Figure 4.5); for example, the vowels /e/, /o/, /ʊ/, and /u/ each have fewer than eleven tokens. Also, certain vowels did not appear in either stressed or unstressed position. For instance, [ə] only appeared in unstressed position because this allophone never appears in stressed syllables in English. The phonemes /e/ and /ʊ/ have no tokens in unstressed position and the vowel /æ/ has only one token in that context due to vowel reduction to [ə]. The vowels /o/ and /u/ yielded only one token each in stressed context and /ɪ/ did not appear at all in stressed position. On the other hand, /i/, /ɛ/, [ə], and /ʌ/ have the greatest number of tokens among the twelve vowels.

Looking at stressed vowel distribution, the two phonemes that stand out are the vowels /u/ and /o/ (Figure 4.5). While /u/ experienced fronting, /o/ was raised and produced further back. However, these two representations are not reliable since there is only one token representing each of these phonemes. In stressed position, there is also raising of /æ/, fronting of /e/ and lowering of /ɔ/ and /i/ compared to the monolingual English standard depicted in Figure 4.6 (English vowels are marked in red). Interestingly, unstressed vowels, with the exception of /ɪ/, /ɛ/, /ʌ/, /ɑ/, and /u/, more accurately reflect the vowel distribution reported in Bradlow (1995). Unstressed /ɛ/ and /ʌ/ experienced raising and fronting, and /ɑ/ and /u/ underwent fronting and a small degree of lowering. Finally, /ɪ/ was raised in unstressed position. The overall results show

evidence of reduction of certain vowels in the unstressed context, but not all; for example, unstressed /i/, /ε/, /ɔ/, and /u/ are dispersed further away from the centroid than their stressed counterparts. However, since many full vowels were produced as [ə] in unstressed position, the outcome of this data set reaffirms the general English practice of vowel reduction in unstressed position. A two-sample t-test revealed stress to be statistically significant for both F1 ($p < 2 \cdot 10^{-16}$) and F2 ($p < .000287$) values, meaning it influences both tongue height and backness.

Table 4.5. Mean frequencies (Hz) in English produced by the L1 English control group

Phoneme	Mean / SD	Mean / SD stressed position	Stressed tokens	Mean / SD unstressed position	Unstressed tokens	Total tokens
/i/	F1: 409.8 / 86.2	F1: 445.9 / 106	18	F1: 396.8 / 74.9	50	68
	F2: 2154.8 / 410.1	F2: 2073 / 431.2		F2: 2184.2 / 402.7		
/e/	F1: 543.8 / 107.9	F1: 543.8 / 107.9	9	F1: NA	0	9
	F2: 2194.4 / 279.6	F2: 2194.4 / 279.6		F2: NA		
/ɪ/	F1: 427.1 / 131.5	F1: NA	0	F1: 427.1 / 131.5	18	18
	F2: 1945.1 / 334.5	F2: NA		F2: 1945.1 / 334.5		
/ε/	F1: 681.4 / 125	F1: 684.9 / 124.5	42	F1: 632.8 / 148.4	3	45
	F2: 1776.3 / 252.5	F2: 1764.4 / 250.6		F2: 1942.8 / 266.6		
/æ/	F1: 670.6 / 139.3	F1: 667.6 / 141.8	22	F1: 737 / NA	1	23
	F2: 1839.2 / 200.9	F2: 1844.5 / 203.9		F2: 1721 / NA		
/ɑ/	F1: 754.4 / 180	F1: 742.8 / 127.7	12	F1: 789.2 / 316.3	4	16
	F2: 1536.4 / 259.6	F2: 1468.6 / 262.8		F2: 1739.9 / 100.3		
[ə]	F1: 487.4 / 101	F1: NA	0	F1: 487.4 / 101	63	63
	F2: 1738.2 / 312.5	F2: NA		F2: 1738.2 / 312.5		
/ʌ/	F1: 661.2 / 118.8	F1: 681 / 126.6	26	F1: 621.4 / 93.5	13	39
	F2: 1620.4 / 311.1	F2: 1522 / 300.9		F2: 1817.3 / 234.1		
/ɔ/	F1: 664.7 / 107.1	F1: 671 / 112	16	F1: 614.6 / 34.5	2	18
	F2: 1409.6 / 428.6	F2: 1435.2 / 447.3		F2: 1205.4 / 168.7		
/o/	F1: 571.7 / 80.7	F1: 399.3 / NA	1	F1: 590.9 / 56.6	9	10
	F2: 1329 / 254.6	F2: 856.9 / NA		F2: 1381.4 / 204.9		
/ʊ/	F1: 585.4 / 69.1	F1: 585.4 / 69.1	10	F1: NA	0	10
	F2: 1439 / 391.4	F2: 1439 / 391.4		F2: NA		
/u/	F1: 418.8 / 49.2	F1: 360.4 / NA	1	F1: 424.6 / 47.6	10	11
	F2: 1688.7 / 367.8	F2: 1791 / NA		F2: 1678.5 / 386		

Table 4.6. Euclidean distance measurements in English vowels produced by the L1 English control group

Phoneme	Distance between stressed and unstressed vowels	Distance from centroid	Phonemes	Distance between vowel pairs
/i/	0.5	1.5	/i/ - /e/	0.7
/e/	NA	1.2	/e/ - /ɪ/	0.8
/ɪ/	NA	1.1	/ɪ/ - /ε/	1.6
/ε/	0.4	0.6	/ε/ - /æ/	0.2
/æ/	0.6	0.8	/æ/ - /ɑ/	0.9

/α/	0.7	1.2	/α/ - /Λ/	0.6
[ə]	NA	0.5	NA	NA
/Λ/	0.8	0.6	/Λ/ - /ɔ/	0.6
/ɔ/	0.7	1.1	/ɔ/ - /o/	0.8
/o/	1.7	1	/o/ - /ʊ/	0.4
/ʊ/	NA	0.7	/ʊ/ - /u/	1.2
/u/	0.5	1	/u/ - /i/	1.1

Figure 4.5. Mean frequencies (Hz) in English produced by the L1 English control group

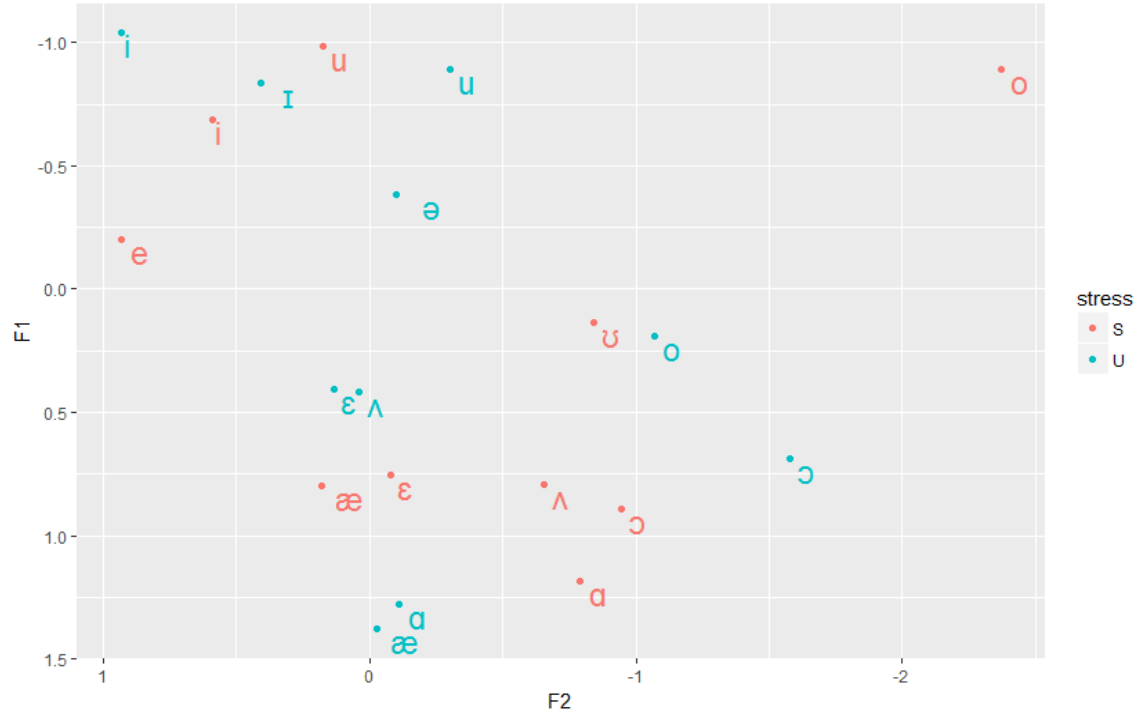
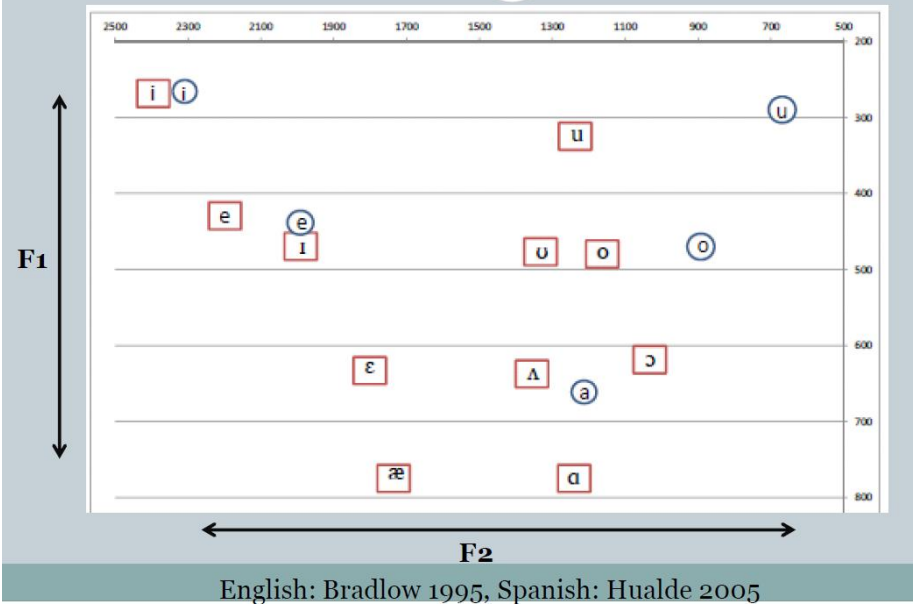


Figure 4.6. Spanish and English vowels (Boomershine 2012)



4.2.3.2 L1 Spanish control group

The L1 Spanish control group produced a total of 1,173 vowels in the English narrative task, displaying a considerably larger number of tokens than the L1 English control group (Table 4.7). The vowels with the largest token counts are /i/, [ə], /ε/, and /ʌ/, and the vowels /ɪ/, /ʊ/, /o/ and /u/ have the smallest number of tokens in their inventories. As in the L1 English control group's data, certain categories in the L1 Spanish speakers' results are empty; for example, the vowels /ɪ/ and [ə] did not appear in stressed syllables and the segments /ε/ and /æ/ each have one and two tokens in unstressed position, respectively. The vowel /ʊ/ does not appear in the unstressed context. The vowel chart shows that the stressed vowels produced by the L1 Spanish speakers are more spread out, while the unstressed vowels appear clustered in the center, which is in line with English vowel pronunciation norms (Figure 4.7). The only unstressed vowel that stands out is /ɔ/, which appears further back in the unstressed context. The stressed vowel distribution also displays some discrepancies with the English native norm; for example, the L1 Spanish speakers cluster /ʌ/ and /ɑ/ closely together, /u/ is fronted, while /ε/, /o/ and /ʊ/ were produced further back.

A comparison of the L1 English and L1 Spanish speakers' productions of English vowels can be viewed in Figure 4.8, where the stressed vowels are plotted on the left and the unstressed vowels are presented on the right. The Euclidean distance measurements of both groups, more specifically, the distance from each phoneme to its centroid, reveal that the L1 English speakers produced a more dispersed vowel space than the L1 Spanish speakers. The vowel charts demonstrate that the L1 English speakers produced stressed vowels that are more spread out, while the L1 Spanish speakers show more centering in the production of stressed vowels. In the unstressed context, however, the L1 Spanish control group shows greater evidence of vowel

reduction and centering, while the L1 English control group produced more dispersed unstressed vowels. A two-sample t-test revealed stress to be statistically significant for both F1 ($p < 2*10^{-16}$) and F2 ($p < 1.23*10^{-10}$) values in the L1 Spanish control group's data, as was the case in the L1 English control group.

Table 4.7. Mean frequencies (Hz) in English produced by the L1 Spanish control group

Phoneme	Mean / SD	Mean / SD stressed position	Stressed tokens	Mean / SD unstressed position	Unstressed tokens	Total tokens
/i/	F1: 377.8 / 56.1	F1: 379.1 / 47	23	F1: 377.6 / 58	110	133
	F2: 2335.2 / 289	F2: 2403.2 / 300.2		F2: 2321 / 285.9		
/e/	F1: 442.6 / 103.2	F1: 481.8 / 45.3	8	F1: 428.4 / 115	22	30
	F2: 1761.2 / 313.1	F2: 1950.4 / 242.3		F2: 1692.4 / 311.8		
/ɪ/	F1: 446.8 / 94.3	F1: NA	0	F1: 446.8 / 94.3	17	17
	F2: 2113.8 / 330.2	F2: NA		F2: 2113.8 / 330.2		
/ɛ/	F1: 539.8 / 110.4	F1: 540.3 / 111.3	61	F1: 510.1 / NA	1	62
	F2: 1817.1 / 297.4	F2: 1816.8 / 299.9		F2: 1837.6 / NA		
/æ/	F1: 712.3 / 163.6	F1: 719.2 / 167.2	28	F1: 614.7 / 34.6	2	30
	F2: 1712.7 / 138.9	F2: 1716.6 / 142.6		F2: 1659.2 / 63.8		
/ɑ/	F1: 638.3 / 154	F1: 621.8 / 163.3	31	F1: 695.1 / 104.7	9	40
	F2: 1497.8 / 296.7	F2: 1483.5 / 316.5		F2: 1547.1 / 223.5		
[ə]	F1: 457.3 / 95.8	F1: NA	0	F1: 457.3 / 95.8	117	117
	F2: 1773.1 / 243.5	F2: NA		F2: 1773.1 / 243.5		
/ʌ/	F1: 596.2 / 124	F1: 614.9 / 131.4	34	F1: 558.8 / 101.2	17	51
	F2: 1555.5 / 290.7	F2: 1482.6 / 310		F2: 1701.3 / 179		
/ɔ/	F1: 518.7 / 99.7	F1: 521.4 / 90.9	27	F1: 504.6 / 151.5	5	32
	F2: 1396 / 503.8	F2: 1442.2 / 520.4		F2: 1146.4 / 339.1		
/o/	F1: 472.6 / 97.8	F1: 502 / 31.5	3	F1: 468.2 / 104	20	23
	F2: 1501 / 382.4	F2: 1149.2 / 253.1		F2: 1553.7 / 374.3		
/ʊ/	F1: 418.3 / 57.1	F1: 418.3 / 57.1	14	F1: NA	0	14
	F2: 1369.2 / 498.2	F2: 1369.2 / 498.2		F2: NA		
/u/	F1: 399.2 / 66.5	F1: 346.5 / 50.8	3	F1: 406.8 / 65.9	21	24
	F2: 1778.5 / 450	F2: 1808.2 / 525.2		F2: 1774.2 / 452.9		

Table 4.8. Euclidean distance measurements of English vowels produced by the L1 Spanish control group

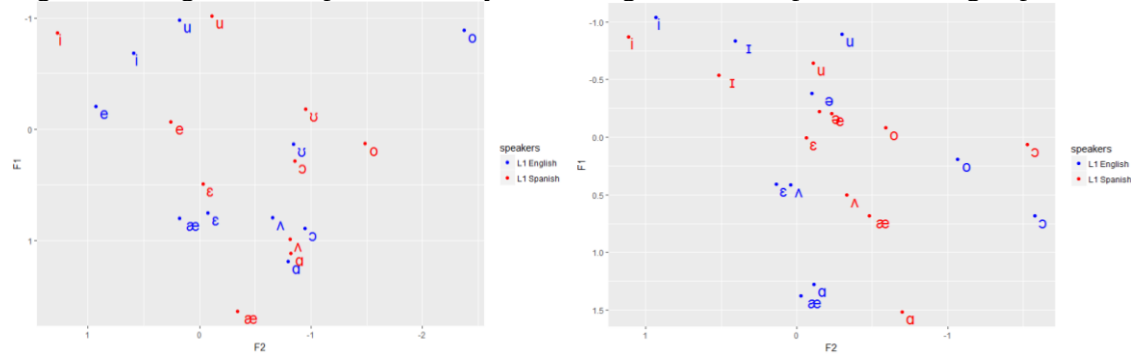
Phoneme	Distance between stressed and unstressed vowels	Distance from centroid	Phonemes	Distance between vowel pairs
/i/	0.2	1.7	/i/ - /e/	1.4
/e/	0.5	0.3	/e/ - /ɪ/	0.7
/ɪ/	NA	1	/ɪ/ - /ɛ/	1.2
/ɛ/	0.5	0.4	/ɛ/ - /æ/	1.1
/æ/	1	1.4	/æ/ - /ɑ/	0.6
/ɑ/	0.4	1.2	/ɑ/ - /ʌ/	0.4
[ə]	NA	0.4	NA	NA
/ʌ/	0.7	0.8	/ʌ/ - /ɔ/	0.7
/ɔ/	0.7	0.7	/ɔ/ - /o/	0.4

/o/	0.9	0.5	/o/ - /ʊ/	0.3
/ʊ/	NA	0.8	/ʊ/ - /u/	1
/u/	0.4	0.8	/u/ - /i/	1.3

Figure 4.7. Mean frequencies (Hz) in English produced by the L1 Spanish control group



Figure 4.8. English vowel productions by the L1 English and L1 Spanish control groups



4.2.3.3 Ukrainian HSs

A total of 458 productions of English vowels were analyzed from the Ukrainian HSs data set (Table 4.9). The Ukrainian HSs produced a relatively evenly distributed token count across vowels. Similar to the control groups' results, the vowels /i/, /ε/, [ə], and /ʌ/ have the largest token counts in the Ukrainian HSs inventory, while the segments /ɪ/, /ʊ/, /o/, and /u/ have the

smallest number of tokens. Several phonemes were not realized in either stressed or unstressed position; the segments /ɪ/ and [ə] have no tokens in the stressed context and the segments /ɔ/ and /ʊ/ do not appear in unstressed position, /o/ has only two tokens in stressed position, and /æ/ has only two tokens in the unstressed context.

The vowel distribution chart (Figure 4.9) shows that unstressed vowels produced by the Ukrainian HSs are more centered, while the stressed counterparts are more spread out, which supports earlier findings in the literature (Delattre 1969). Figure 4.10 presents a comparison of the vowel productions by the Ukrainian HSs, as well as the L1 English and L1 Spanish control groups. Stressed vowels are plotted on the left-hand-side and unstressed vowels are presented on the right. The stressed vowel chart shows that in comparison to the control groups' results, the Ukrainian HSs' stressed vowels experienced less centering and appear to be more spread out (e.g., /æ/, /ʊ/, /ɔ/, /o/). The unstressed vowels produced by the Ukrainian HSs show more reduction in comparison to the L1 English control group (e.g., /æ/, /ɛ/, /ʌ/, /o/), displaying greater similarity to the L1 Spanish speakers' production.

As in the control groups' results, stressed /u/ is also fronted in the HS's data. The vowels /ɛ/, /ʊ/, and /o/ were produced further back in stressed position, while /ɑ/ is fronted and raised. The phoneme /ɛ/ is also lower in stressed position. In unstressed context, the central vowels are clustered in the middle, while the high vowels do not undergo reduction. In comparison to the control groups' results, the Ukrainian HSs showed the highest degree of dispersion away from the centroid of the vowels /i/, /ɪ/, /ɛ/, /u/. Out of the three speaker groups, the Ukrainian HSs display the highest degree of reduction for /e/, /ɛ/, /æ/, and /u/. Finally, the HSs' data reflects the control groups' results, with a two-sample t-test showing that stress is statistically significant for both F1 ($p < 2 \cdot 10^{-16}$) and F2 ($p < 9.38 \cdot 10^{-11}$) values.

Table 4.9. Mean frequencies (Hz) in English produced by the Ukrainian HSs

Phoneme	Mean / SD	Mean / SD stressed position	Stressed tokens	Mean / SD unstressed position	Unstressed tokens	Total tokens
/i/	F1: 408.9 / 48.4	F1: 430.5 / 55.4	18	F1: 404.8 / 46.2	95	113
	F2: 2296.5 / 337.4	F2: 2299.7 / 362		F2: 2295.9 / 334.6		
/e/	F1: 569.8 / 96.1	F1: 511.7 / 60	6	F1: 584.3 / 98.7	24	30
	F2: 1706.4 / 364.9	F2: 2189 / 244.8		F2: 1585.8 / 280.9		
/ɪ/	F1: 431.5 / 99.7	F1: NA	0	F1: 431.5 / 99.7	16	16
	F2: 2026.6 / 380.4	F2: NA		F2: 2026.6 / 380.4		
/ɛ/	F1: 679.7 / 100.2	F1: 692 / 96.7	39	F1: 559.8 / 30.9	4	43
	F2: 1808.7 / 167.3	F2: 1803.7 / 164.2		F2: 1857.4 / 216.3		
/æ/	F1: 755.1 / 139.8	F1: 767.3 / 138.4	22	F1: 620.9 / 89.5	2	24
	F2: 1906.4 / 166	F2: 1911.4 / 152.8		F2: 1851.6 / 370.3		
/ɑ/	F1: 748.1 / 155.8	F1: 756.1 / 128.8	18	F1: 736.1 / 195.3	12	30
	F2: 1676.7 / 124	F2: 1688.2 / 121.7		F2: 1659.5 / 130.8		
[ə]	F1: 485.1 / 114.6	F1: NA	0	F1: 485.1 / 114.6	75	75
	F2: 1852.3 / 295.5	F2: NA		F2: 1852.3 / 295.5		
/ʌ/	F1: 645.4 / 105.8	F1: 665.1 / 98.1	44	F1: 597.1 / 111.1	18	62
	F2: 1566.9 / 219.6	F2: 1523.8 / 217.4		F2: 1672.1 / 192.2		
/ɔ/	F1: 624.7 / 109	F1: 624.7 / 109	20	F1: NA	0	20
	F2: 1254.2 / 322.2	F2: 1254.2 / 322.2		F2: NA		
/o/	F1: 583.6 / 79	F1: 545.6 / 6.5	2	F1: 589.4 / 83.7	13	15
	F2: 1404.2 / 276.6	F2: 954.4 / 87		F2: 1473.4 / 223		
/ʊ/	F1: 604.8 / 86.9	F1: 604.8 / 86.9	16	F1: NA	0	16
	F2: 1219.7 / 223	F2: 1219.7 / 223		F2: NA		
/u/	F1: 459.6 / 108.6	F1: 493.4 / 141.5	7	F1: 425.8 / 53.5	7	14
	F2: 1547.3 / 525.8	F2: 1750.2 / 589.5		F2: 1344.3 / 394.2		

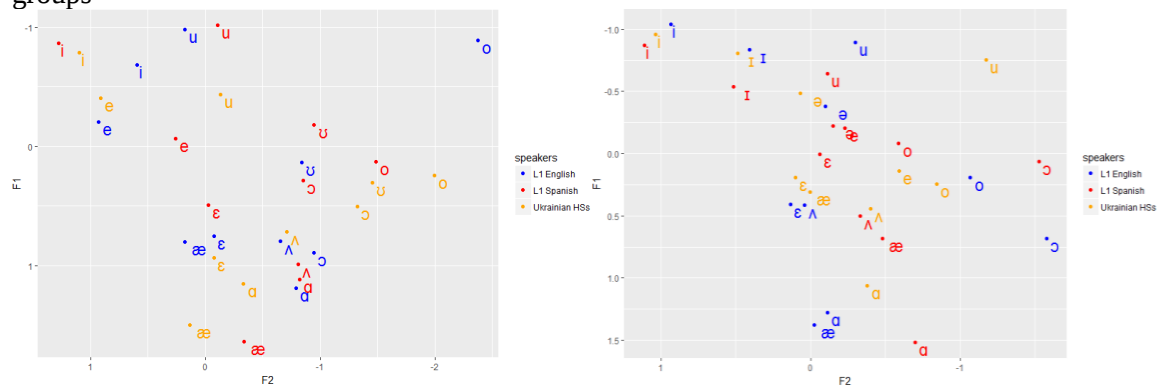
Table 4.10. Euclidean distance measurements in English vowels for Ukrainian HSs

Phoneme	Distance between stressed and unstressed vowels	Distance from centroid	Phonemes	Distance between vowel pairs
/i/	0.2	1.8	/i/ - /e/	1.6
/e/	1.6	0.2	/e/ - /ɪ/	1.1
/ɪ/	NA	1.3	/ɪ/ - /ɛ/	1.8
/ɛ/	0.8	0.7	/ɛ/ - /æ/	0.6
/æ/	1.2	1.3	/æ/ - /ɑ/	0.6
/ɑ/	0.1	0.9	/ɑ/ - /ʌ/	0.5
[ə]	NA	0.8	NA	NA
/ʌ/	0.4	0.5	/ʌ/ - /ɔ/	0.7
/ɔ/	NA	1	/ɔ/ - /o/	0.4
/o/	1.2	0.7	/o/ - /ʊ/	0.5
/ʊ/	NA	1.1	/ʊ/ - /u/	1.2
/u/	1.1	0.8	/u/ - /i/	1.7

Figure 4.9. Mean frequencies (Hz) in English produced by the Ukrainian HSs



Figure 4.10. English vowel productions by the Ukrainian HSs and the L1 English and L1 Spanish control groups



4.2.3.4 Polish HSs

A total of 757 vowel tokens were analyzed in the Polish HSs' English narrative elicitation (Table 4.11). Similar to the other speaker groups, the Polish HSs produced the highest token count of /i/, /ε/, [ə], and /ʌ/ and the smallest number of /ɪ/, /ʊ/, /o/, and /u/. Also, mimicking the other groups' token distributions, /ɪ/ and [ə] do not appear in stressed syllables and /æ/ has only one token in the unstressed context.

The vowel distribution graph shows that the stressed vowels are more spread out toward the outer edges of the plot, while the unstressed vowels, with some exceptions, appear closer to the center (Figure 4.11). For instance, the unstressed high vowels /i/, /ɪ/, and /u/ do not demonstrate any lowering, but rather were produced with lower F1 frequencies than their stressed counterparts. The unstressed /ɑ/ was produced lower than its stressed counterpart, and unstressed /ʊ/ shows considerable raising. In stressed position, the vowel /ɛ/ was produced lower and further back in comparison to the English norm. The stressed /æ/ and /a/ both display raising. The segments /e/ and /u/ show fronting, but the vowel /u/ is not as fronted in the Polish HSs' data as it was in the previous groups' results. Finally, both /ʊ/ and /o/ were produced further back in stressed position in comparison to the standard English production.

A comparison of the Polish HSs' results to the productions of the L1 English and L1 Spanish control groups can be found in Figure 4.12, where stressed vowels are presented on the left and unstressed vowels are on the right. When looking at stressed vowels, the Polish HSs' results show a greater resemblance to those of the L1 English speakers', especially when considering the low and middle vowels (e.g., /ɛ/, /æ/, /ʌ/, /ɔ/). The front vowels /i/ and /e/ also show a resemblance to the L1 English speakers' productions, but they appear more fronted in the Polish HSs results. The unstressed vowels produced by the Polish HSs show evidence of reduction, similar to the control groups' results; however, once again, there appears to be more fronting in the HSs' data than in the control groups' productions (e.g., /i/, /ɪ/, /ɛ/, /ɔ/, /o/, /u/). The Euclidean distance measurements reveal that the Polish HS display the highest degree of reduction in unstressed position of /e/, /ɛ/, /ʊ/, and /u/ in comparison to the control groups' productions. Similar to the other three groups, a two-sample t-test showed stress to be statistically significant for both F1 ($p < 2 \cdot 10^{-16}$) and F2 ($p < 3.6 \cdot 10^{-14}$) values. Finally, the Polish

HSs display greater dispersion from the centroid of vowels /i/, /ɪ/, /ɛ/, /ɑ/, /ɔ/, and /ʊ/ in comparison to the control groups' productions.

Table 4.11. Mean frequencies in English (Hz) produced by the Polish HSs

Phoneme	Mean / SD	Mean / SD stressed position	Stressed tokens	Mean / SD unstressed position	Unstressed tokens	Total tokens
/i/	F1: 408.7 / 70.4	F1: 421.5 / 78.2	26	F1: 405.9 / 68.6	119	145
	F2: 2198.6 / 350.8	F2: 2093.6 / 292.2		F2: 2221.6 / 359.4		
/e/	F1: 554.4 / 95	F1: 497.4 / 49.7	17	F1: 572 / 99	55	72
	F2: 1746.8 / 454.7	F2: 2191.4 / 263.6		F2: 1609.4 / 412.1		
/ɪ/	F1: 436.3 / 102	F1: NA	0	F1: 436.3 / 102	23	23
	F2: 2114.8 / 325.8	F2: NA		F2: 2114.8 / 325.8		
/ɛ/	F1: 675.4 / 103.9	F1: 679.6 / 101.5	90	F1: 547.8 / 114.3	3	93
	F2: 1709.4 / 215.1	F2: 1704.8 / 215.9		F2: 1846.6 / 156.6		
/æ/	F1: 681.1 / 115.9	F1: 683.7 / 115.9	46	F1: 563.7 / NA	1	47
	F2: 1848.9 / 251.2	F2: 1850.5 / 253.8		F2: 1776.8 / NA		
/ɑ/	F1: 736.8 / 88.8	F1: 738.2 / 90.2	35	F1: 733.3 / 88.3	14	49
	F2: 1497.5 / 241.6	F2: 1468.5 / 257.6		F2: 1570.1 / 184.5		
[ə]	F1: 503.6 / 102.3	F1: NA	0	F1: 503.6 / 102.3	115	115
	F2: 1670.4 / 304.6	F2: NA		F2: 1670.4 / 304.6		
/ʌ/	F1: 637.7 / 99	F1: 644.2 / 90.3	71	F1: 616.8 / 123.3	22	93
	F2: 1439.5 / 244	F2: 1411.5 / 242.4		F2: 1530.1 / 231.7		
/ɔ/	F1: 653.2 / 116.4	F1: 655.1 / 122.5	34	F1: 637.4 / 41.1	4	38
	F2: 1233.1 / 294.5	F2: 1225.7 / 298.3		F2: 1296.1 / 291.4		
/o/	F1: 584.9 / 70.3	F1: 581.3 / 66.2	10	F1: 587.6 / 75.9	13	23
	F2: 1298.7 / 235.8	F2: 1217.8 / 221.6		F2: 1361 / 235.5		
/ʊ/	F1: 550.3 / 93.7	F1: 580.6 / 80.4	28	F1: 444.2 / 49.4	8	36
	F2: 1262 / 352.8	F2: 1152.3 / 223		F2: 1646.2 / 462.3		
/u/	F1: 436.8 / 88.2	F1: 471.7 / 177.2	4	F1: 429.4 / 62.8	19	23
	F2: 1758 / 410.8	F2: 1740.1 / 329.2		F2: 1761.8 / 433.7		

Table 4.12. Euclidean distance measurements in the English vowels produced by Polish HSs

Phoneme	Distance between stressed and unstressed vowels	Distance from centroid	Phonemes	Distance between vowel pairs
/i/	0.3	1.7	/i/ - /e/	1.4
/e/	1.5	0.3	/e/ - /ɪ/	1.1
/ɪ/	NA	1.4	/ɪ/ - /ɛ/	1.9
/ɛ/	0.8	0.8	/ɛ/ - /æ/	0.3
/æ/	0.4	1	/æ/ - /ɑ/	0.9
/ɑ/	0.2	1.3	/ɑ/ - /ʌ/	0.8
[ə]	NA	0.5	NA	NA
/ʌ/	0.3	0.7	/ʌ/ - /ɔ/	0.5
/ɔ/	0.1	1.1	/ɔ/ - /o/	0.5
/o/	0.4	0.8	/o/ - /ʊ/	0.2
/ʊ/	1.4	0.9	/ʊ/ - /u/	1.2
/u/	0.5	0.8	/u/ - /i/	1.2

Figure 4.11. Mean frequencies (Hz) in English produced by the Polish HSs

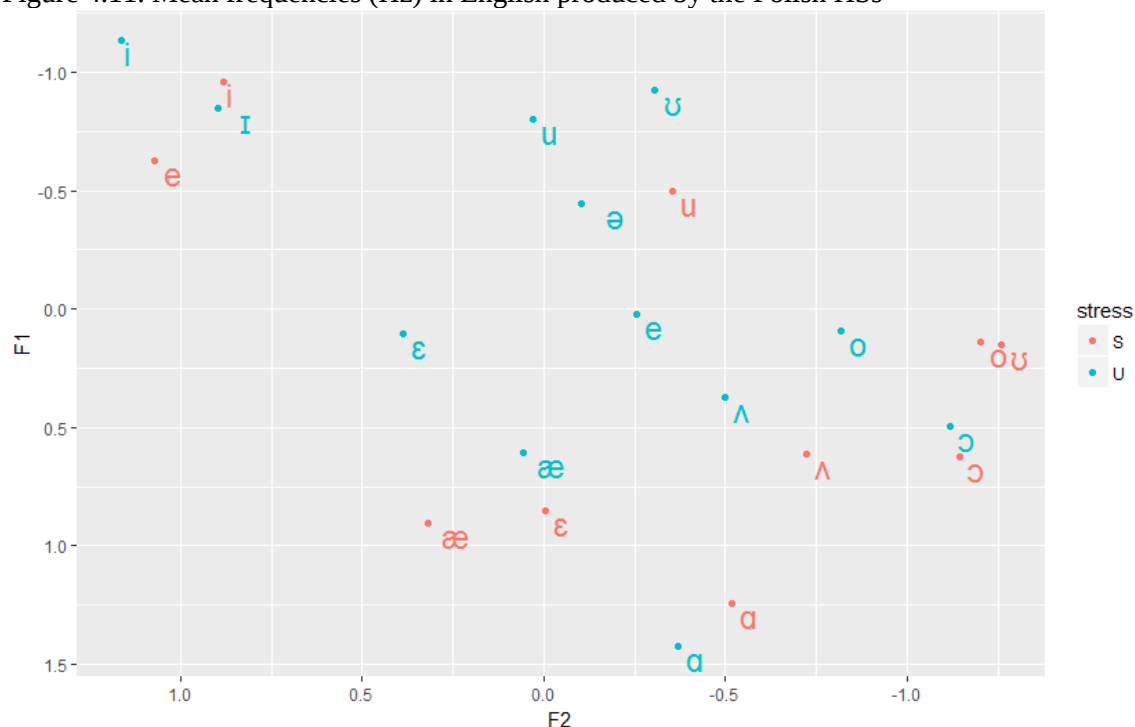
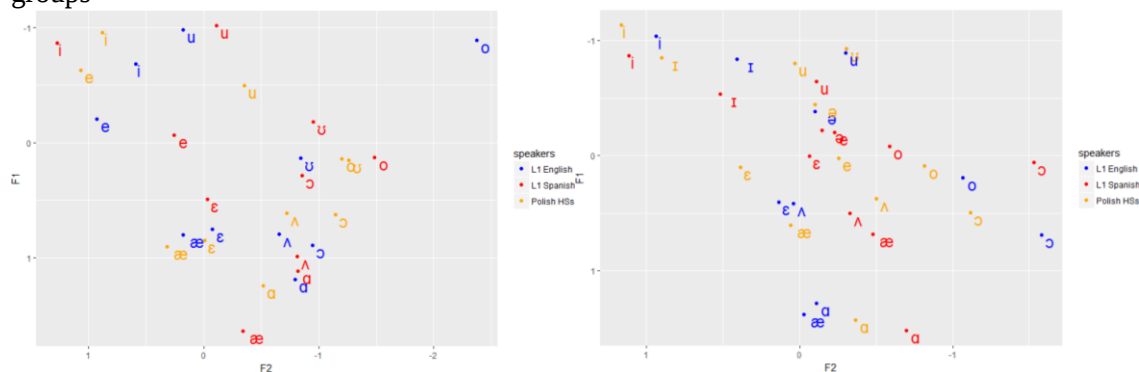


Figure 4.12. English vowel productions by the Polish HSs and the L1 English and L1 Spanish control groups



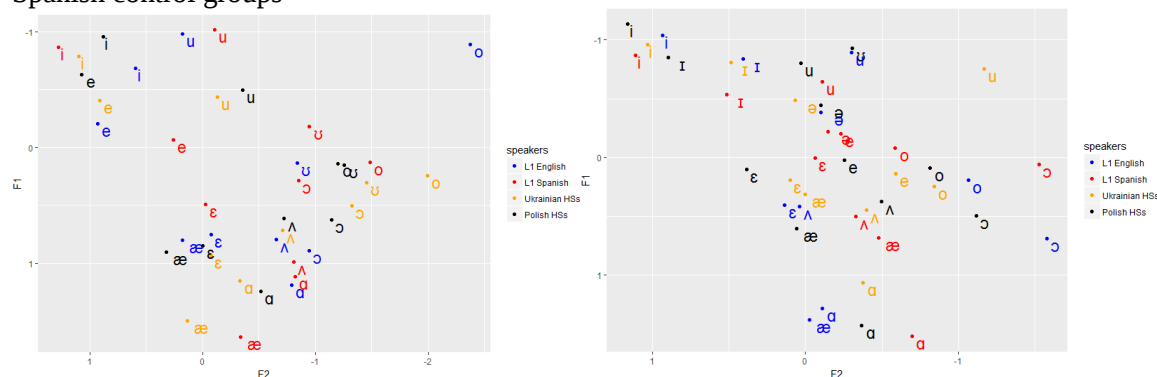
4.2.3.5 Summary of English vowel productions

Figure 4.13 summarizes the English vowels productions by the four groups of speakers. Stressed vowels are plotted on the left and unstressed vowels are presented on the right. All four speaker groups show evidence of vowel reduction in unstressed syllables and stress was shown to significantly effect both tongue height and backness in all four groups. Out of the four groups of speakers, the L1 English participants produced unstressed /i/, /ε/, /ɔ/, and /u/ segments with less fronting than their stressed counterparts. The L1 English speakers also showed the greatest

degree of reduction in the production of unstressed /ɑ/, /ʌ/, and /o/. The L1 Spanish speakers produced the unstressed /ɔ/ with the highest degree of reduction, while the Ukrainian HSs displayed the most reduced productions of unstressed /e/, /æ/, and /u/. Finally, the Polish HSs produced the most reduced /i/ and /ʊ/. The Ukrainian and Polish HSs displayed the greatest reduction of /ɛ/ out of the four speaker groups.

In terms of vowel dispersion away from centroid, the L1 English speakers produced the most dispersed /e/ and /ʌ/ segments out of the four speaker groups. The L1 Spanish speakers produced /æ/ furthest away from the centroid, and the Ukrainian HSs produced the most dispersed /i/, [ə], /ɔ/, and /u/ segments. Finally, the Polish HSs produced the segments /ɪ/, /ɛ/, /ɑ/, and /ʊ/ with the longest Euclidean distances away from centroids among the four groups.

Figure 4.13. English vowel productions by the Ukrainian HSs, the Polish HSs, and the L1 English and L1 Spanish control groups



The F1 and F2 values were submitted to a Linear Mixed Effects Model where *phoneme* and *speaker group* were included as fixed effect and *individual speaker* acted as random effect to determine whether there were any statistically significant differences between the acoustic means of the four groups of participants. The test revealed no statistically significant difference in the F1 ($p < .05035$) and F2 ($p < .8792$) values of the four groups of speakers. Figures 4.14 and 4.15 summarizes the F1 and F2 productions of the four groups utilizing raw data, showing comparable productions in all speaker groups.

Figure 4.14. F1 measurements in English vowels produced by the Ukrainian HSs, the Polish HSs, and the L1 English and L1 Spanish control groups

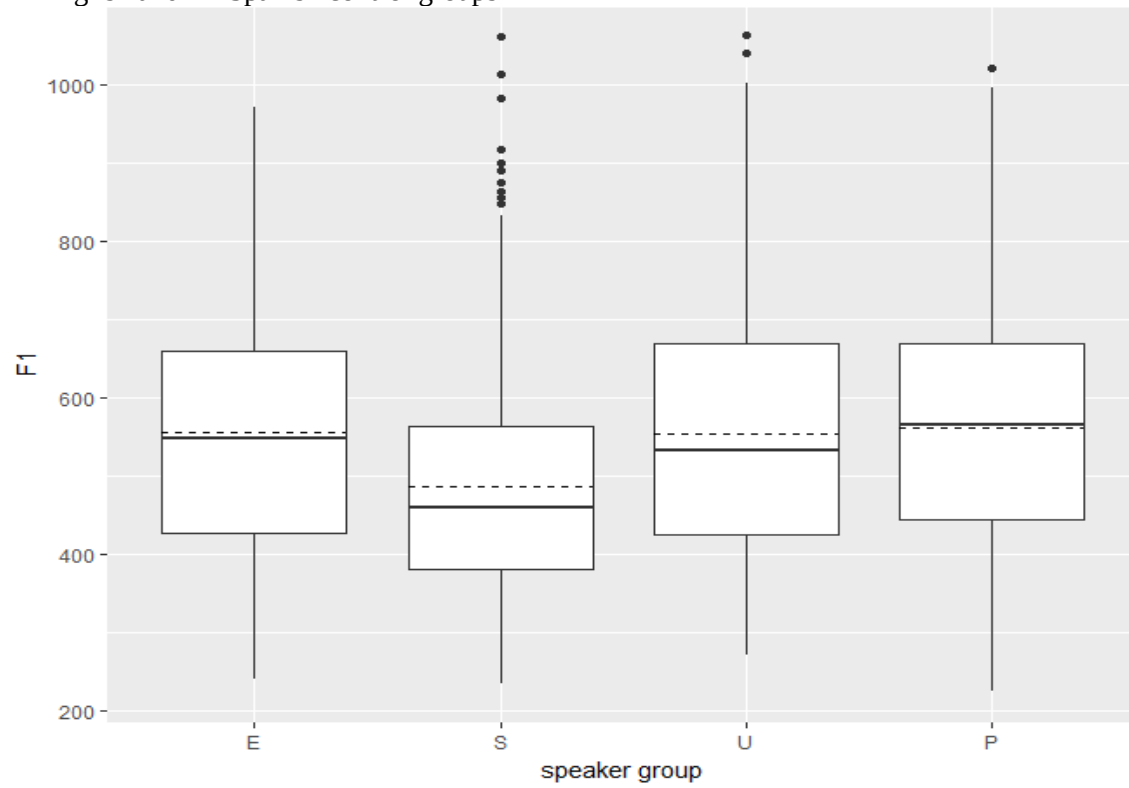
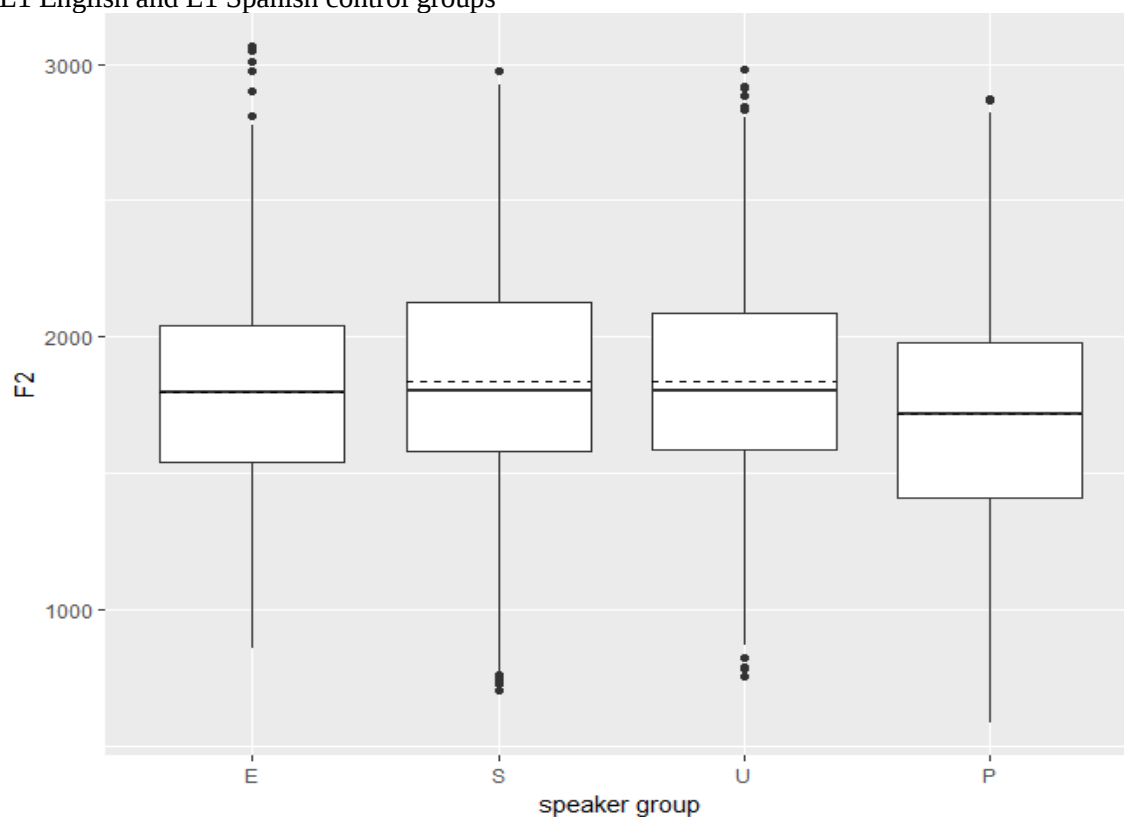
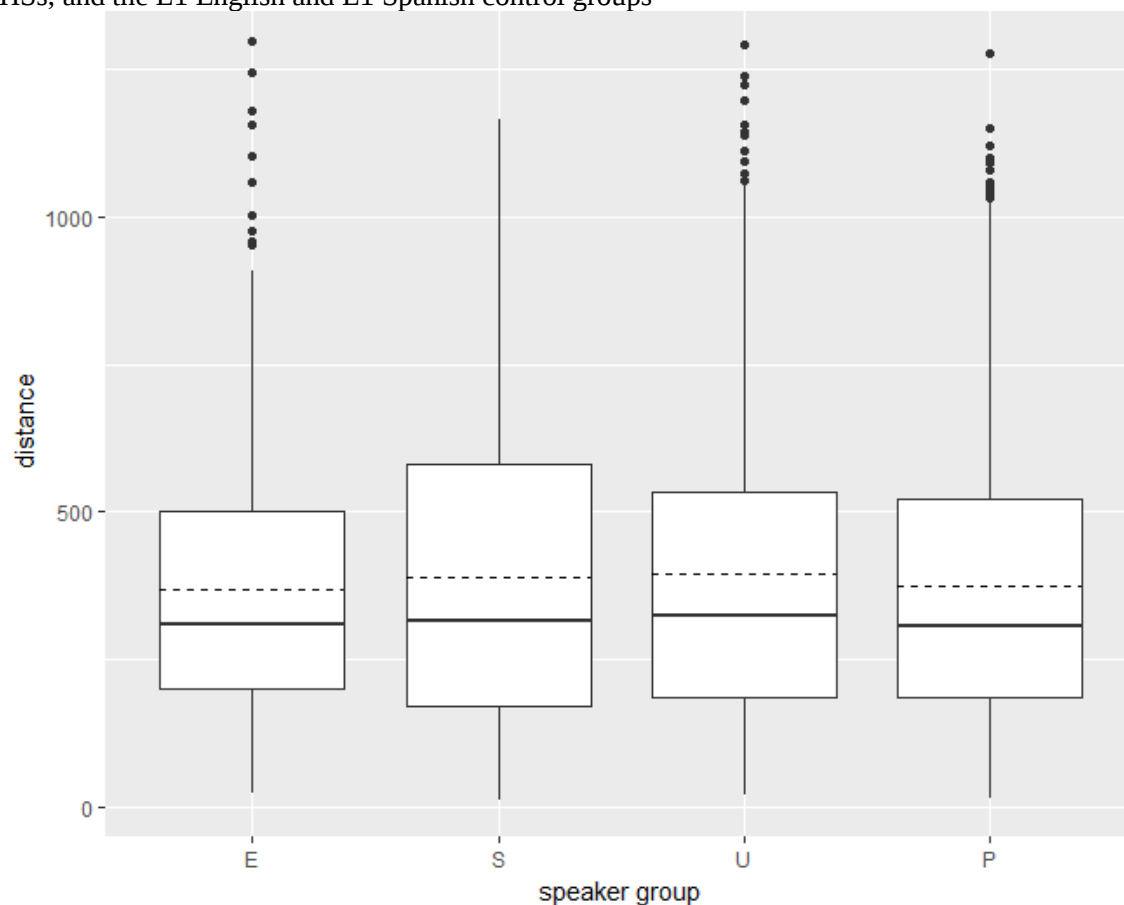


Figure 4.15. F2 measurements in English vowels produced by the Ukrainian HSs, the Polish HSs, and the L1 English and L1 Spanish control groups



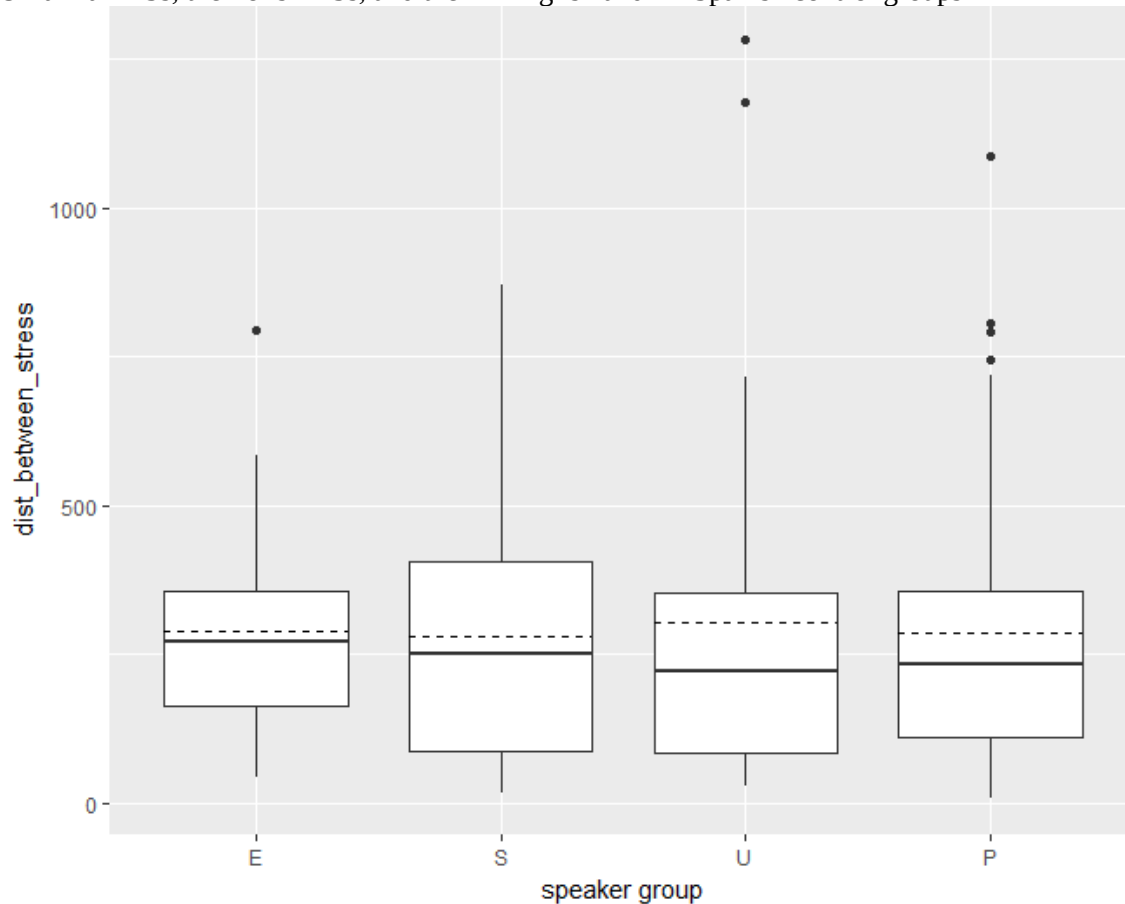
Euclidean distances away from centroid values were also submitted to a Linear Mixed Effects Model, and, once again, did not reveal a statistically significant difference in the degree of vowel dispersion among the four groups of speakers ($p < .962$). Figure 4.16 summarizes the Euclidean distances produced by the four groups of participants utilizing raw data, highlighting the similarities in the productions of the four groups.

Figure 4.16. Euclidean distances from centroids in English produced by the Ukrainian HSs, the Polish HSs, and the L1 English and L1 Spanish control groups



Finally, the Linear Mixed Effects Model was also fitted for the Euclidean distances between stressed and unstressed vowels, revealing no statistically significant differences in the degree of vowel reduction produced by the four groups of speakers ($p < .2131$). Figure 4.17 summarizes the Euclidean distances by stress type as seen in the raw data of the four groups of participants.

Figure 4.17. Euclidean distances between stressed and unstressed vowels in English produced by the Ukrainian HSs, the Polish HSs, and the L1 English and L1 Spanish control groups



It is interesting to note that the L1 Spanish control group behaved similarly to the other three groups in the production of English vowels. Given that Spanish vowels do not undergo reduction in unstressed position, it was predicted that the L1 Spanish speakers would not transfer this feature from Spanish to English and demonstrate productions that differ the most from the L1 English base. However, the L1 Spanish control group only produced F1 values that were furthest away from the L1 English speakers' results. This phenomenon will be discussed in greater detail in the next chapter, but it is possible that due to the L1 Spanish speakers' high proficiency in L2 English, as well as prolonged residence in the United States, the L1 Spanish participants adapted the English reduction norm in the production of unstressed vowels.

4.2.4 Spanish vowels

The unit on Spanish vowels is divided into four parts that present the participants' data in the following order: L1 Spanish control group, L1 English control group, Ukrainian HSs and Polish HSs. The results of each of the four tasks are discussed within each groups' section in the order they were administered during the elicitation process, from least to most controlled (i.e., narrative, picture-naming, sentence-reading, nonce words reading).

4.2.4.1 L1 Spanish control group

A total of 3,304 vowel tokens were analyzed in the L1 Spanish control group's data: 907 tokens in the narrative task, 609 tokens in the picture-naming task, 1,341 productions in the sentence-reading, and 447 productions in the nonce words reading task.

The narrative task yielded a well distributed token count in the L1 Spanish control group's data (Table 4.13). The vowels /e/ and /a/ were the most produced segments, while /i/ and /u/ have the smallest number of tokens. The overall shape of the L1 Spanish control group's vowel space closely resembles that of Spanish standard described in Hualde (2005) (Figure 4.19). The main difference between the two charts is the position of /u/, which, in the L1 Spanish control speakers' data, is more fronted. The middle vowel /o/ also shows evidence of a more posterior production. The unstressed vowel distribution reveals that the L1 Spanish speakers do not tend to reduce Spanish vowels in unstressed syllables (Table 4.14 and Figure 4.18). The vowel that shows the greatest degree of reduction is /e/. The vowels that display the smallest degree of reduction are /a/ and /u/. A two-sample t-test showed stress to be statistically significant for F2 ($p < .0108$), but not for F1 ($p < .296$) values in the narrative task, thus affecting tongue backness, but not tongue height.

Table 4.13. Mean frequencies (Hz) in Spanish produced by the L1 Spanish control group in the narrative task

Phoneme	Mean / SD	Mean / SD stressed position	Stressed tokens	Mean / SD unstressed position	Unstressed tokens	Total tokens
/i/	F1: 366.1 / 51.7	F1: 360 / 48.1	42	F1: 370.1 / 53.9	64	106
	F2: 2297 / 361.5	F2: 2324.3 / 268.1		F2: 2279.1 / 412.5		
/e/	F1: 467.5 / 80	F1: 474.9 / 70.2	77	F1: 464.6 / 83.6	195	272
	F2: 1976.8 / 250	F2: 2072.7 / 236.3		F2: 1938.9 / 245.6		
/a/	F1: 582.7 / 166.2	F1: 585 / 143.6	68	F1: 581.9 / 173.7	195	263
	F2: 1671.8 / 215.3	F2: 1657.6 / 187.1		F2: 1676.7 / 224.5		
/o/	F1: 497.8 / 104.3	F1: 496.8 / 70.8	44	F1: 498.1 / 111.7	164	208
	F2: 1319.1 / 350.1	F2: 1237.9 / 328		F2: 1340.9 / 353.6		
/u/	F1: 409.6 / 68.1	F1: 394.3 / 79.6	23	F1: 419.7 / 58.4	35	58
	F2: 1350.8 / 366.4	F2: 1341.1 / 404.4		F2: 1357.2 / 345.2		

Table 4.14. Euclidean distance measurements in the Spanish vowels of the L1 Spanish control group in the narrative task

Phoneme	Distance between stressed and unstressed vowels	Distance from centroid	Phonemes	Distance between vowel pairs
/i/	0.2	1.5	/i/ - /e/	1.1
/e/	0.3	0.6	/e/ - /a/	1.3
/a/	0.1	1.1	/a/ - /o/	1.2
/o/	0.2	1	/o/ - /u/	0.9
/u/	0.1	1.1	/u/ - /i/	2.2

Figure 4.18. Mean frequencies (Hz) in Spanish produced by the L1 Spanish control group in the narrative task

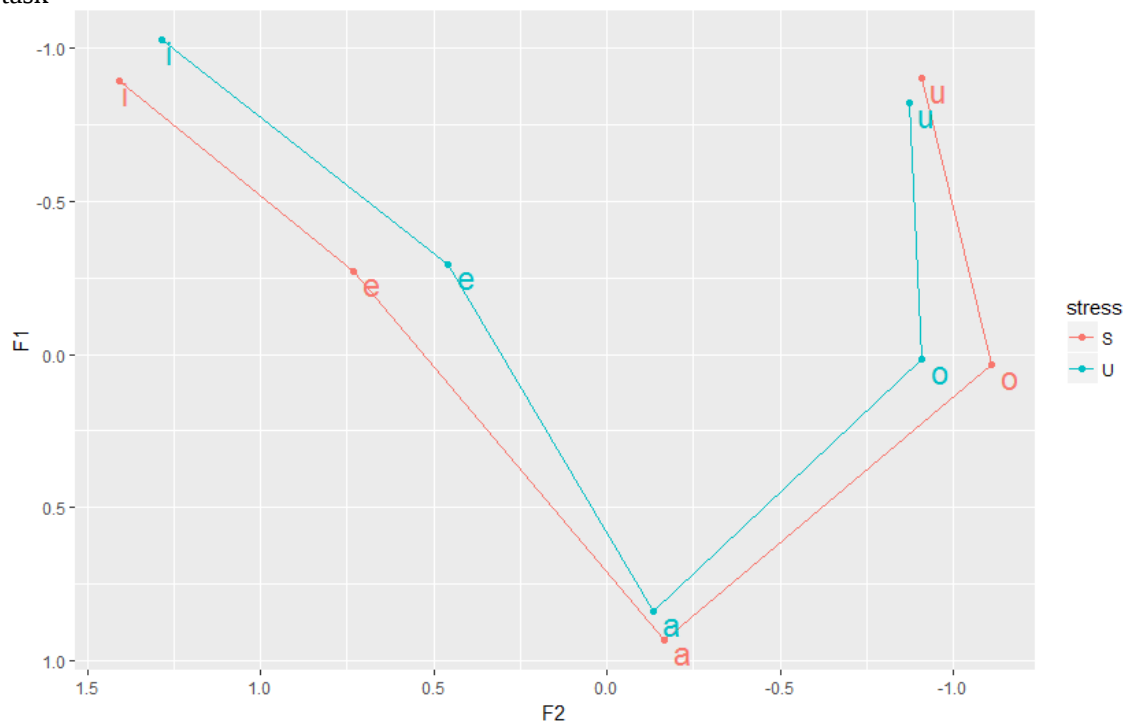
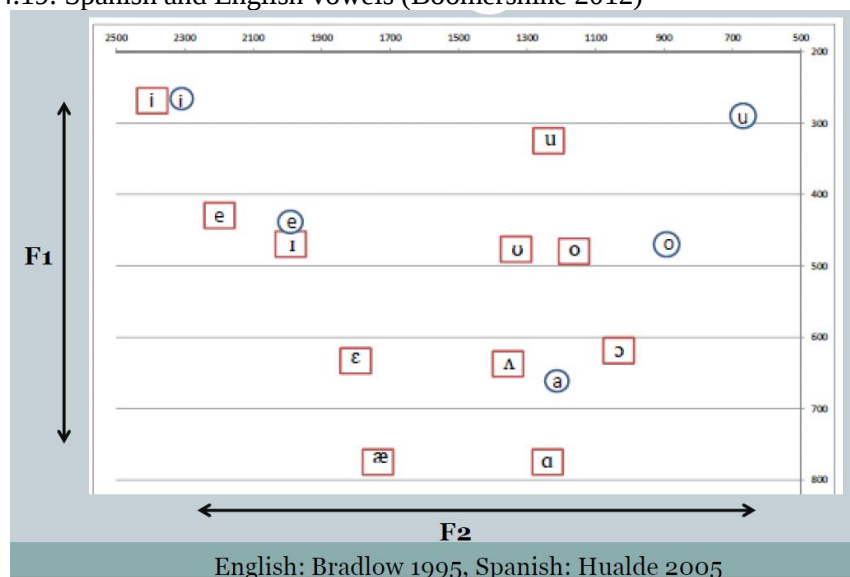


Figure 4.19. Spanish and English vowels (Boomershine 2012)



The picture-naming task yielded a well distributed token count among the five vowels, as well as among the speakers in the group (Table 4.15). The vowel distribution in the picture-naming task resembles the vowel space in the narrative task (Figure 4.20). The high back vowel /u/ was, once again, produced closer to the center, while the middle back vowel /o/ was produced further back. From a comparison of the stressed and unstressed vowel distributions, it is evident that the picture-naming task yielded a greater degree of unstressed vowel reduction than what was seen in the narrative task for /a/, /o/, and /u/ (Table 4.16). The low vowel /a/ underwent the most reduction. Interestingly, the middle back vowel /o/ does not show any evidence of reduction, but rather was produced even further back in unstressed syllables. The segments /e/, /i/, and /u/ display very similar degrees of reduction. Similar to the previous task, a two-sample t-test showed that stress was statistically significant for F2 ($p < .00963$) values, but not for F1 ($p < .493$) measurements, once again affecting tongue backness and not tongue height.

The vowels /i/, /a/, and /o/ were produced further away from the centroid in the picture-naming task than in the narrative task, while the segments /e/ and /u/ appear the same distance or

further away from the centroid in the narrative task. The segments in the picture-naming task also appear further dispersed from each other than the vowels in the narrative task.

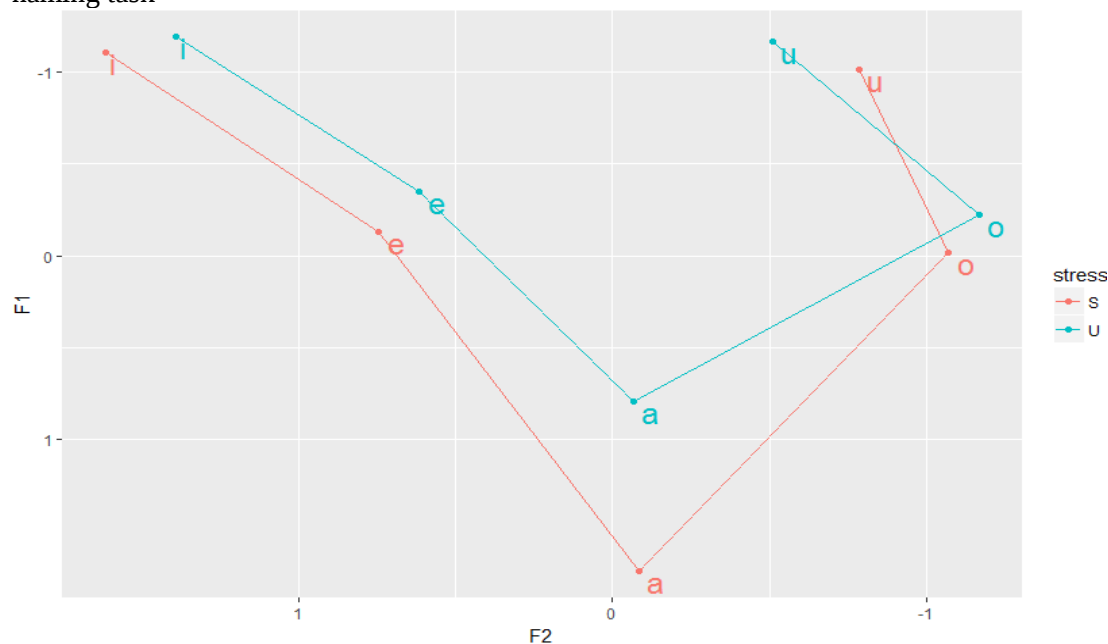
Table 4.15. Mean frequencies (Hz) in Spanish produced by the L1 Spanish control group in the picture-naming task

Phoneme	Mean / SD	Mean / SD stressed position	Stressed tokens	Mean / SD unstressed position	Unstressed tokens	Total tokens
/i/	F1: 379.5 / 52.2	F1: 383.1 / 55.5	32	F1: 375.7 / 49.1	31	63
	F2: 2375.3 / 348.6	F2: 2400.5 / 370.1		F2: 2349.2 / 328.8		
/e/	F1: 475.5 / 61.5	F1: 494.8 / 59.2	42	F1: 463.2 / 60.2	66	108
	F2: 1981 / 246.3	F2: 2025 / 264.1		F2: 1953.1 / 232		
/a/	F1: 632.8 / 155.3	F1: 713.4 / 169	34	F1: 613.7 / 146.1	143	177
	F2: 1636.1 / 234.1	F2: 1626.9 / 199.1		F2: 1638.3 / 242.2		
/o/	F1: 487.1 / 63.8	F1: 500.1 / 60.1	32	F1: 481.6 / 65	76	108
	F2: 1131 / 266.6	F2: 1159.2 / 214.9		F2: 1119.1 / 286		
/u/	F1: 383.5 / 55.9	F1: 392.5 / 57.4	24	F1: 374.9 / 54.1	25	49
	F2: 1338.7 / 389.5	F2: 1265.8 / 463.6		F2: 1408.7 / 294.9		

Table 4.16. Euclidean distance measurements in the Spanish vowels of the L1 Spanish control group in the picture-naming task

Phoneme	Distance between stressed and unstressed vowels	Distance from centroid	Phonemes	Distance between vowel pairs
/i/	0.2	1.7	/i/ - /e/	1.2
/e/	0.3	0.6	/e/ - /a/	1.4
/a/	1	1.3	/a/ - /o/	1.6
/o/	0.2	1.2	/o/ - /u/	1.1
/u/	0.3	1	/u/ - /i/	2.1

Figure 4.20. Mean frequencies (Hz) in Spanish produced by the L1 Spanish control group in the picture-naming task



The vowel distribution in the sentence-reading task reflects the vowel space shape that was produced in the previous two tasks (Figure 4.21). While the high back vowel /u/ does show some fronting, it is not as fronted as in the picture-naming task. Also, the middle back vowel /o/ is more fronted and was not produced as far back as in the previous two tasks. There is evidence of some unstressed vowel reduction (Table 4.18). As in the picture-naming task, /a/ is the most reduced segment, however, it underwent less reduction than in the previous task. The vowel /u/ is the second most reduced segment; in fact, it shows greater reduction in the sentence-reading task in comparison to the previous two tasks. The segments /i/, /e/, and /o/ exhibit almost the same degree of reduction as in the previous two tasks. Unlike in the previous two tasks, a two-sample t-test revealed that stress was statistically significant for F1 ($p < .00546$) values, but not for F2 ($p < .0548$) values, this time affecting tongue height and not tongue backness. As in the picture-naming task, the vowels generally demonstrated more dispersion in the sentence-reading task than in the narrative task, appearing further away from the centroid and showing greater distance between vowel pairs.

Table 4.17. Mean frequencies (Hz) in Spanish produced by the L1 Spanish control group in the sentence-reading task

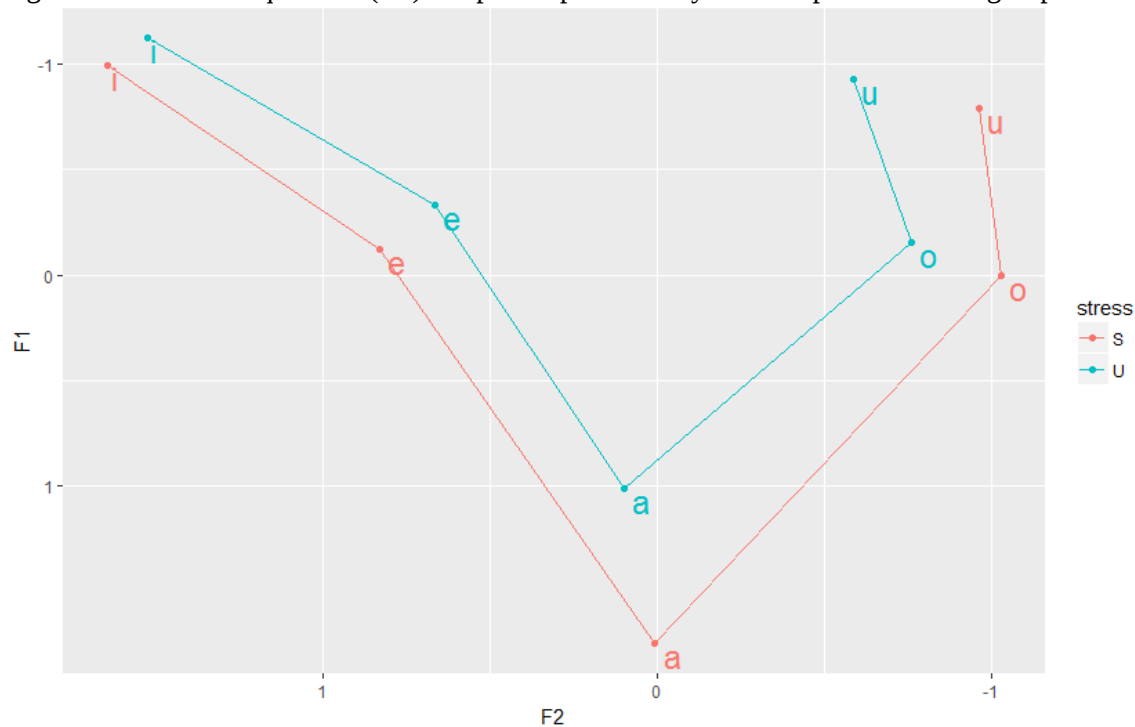
Phoneme	Mean / SD	Mean / SD stressed position	Stressed tokens	Mean / SD unstressed position	Unstressed tokens	Total tokens
/i/	F1: 372.9 / 54.9	F1: 380.5 / 54.9	84	F1: 367.1 / 54.5	109	193
	F2: 2374.9 / 370.3	F2: 2412.3 / 368.4		F2: 2346 / 370.9		
/e/	F1: 467.7 / 77.3	F1: 477.2 / 70.9	89	F1: 459.6 / 81.9	104	193
	F2: 1959.7 / 219.1	F2: 2004.5 / 226.1		F2: 1921.5 / 206.3		
/a/	F1: 642.2 / 137.9	F1: 694.1 / 127	120	F1: 616.8 / 136.2	245	365
	F2: 1619.4 / 207.7	F2: 1587.9 / 192.5		F2: 1634.9 / 213.4		
/o/	F1: 480.5 / 77.3	F1: 492.7 / 68.8	95	F1: 476.8 / 79.4	310	405
	F2: 1167.1 / 294.1	F2: 1064.3 / 239.9		F2: 1198.6 / 302.3		
/u/	F1: 394.8 / 56.9	F1: 402.3 / 59.2	85	F1: 388.5 / 54.4	100	185
	F2: 1192.8 / 352.5	F2: 1087.2 / 334.9		F2: 1282.6 / 343.6		

Table 4.18. Euclidean distance measurements in the Spanish vowels of the L1 Spanish control group in the sentence-reading task

Phoneme	Distance between stressed and unstressed vowels	Distance from centroid	Phonemes	Distance between vowel pairs
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/i/	0.2	1.7	/i/ - /e/	1.2
/e/	0.3	0.6	/e/ - /a/	1.6
/a/	0.7	1.5	/a/ - /o/	1.6
/o/	0.3	1	/o/ - /u/	0.8
/u/	0.4	1.1	/u/ - /i/	2.4

Figure 4.21. Mean frequencies (Hz) in Spanish produced by the L1 Spanish control group



Finally, the vowel space shape in the nonce words reading task reflects the general vocalic shape produced by the L1 Spanish control group in the previous three tasks (Figure 4.22). Once again, the high back vowel /u/ shows evidence of fronting, to a similar degree as in the narrative and sentence-reading tasks. The other four vowels share very similar positions to those of the previous task results. The unstressed vowels distribution shows evidence of reduction (Table 4.20). The vowels /i/ and /a/ are the most reduced segments, while /e/, /o/ and /u/ all undergo the same degree of reduction. While in the previous three tasks the segments /a/ and /u/ demonstrated noticeable reduction, this is the first time that the high front vowel /i/ is significantly reduced by the L1 Spanish control group. Similar to the previous task, a two-sample t-test showed stress to be statistically significant for F1 ($p < .0459$) values, but not for F2 ($p < .7$)

values, thus affecting tongue height, but not tongue backness. The distance between vowel pairs lies between the values in the narrative task and the values in the picture-naming and sentence-reading tasks.

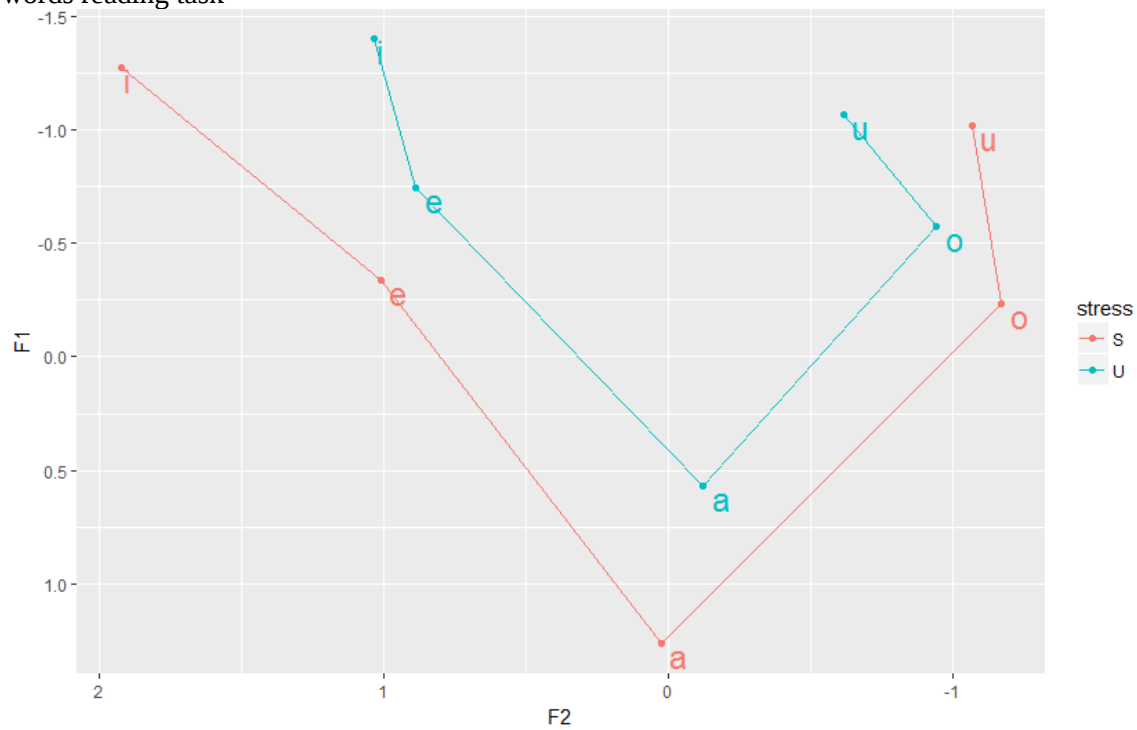
Table 4.19. Mean frequencies (Hz) in Spanish produced by the L1 Spanish control group in the nonce words reading task

Phoneme	Mean / SD	Mean / SD stressed position	Stressed tokens	Mean / SD unstressed position	Unstressed tokens	Total tokens
/i/	F1: 355 / 48.7	F1: 361.3 / 58.6	21	F1: 350.3 / 40.6	29	50
	F2: 2189.4 / 606.1	F2: 2390.3 / 497.2		F2: 2043.9 / 643.6		
/e/	F1: 463.7 / 65.7	F1: 486.4 / 62.2	31	F1: 435.5 / 59.7	25	56
	F2: 2027.2 / 225.8	F2: 2055.3 / 254.6		F2: 1992.3 / 183.2		
/a/	F1: 640.6 / 157.6	F1: 696.1 / 138	45	F1: 627.8 / 159.4	194	329
	F2: 1571 / 207	F2: 1619.7 / 153.1		F2: 1559.7 / 216.3		
/o/	F1: 483.1 / 74.7	F1: 502.1 / 76.6	30	F1: 459.3 / 66.3	24	54
	F2: 1137.6 / 159	F2: 1096 / 145.2		F2: 1189.6 / 163.1		
/u/	F1: 392 / 66.3	F1: 399.1 / 47.4	31	F1: 378.9 / 91.7	17	48
	F2: 1189.7 / 416.3	F2: 1115.2 / 397.3		F2: 1325.5 / 427.6		

Table 4.20. Euclidean distance measurements in the Spanish vowels of the L1 Spanish control group in the nonce words reading task

Phoneme	Distance between stressed and unstressed vowels	Distance from centroid	Phonemes	Distance between vowel pairs
/i/	0.9	1.6	/i/ - /e/	1
/e/	0.4	0.9	/e/ - /a/	1.6
/a/	0.7	1.2	/a/ - /o/	1.5
/o/	0.4	1.1	/o/ - /u/	0.6
/u/	0.4	1.1	/u/ - /i/	2.4

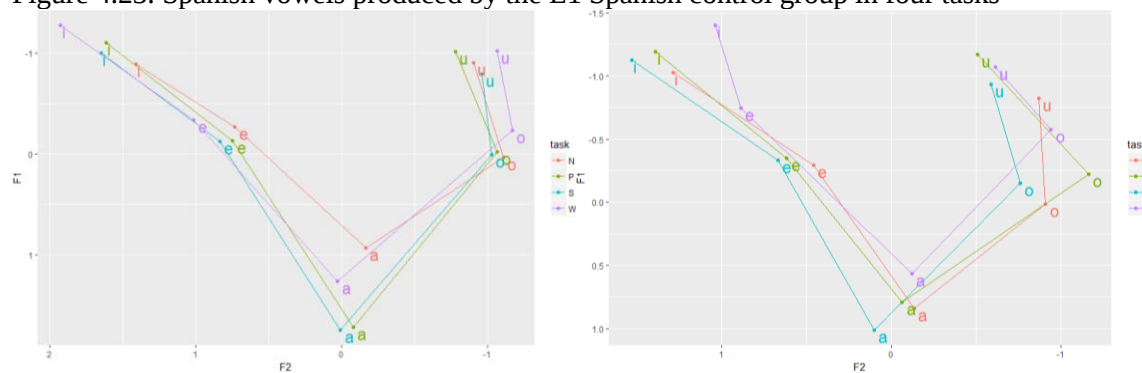
Figure 4.22. Mean frequencies (Hz) in Spanish produced by the L1 Spanish control group in the nonce words reading task



4.2.4.1.1 Summary

Figure 4.23 summarizes the stressed and unstressed vowel production in all four tasks by the L1 Spanish control group, with the stressed vowels presented on the left and the unstressed vowels plotted on the right. In the two graphs, N stands for the narrative task, P for the picture-naming task, S for the sentence-reading task, and W for the nonce words reading task.

Figure 4.23. Spanish vowels produced by the L1 Spanish control group in four tasks



The L1 Spanish speakers showed evidence of unstressed vowel reduction in all four tasks. All vowels, except for /a/, showed the greatest degree of reduction in the nonce words reading task. The low vowel /a/ was most reduced in the picture-naming task. The narrative task yielded the smallest degree of reduction out of the four tasks. The vowels /i/, /a/, and /o/ appeared furthest away from the centroid in the picture-naming task, while /e/ was furthest away in the nonce words reading task. The high vowel /u/ displayed the same distance in the narrative, sentence-reading, and nonce words tasks.

A Linear Mixed Effects Model was run to determine the significance of task type on the frequencies of each vowel. The test revealed task type to be statistically significant in the production of F1 for the vowels /i/ ($p < .00556$), /e/ ($p < .006853$) and /a/ ($p < 1.93 \cdot 10^{-10}$), but not for vowels /o/ ($p < .08086$) and /u/ ($p < .2418$). In the production of F2 values, task type was shown to be statistically significant for vowels /i/ ($p < .01717$), /a/ ($p < 7.003 \cdot 10^{-14}$), /o/ ($p < 9.271 \cdot 10^{-13}$) and /u/ ($p < .001135$), but not for /e/ ($p < .06255$). While these results show that frequencies are affected by task type, there is no consistency with respect to F1 and F2 values, meaning that one axis is not affected more than the other.

Another Linear Mixed Effects Model was implemented to determine whether task type was significant for Euclidean distance from centroids. The test revealed that task type was not significant in the degree of dispersion of the front vowels /i/ ($p < .566$) and /e/ ($p < .1003$); however, it was shown to be statistically significant in the degree of dispersion displayed by the central and back vowels: /a/ ($p < .04504$), /o/ ($p < .00001621$), /u/ ($p < .005441$).

Finally, the Euclidean distance between stressed and unstressed vowels was submitted to another Linear Mixed Effects Model, revealing that task type was not statistically significant in

the degree of reduction for any of the five vowels: /i/ ($p < .1594$), /e/ ($p < .3671$), /a/ ($p < .1076$), /o/ ($p < .08058$), /u/ ($p < .1841$).

From the acoustic data, it is evident that the most natural task (i.e., the narrative task) yielded the smallest degree of reduction, while the least natural task (i.e., the nonce words reading) caused the greatest degree of reduction in the L1 Spanish speakers' speech. The relationship between task formality and unstressed vowel reduction will be discussed in greater detail in the next chapter, tying the results of this study with those of Ronquest (2012, 2016) who reported on differences in vowel spaces in formal and informal contexts. The statistical results demonstrate that task type was most significant for the F1 and F2 values in the production of /i/ and /a/. Task design also significantly influenced the dispersions of vowels /a/, /o/, and /u/, while it did not have a significant role in the rate of reduction of any of the vowels.

4.2.4.2 L1 English control group

A total of 2,598 Spanish vowels were analyzed in the data of the L1 English control group: 428 tokens in the narrative task, 382 tokens in the picture-naming task, 1,339 tokens in the sentence-reading task, and 449 tokens in the nonce words reading task.

Although the L1 English control group produced only half as many vowel tokens in the narrative task as the L1 Spanish control group, each vowel is still well represented and every speaker produced at least five tokens of each segment (Table 4.21). The segments /e/ and /a/ were produced with the greatest number of tokens, while /u/ has the fewest data points. The L1 English speakers' vowel distribution is similar to the vowel shape reflected in the L1 Spanish speakers' data, with some exceptions (Figure 4.24). For example, the high vowel /u/ was produced with a more fronted realization by the L1 English speakers. Also, the vowels /e/, /a/

and /o/ were realized with higher F1 values, reflecting lowered productions of these segments. Meanwhile, /i/ was produced with a lower F1 value, resulting in a higher vowel position.

Figure 4.25 provides a comparison between the L1 English and L1 Spanish control groups' results. The L1 English speakers' data reveals a small degree of vowel reduction in unstressed position; however, it is not significantly greater than the degree of reduction observed in the L1 Spanish control groups' results (Table 4.22). For example, the vowels /i/ and /o/ undergo the same amount of reduction in both groups' productions and /e/ is less reduced in the L1 English groups' pronunciation. The vowels /a/ and /u/, on the other hand, are more reduced in L1 English speakers' production. Similar to the L1 Spanish control group's results, a two-sample t-test showed stress to be statistically significant for F2 ($p < .0476$) values, but not for F1 ($p < .398$) measurements in the L1 English speakers' data, meaning there are effects on backness, but not height. Finally, the vowels /i/ and /a/ appeared further away from the centroid in the L1 English speakers' data than they did in the L1 Spanish group's production, while /e/, /o/, and /u/ were clustered closer to the central point.

Table 4.21. Mean frequencies (Hz) in Spanish produced by the L1 English control group in the narrative task

Phoneme	Mean / SD	Mean / SD stressed position	Stressed tokens	Mean / SD unstressed position	Unstressed tokens	Total tokens
/i/	F1: 361.4 / 54.6	F1: 377.6 / 58.8	25	F1: 352.9 / 50.9	47	72
	F2: 2387 / 361.5	F2: 2397.7 / 337.4		F2: 2381.4 / 377.1		
/e/	F1: 539.3 / 88.6	F1: 550.4 / 73.2	40	F1: 534 / 95	84	124
	F2: 1938.7 / 299.9	F2: 1983 / 305.8		F2: 1917.6 / 296.6		
/a/	F1: 703.8 / 107.4	F1: 745 / 85.8	30	F1: 689.4 / 110.8	86	116
	F2: 1585.4 / 218.4	F2: 1562.2 / 212.9		F2: 1593.5 / 221		
/o/	F1: 573.3 / 103.1	F1: 583.6 / 96.2	16	F1: 570.9 / 105.2	67	83
	F2: 1303.8 / 347	F2: 1299.9 / 404.4		F2: 1304.7 / 335.3		
/u/	F1: 421.5 / 103.4	F1: 446.6 / 118.6	8	F1: 413.5 / 99.3	25	33
	F2: 1513.9 / 493.6	F2: 1445.9 / 537.7		F2: 1535.6 / 488.3		

Table 4.22. Euclidean distance measurements in the Spanish vowels of the L1 English control group in the narrative task

Phoneme	Distance between stressed and unstressed vowels	Distance from centroid	Phonemes	Distance between vowel pairs
---------	---	------------------------	----------	------------------------------

/i/	0.2	1.7	/i/ - /e/	1.6
/e/	0.2	0.4	/e/ - /a/	1.3
/a/	0.3	1.3	/a/ - /o/	1
/o/	0.2	1	/o/ - /u/	1.2
/u/	0.3	0.8	/u/ - /i/	1.7

Figure 4.24. Mean frequencies (Hz) in Spanish produced by the L1 English control group in the narrative task

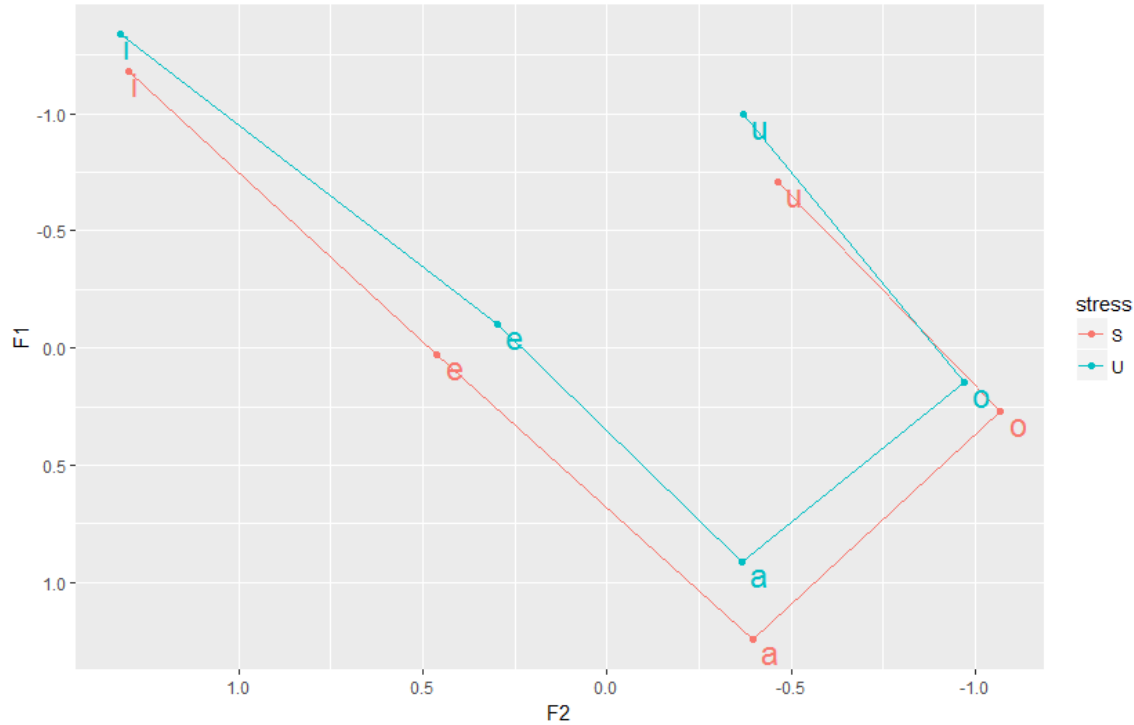
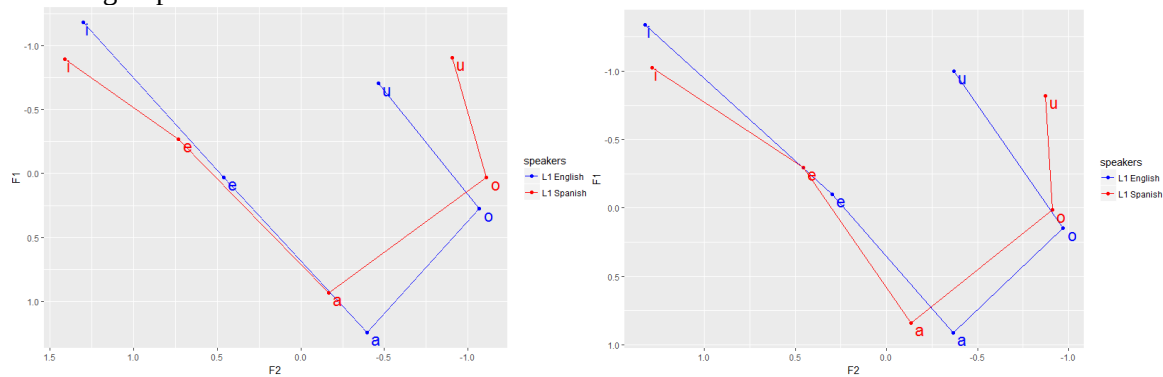


Figure 4.25. Stressed and unstressed vowel productions in Spanish by the L1 English and L1 Spanish control groups in the narrative task



Similar to the narrative task, the picture-naming task yielded a well distributed token count among the five vowels and every participant produced at least seven instances of each segment (Table 4.23). The low vowel /a/ was articulated the most, while /u/ and /o/ show the

lowest token counts. While the vowel shape in the picture-naming task is similar to the one displayed in the narrative task (and the one produced by the L1 Spanish control group in the picture-naming task), there is one notable difference – the position of /u/ (Figure 4.26). The high back vowel was more fronted and produced as a central vowel in the picture-naming task. The vowel /e/ experienced more fronting and the segments /a/ and /o/ were produced further back in the L1 English speakers' results in comparison to those of the L1 Spanish speakers', while the high vowel /i/ shares the same position in the two groups' realizations.

Figure 4.27 summarizes the L1 English speakers' productions and the L1 Spanish control groups' realizations in the picture-naming task. The stressed segments are presented on the left and the unstressed segments are plotted on the right. The stressed and unstressed vowel distributions clearly show a pattern of vowel reduction in the unstressed context (Table 4.24). The amount of reduction produced by the L1 English speakers in the picture-naming task is greater than the degree of reduction observed in the narrative task results of the same speaker group. It is also greater than the reduction observed in the L1 Spanish control groups' data in the picture-naming task. Once again, mimicking the L1 Spanish speakers' results, a two-sample t-test revealed stress to be very significant for F2 ($p < .0000085$) values, but not significant for F1 ($p < .122$) values. A greater degree of dispersion was observed between the vowels /e/, /a/, /o/, and /u/ in the picture-naming task in comparison to the narrative task, while the distance between the vowels /u/, /i/, and /e/ was smaller.

Table 4.23. Mean frequencies (Hz) in Spanish produced by the L1 English control group in the picture-naming task

Phoneme	Mean / SD	Mean / SD stressed position	Stressed tokens	Mean / SD unstressed position	Unstressed tokens	Total tokens
/i/	F1: 412.1 / 85.8	F1: 414.4 / 92.7	28	F1: 409.4 / 79.1	25	53
	F2: 2288.2 / 338.4	F2: 2366.1 / 311		F2: 2201 / 352.6		
/e/	F1: 546.6 / 76.7	F1: 563.6 / 76.3	30	F1: 534.8 / 75.5	43	73
	F2: 1940.5 / 305.1	F2: 2082.6 / 210.3		F2: 1841.3 / 323.3		
/a/	F1: 707.5 / 111	F1: 815.8 / 97.7	26	F1: 681.1 / 97.5	107	133

	F2: 1585 / 225	F2: 1514.5 / 242.1		F2: 1602.1 / 218.4		
/o/	F1: 552.8 / 66.5	F1: 568.9 / 37.5	20	F1: 547.4 / 73.3	59	79
	F2: 1244.3 / 220.5	F2: 1198.8 / 156.8		F2: 1259.8 / 237.5		
/u/	F1: 428.4 / 88.1	F1: 398.8 / 74.3	21	F1: 455.4 / 92.5	23	44
	F2: 1713.7 / 305.5	F2: 1738.2 / 321.6		F2: 1691.4 / 295.4		

Table 4.24. Euclidean distance measurements in the Spanish vowels of the L1 English control group in the picture-naming task

Phoneme	Distance between stressed and unstressed vowels	Distance from centroid	Phonemes	Distance between vowel pairs
/i/	0.4	1.5	/i/ - /e/	1.3
/e/	0.6	0.5	/e/ - /a/	1.4
/a/	1	1.3	/a/ - /o/	1.4
/o/	0.2	1.2	/o/ - /u/	1.5
/u/	0.4	0.7	/u/ - /i/	1.3

Figure 4.26. Mean frequencies (Hz) in Spanish produced by the L1 English control group in the picture-naming task

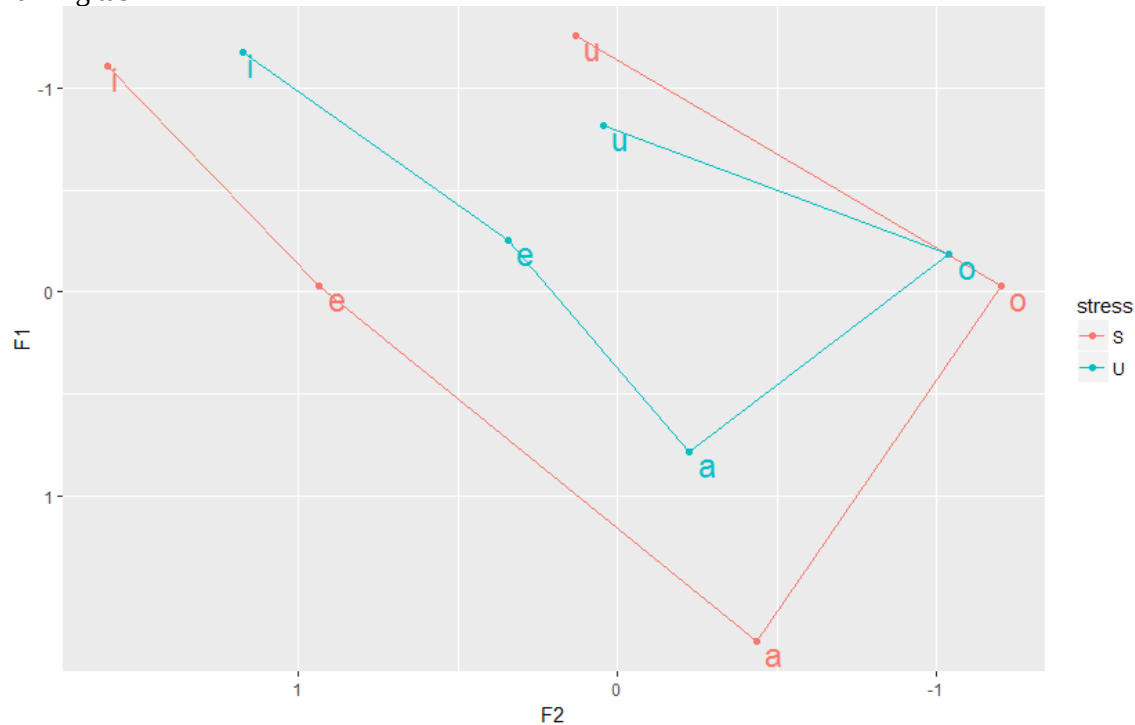
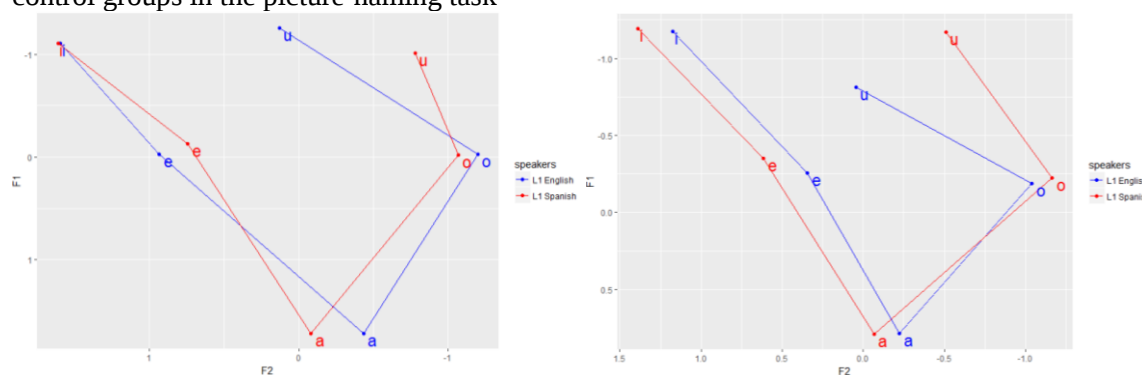


Figure 4.27. Stressed and unstressed vowel productions in Spanish by the L1 English and L1 Spanish control groups in the picture-naming task



In this task, the vowel /o/ has the greatest number of tokens, while /u/ has the smallest (Table 4.25). All speakers produced at least 37 instances of each segment. The overall vowel shape is similar to the distribution displayed by the L1 Spanish control group in the same task, with some exceptions (Figure 4.28). For instance, the high segment /u/ shows evidence of fronting, however, it is not as centralized in this task as it was in previous elicitations.

When looking at the comparison of the control groups' results in Figure 4.29, it is evident that the English speakers' stressed vowels, with the exception of /a/, are further dispersed from the centroid than the L1 Spanish speakers' productions. The unstressed vowel plot reveals that while the L1 English control group does show vowel reduction in unstressed position, it is smaller than the reduction seen in the L1 Spanish control group's data (Table 4.26). The segment /a/ is the most reduced vowel, while the vowels /i/, /e/, and /u/ exhibit the smallest degree of reduction. Similar to the previous two tasks, but unlike the L1 Spanish speakers' results in the sentence-reading task, a two-sample t-test revealed stress to be significant for F2 ($p < .00245$) values, but not for F1 ($p < .451$) measurements in the L1 English speakers' data.

Table 4.25. Mean frequencies (Hz) in Spanish produced by the L1 English control group in the sentence-reading task

Phoneme	Mean / SD	Mean / SD stressed position	Stressed tokens	Mean / SD unstressed position	Unstressed tokens	Total tokens
/i/	F1: 375.8 / 69.9	F1: 379.4 / 68.8	85	F1: 372.9 / 71	106	191
	F2: 2425.1 / 312.6	F2: 2467.5 / 311.9		F2: 2391.1 / 310.4		

/e/	F1: 566.5 / 79.3	F1: 573.8 / 83.3	86	F1: 560.7 / 75.7	107	193
	F2: 2019.5 / 274.4	F2: 2032.8 / 253.8		F2: 2008.9 / 290.7		
/a/	F1: 726.8 / 99.9	F1: 773.7 / 82.2	119	F1: 704.3 / 100	248	367
	F2: 1564 / 208.2	F2: 1487.2 / 202.9		F2: 1600.8 / 200.9		
/o/	F1: 563.4 / 56.3	F1: 554.8 / 47.3	93	F1: 565.9 / 58.5	313	406
	F2: 1129.8 / 217.3	F2: 1053.4 / 172		F2: 1152.6 / 224.3		
/u/	F1: 388.3 / 64.1	F1: 394.5 / 67.3	82	F1: 383.3 / 61.2	100	182
	F2: 1332.8 / 398.2	F2: 1300.4 / 375.5		F2: 1359.3 / 415.9		

Table 4.26. Euclidean distance measurements in the Spanish vowels of the L1 English control group in the sentence-reading task

Phoneme	Distance between stressed and unstressed vowels	Distance from centroid	Phonemes	Distance between vowel pairs
/i/	0.1	1.8	/i/ - /e/	1.5
/e/	0.1	0.7	/e/ - /a/	1.4
/a/	0.5	1.4	/a/ - /o/	1.4
/o/	0.2	1.1	/o/ - /u/	1.3
/u/	0.1	1.2	/u/ - /i/	2.1

Figure 4.28. Mean frequencies (Hz) in Spanish produced by the L1 English control group in the sentence-reading task

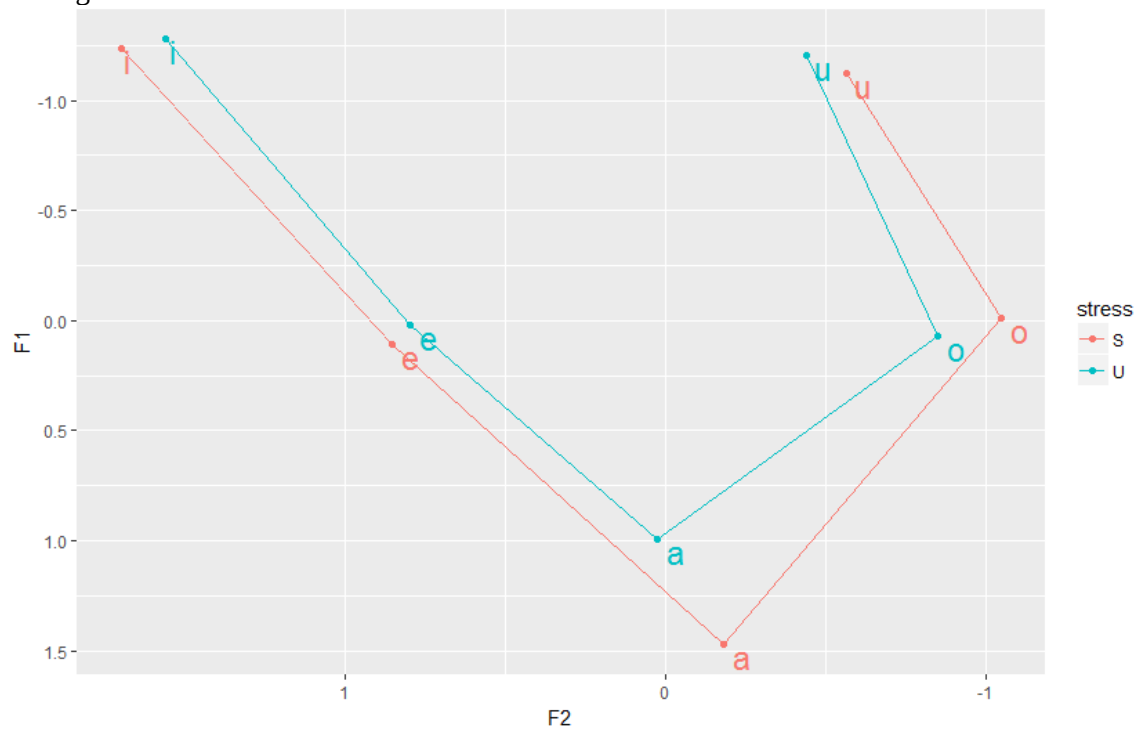
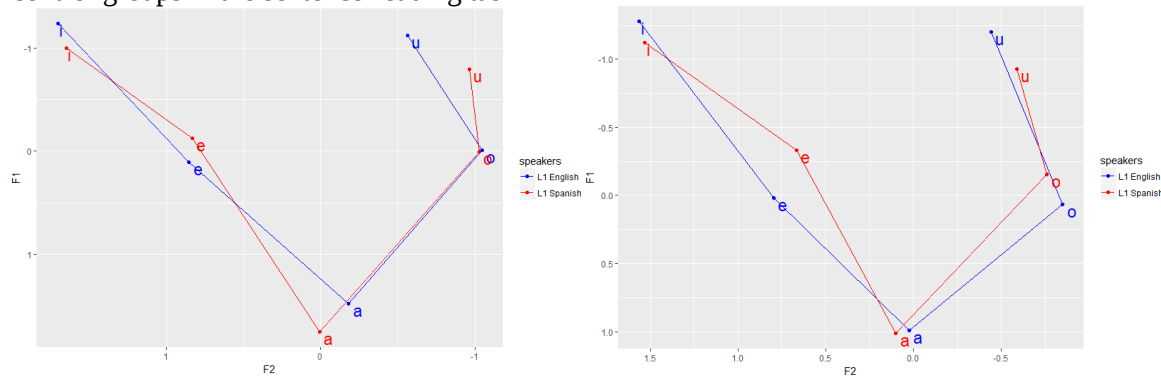


Figure 4.29. Stressed and unstressed vowel productions in Spanish by the L1 English and L1 Spanish control groups in the sentence-reading task



The vowel space produced by the L1 English control group in the nonce words reading task closely resemblances that of the L1 Spanish speakers' production in this same task. A comparison of the control groups' results is outlined in Figure 4.31, where stressed vowels appear on the left and unstressed vowels on the right. Most notably, the high vowel /u/ is not fronted as it was in the previous three tasks. The degree of vowel reduction in unstressed position is very similar to the reduction displayed in the L1 Spanish speakers' data in the nonce words reading (Table 4.28). While in the previous three tasks the low segment /a/ underwent the greatest reduction, in this task the high vowels /i/ and /u/ are the most reduced segments. The mid vowels evidence the smallest change in quality. Unlike the previous three elicitations, but similar to the L1 Spanish control group's results in the nonce words reading task, a two-sample t-test showed that stress was significant for F1 ($p < .000000168$) values, but not for F2 ($p < .188$) measurements in the L1 English speakers' data, which points to effects on tongue height, but not backness. Finally, the L1 English speakers' vowels display greater dispersion from the centroid, as well as a greater distance between vowel pairs than the L1 Spanish speakers' results.

Table 4.27. Mean frequencies (Hz) in Spanish produced by the L1 English control group in the nonce words reading task

Phoneme	Mean / SD	Mean / SD stressed position	Stressed tokens	Mean / SD unstressed position	Unstressed tokens	Total tokens
/i/	F1: 394.5 / 83.9	F1: 383.3 / 64.2	24	F1: 405.2 / 99.4	25	49
	F2: 2456 / 348.3	F2: 2658.2 / 260.2		F2: 2261.9 / 312.5		

/e/	F1: 527.4 / 63.8	F1: 522.6 / 50.3	31	F1: 533.7 / 79.4	23	54
	F2: 2124.7 / 304.4	F2: 2174.2 / 235.1		F2: 2058.1 / 373.9		
/a/	F1: 761.6 / 122.2	F1: 832.3 / 125.1	46	F1: 745.2 / 115.7	198	244
	F2: 1544.6 / 198.9	F2: 1514 / 206.9		F2: 1551.7 / 196.9		
/o/	F1: 542.8 / 72	F1: 557.3 / 44.1	27	F1: 528.3 / 90.5	27	54
	F2: 1185.4 / 253.7	F2: 1168.7 / 209.6		F2: 1202.1 / 294.5		
/u/	F1: 394.4 / 54.2	F1: 398.4 / 50.7	33	F1: 385.6 / 62.2	15	48
	F2: 1188.8 / 395.7	F2: 1111.8 / 328.2		F2: 1358.2 / 484.4		

Table 4.28. Euclidean distance measurements in the Spanish vowels of the L1 English control group in the nonce words reading task

Phoneme	Distance between stressed and unstressed vowels	Distance from centroid	Phonemes	Distance between vowel pairs
/i/	0.9	1.8	/i/ - /e/	1.1
/e/	0.3	0.9	/e/ - /a/	1.8
/a/	0.5	1.4	/a/ - /o/	1.5
/o/	0.2	1.1	/o/ - /u/	0.9
/u/	0.6	1.3	/u/ - /i/	2.7

Figure 4.30. Mean frequencies (Hz) in Spanish produced by the L1 English control group in the nonce words reading task

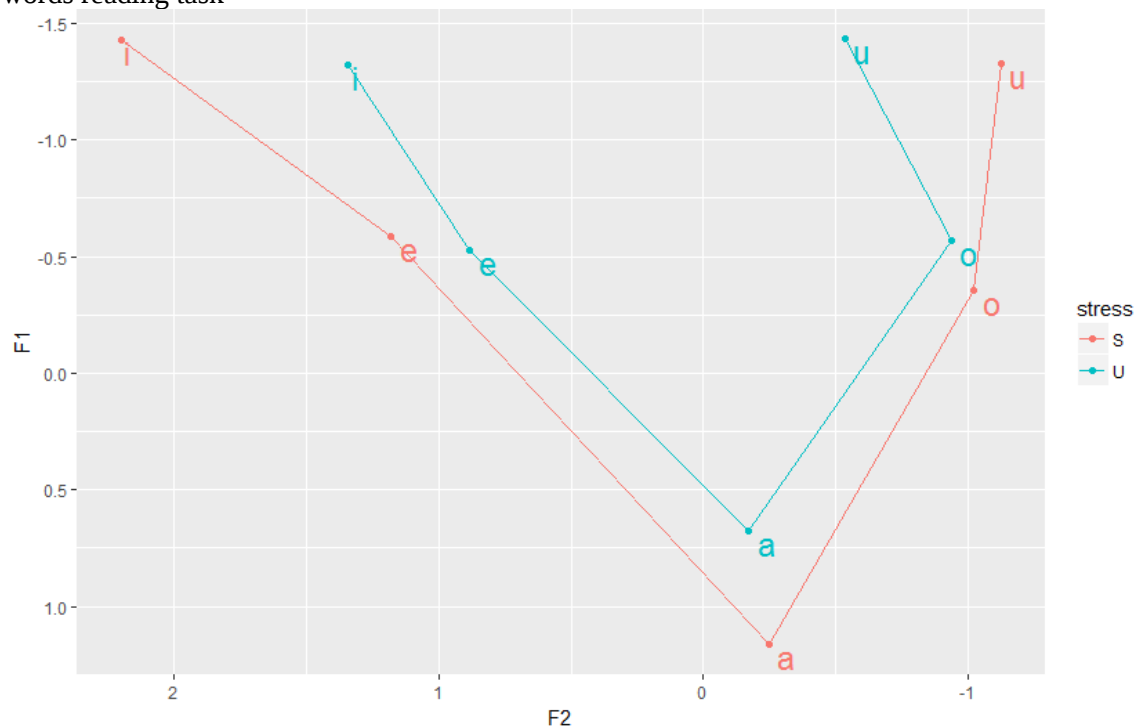
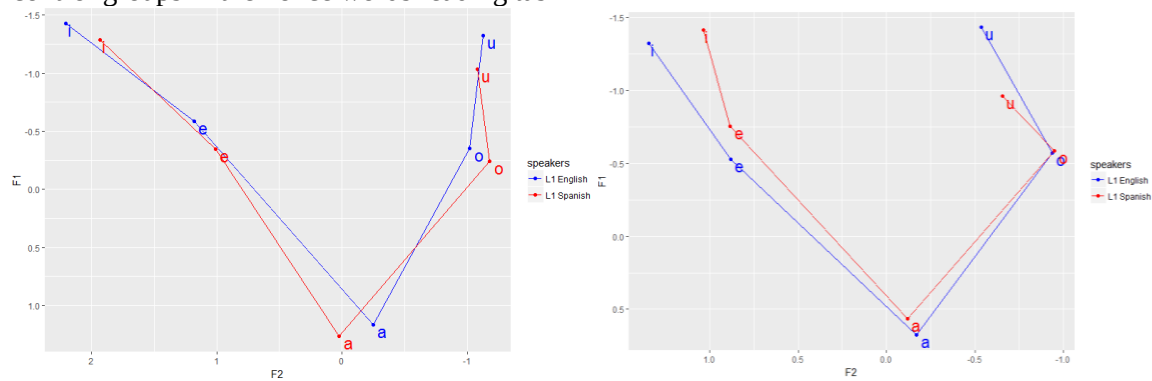


Figure 4.31. Stressed and unstressed vowel productions in Spanish by the L1 English and L1 Spanish control groups in the nonce words reading task

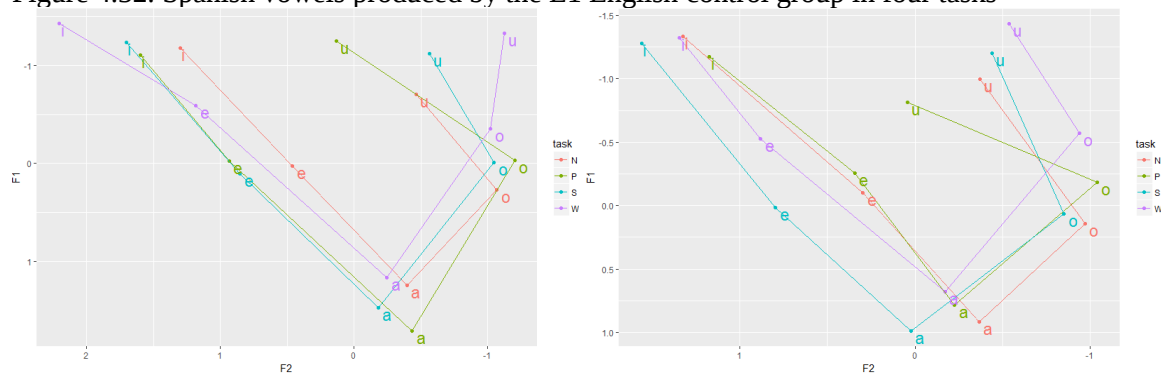


4.2.4.2.1 Summary

Figure 4.32 summarizes the stressed and unstressed vowel productions by the L1 English control group in all four tasks. The stressed vowels are outlined on the left and the unstressed vowels are presented on the right.

There is evidence of vowel reduction in unstressed position in all four tasks. The high vowels /i/ and /u/ demonstrate the greatest degree of reduction in the nonce words reading task. The low vowel /a/ and the middle segment /e/ were most reduced in the picture-naming task. Finally, the back segment /o/ displays the same degree of reduction in all four tasks. All vowels, with the exception of /a/, were least reduced in the sentence-reading task. The segment /a/ showed the smallest degree of reduction in the narrative task. Finally, all vowels display the biggest degree of dispersion in the nonce words reading task.

Figure 4.32. Spanish vowels produced by the L1 English control group in four tasks



A Linear Mixed Effects Model was used to determine the significance of task type on the F1 and F2 values of each vowel. The test revealed that for all five vowels, task type was statistically significant in the production of F1: /i/ ($p < .0009916$), /e/ ($p < .00553$), /a/ ($p < 8.75 \times 10^{-9}$), /o/ ($p < .03155$), /u/ ($p < .000196$). It also showed task type to be statistically significant in the production of F2 values for vowels /i/ ($p < .00655$), /e/ ($p < .002611$), /o/ ($p < 2.886 \times 10^{-8}$) and /u/ ($p < 3.159 \times 10^{-10}$), but not for /a/ ($p < .1985$). Overall, task type is shown to affect both F1 and F2 values in a more consistent manner than is observed in the L1 Spanish speakers' results.

Another Linear Mixed Effects Model was fitted for Euclidean distance from centroid values to determine whether task type played a statistically significant role in the degree of vowel dispersion. The results revealed that task type was significant in the degree of dispersion for all five vowels /i/ ($p < .0009081$), /e/ ($p < .0008318$), /a/ ($p < .00236$), /o/ ($p < 5.63 \times 10^{-7}$) and /u/ ($p < 7.758 \times 10^{-9}$).

Finally, Euclidean distance between stressed and unstressed vowels was run in a Linear Mixed Effects Model, which showed that task type was significant for the degree of reduction observed in the production of the front vowels /i/ ($p < .002191$) and /e/ ($p < .04718$), but not in the production of central and back segments /a/ ($p < .1096$), /o/ ($p < .9042$) and /u/ ($p < .3785$).

The acoustic data signals that the L1 English speakers tend to produce less reduced segments in more controlled tasks, which is contrary to the results observed in the L1 Spanish speakers' data. The statistic results show that task type plays a significant role in the production of both F1 and F2 values. Also, it is significant in the dispersion of all five vowels. In terms of vowel reduction, task type was significant for two of the five vowels. These results demonstrate

that task design effects the L1 English speakers' vowel production much more than those of the L1 Spanish speakers.

4.2.4.3 Ukrainian HSs

The Ukrainian HSs produced a total of 3,228 Spanish vowels. 639 tokens appeared in the narrative task, 441 in the picture-naming task, 1,609 in the sentence-reading task, and 539 in the nonce words reading task.

The Ukrainian HSs group produced a well-distributed token count in the narrative task, with /a/ being the most represented vowel and /u/ exhibiting the smallest number of tokens (Table 4.29). Every speaker produced at least three tokens of each segment. The HSs' vowel shape reflects most closely the vowel distribution produced by the L1 Spanish control group in the narrative task (Figure 4.33). While the high vowel /u/ is fronted, it is not centralized to the same extent as in the L1 English control groups' data. Overall, the Ukrainian HSs display a more dispersed vowel space for stressed vowels than the control groups, as seen in the comparison of the HSs' and the control groups' results in Figure 4.34. The group's vowel plot shows evidence of reduction in unstressed position. The low vowel /a/ is the most reduced segment, followed by the middle segment /o/. The high vowels /i/ and /u/ are the least reduced segments. On the unstressed vowel plot of the HSs' and control groups' results, it appears that the Ukrainian HSs' vowels are, for the most part, less reduced than those produced by the L1 English speakers; however, since the Ukrainian HSs' vowels were more dispersed in stressed position, the degree of reduction was actually greater for vowels /e/, /a/, and /o/ (Table 4.30). Mimicking the results of the two control groups, a two-sample t-test revealed stress to be statistically significant for F2 ($p < .00239$) values, but not for F1 ($p < .806$) values in the Ukrainian HSs' data set, thus demonstrating an influence on tongue backness, but not height.

Table 4.29. Mean frequencies (Hz) in Spanish produced by Ukrainian HSs in the narrative task

Phoneme	Mean / SD	Mean / SD stressed position	Stressed tokens	Mean / SD unstressed position	Unstressed tokens	Total tokens
/i/	F1: 405.6 / 42.9	F1: 403 / 48.3	50	F1: 408.7 / 35.9	42	92
	F2: 2497.9 / 284.9	F2: 2471.9 / 279.3		F2: 2528.9 / 291.8		
/e/	F1: 540.9 / 82.1	F1: 565.5 / 83.7	62	F1: 527.5 / 78.4	114	176
	F2: 2111.5 / 261.6	F2: 2157.5 / 264.3		F2: 2086.5 / 257.8		
/a/	F1: 683.1 / 133.2	F1: 768.5 / 116	47	F1: 658 / 127.7	160	207
	F2: 1685 / 235.3	F2: 1652.8 / 171.1		F2: 1694.5 / 250.7		
/o/	F1: 570 / 69.4	F1: 577 / 57.8	34	F1: 567.4 / 73.3	94	128
	F2: 1287.2 / 240.2	F2: 1154.8 / 182.2		F2: 1335.2 / 241.4		
/u/	F1: 467.3 / 83.5	F1: 458.8 / 61.6	13	F1: 472.1 / 94.7	23	36
	F2: 1331.4 / 365.7	F2: 1299 / 331		F2: 1349.6 / 389.9		

Table 4.30. Euclidean distance measurements in the Spanish vowels of the Ukrainian HSs in the narrative task

Phoneme	Distance between stressed and unstressed vowels	Distance from centroid	Phonemes	Distance between vowel pairs
/i/	0.1	1.8	/i/ - /e/	1.3
/e/	0.3	0.7	/e/ - /a/	1.4
/a/	0.9	1.2	/a/ - /o/	1.2
/o/	0.4	1.1	/o/ - /u/	0.9
/u/	0.2	1.1	/u/ - /i/	2.5

Figure 4.33. Mean frequencies (Hz) in Spanish produced by the Ukrainian HSs in the narrative task

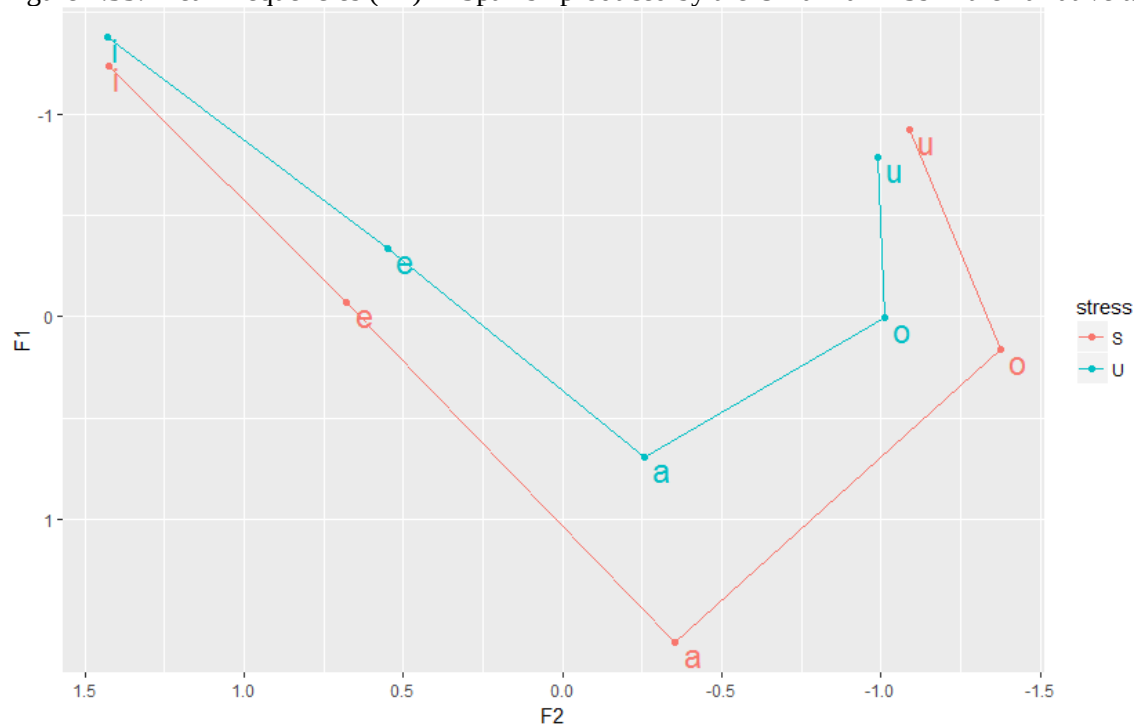
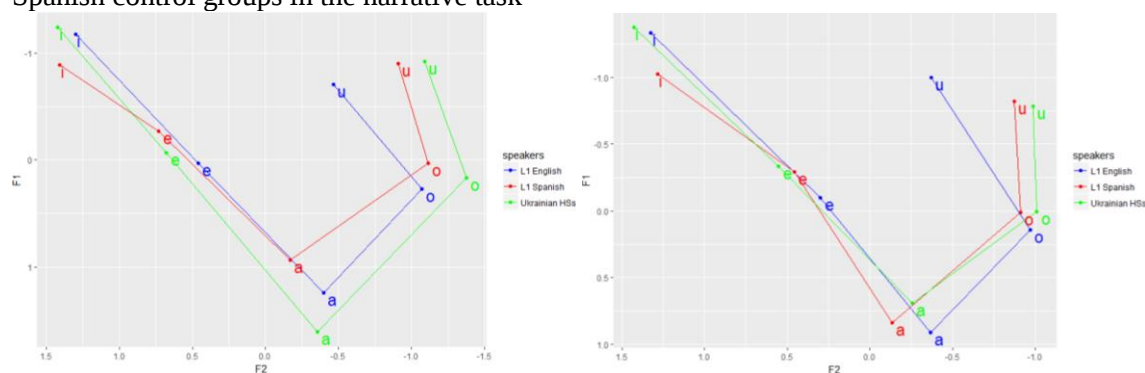


Figure 4.34. Stressed and unstressed vowel production by the Ukrainian HSs, and the L1 English and L1 Spanish control groups in the narrative task



As in the narrative task, the Ukrainian HSs produced a well distributed token count among the five vowels in the picture-naming task, with /a/ being the most represented segment and /u/ the least represented (Table 4.31). All speakers produced at least four tokens of each vowel. In this task, the vowel shape reflects more closely the distribution displayed by the L1 English control group than the results of the L1 Spanish speakers (Figure 4.35). The high segment /u/ undergoes a greater degree of fronting than it did in the narrative task, mimicking the L1 English speakers' results. Speaking of which, a comparison of the Ukrainian HSs and the control groups' results can be viewed in Figure 4.36. All vowels are reduced in unstressed position (Table 4.32). The segments /i/, /e/, and /a/ are more reduced in the picture-naming task than in the narrative task. The segment /o/ is slightly less reduced and /u/ shows the same amount of reduction in both tasks. Spanish vowels were more reduced by the Ukrainian HSs than by the L1 Spanish control group (with the exception of /u/) and display a comparable degree of reduction as those of the L1 English speakers. Finally, the Ukrainian HSs' vowels show a very similar degree of dispersion from the centroid to the one that was seen in the L1 Spanish speakers' data (greater dispersion was observed for /i/ and /e/). Once again, similar to the two control groups and the previous task, a two-sample t-test showed that stress was significant for F2 ($p < .011$) measurements, but not for F1 ($p < .654$) values in the Ukrainian HSs' data.

Table 4.31. Mean frequencies (Hz) in Spanish produced by the Ukrainian HSs in the picture-naming task

Phoneme	Mean / SD	Mean / SD stressed position	Stressed tokens	Mean / SD unstressed position	Unstressed tokens	Total tokens
/i/	F1: 412.6 / 47.6	F1: 412.9 / 51.8	30	F1: 412.3 / 43.8	29	59
	F2: 2464.2 / 330.9	F2: 2547 / 308.1		F2: 2378.4 / 337		
/e/	F1: 561.6 / 102.3	F1: 608.6 / 115.1	36	F1: 530.2 / 79.6	54	90
	F2: 2074.9 / 211.6	F2: 2102.4 / 198.8		F2: 2056.6 / 219.7		
/a/	F1: 719.1 / 126.1	F1: 820.3 / 93.3	32	F1: 693.2 / 120.5	125	157
	F2: 1669.8 / 191.2	F2: 1610.2 / 146.8		F2: 1685.1 / 198.6		
/o/	F1: 543.8 / 85.7	F1: 551.4 / 68.8	22	F1: 541.2 / 91.1	64	86
	F2: 1173.9 / 247.7	F2: 1099.6 / 192.3		F2: 1199.5 / 260.5		
/u/	F1: 427.8 / 51.8	F1: 413.6 / 47.5	24	F1: 441.3 / 53.1	25	49
	F2: 1435 / 364.3	F2: 1441.7 / 330.5		F2: 1428.6 / 400.8		

Table 4.32. Euclidean distance measurements in the Spanish vowels of the Ukrainian HSs in the picture-naming task

Phoneme	Distance between stressed and unstressed vowels	Distance from centroid	Phonemes	Distance between vowel pairs
/i/	0.4	1.7	/i/ - /e/	1.3
/e/	0.5	0.7	/e/ - /a/	1.4
/a/	1	1.3	/a/ - /o/	1.6
/o/	0.3	1.2	/o/ - /u/	1
/u/	0.2	1	/u/ - /i/	2.1

Figure 4.35. Mean frequencies (Hz) in Spanish produced by the Ukrainian HSs in the picture-naming task

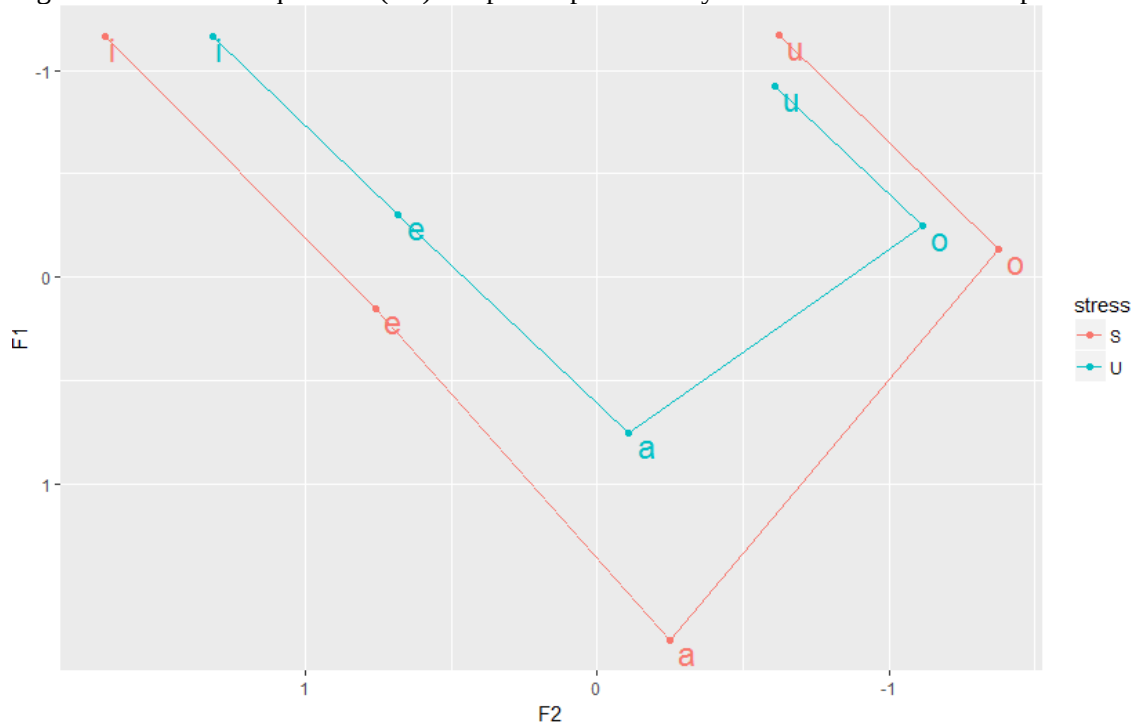
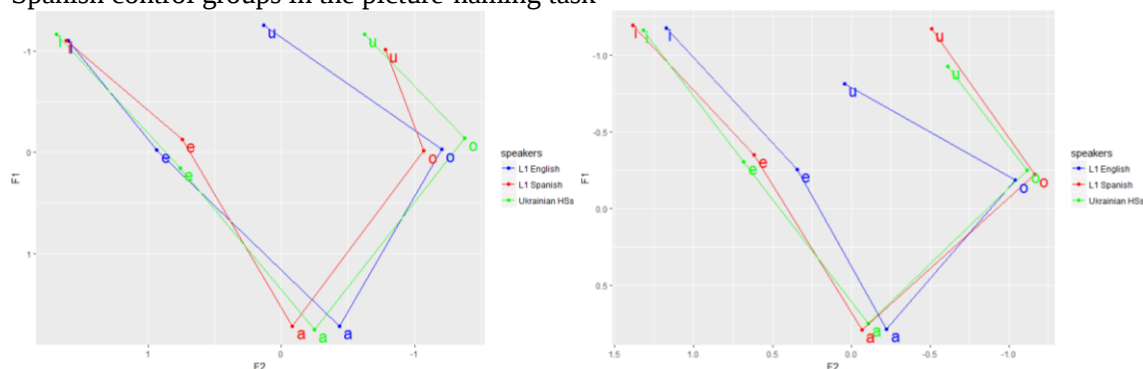


Figure 4.36. Stressed and unstressed vowel production by the Ukrainian HSs, and the L1 English and L1 Spanish control groups in the picture-naming task



As in the picture-naming task, the general vowel shape of the Ukrainian HSs in the sentence-reading task resemble more closely the stressed vowel distribution observed in the L1 English speakers' data (Figure 4.37). For instance, the high vowel /u/ once again displays fronting, however, not to same degree as in the L1 English control group's results. Also, the middle vowel /e/ is not centralized as it was in the L1 Spanish speakers' production. However, the low segment /a/ is positioned more closely to the L1 Spanish control group's /a/. A comparison of the Ukrainian HSs' to the control groups' productions can be viewed in Figure 4.38. As in the previous two tasks, unstressed vowels undergo reduction (Table 4.34); /a/ is the most reduced segment, while /i/ is the least reduced. The vowels in the sentence-reading are more reduced than in the narrative elicitation, but less reduced than those of the picture-naming task. In comparison to the control groups' results, the Ukrainian HSs produced the most reduced /a/ and /o/ segments and the least reduced /i/ vowel (which experienced the same degree of reduction in the L1 English speakers' production). Finally, similar to the L1 Spanish control group, but not the L1 English speakers, a two-sample t-test showed that stress was statistically significant for F1 ($p < .000525$) values (tongue height), but not for F2 ($p < .0555$) measurements (tongue backness) in the sentence-reading task completed by the Ukrainian HSs.

Table 4.33. Mean frequencies (Hz) in Spanish produced by the Ukrainian HSs in sentence-reading task

Phoneme	Mean / SD	Mean / SD stressed position	Stressed tokens	Mean / SD unstressed position	Unstressed tokens	Total tokens
/i/	F1: 381.6 / 46.3	F1: 386.9 / 42.3	101	F1: 377.4 / 48.9	129	230
	F2: 2458 / 358.7	F2: 2481.8 / 351.7		F2: 2439.3 / 364.3		
/e/	F1: 569.2 / 93.9	F1: 601 / 101.3	101	F1: 544.6 / 79.8	131	232
	F2: 2058.8 / 209.6	F2: 2085.3 / 173.2		F2: 2038.3 / 232.4		
/a/	F1: 715 / 126.3	F1: 797.9 / 120.2	141	F1: 676 / 109.3	300	441
	F2: 1641.9 / 163	F2: 1612.9 / 145.4		F2: 1655.6 / 169.1		
/o/	F1: 567 / 69.2	F1: 587 / 63.8	117	F1: 560.8 / 69.7	375	492
	F2: 1227 / 280.8	F2: 1094.9 / 219.9		F2: 1268.3 / 285.3		
/u/	F1: 426.1 / 46.8	F1: 432.4 / 48.3	98	F1: 420.7 / 45.1	116	214
	F2: 1290.8 / 365.9	F2: 1225.5 / 368.2		F2: 1345.9 / 356.2		

Table 4.34. Euclidean distance measurements in the Spanish vowels of the Ukrainian HSs in the sentence-reading task

Phoneme	Distance between stressed and unstressed vowels	Distance from centroid	Phonemes	Distance between vowel pairs
/i/	0.1	1.8	/i/ - /e/	1.6
/e/	0.4	0.7	/e/ - /a/	1.3
/a/	0.9	1.3	/a/ - /o/	1.3
/o/	0.4	1	/o/ - /u/	1.1
/u/	0.3	1.2	/u/ - /i/	2.3

Figure 4.37. Mean frequencies (Hz) in Spanish produced by the Ukrainian HSs in the sentence-reading task

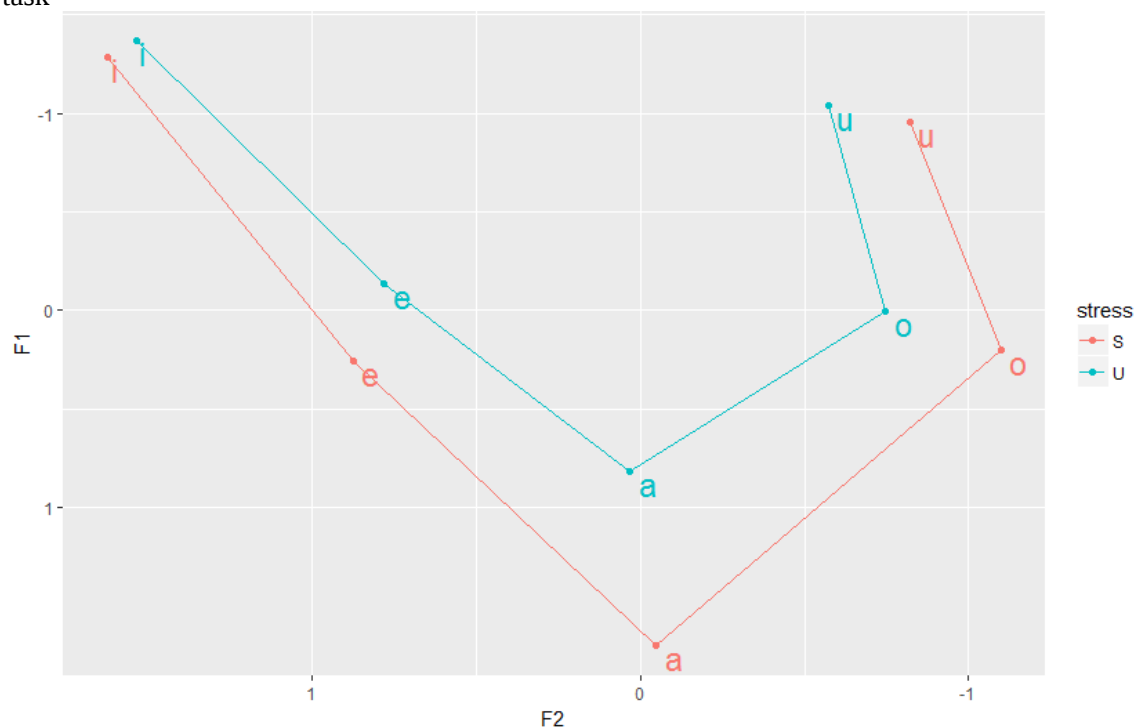
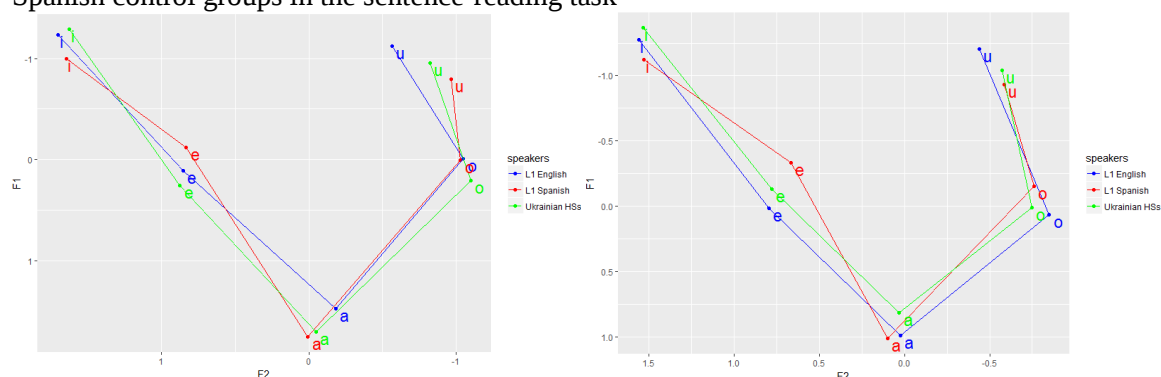


Figure 4.38. Stressed and unstressed vowel productions by the Ukrainian HSs, and the L1 English and L1 Spanish control groups in the sentence-reading task



As in the picture-naming task, the Ukrainian HSs vowel space produced in the nonce words reading task reflects more closely the vowel distribution produced by the L1 English control group rather than that of the L1 Spanish speakers' (Figure 4.39). For example, while the L1 Spanish speakers produced a fronted realization of /u/, the Ukrainian HSs, like the L1 English participants, do not centralize the high vowel in stressed position. Also, the high front segment /i/ was produced with a higher realization, similar to the L1 English speakers' data. Figure 4.40 summarizes the Ukrainian HSs' and the control groups' results. The unstressed vowel distribution shows evidence of vowel reduction in the unstressed context (Table 4.36). While the segments /i/, /e/, and /a/ are fronted, the vowels /u/ and /o/ are raised; /u/ shows very minimal centralization and /o/ was produced further back than its stressed counterpart. The vowel /a/ is the most reduced in this task, while /u/ is the least reduced vowel. The degree of reduction produced in the nonce words reading task is generally greater than the reduction observed in the narrative and sentence-reading tasks (with the exception of /a/ and /u/), but it is smaller than the reduction in the picture-naming task (with the exception of /o/). The Ukrainian HSs produced less unstressed vowel reduction than the L1 Spanish control group. The vowels /a/ and /o/ are more reduced in the HSs' production than in the L1 English speakers' data, while the segments /i/ and /u/ are less reduced and /o/ is similarly reduced. Reflecting the control groups' results, as

well as the previous task's outcome, a two-sample t-test revealed that stress was significant for F1 ($p < 2.27 \cdot 10^{-7}$) values, but not for F2 ($p < .404$) values in the Ukrainian HSs' data.

Table 4.35. Mean frequencies (Hz) in Spanish produced by the Ukrainian HSs in the nonce words reading task

Phoneme	Mean / SD	Mean / SD stressed position	Stressed tokens	Mean / SD unstressed position	Unstressed tokens	Total tokens
/i/	F1: 385.9 / 45	F1: 385.7 / 49.8	28	F1: 386 / 41.1	32	60
	F2: 2492.9 / 330.1	F2: 2582.8 / 399.8		F2: 2414.1 / 233.3		
/e/	F1: 560.6 / 90.6	F1: 566.1 / 94.7	38	F1: 552.9 / 85.7	27	65
	F2: 2149.7 / 232	F2: 2205.8 / 177.4		F2: 2070.7 / 276.9		
/a/	F1: 743.5 / 95	F1: 829.2 / 107.2	47	F1: 726.8 / 82.9	241	288
	F2: 1635.5 / 156.3	F2: 1610.1 / 147		F2: 1640.4 / 157.8		
/o/	F1: 575.7 / 71.6	F1: 600.6 / 70.7	36	F1: 545.7 / 61.5	30	66
	F2: 1271.6 / 259.8	F2: 1291.8 / 277.6		F2: 1247.4 / 239.1		
/u/	F1: 418.6 / 45.2	F1: 426.7 / 38.8	43	F1: 398.3 / 54.5	17	60
	F2: 1240.8 / 466.4	F2: 1237.8 / 466.7		F2: 1248.4 / 479.8		

Table 4.36. Euclidean distance measurements in the Spanish vowels of the Ukrainian HSs in the nonce words reading task

Phoneme	Distance between stressed and unstressed vowels	Distance from centroid	Phonemes	Distance between vowel pairs
/i/	0.4	1.4	/i/ - /e/	1.8
/e/	0.3	1.6	/e/ - /a/	0.9
/a/	0.6	1.3	/a/ - /o/	1.3
/o/	0.4	1	/o/ - /u/	1.1
/u/	0.1	2.8	/u/ - /i/	1.4

Figure 4.39. Mean frequencies (Hz) in Spanish produced by the Ukrainian HSs in the nonce words reading task

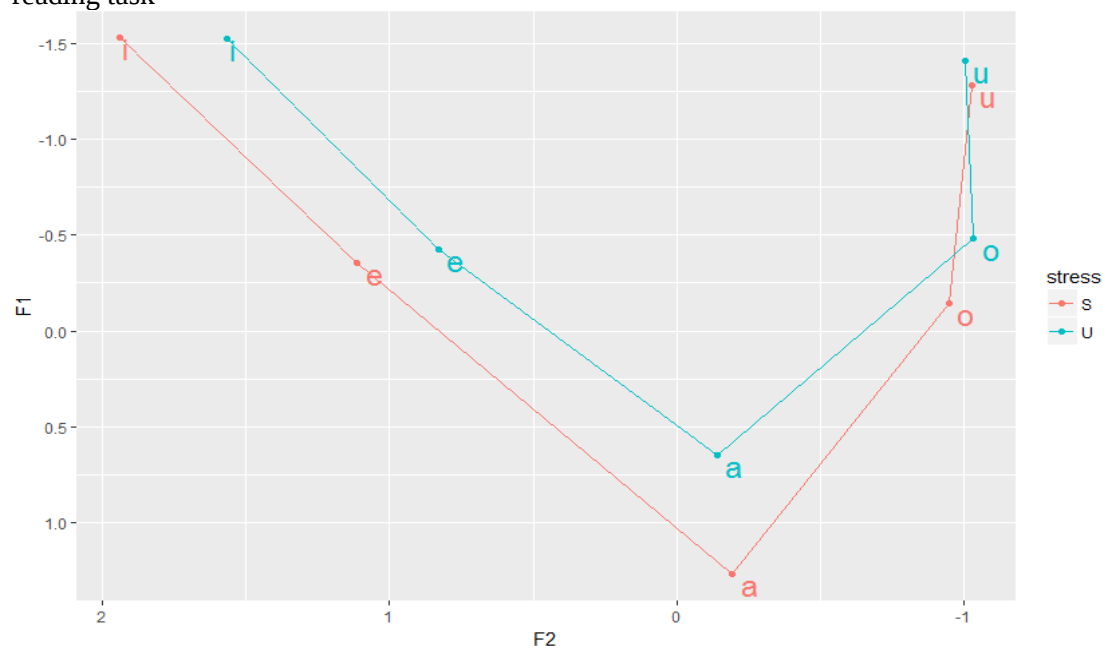
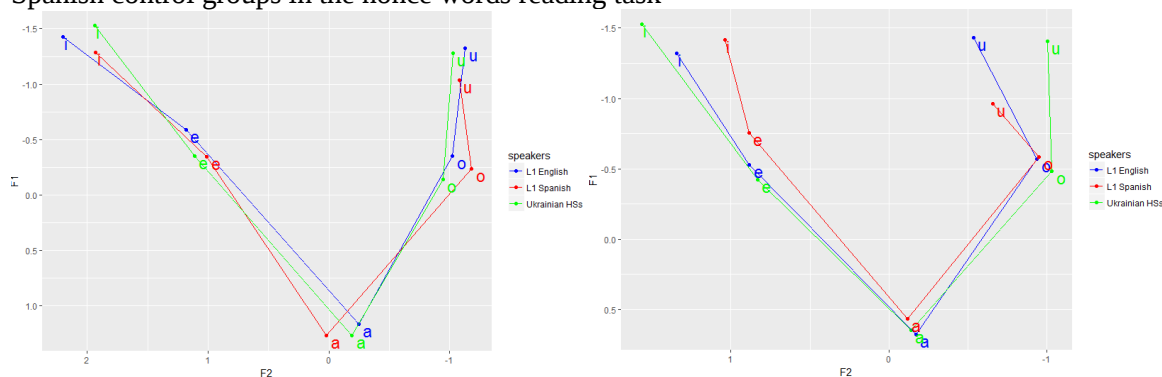


Figure 4.40. Stressed and unstressed vowel productions by the Ukrainian HSs, and the L1 English and L1 Spanish control groups in the nonce words reading task



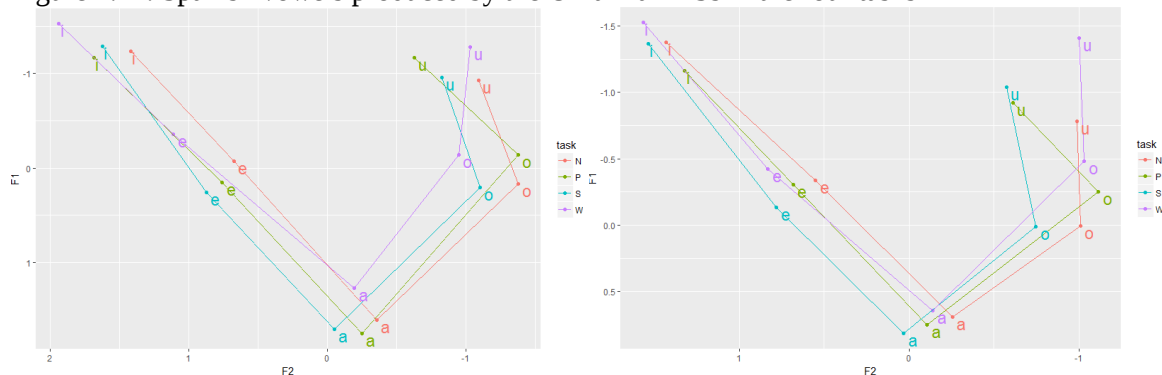
4.2.4.3.1 Summary

The Ukrainian HSs' vowel productions in all four tasks are summarized in Figure 4.41.

Stressed vowels are plotted on the left and unstressed vowels are presented on the right.

Unstressed vowels underwent reduction in all four tasks. The vowels /i/, /e/, and /a/ were most reduced in the picture-naming task, while the high vowel /u/ was most reduced in the sentence-reading task. The vowel /o/ was produced with the same degree of reduction in the narrative, sentence-reading, and nonce words reading tasks. The segment /i/ was least reduced in the narrative and sentence-reading elicitations. Next, /e/ showed the least reduction in the narrative and nonce words reading tasks, and /a/ and /u/ were least reduced in the nonce words reading task. Finally, /o/ experienced the smallest degree of reduction in the picture-naming task.

Figure 4.41. Spanish vowels produced by the Ukrainian HSs in the four tasks



The F1 and F2 frequencies were subjected to the Linear Mixed Effects Model to determine the significance of task type on the production of each vowel. Task type was shown to be statistically significant in the production of F1 values for vowels /i/ ($p < 9.401 \cdot 10^{-9}$), /a/ ($p < 2.411 \cdot 10^{-6}$), /o/ ($p < .01128$) and /u/ ($p < 4.047 \cdot 10^{-7}$) but not /e/ ($p < .1328$). Task type was also revealed to be statistically significant in the production of F2 values for /e/ ($p < .008175$), /a/ ($p < .005893$) and /o/ ($p < .005578$), but not for /i/ ($p < .447$) and /u/ ($p < .1012$). Similar to the L1 Spanish speakers' results, task type affected both the F1 and the F2 values; however, it did not consistently affect one axis over the other.

Euclidean distance from the centroid values were entered in a Linear Mixed Effects Model to determine the significance of stress on the degree of dispersion. The results revealed that task type was statistically significant for the degree of dispersion seen in the production of /e/ ($p < .01882$), /a/ ($p < .04979$), /o/ ($p < .000835$), and /u/ ($p < .006945$), but was not significant for the dispersion observed in the pronunciation of /i/ ($p < .5229$)

Finally, a Linear Mixed Effects Model was fitted for the Euclidean distance between stressed and unstressed vowels to determine whether task type influenced the production of unstressed vowel reduction. The results revealed that task type was significant for the degree of reduction observed in the pronunciation of the vowels /a/ ($p < .001364$) and /u/ ($p < .003222$), while it was not significant for the reduction displayed in vowels /i/ ($p < .06864$), /e/ ($p < .3343$) and /o/ ($p < .09691$).

Similar to the L1 English speakers' results, the acoustic evidence in the Ukrainian HSs' vowel productions does not show a clear connection between task formality and the degree of vowel reduction. Some vowels are more reduced in least controlled tasks (/i/, /e/, /a/), while other vowels (/u/, /o/) undergo greater reduction in more controlled tasks. The statistical results show

task type to be generally significant for both F1 (/i/, /a/, /o/, /u/) and F2 values (/e/, /a/, /o/), as well as the degree of dispersion (/e/, /a/, /o/, /u/); however, it is only significant in the degree of reduction for two vowels (/a/, /u/). The significance of task type in the Ukrainian HSs' data is overall more similar to that of the L1 English speakers rather than of the L1 Spanish speakers.

4.2.4.4 Polish HSs

The Polish HSs produced a total of 5,428 Spanish vowels. 761 tokens appeared in the narrative task, 756 in the picture-naming task, 2,934 in the sentence-reading task, and 977 in the nonce words reading task.

While all vowels are represented in the narrative task completed by the Polish HSs, the high back segment /u/ has a considerably lower token count than the other four vowels' (Table 4.37). Speaker P4¹⁴ did not produce any instances of /u/ and speakers P2, P3, and P10 each produced only one /u/ token. The other four vowels were produced at least three times by each participant. The Polish HSs' stressed vowel distribution closely resembles the L1 English control groups' results. For example, as in the L1 English speakers' production, the back segment /u/ is fronted in the Polish HSs' production. The position of the vowels /a/ and /o/ is also very similar to the position of these vowels in the English control group's data. The main difference between the two groups' results is the position of /i/, which, in the HSs' data, appears higher and more centered than in the L1 English speakers' vowel space. Also, the Polish HSs' /e/ shares a very similar position with L1 Spanish speakers' /e/, while the L1 English speakers produced it with a lower and more centralized realization. The vowel distributions produced by the Polish HSs and the control groups can be viewed in Figure 4.43. The unstressed vowel distribution shows an interesting treatment of vowels in the unstressed context by the Polish HSs (Figure 4.42). While

¹⁴ Individual speaker results can be found in Appendix B

the vowels /e/ and /a/ undergo the process of reduction and appear centralized in unstressed position, unstressed /i/, /o/, and /u/ were produced further away from the centroid than their stressed counterparts. This behavior reflects the Polish HSs' vowel distribution pattern in the Polish data, where the segments /i/, /i/, /ɔ/, and /u/ were further dispersed and less centralized than their stressed counterparts. This production pattern was not observed in either the Ukrainian HSs' or the control groups' results in the narrative task. Unlike the previous groups' results, a two-sample t-test revealed stress to be statistically significant for both F1 ($p < .00316$) and F2 ($p < 1.65 \cdot 10^{-7}$) values produced by the Polish HSs in the narrative task, meaning it influenced both tongue height and backness.

Table 4.37. Mean frequencies (Hz) in Spanish produced by the Polish HSs in the narrative task

Phoneme	Mean / SD	Mean / SD stressed position	Stressed tokens	Mean / SD unstressed position	Unstressed tokens	Total tokens
/i/	F1: 391.8 / 58.7	F1: 399.1 / 54.8	64	F1: 385.2 / 61.7	71	135
	F2: 2331.2 / 349.7	F2: 2298.5 / 364.4		F2: 2360.7 / 335.7		
/e/	F1: 539 / 92.4	F1: 539.7 / 97.4	88	F1: 538.4 / 88	95	183
	F2: 1993 / 272.5	F2: 2025.1 / 275.3		F2: 1963.3 / 268		
/a/	F1: 716 / 113.9	F1: 731.2 / 116.1	60	F1: 710.8 / 113.1	177	237
	F2: 1589.5 / 190.6	F2: 1556.7 / 189		F2: 1600.6 / 190.4		
/o/	F1: 595.4 / 95.5	F1: 601.1 / 100.8	31	F1: 594 / 94.5	123	154
	F2: 1249.3 / 312.4	F2: 1242.1 / 294.2		F2: 1251.1 / 318		
/u/	F1: 473.8 / 111.3	F1: 512.9 / 104.5	23	F1: 442.9 / 108.3	29	52
	F2: 1315.9 / 504.7	F2: 1410.6 / 528.2		F2: 1240.7 / 481.1		

Table 4.38. Euclidean distance measurements in the Spanish vowels of the Polish HSs in the narrative task

Phoneme	Distance between stressed and unstressed vowels	Distance from centroid	Phonemes	Distance between vowel pairs
/i/	0.2	1.7	/i/ - /e/	1.2
/e/	0.3	0.7	/e/ - /a/	1.5
/a/	0.2	1.2	/a/ - /o/	1.1
/o/	0.1	1	/o/ - /u/	0.8
/u/	0.7	0.9	/u/ - /i/	2.1

Figure 4.42. Mean frequencies (Hz) in Spanish produced by the Polish HSs in the narrative task

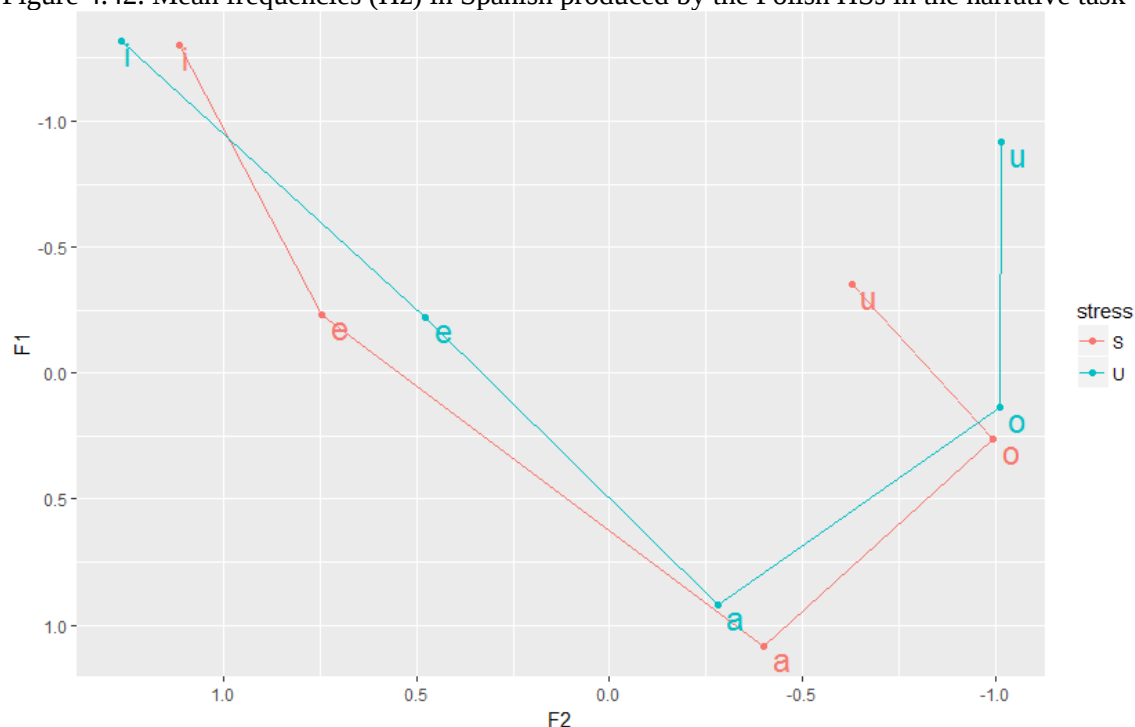
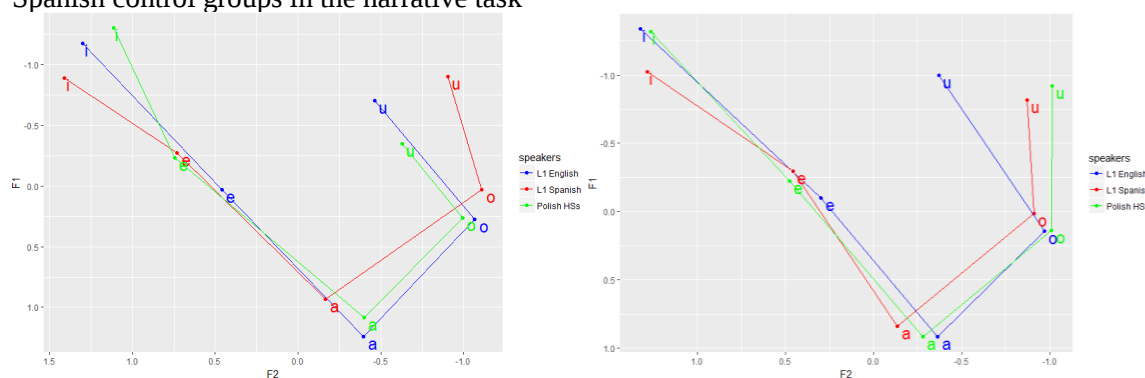


Figure 4.43. Stressed and unstressed vowel productions by the Polish HSs, and the L1 English and L1 Spanish control groups in the narrative task



The picture-naming task yielded a better distribution of tokens than the narrative task and each participant produced at least four instances of every phoneme (Table 4.39). The segment /a/ has the greatest number of tokens and /u/ is the least represented segment. The overall vowel shape produced by the Polish HSs in this task is similar to the one displayed in the narrative task, with some exceptions (Figure 4.44). For example, while /u/ is fronted, it was produced as a higher segment. The vowel /i/ is not centralized in the picture-naming task and was produced

with a more fronted realization. While the segment /o/ was produced as a higher and further back segment than the /o/ in the narrative task, /e/ experienced lowering and fronting. The phoneme /a/ was produced as lowered and with a very small degree of fronting. The vowels /i/, /a/, and /u/ were produced further away from the centroid in the present task, while /e/ and o/ appeared more dispersed in the narrative task.

The unstressed vowel distribution shows evidence of vowel reduction in unstressed position (Table 4.40). In this task, all five vowels are centralized and no unstressed vowel appears further away from the centroid than its stressed counterpart. The unstressed vowel shape of the Polish HSs' reflects more closely the L1 Spanish speakers' productions than the L1 English speakers' results. A comparison of the Polish HSs' and the control groups' results can be viewed in Figure 4.45, where we note that /i/ and /a/ are the most reduced segments, while /o/ and /u/ experience the smallest degree of reduction. In comparison to the other speaker groups, the Polish HSs show a considerably smaller degree of reduction of the segment /a/, which was more reduced by the Ukrainian HSs and the control groups in the picture-naming. Once again, a two-sample t-test showed that stress was statistically significant for both F1 ($p < .000299$) and F2 ($p < .000036$) values in the Polish HSs' picture-naming vowel productions. The effects on both tongue height and backness is result that is different from that of the other three groups.

Table 4.39. Mean frequencies (Hz) in Spanish produced by the Polish HSs in the picture-naming task

Phoneme	Mean / SD	Mean / SD stressed position	Stressed tokens	Mean / SD unstressed position	Unstressed tokens	Total tokens
/i/	F1: 394.1 / 54	F1: 393.7 / 59	60	F1: 394.5 / 48.8	56	116
	F2: 2355.7 / 250.3	F2: 2423.4 / 202.5		F2: 2283.2 / 276.9		
/e/	F1: 561.1 / 90.6	F1: 587.1 / 79.9	57	F1: 545.2 / 93.5	93	150
	F2: 1931 / 234.4	F2: 1950.1 / 188.7		F2: 1919.3 / 258.7		
/a/	F1: 707.8 / 103	F1: 750 / 109.8	51	F1: 697.7 / 99	214	265
	F2: 1555.8 / 241.8	F2: 1495.5 / 259.2		F2: 1570.2 / 235.9		
/o/	F1: 551.1 / 88.4	F1: 554.9 / 52.4	33	F1: 550 / 96.9	109	142
	F2: 1165.5 / 303.6	F2: 1104.1 / 201.2		F2: 1184.1 / 326.9		
/u/	F1: 424.5 / 51.2	F1: 420.6 / 44.2	36	F1: 427.5 / 56.3	47	83

	F2: 1385.7 / 410.5	F2: 1320.5 / 408.7		F2: 1435.7 / 409.2		
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Table 4.40. Euclidean distance measurements in the Spanish vowels of the Polish HSs in the picture-naming task

Phoneme	Distance between stressed and unstressed vowels	Distance from centroid	Phonemes	Distance between vowel pairs
/i/	0.4	1.8	/i/ - /e/	1.5
/e/	0.3	0.6	/e/ - /a/	1.3
/a/	0.4	1.3	/a/ - /o/	1.4
/o/	0.2	1.1	/o/ - /u/	1.1
/u/	0.2	1	/u/ - /i/	2.1

Figure 4.44. Mean frequencies (Hz) in Spanish produced by the Polish HSs in the picture-naming task

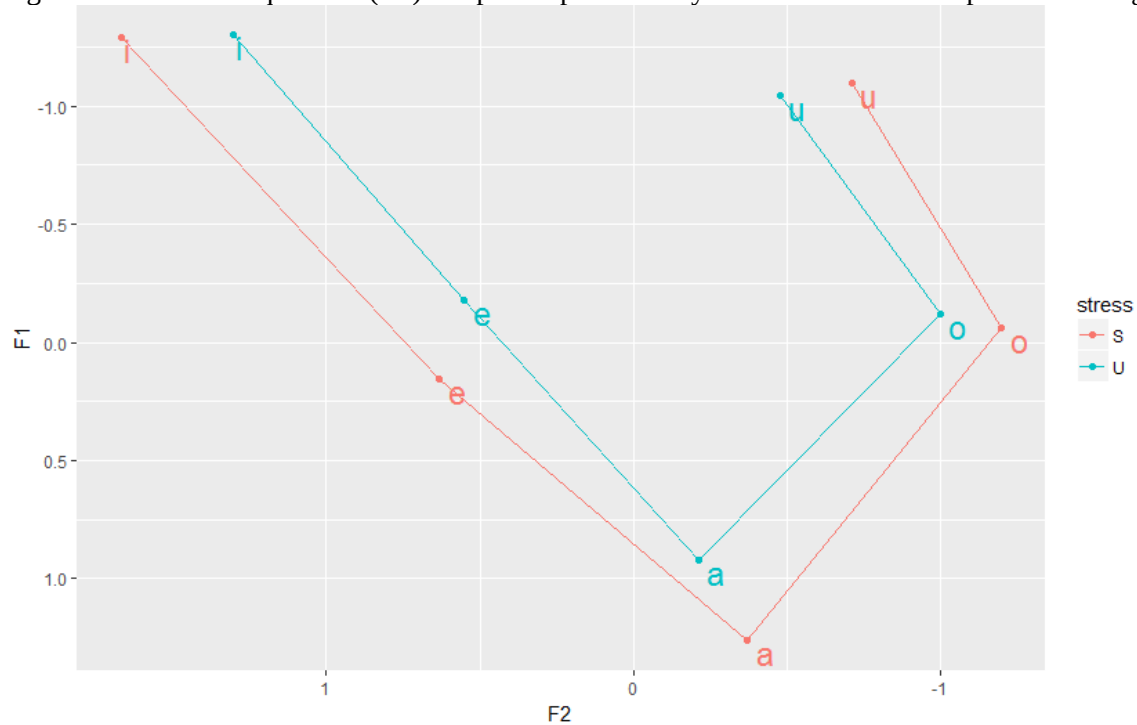
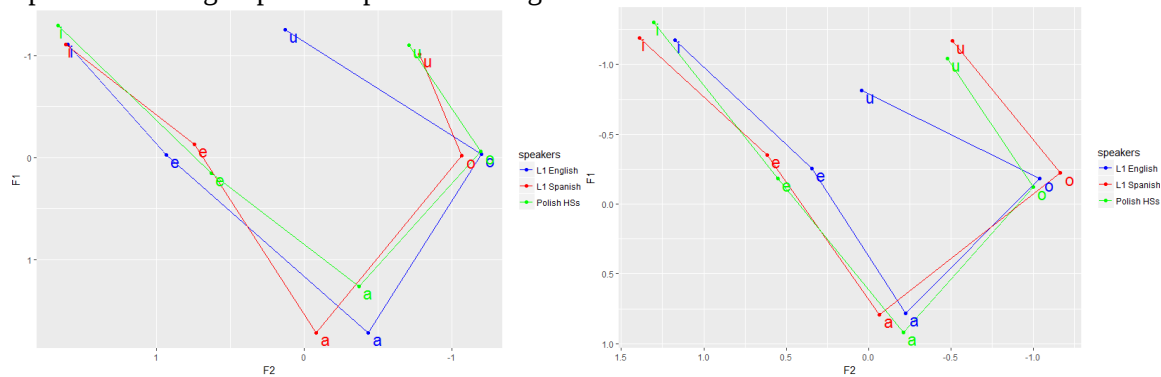


Figure 4.45. Stressed and unstressed vowel productions by the Polish HSs, and the L1 English and L1 Spanish control groups in the picture-naming task



The vowel distribution shape produced in the sentence-reading task is slightly different that the vowel shapes observed in the previous two tasks (Figure 4.46). While the front segments /i/ and /e/ shared a similar position with /i/ and /e/ in the picture-naming task, /a/, /o/, and /u/ display different positioning. For example, /a/ in the sentence-reading task appears more lowered and centralized than the same segment in the previous two tasks. The segment /o/ shares a similar height as the /o/ in the narrative task, but it appears more centered in this task. Finally, unlike in the previous two tasks, /u/ does not experience a great degree of centralization. In fact, it is less centralized than the control groups' realizations observed in this task. Finally, the segments /i/, /a/, and /o/ appear further dispersed from the centroid than in the previous two tasks. The position of the stressed front and the central segments closely reflects the productions of the L1 English speakers, while /o/ and /u/ display positioning that is different from both groups. Figure 4.47 summarizes the stressed and unstressed vowel distributions of the Polish HSs and the control groups. While unstressed vowels are reduced in the sentence-reading task, the degree of reduction displayed in this task is the smallest out of the three tasks (Table 4.42). The high front segment /i/ is the least reduced segment, while /a/ is the most reduced vowel. In fact, the Polish HSs produce the least reduced /i/, /a/, and /o/ segments out of the four speaker groups in this task. A two-sample t-test revealed stress to be statistically significant for F2 ($p < .00377$) values, but not for F1 ($p < .388$) values produced by the Polish HSs in the sentence-reading task, mimicking the results of the L1 English control group, but not the L1 Spanish speakers' or the Ukrainian HSs'.

Table 4.41. Mean frequencies (Hz) in Spanish produced by the Polish HSs in the sentence-reading task

Phoneme	Mean / SD	Mean / SD stressed position	Stressed tokens	Mean / SD unstressed position	Unstressed tokens	Total tokens
/i/	F1: 378.9 / 50.5	F1: 381.3 / 50.3	184	F1: 377 / 50.7	233	417
	F2: 2381 / 376	F2: 2384.8 / 365.7		F2: 2377.9 / 384.7		
/e/	F1: 577.5 / 86.8	F1: 596.4 / 80.7	183	F1: 562.5 / 88.6	231	414
	F2: 1888 / 238.2	F2: 1876.3 / 235.2		F2: 1897.3 / 240.7		

/a/	F1: 719.1 / 88.6	F1: 749.6 / 77.5	263	F1: 704.4 / 89.9	545	808
	F2: 1509 / 216.5	F2: 1479.3 / 194.9		F2: 1523.3 / 224.9		
/o/	F1: 589.5 / 79.5	F1: 597.4 / 65.2	210	F1: 587.1 / 83.4	682	892
	F2: 1119.5 / 238.4	F2: 1077.3 / 210.7		F2: 1132.5 / 245		
/u/	F1: 419.1 / 52.9	F1: 425.1 / 54.7	183	F1: 414 / 50.9	220	403
	F2: 1105 / 331	F2: 1026.1 / 270.1		F2: 1170.6 / 361.9		

Table 4.42. Euclidean distance measurements in the Spanish vowels of the Polish HSs in the sentence-reading task

Phoneme	Distance between stressed and unstressed vowels	Distance from centroid	Phonemes	Distance between vowel pairs
/i/	0.04	1.9	/i/ - /e/	1.8
/e/	0.2	0.6	/e/ - /a/	1.3
/a/	0.4	1.4	/a/ - /o/	1.2
/o/	0.1	1	/o/ - /u/	1.3
/u/	0.3	1.3	/u/ - /i/	2.5

Figure 4.46. Mean frequencies (Hz) in Spanish produced by the Polish HSs in the sentence-reading task

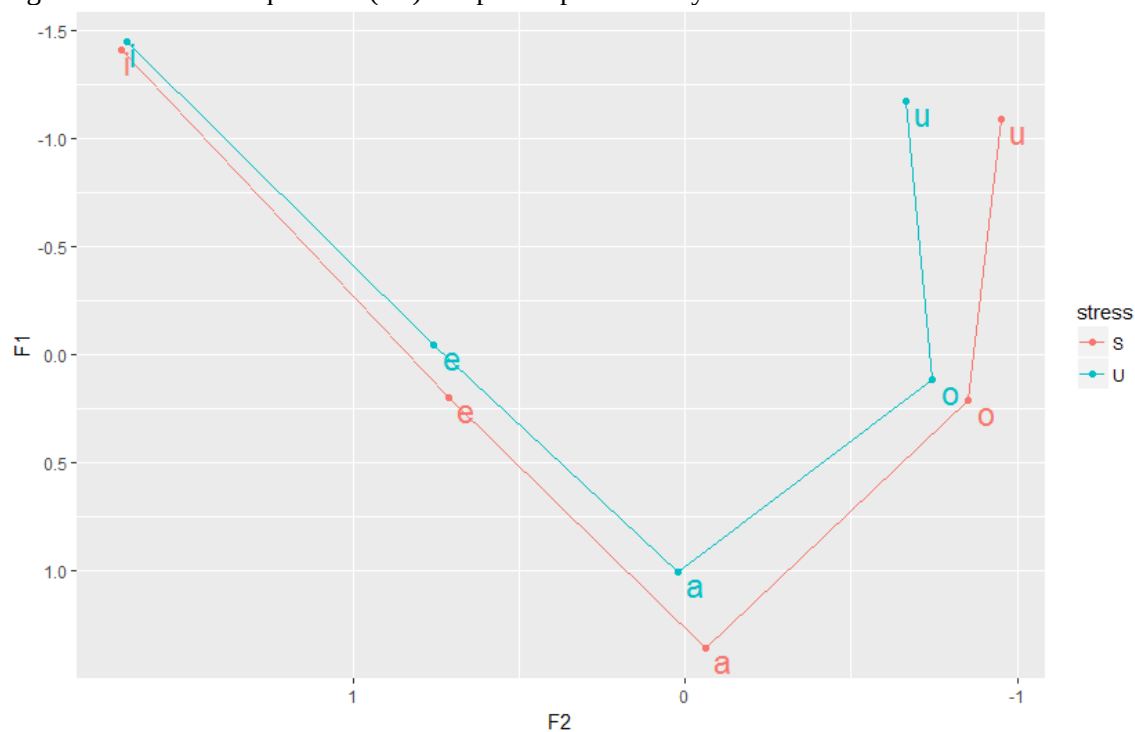
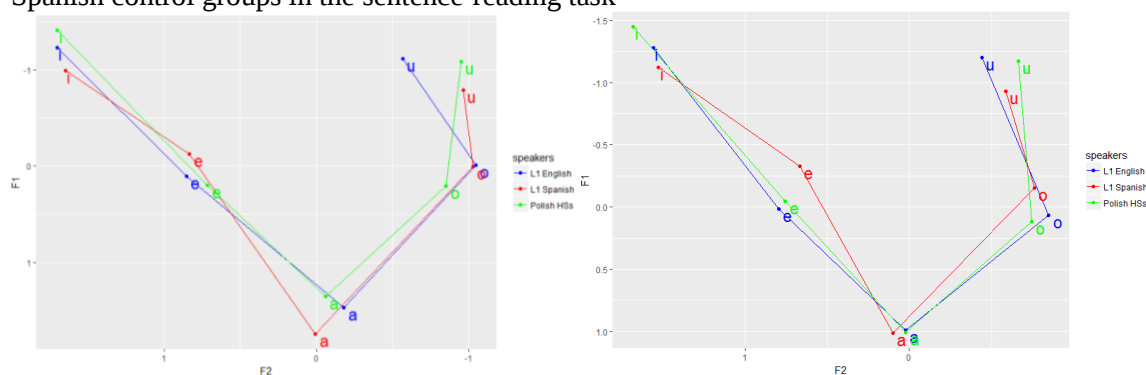


Figure 4.47. Stressed and unstressed vowel productions by the Polish HSs and the L1 English and L1 Spanish control groups in the sentence-reading task



The vowel space produced in the nonce words reading task displays some similarities with the vowel space observed in the sentence-reading task (Figure 4.48). For example, the high back vowel /u/ is not centralized in stressed position. Also, the low segment /a/ shares the central position with /a/ in the sentence-reading task, although it was produced higher in this elicitation. The other segments, however, display their own unique positioning. The phoneme /i/ was realized as the highest and the most fronted vowel in the nonce words reading task, while /e/ displays a similar height as the /e/ in the narrative task, but was produced with a more fronted realization. Finally, /o/ was produced at a similar height as the /o/ in the picture-naming task, but is more central. All five vowels display the greatest dispersion from the centroid in the nonce words reading task out of the four tasks (Table 4.44). The stressed vowel distribution of the Polish HSs is similar to the vowel space produced by the L1 English control group. The main difference between the two groups is the production of the middle segments, which appear lowered in the HSs' data than in the L1 English speakers' productions. The Polish HSs' and the control groups' vowel distributions are illustrated in Figure 4.49. All five vowels are reduced in unstressed position, but /e/ is the least reduced segment and /i/, /a/, /o/, and /u/ are all reduced to the same degree. The segments /i/, /e/, and /a/ show less reduction in the Polish HSs' production than in the L1 Spanish control group's results and the segments /o/ and /u/ are reduced to the

same extent by both groups. The vowels /i/, /a/, and /u/ are less reduced by the Polish HSs' than by the L1 English speakers, while /e/ is similarly reduced in both groups' productions. The segment /o/ was less reduced by the L1 English control group. Finally, reflecting the other groups' results, a two-sample t-test showed stress to be statistically significant for F1 ($p < 8.5 \cdot 10^{-7}$) values, but not for F2 ($p < .563$) measurements in the vowels produced by the Polish HSs, thus affecting tongue height, but not tongue backness.

Table 4.43. Mean frequencies (Hz) in Spanish produced by the Polish HSs in the nonce words reading task

Phoneme	Mean / SD	Mean / SD stressed position	Stressed tokens	Mean / SD unstressed position	Unstressed tokens	Total tokens
/i/	F1: 379 / 52.1	F1: 396.6 / 64.3	39	F1: 369.2 / 41.1	70	109
	F2: 2434.5 / 339.9	F2: 2533.6 / 384.8		F2: 2379.4 / 301		
/e/	F1: 576.8 / 88.2	F1: 589.1 / 81.7	78	F1: 551.5 / 96.5	38	116
	F2: 1967.6 / 224.6	F2: 1978.4 / 213.3		F2: 1945.3 / 247.6		
/a/	F1: 741.6 / 93.2	F1: 803.1 / 78.6	92	F1: 728.5 / 90.8	431	523
	F2: 1493.5 / 208.1	F2: 1534.5 / 158		F2: 1484.7 / 216.5		
/o/	F1: 570.1 / 73.1	F1: 602.9 / 60.1	57	F1: 540.9 / 71.6	64	121
	F2: 1124.1 / 208.5	F2: 1122.6 / 197.3		F2: 1125.4 / 219.6		
/u/	F1: 409.1 / 60.2	F1: 409.6 / 44	67	F1: 408.2 / 80.7	41	108
	F2: 1069 / 389.8	F2: 995.2 / 329.7		F2: 1189.5 / 450.6		

Table 4.44. Euclidean distance measurements in the Spanish vowels of the Polish HSs in the nonce words reading task

Phoneme	Distance between stressed and unstressed vowels	Distance from centroid	Phonemes	Distance between vowel pairs
/i/	0.4	2	/i/ - /e/	1.6
/e/	0.3	0.8	/e/ - /a/	1.5
/a/	0.4	1.4	/a/ - /o/	1.4
/o/	0.4	1.1	/o/ - /u/	1.1
/u/	0.4	1.5	/u/ - /i/	3

Figure 4.48. Mean frequencies (Hz) in Spanish produced by the Polish HSs in the nonce word reading task

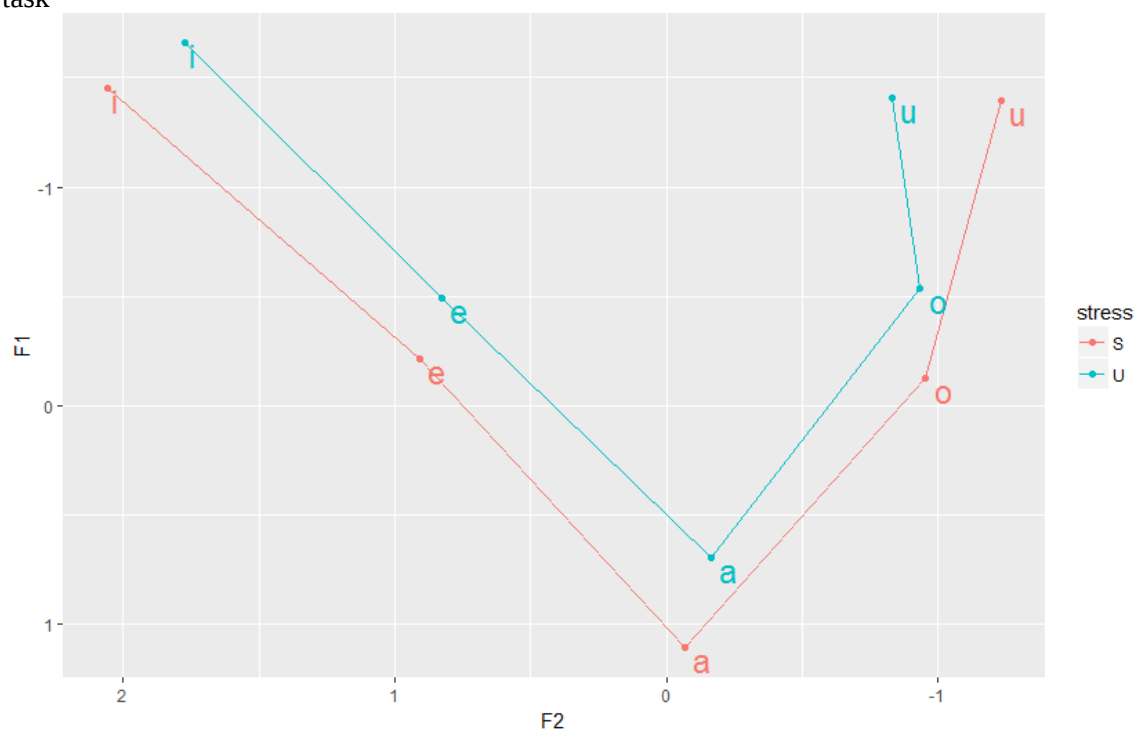
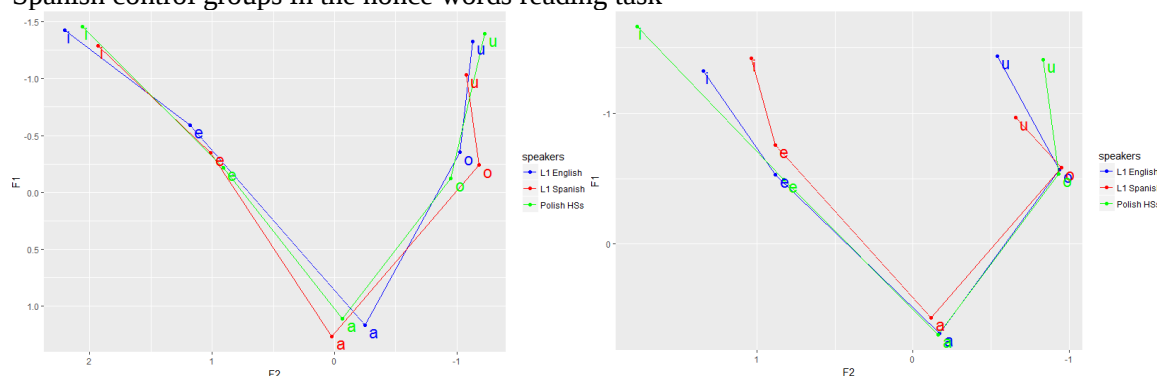


Figure 4.49. Stressed and unstressed vowel productions by the Polish HSs and the L1 English and L1 Spanish control groups in the nonce words reading task

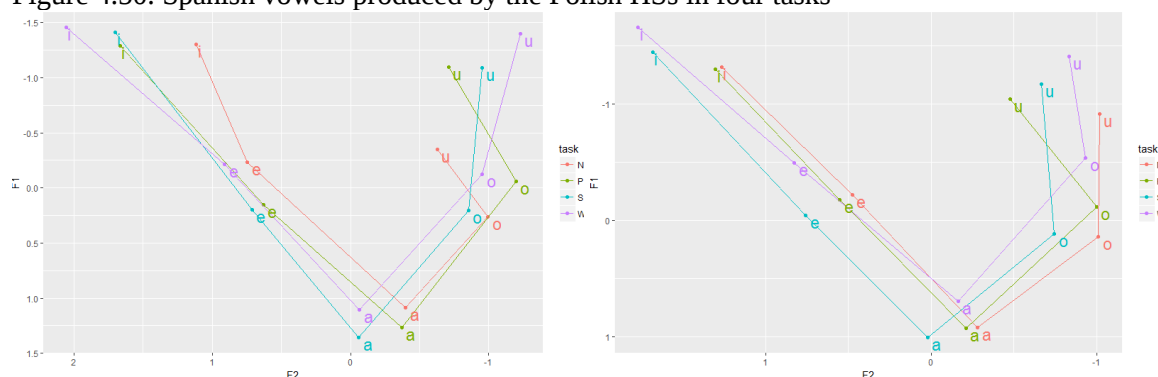


4.2.4.4.1 Summary

Figure 4.50 summarizes the Spanish vowel productions of the Polish HSs in the narrative, picture-naming, sentence-reading and nonce words reading tasks. The stressed vowels are plotted on the left and the unstressed vowels are presented on the right. The vowels were reduced in unstressed syllables in all four tasks. There was one exception, where the unstressed segments /i/, /o/, and /u/ were less reduced than their stressed counterparts in the narrative task. However, in

all other tasks, all segments underwent at least some reduction in the unstressed context: the vowels /o/ and /u/ experienced the most reduction in the nonce words reading task; the segment /i/ was most reduced in the picture-naming and nonce words reading tasks; /e/ was most reduced in the narrative, picture-naming and nonce word reading tasks; finally, /a/ experienced the greatest reduction in the picture-naming, sentence-reading, and nonce words reading elicitations. The segments /i/, /e/, and /o/ underwent the smallest degree of reduction in the sentence-reading task (also the narrative task for /o/), while /a/ experienced the smallest reduction in the narrative task, and /u/ was the least reduced in the picture-naming task. Finally, the vowels in the nonce words reading task displayed the most dispersion from centroid in comparison to the other tasks, while the vowels in the narrative task displayed the smallest degree of dispersion away from centroid.

Figure 4.50. Spanish vowels produced by the Polish HSs in four tasks



The frequency measurements were subjected to a Linear Mixed Effects Model to determine the significance of task type on the production of each vowel. The test revealed task type to be statistically significant for F1 values in the production of all five vowels: /i/ ($p < .0001313$), /e/ ($p < .000266$), /a/ ($p < 2.703 \cdot 10^{-12}$), /o/ ($6.725 \cdot 10^{-8}$), /u/ ($p < 3.121 \cdot 10^{-10}$). It also showed task type to be statistically significant for F2 values in the production of /e/ ($p < 4.109 \cdot 10^{-7}$), /a/ ($p < 1.517 \cdot 10^{-9}$), /o/ ($p < 1.022 \cdot 10^{-7}$) and /u/ ($p < 4.196 \cdot 10^{-12}$), but not in the

pronunciation of /i/ ($p < .2445$). Reflecting the L1 English speakers' results, the Polish HSs' outcome shows a more consistent effect of task type on both axes.

A Linear Mixed Effects Model was also fitted for Euclidean distance from centroid to establish whether task type was significant for the degree of dispersion observed in the production of each vowel. The results revealed that task type was statistically significant for the degree of dispersion observed in the production of all five vowels: /i/ ($p < .04654$), /e/ ($p < 8.4 \times 10^{-9}$), /a/ ($p < .002497$), /o/ ($p < .0004387$), /u/ ($p < 3.007 \times 10^{-9}$).

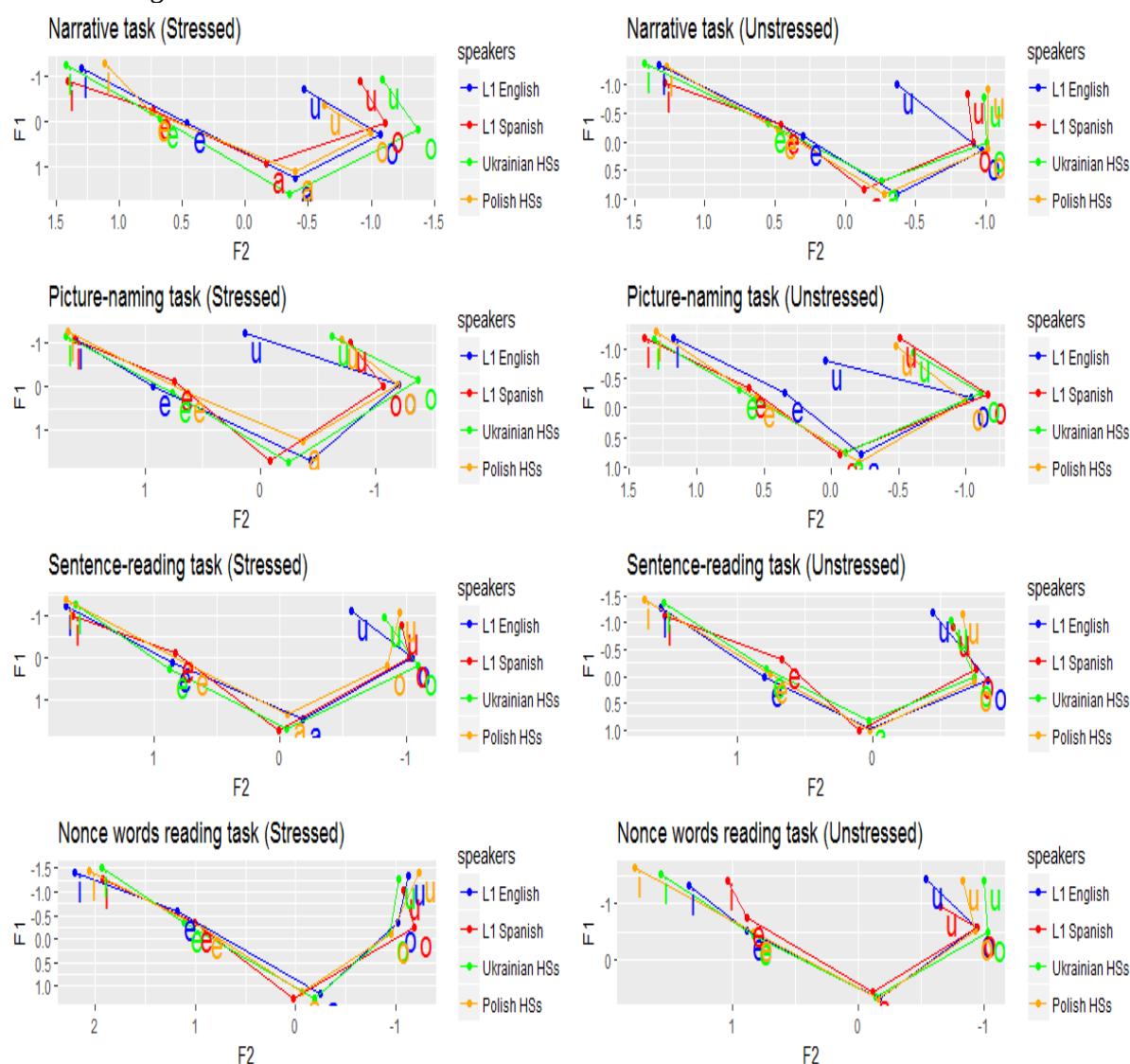
Finally, Euclidean distance between stressed and unstressed vowels was also submitted to a Linear Mixed Effects Model to determine whether task type significantly influenced the degree of reduction produced in unstressed vowels. The results confirmed task type to be statistically significant for the degree of reduction observed in the production of /i/ ($p < .004466$), /e/ ($p < .01403$) and /o/ ($p < .02406$), but not in the pronunciation of /a/ ($p < .3343$) and /u/ ($p < .09499$).

Similar to the L1 English control group and the Ukrainian HSs, the acoustic evidence in the Polish HSs' data do not demonstrate a clear relationship between task formality and the degree of reduction. However, the statistical evidence shows that task type was significant in the production of F1 values for all five vowels and F2 values for four of the vowels (/e/, /a/, /o/, /u/). Task type was also significant for the degree of dispersion for all five vowels and the degree of reduction for three vowels (/i/, /e/, /o/). The statistical results for the Polish HSs' data are very similar to those of the L1 English speakers, further highlighting the similarities between the two groups.

4.2.4.5 Summary of Spanish vowel productions

Figure 4.51 summarizes the productions of the Spanish /i e a o u/ by the Ukrainian HSs, the Polish HSs, and the L1 English and L1 Spanish control groups in the narrative, picture-naming, sentence-reading, and nonce words reading tasks.

Figure 4.51. Stressed and unstressed vowels produced by the Ukrainian HSs, the Polish HSs, and the L1 English and L1 Spanish control groups in the narrative, picture-naming, sentence-reading, and nonce words reading tasks



The mean frequency measurements were statistically analyzed through a Linear Mixed Effects Model, where *phoneme* and *speaker group* were included as fixed effects and *individual speaker* acted as random effect, in order to determine whether there were any statistically

significant differences between the means of the four groups of speakers. The statistical results are presented below according to each task. Figures 4.52 and 4.53 summarize the frequency measurements of the four groups of speakers utilizing the raw data, and grouping productions by task, but not by phoneme. The asterisk symbol (*) specifies which results are statistically significant.

The Linear Mixed Effects Model showed F1 productions to be significantly different among the four speaker groups in the narrative task ($p < .009211$). A closer examination of the four groups of participants via post-hoc pairwise comparisons with a Bonferroni adjustment revealed that the Ukrainian ($p < .02451$) and Polish HSs' ($p < .00663$) productions were significantly different from the productions of the L1 Spanish control group, with the differences between the average means of the L1 Spanish group and the HSs being 90.3 Hz and 91.7 Hz, respectively. The L1 English speakers' ($p < .05624$) results, however, did not differ significantly from the L1 Spanish base. The F2 values, on the other hand, were not shown to differ significantly among the four groups of speakers in the narrative task ($p < 0.2839$). The results show that the L1 English control group produced the closest F1 values to those produced by the L1 Spanish control group, while the Polish HSs produced F1 values that were the furthest away from the L1 Spanish base. On the other hand, the Polish HSs produced the closest F2 values to the L1 Spanish base and the Ukrainian HSs produced F2 values that differed the most from the production of the L1 Spanish control group.

A Linear Mixed Effects Model revealed no statistically significant difference between the F1 productions of the four groups of speakers in the picture-naming task ($p < .06988$). The F2 values were also shown to not differ significantly among the four speaker groups in the picture-naming task ($p < .2319$). The L1 English speakers produced F1 values that were the closest to the

L1 Spanish speakers' production, while the Ukrainian HSs produced F1 values that differed the most from the L1 Spanish base. In terms of F2 values, the Polish HSs showed the greatest similarity to the L1 Spanish speakers' results, while the Ukrainian HSs produced F2 values that differed the most from those of the L1 Spanish control group.

The difference between the F1 values produced by the four groups of participants in the sentence-reading task was also shown to be not statistically significant ($p < .05657$). However, the Linear Mixed Effects Model revealed that the difference in the productions of F2 values by the four groups of speakers in the sentence-reading task was statistically significant ($p < .02742$). The post-hoc test, however, showed that the individual comparison of the L1 English speakers ($p < 1$), the Ukrainian HSs ($p < .9229$) and the Polish HSs ($p < 1$) to the L1 Spanish control group were not significant. In the sentence-reading task, the L1 English speakers produced F1 and F2 values that were the closest to the productions of the L1 Spanish control group. Meanwhile, the Polish HSs speakers produced F1 and F2 values that were the furthest from the L1 Spanish base.

As in the picture-naming and the sentence-reading tasks, the difference between the F1 productions in the nonce words reading task was not shown to be statistically significant among the four groups of speakers ($p < .06002$). Unlike the F1 results, the Linear Mixed Effects Model revealed a difference in the productions of F2 values to be statistically significant among the four speaker groups in the nonce words reading task ($p < .01584$). However, the post-hoc test did not show a statistically significant difference between the productions of each individual speaker group and the L1 Spanish control group (L1 English: $p < 1$, Polish HSs: $p < 1$, Ukrainian HSs: $p < .27499$). In the nonce words reading task, the Polish HSs produced F1 values that were the closest to the L1 Spanish base, while the L1 English speakers produced F1 values that were the furthest from L1 Spanish speakers' result. On the other hand, the L1 English control group

produced the closest F2 values to the L1 Spanish base, while the Ukrainian HSs produced F2 values that were the furthest from the L1 Spanish speakers' productions.

Figure 4.52. F1 measurements in Spanish vowels produced by the Ukrainian HSs, the Polish HSs, and the L1 English and L1 Spanish control groups in the narrative, picture-naming, sentence-reading and nonce words reading tasks

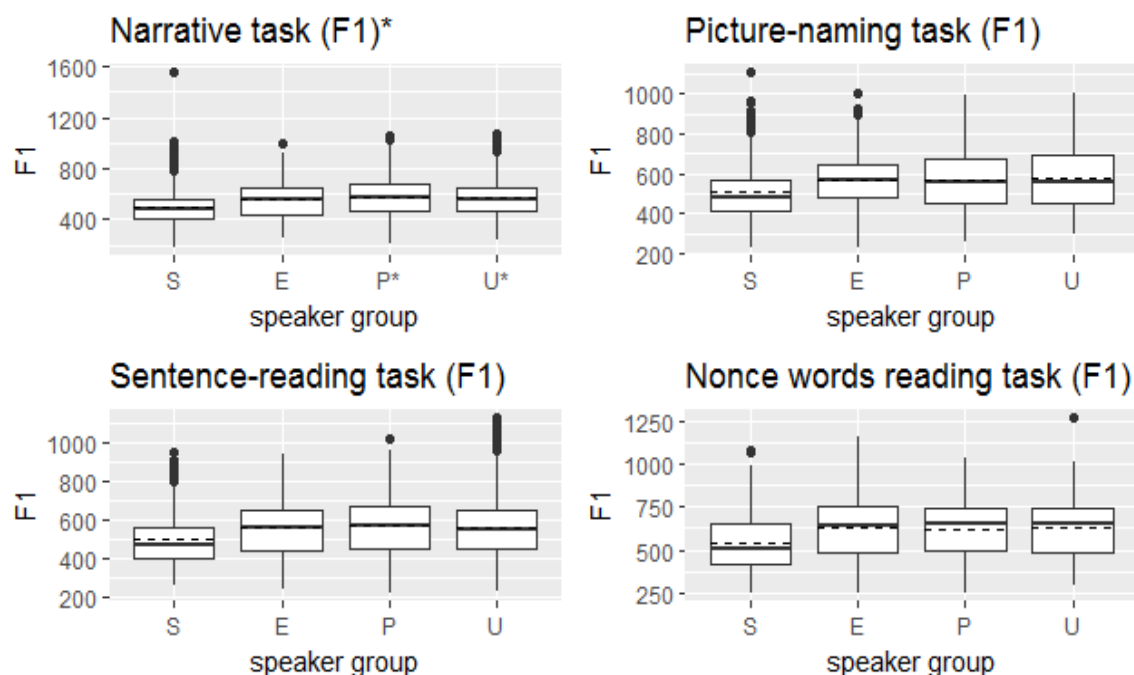
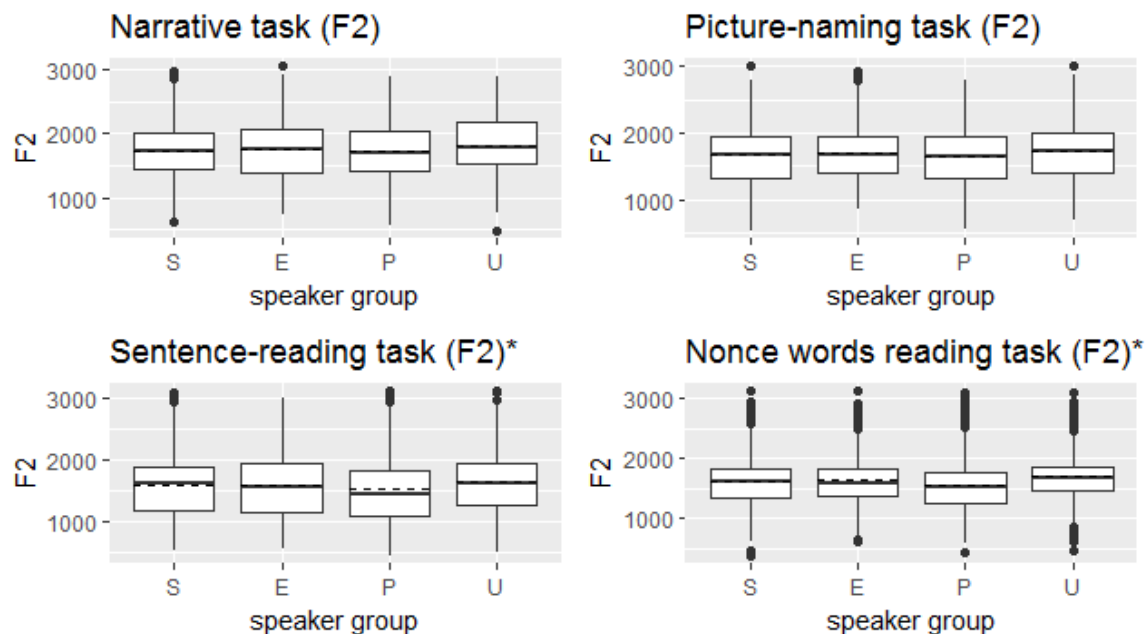
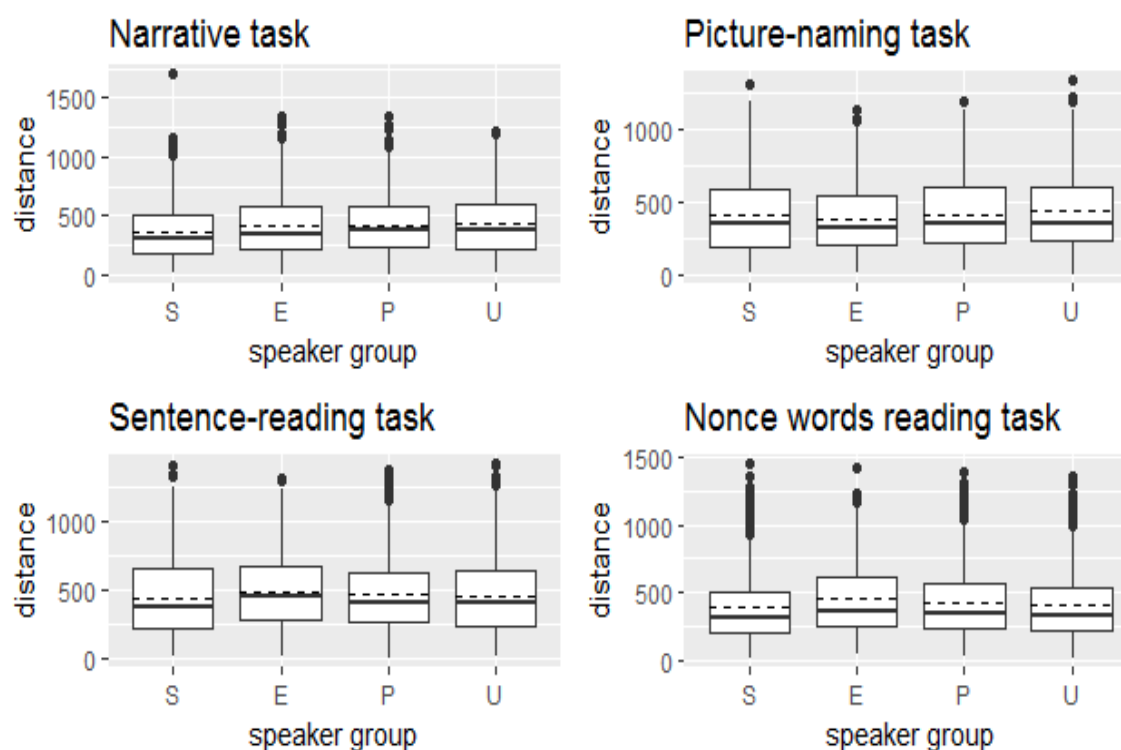


Figure 4.53. F2 measurements produced by the Spanish vowels by the Ukrainian HSs, the Polish HSs, and the L1 English and L1 Spanish control groups in the narrative, picture-naming, sentence-reading and nonce words reading tasks



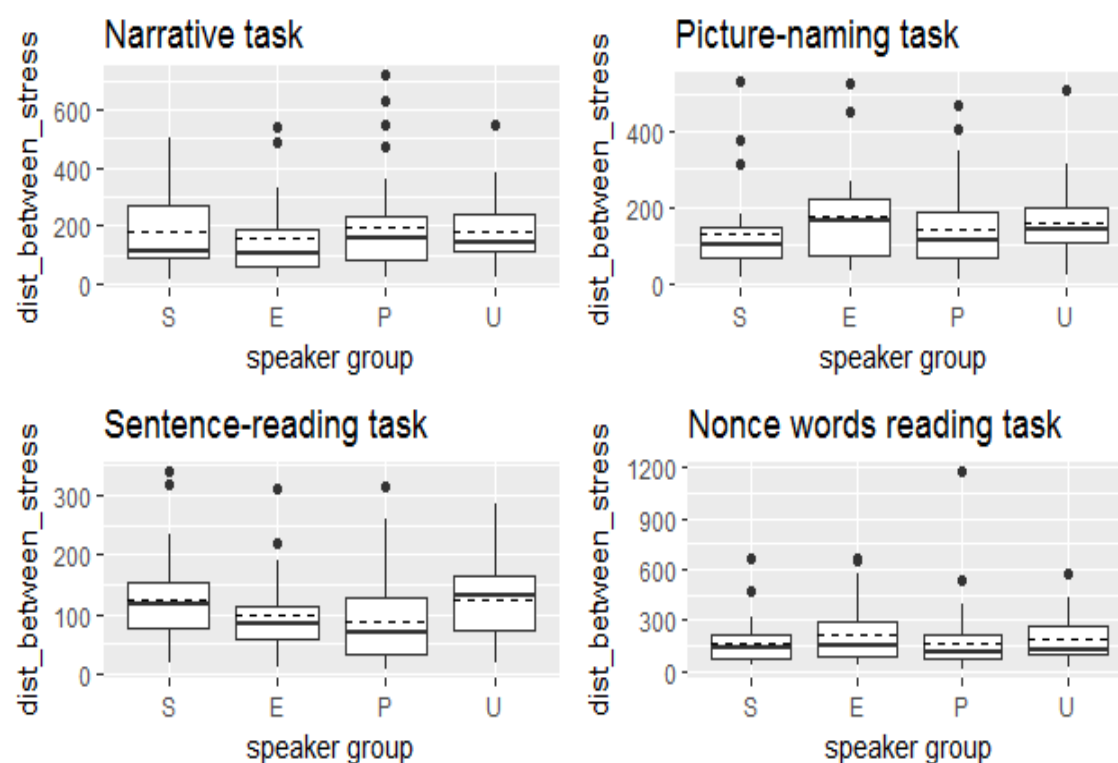
A Linear Mixed Effects Model was also fitted for the Euclidean distance from the centroid values produced by the four groups of speakers. Figure 4.54 uses raw values to summarize the Euclidean distances produced by the participant groups across the four tasks. The difference in Euclidean distances from centroid between the four groups of speakers was not statistically significant in any of the four tasks (narrative: $p < .0589$, picture-naming: $p < .358$, sentence-reading: $p < .6827$, nonce words reading: $p < .2888$). The post-hoc pairwise comparisons with a Bonferroni adjustment revealed that the Polish HSs produced distances that were the closest to the L1 Spanish base in the narrative and picture-naming tasks, while the Ukrainian HSs did so in the sentence-reading and nonce words reading elicitations. The Ukrainian HSs produced the distances that were furthest away from the L1 Spanish base in the narrative task, meanwhile L1 English speakers did so in the other three tasks.

Figure 4.54. Euclidean distances from centroid produced by the Ukrainian HSs, the Polish HSs, and the L1 English and L1 Spanish control groups in the narrative, picture-naming, sentence-reading and nonce words reading tasks



The Euclidean distances between stressed and unstressed vowels were also subjected to a Linear Mixed Effects Model. Figure 4.55 uses the raw data to summarize the groups' values across the four tasks. As with the Euclidean distances from the centroid, there were no statistically significant differences in the Euclidean distances between stressed unstressed vowels produced by the four groups of speakers in any of the four tasks (narrative: $p < 0.4893$, picture-naming: $p < 358$, sentence-reading: $p < 0.6827$, nonce words reading: $p < 0.2888$). The post-hoc test showed that the Ukrainian HSs produced mean distances that are the closest to the L1 Spanish base in the narrative and sentence-reading tasks, while the Polish HSs did so in the picture-naming and nonce words reading tasks. The L1 English speakers show the biggest discrepancy with the L1 Spanish speakers' results in the narrative, picture-naming and nonce words reading tasks, while the Polish HSs do so in the sentence-reading task.

Figure 4.55. Euclidean distances between stressed and unstressed vowels produced by the Ukrainian HSs, the Polish HSs, and the L1 English and L1 Spanish control groups in the narrative, picture-naming, sentence-reading and nonce words reading tasks



4.2.6 Summary of the main findings from the vowel analyses

The following list summarizes the main findings in the Ukrainian, Polish, English, and Spanish data analyses.

- The Ukrainian HSs did not produce the Ukrainian vowels according to the standard described in the literature. Certain segments did not resemble the standard Ukrainian vowel shape and there was evidence of vowel reduction in unstressed position.
- The Polish HSs produced the Polish vowel shape that is very comparable to the standard Polish vowel distribution; however, there was evidence of unstressed vowel reduction.
- All four speaker groups displayed unstressed vowel reduction in the production of the English vowels, with stress significantly affecting both the horizontal and the vertical axes equally. The L1 Spanish control group and the Ukrainian HSs approximated the L1 English speakers' results more closely than the Polish HSs.
- All four groups of speakers also produced unstressed vowel reduction in the pronunciation of the Spanish vowels. Stress only affected the F1 and F2 values equally in the production of the Polish HSs in the narrative and picture-naming tasks. In other groups' results, it either affected the horizontal or the vertical axis. The L1 Spanish speakers produced the smallest degree of reduction and the Ukrainian and Polish HSs produced comparable rates of reduction, which approximated the L1 Spanish results more closely than the productions of the L1 English group.
- The L1 Spanish control group produced the least unstressed vowel reduction in the pronunciation of the Spanish vowels in the narrative task, while the other three groups did so in either semi- or highly-controlled tasks.

4.3 Voiceless stops

Every subsection of this unit contains a table that summarizes the mean VOT values of each speaker group, reporting the overall means, the means associated with the independent variables of interest (stress, syllable type, and word position), standard deviations, and token counts. The figures provide a graphical representation of the groups' VOT measurements, indicating the mean (dashed line) and the median (bolded solid line). Individual variation discussion is reserved only for cases that are very relevant to the interpretation of the results. Only statistically significant independent variables are included in the discussion and they are calculated using a two-sample t-test. The statistically significant differences between the four groups of speakers are described using a Linear Mixed Effects Model and post-hoc pairwise comparisons with a Bonferroni adjustment.

4.3.1 Ukrainian voiceless stops

A total of 199 productions of /p t k/ were analyzed. Fifteen tokens that were followed by the front vowel /i/ were excluded from the analyses because they underwent palatalization.

The group's VOT averages of 24.2 ms for /p/, 23.3 for /t/, and 30.9 for /k/ (Table 4.45 and Figure 4.56) demonstrate that the Ukrainian HSs' production of voiceless stops falls within the short-lag category, which is in line with the native Slavic language norms reported in the literature (/p/ - 18 ms, /t/ - 20 ms, /k/ - 38 ms, Ringen and Kulikov 2010). The velar stops demonstrate the longest VOT measurements out of the three places of articulation and the dental segment the shortest. In order to determine the statistical significance of stress, word position, and syllable type on the voiceless stop VOTs, a two-sample t-test was conducted. While stress ($p < .48$) and syllable type ($p < .601$) showed no effect, word position proved to be statistically significant ($p < .0217$) at the $\alpha < 0.05$ level. All three phonemes were produced with longer

VOTs in word-initial position compared to word internal position, which displays shorter durations.

When looking at the individual results¹⁵, one speaker stands out from the rest of the group by producing all three stops with long-lag VOTs, while the rest of the speakers produced their stops with short-lag VOTs. In fact, the same participant produced all the outliers (data points that are three standard deviations away from the mean) in the Ukrainian HSs' data¹⁶. It is also important to note that this speaker has the highest standard deviation measurements for the three segments out of the whole group, which indicates that this particular data set is more spread out over a wider range of values than the data produced by the rest of the speakers.

Table 4.45. Mean VOT values (ms) in Ukrainian produced by the Ukrainian HSs

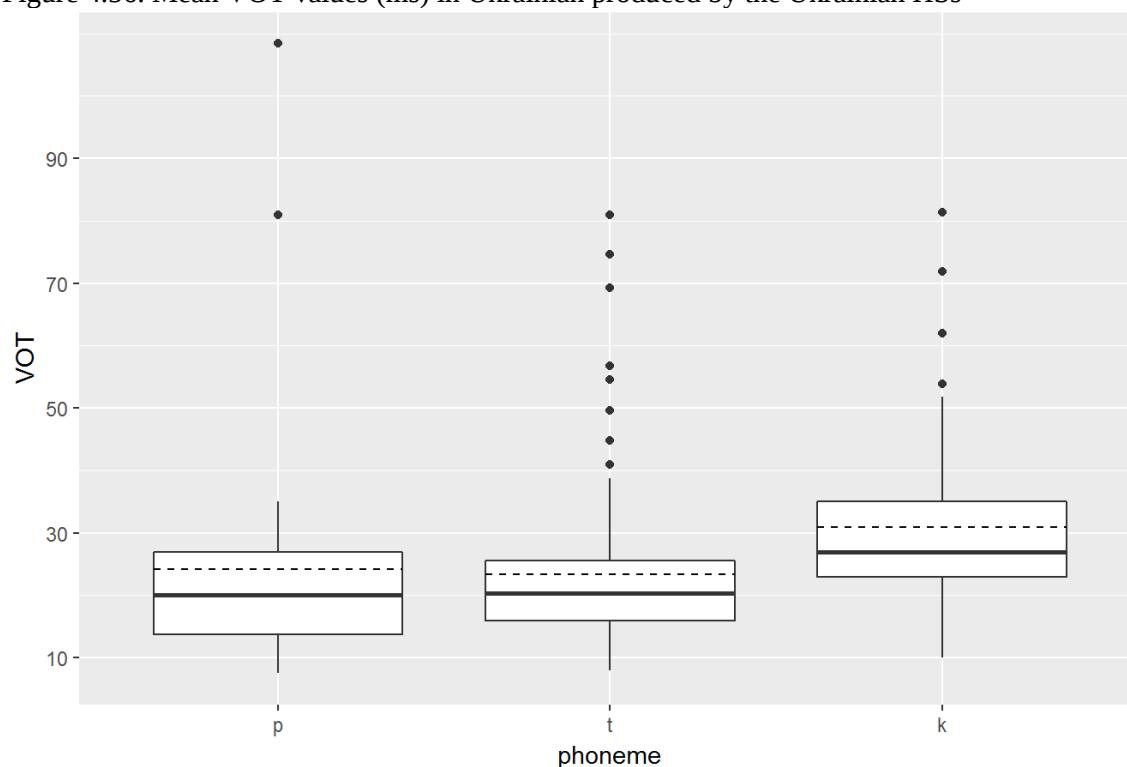
Phoneme	Mean / SD	Mean / SD by stress	Mean / SD by syllable type	Mean / SD by word position*	Total tokens
/p/	24.2 / 18.9	stressed (t<15): 27.5 / 28.2	open (t<32): 25.4 / 20	initial (t<29): 25.9 / 20.8	37
		unstressed (t<22): 21.9 / 8.2	closed (t<5): 16.5 / 3.7	internal (t<8): 18 / 6.2	
/t/	23.3 / 12.4	stressed (t<23): 19.2 / 5.8	open (t<65): 22.2 / 8.6	initial (t<65): 26 / 14.7	107
		unstressed (t<84): 24.5 / 13.5	closed (t<42): 25.1 / 16.7	internal (t<42): 19.3 / 5.6	
/k/	30.9 / 14.1	stressed (t<21): 34.4 / 14.9	open (t<47): 29.3 / 13	initial (t<9): 48 / 19.7	55
		unstressed (t<34): 28.8 / 13.3	closed (t<8): 40.1 / 17.7	internal (t<46): 27.5 / 9.9	

*significant at the $\alpha < 0.05$ level

¹⁵ The individual speaker results tables can be found in Appendix B.

¹⁶ The detailed summary of the outliers can be referenced in Appendix C.

Figure 4.56. Mean VOT values (ms) in Ukrainian produced by the Ukrainian HSs



4.3.2 Polish voiceless stops

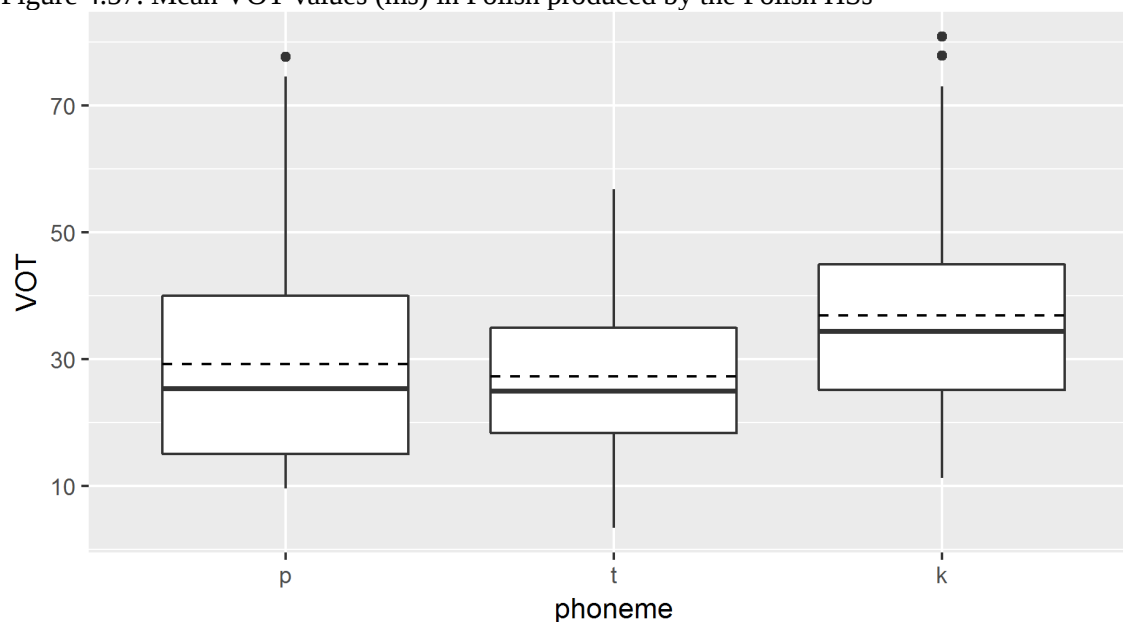
281 tokens of /p t k/ were analyzed in the Polish narrative task (Table 4.46). All segments were produced as stops and no tokens needed to be excluded from the Polish data due to their production as palatals. The VOT averages of 29.3 ms for /p/, 27.3 for /t/ and 36.9 for /k/ indicate that the Polish HSs' pronunciation of the voiceless stops is within the short-lag production range, which is in line with the native Slavic language norms reported in the literature (/p/ - 18 ms, /t/ - 20 ms, /k/ - 38 ms, Ringen and Kulikov 2010). The velar stop displays the longest VOT duration and the dental segment the shortest. In a two-sample t-test syllable type showed no statistically significant effect ($p < .678$), but both stress ($p < .014$) and word position ($p < .047$) proved to be significantly significant. All three segments have longer VOT durations in stressed and word-initial positions compared to unstressed and word internal positions, respectively.

Table 4.46. Mean VOT values (ms) in Polish produced by the Polish HSs

Phoneme	Mean / SD	Mean / SD by stress*	Mean / SD by syllable type	Mean / SD by word position*	Total tokens
/p/	29.3 / 16.5	stressed (t<60): 30.8 / 17.6	open (t<48): 27.9 / 14.3	initial (t<69): 30 / 16.8	76
		unstressed (t<16): 23.4 / 9.3	closed (t<28): 31.5 / 19.7	internal (t<7): 21.7 / 10.2	
/t/	27.3 / 11.1	stressed (t<36): 30.5 / 12.2	open (t<73): 27.6 / 11.6	initial (t<62): 28.7 / 11.2	123
		unstressed (t<87): 25.9 / 10.3	closed (t<50): 26.8 / 10.3	internal (t<61): 25.8 / 10.8	
/k/	36.9 / 15.4	stressed (t<30): 40.3 / 13.4	open (t<65): 36.8 / 16.1	initial (t<34): 42.4 / 14.1	82
		unstressed (t<52): 35 / 16.3	closed (t<17): 37.6 / 12.9	internal (t<48): 33.1 / 15.2	

*significant at the $\alpha < 0.05$ level

Figure 4.57. Mean VOT values (ms) in Polish produced by the Polish HSs



4.3.3 English voiceless stops

A total of 381 production of /p t k/ were analyzed. All four speaker groups (L1 English, L1 Spanish, Ukrainian HSs, Polish HSs) completed the narration task in English and the results are presented for each group individually.

4.3.3.1 L1 English control group

The L1 English control group produced 43 tokens of the voiceless stops (Table 4.47). The L1 English speakers' results demonstrate that the control group produced the voiceless stops with long-lag VOT (53.6 for /p/, 76.4 for /t/ and 58.7 for /k/), in line with the native English norms indicated in the literature (Nagy and Kochetov 2013). Interestingly, the alveolar stop /t/ displays the longest mean VOT in this group of speakers, while the velar segment has the second longest VOT duration. When stress ($p < .23$), syllable type ($p < .0685$) and word position ($p < .0683$) were run through a two-sample t-test, none of the independent variables proved to be significant.

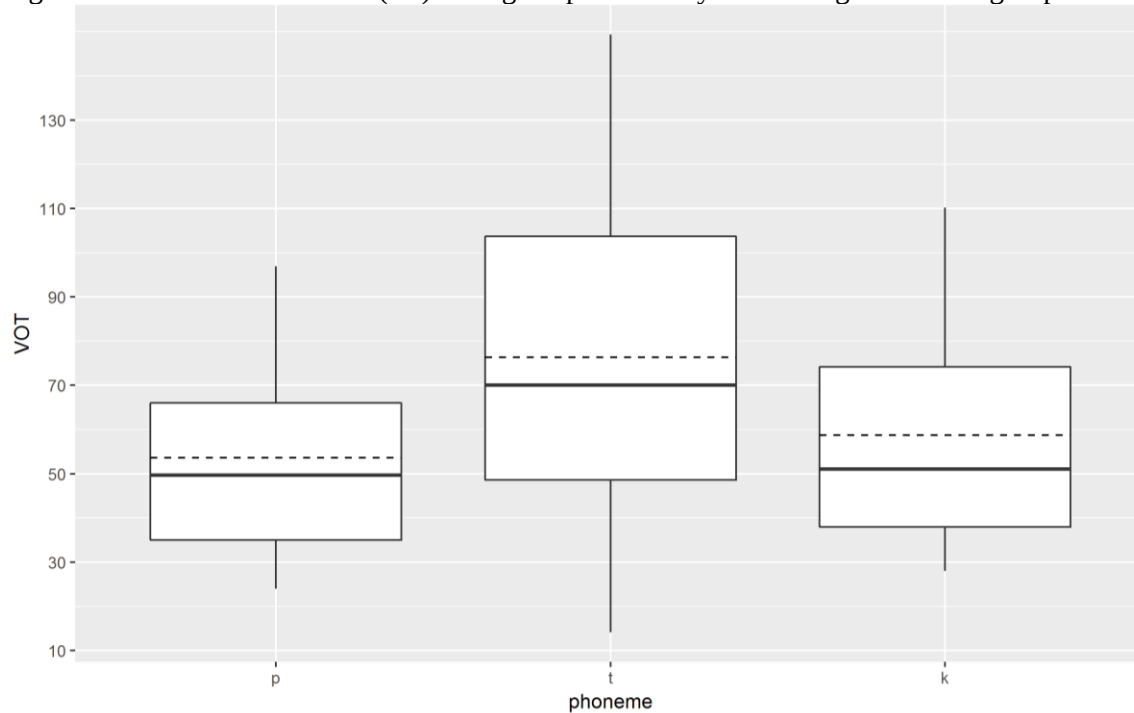
One of the most notable aspects of the L1 English control group's data is the small number of tokens. For instance, one speaker did not produce either /p/ or /k/ and has only two instances of /t/. Another participant does not have any bilabial tokens and yet another informant did not produce any velar segments, while producing only one instance of both /p/ and /t/. The limited number of tokens contributes to a complete absence of segments in certain categories (e.g., /k/ did not appear in unstressed position or in open syllables) or to a very small number of tokens in some categories (e.g., /p/ only has one token in unstressed position and in open syllables and two tokens in word-initial position). The small token count also contributes to a very high standard deviation in the group results, signaling that the data is widely spread out.

Table 4.47. Mean VOT values (ms) in English produced by the L1 English control group

Phoneme	Mean / SD	Mean / SD by stress	Mean / SD by syllable type	Mean / SD by word position	Total tokens
/p/	53.6 / 26.8	stressed (t<5): 57.7 / 27.7	open (t<1): 24 / NA	initial (t<4): 48 / 19.6	6
		unstressed (t<1): 33 / NA	closed (t<5): 59.6 / 25.1	internal (t<2): 65 / 45.2	
/t/	76.4 / 37.4	stressed (t<6): 74.1 / 20.5	open (t<13): 83.4 / 40.1	initial (t<5): 73.4 / 22.8	20
		unstressed (t<14): 77.4 / 43.4	closed (t<7): 63.4 / 30.2	internal (t<15): 77.4 / 41.8	

/k/	58.7 / 24.8	stressed (t<17): 58.7 / 24.8	open (t<o): NA	initial (t<10): 50.8 / 21.4	17
		unstressed (t<0): NA	closed (t<17): 58.7 / 24.8	internal (t<7): 70.1 / 26.4	

Figure 4.58. Mean VOT values (ms) in English produced by the L1 English control group



4.3.3.2 L1 Spanish control group

A total of 126 voiceless stop tokens were collected from the L1 Spanish control group (Table 4.48). The mean long-lag VOT values of 40.2 ms for /p/, 49.4 ms for /t/ and 64.6 ms for /k/ produced by the L1 Spanish control group fall in line with the previous findings in the literature (Nagy and Kochetov 2013). Unlike the L1 English control group, the L1 Spanish group produced the velar segment with the longest VOT. A comparison of the L1 Spanish speakers' mean VOTs to the productions of the L1 English speaker group can be viewed in Figure 4.60. As in the L1 English speakers' data, a two-sample t-test showed no statistical significance of any of the independent variables (stress: $p < .293$, syllable type: $p < .667$, word position: $p < .313$).

However, the raw numbers show that /p/ and /k/ pattern the same way regarding VOT measurements and the independent variables.

Table 4.48. Mean VOT values (ms) in English produced by the L1 Spanish control group

Phoneme	Mean / SD	Mean / SD by stress	Mean / SD by syllable type	Mean / SD by word position	Total tokens
/p/	40.2 / 24.3	stressed (t<20): 43.6 / 25.6	open (t<3): 22.1 / 4.6	initial (t<17): 44 / 24.7	25
		unstressed (t<5): 26.8 / 12.2	closed (t<22): 42.7 / 24.9	internal (t<8): 32.3 / 23	
/t/	49.4 / 22.5	stressed (t<16): 39.3 / 18.1	open (t<23): 55.1 / 21.2	initial (t<15): 39.4 / 16.6	53
		unstressed (t<37): 53.7 / 23	closed (t<30): 45 / 22.8	internal (t<38): 53.3 / 23.4	
/k/	64.6 / 27.3	stressed (t<45): 66 / 27	open (t<1): 54.9 / NA	initial (t<33): 69.1 / 30.3	48
		unstressed (t<3): 43.4 / 27.6	closed (t<47): 64.8 / 27.6	internal (t<15): 54.7 / 16.2	

Figure 4.59. Mean VOT values (ms) in English produced by the L1 Spanish control group

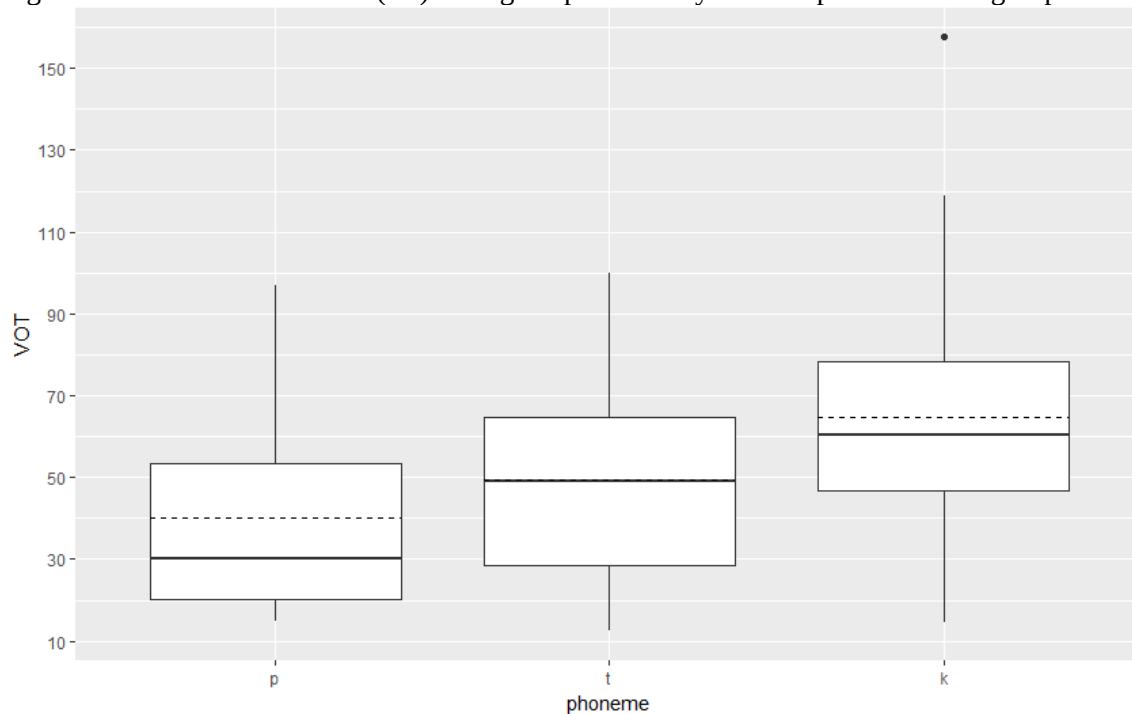
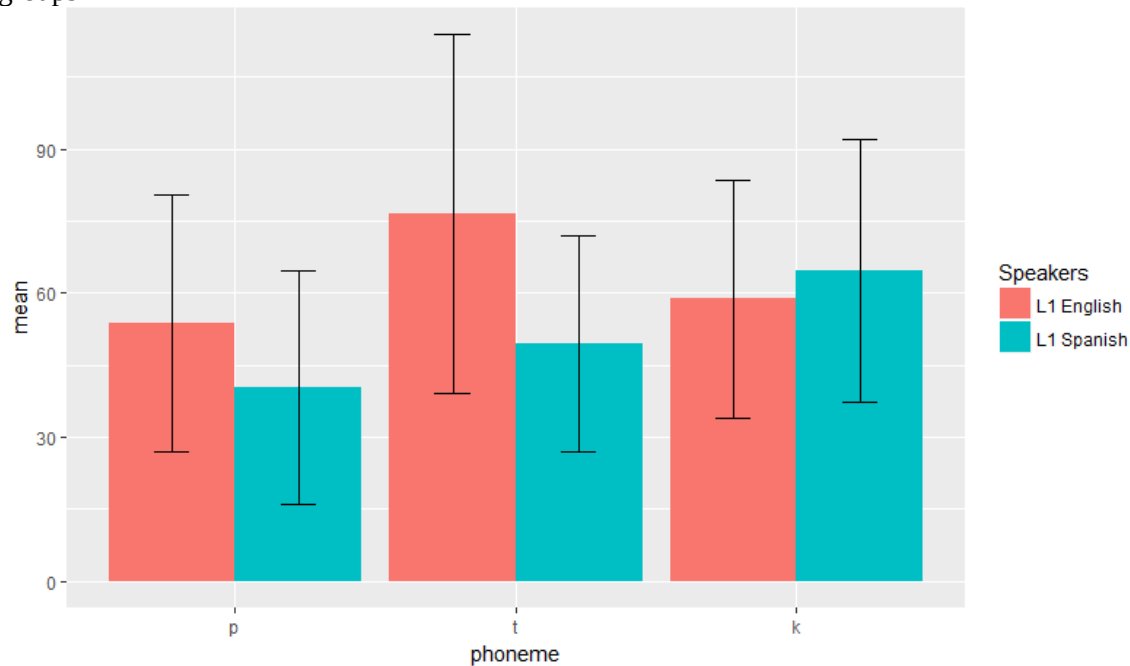


Figure 4.60. Mean VOT (ms) values in English produced by the L1 English and L1 Spanish control groups



4.3.3.3 Ukrainian HSs

84 productions of /p t k/ were analyzed in the data set of the Ukrainian HSs (Table 4.49). The Ukrainian HSs group produced all three stops with long-lag VOTs (58.2 for /p/, 62.8 for /t/, 54.8 for /k/) and the relationship between the place of articulation and VOT resembles that of the L1 English control group, where the alveolar stop /t/ displays the longest measurement. For a visual comparison of the mean VOT values in English stops produced by Ukrainian HSs and the L1 English and L1 Spanish control groups, refer to Figure 4.62. Similar to the two control groups, a two-sample t-test showed no statistical significance of any of the independent variables in the Ukrainian HSs' data (stress $p < .667$, syllable type $p < .539$, word position $p < .64$). However, we do see that all three stops display longer VOTs in stressed position.

Similar to the L1 English control group's data, the Ukrainian HSs' token count is relatively low and is not evenly distributed in all categories. For example, the velar /k/ does not appear at all in open syllables and there is only one instance of /p/ in unstressed position. Four

participants each produced only one instance of /p/, while another speaker only produced one velar segment. It is interesting to note that although the alveolar stop has the greatest token count, it also has the most spread out data set, showing the highest standard deviation in each speaker's individual results, as well as in the group results.

Table 4.49. Mean VOT values (ms) in English produced by the Ukrainian HSs

Phoneme	Mean / SD	Mean / SD by stress	Mean / SD by syllable type	Mean / SD by word position	Total tokens
/p/	58.2 / 22.4	stressed (t<9): 60.3 / 22.6	open (t<2): 58.3 / 26.8	initial (t<9): 60.3 / 22.6	10
		unstressed (t<1): 39.3 / NA	closed (t<8): 58.2 / 23.2	internal (t<1): 39.3 / NA	
/t/	62.8 / 34.7	stressed (t<18): 68 / 27.4	open (t<21): 63.1 / 41.8	initial (t<13): 63 / 30.8	46
		unstressed (t<28): 59.5 / 38.8	closed (t<25): 62.6 / 28.2	internal (t<33): 62.8 / 36.5	
/k/	54.8 / 13.6	stressed (t<27): 55.7 / 12.9	open (t<0): NA	initial (t<21): 54.3 / 12.5	28
		unstressed (t<1): 29.5 / NA	closed (t<28): 54.8 / 13.6	internal (t<7): 56.2 / 17.7	

Figure 4.61. Mean VOT values (ms) in English produced by the Ukrainian HSs

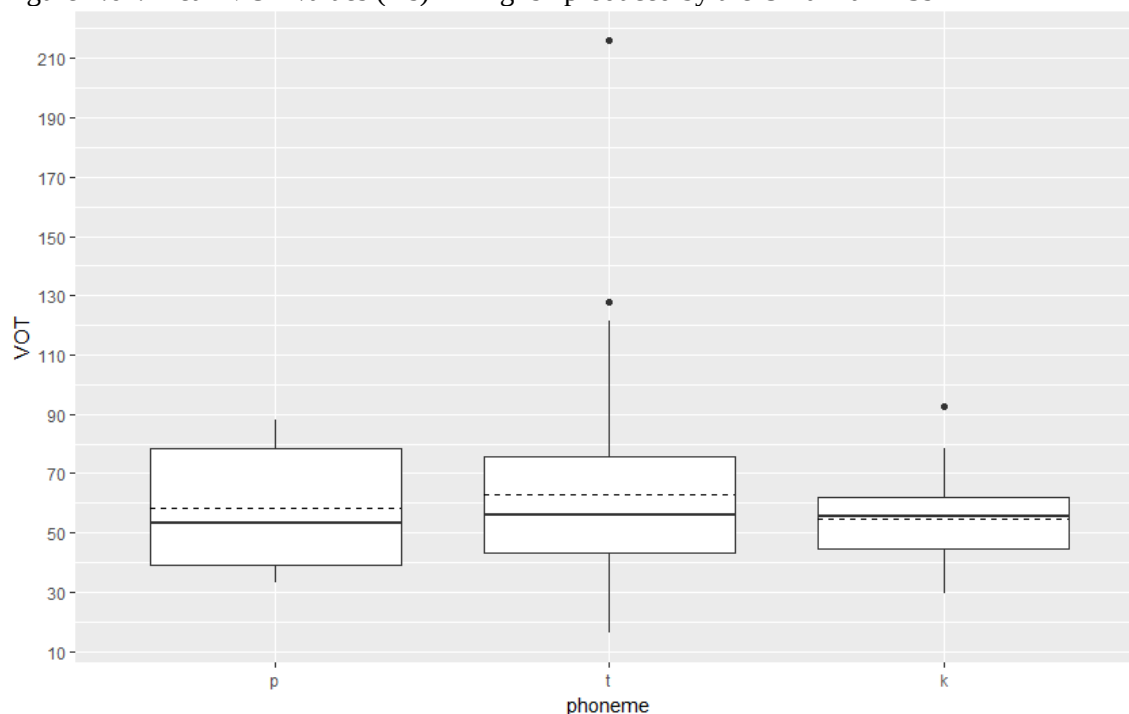
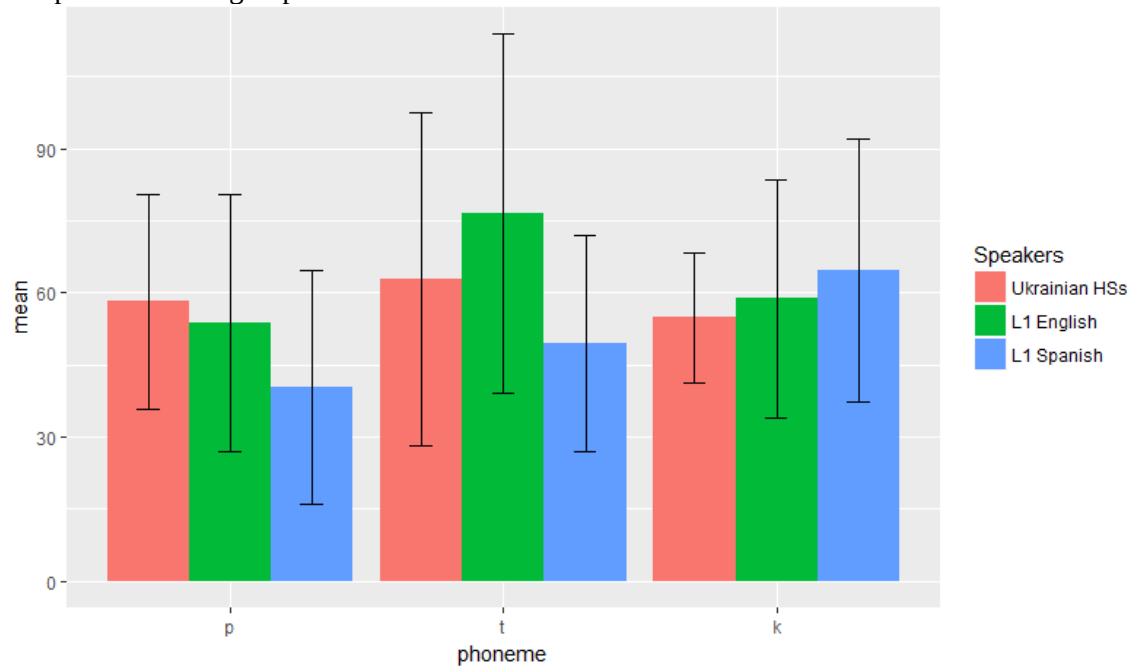


Figure 4.62. Mean VOT (ms) values in English produced by the Ukrainian HSs and the L1 English and L1 Spanish control groups



4.3.3.4 Polish HSs

The Polish HSs group produced a total of 128 tokens of /p t k/ (Table 4.50). All three voiceless stops were produced with long-lag VOTs (43.5 ms for /p/, 68.3 ms for /t/ and 58.4 ms for /k/) and the association between the place of articulation and VOT resembles that of the L1 English control group, with the alveolar segment displaying the longest VOT value. For a comparison of the mean VOT measurements produced by the Polish HSs and the L1 English and L1 Spanish control groups, refer to Figure 4.64. A two-sample t-test revealed no statistical significance of either stress ($p < .411$) or word position ($p < .388$), and a moderate significance of syllable type ($p < .0459$). While the bilabial stop was produced with a longer VOT in closed syllables, the alveolar and velar stops were produced with longer VOT values in open syllables.

The token distribution in the Polish HSs' data is slightly more uniform than in the data of the L1 English control group and the Ukrainian HSs. However, there are still instances where certain categories are underrepresented. For example, there is only one /p/ token and three /k/

tokens in open syllables. Overall, when looking at the standard deviations, the Polish HSs individual data appears to be less spread out from the mean in comparison to the other three groups, whose standard deviations reveal a more widely spread data.

Table 4.50. Mean VOT values (ms) in English produced by the Polish HSs

Phoneme	Mean / SD	Mean / SD by stress	Mean / SD by syllable type*	Mean / SD by word position	Total tokens
/p/	43.5 / 23.6	stressed (t<25): 45.6 / 23.2	open (t<1): 28.3 / NA	initial (t<19): 47.1 / 25.4	27
		unstressed (t<2): 17.2 / 5.9	closed (t<26): 44 / 23.8	internal (t<8): 34.8 / 17	
/t/	68.3 / 27.7	stressed (t<29): 69.2 / 20.8	open (t<23): 69.2 / 35.5	initial (t<28): 68.8 / 21.3	55
		unstressed (t<26): 67.4 / 34.2	closed (t<32): 67.7 / 21	internal (t<27): 68 / 33.5	
/k/	58.4 / 25.8	stressed (t<40): 58.3 / 24.1	open (t<3): 80.5 / 46.9	initial (t<35): 55.2 / 25.4	46
		unstressed (t<6): 58.6 / 38.3	closed (t<43): 56.8 / 23.9	internal (t<11): 68.4 / 25.9	

*significant at the $\alpha < 0.05$ level

Figure 4.63. Mean VOT values (ms) in English produced by the Polish HSs

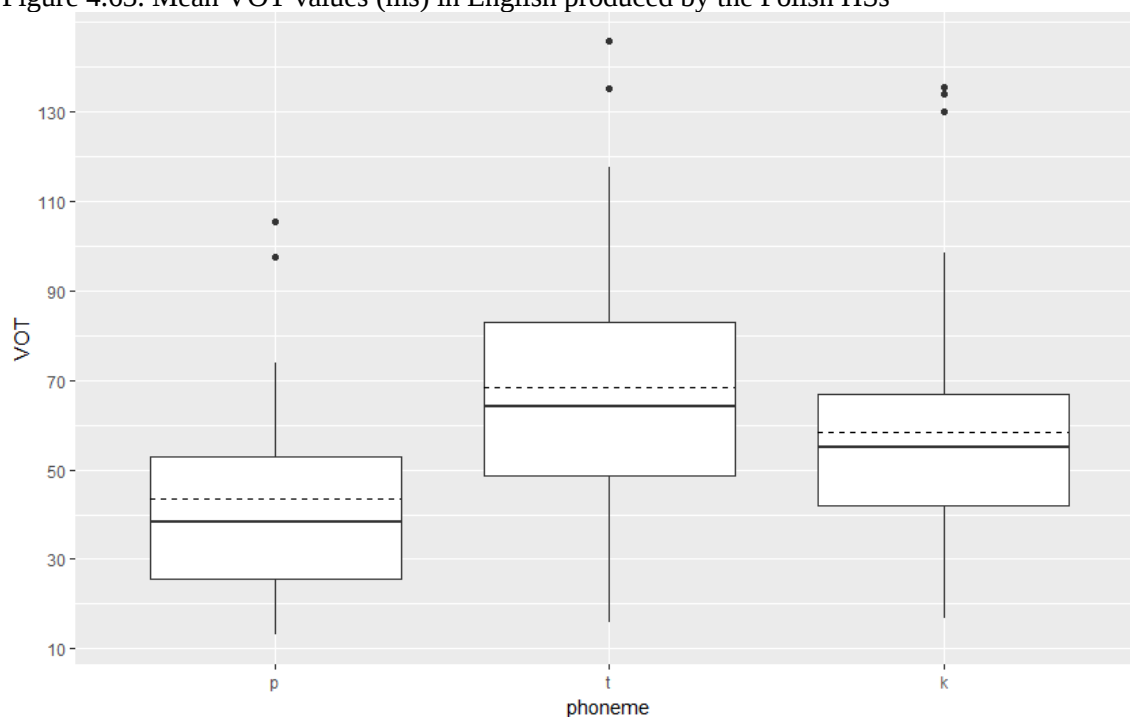
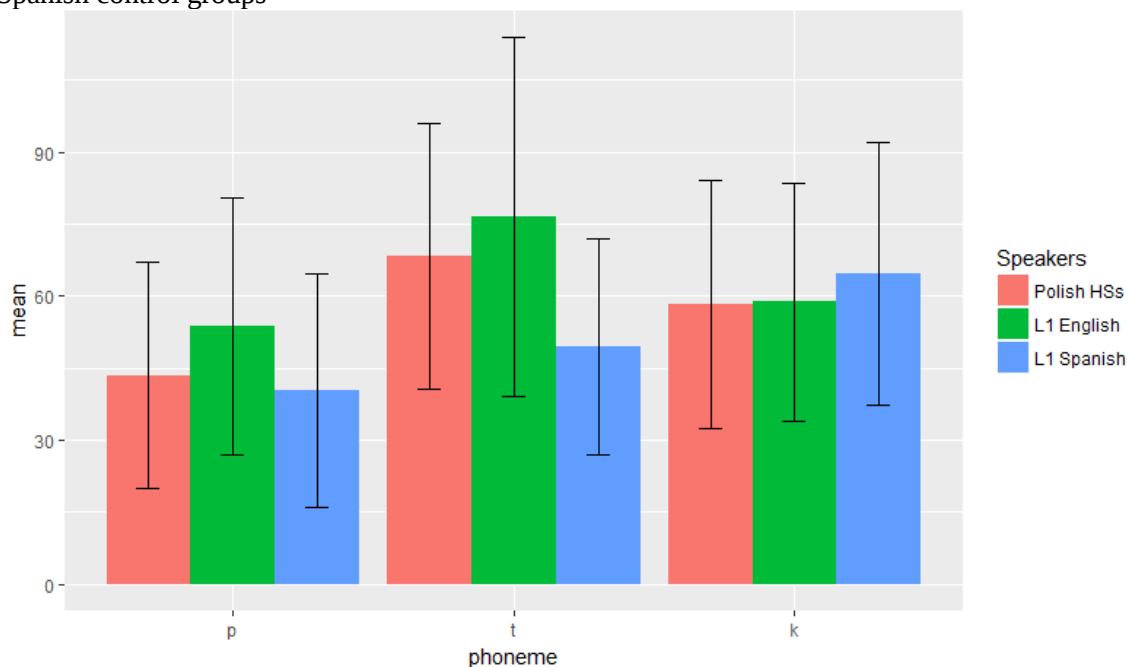


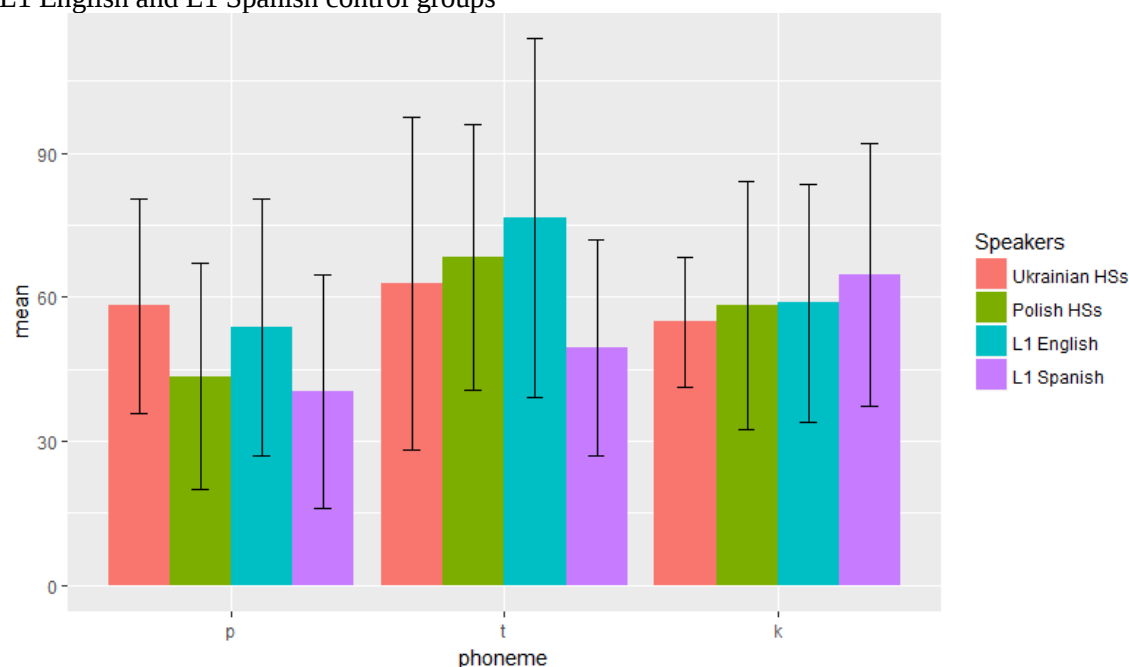
Figure 4.64. Mean VOT (ms) values in English produced by the Polish HSs, the L1 English and L1 Spanish control groups



4.3.3.5 Summary

Figure 4.65 summarizes the productions of the English voiceless stops in the narrative task by the Ukrainian HSs, the Polish HSs, and the L1 English and L1 Spanish control groups. The segment /p/ was produced with the longest VOT duration by the Ukrainian HSs; /t/ displayed the longest VOT in the L1 English group's production; and finally, /k/ was produced with the longest VOT duration by the L1 Spanish control group. Interestingly, the L1 Spanish speakers produced the other two stops with the shortest VOT values out of the four speaker groups.

Figure 4.65. Mean VOT values (ms) in English produced by the Ukrainian HSs, the Polish HSs, and the L1 English and L1 Spanish control groups



The mean VOT measurements were subjected to a Linear Mixed Effects Model where *phoneme* and *speaker group* were included as fixed effect and *individual speaker* acted as random effect to determine whether there were any statistically significant differences between the acoustic means of the four groups of speakers. The results revealed no statistically significant difference in the production of /p t k/ by the four groups ($p < .1714$). The L1 Spanish speakers' productions differed the most from the realizations of the L1 English speakers, while the Polish HSs' results approximated them the most. Although the L1 Spanish participants produced the shortest English /p t k/, they pronounced all three segments as long-lag, following the English norm and showing that they are distinguishing the voiceless stops in their two languages rather than transferring the Spanish short-lag feature to their L2. This finding will be addressed in greater detail in the next chapter.

4.3.4 Spanish voiceless stops

The following section is divided into four parts, presenting each speaker group's data in the following order: L1 Spanish control group, L1 English control group, Ukrainian HSs and Polish HSs. All four groups completed four different tasks in Spanish and the results for each task are discussed within the groups' section in the order they were administered during the elicitation. The narrative task is presented first, followed by the picture-naming task, the sentence-reading task, and finally, the nonce words reading task data is presented.

4.3.4.1 L1 Spanish control group

A total of 1,222 productions of /p t k/ were analyzed in the L1 Spanish speakers' data: 318 tokens in the narrative task, 154 tokens in the picture-naming task, 567 tokens in the sentence-reading task, and finally, 183 tokens in the nonce words reading task.

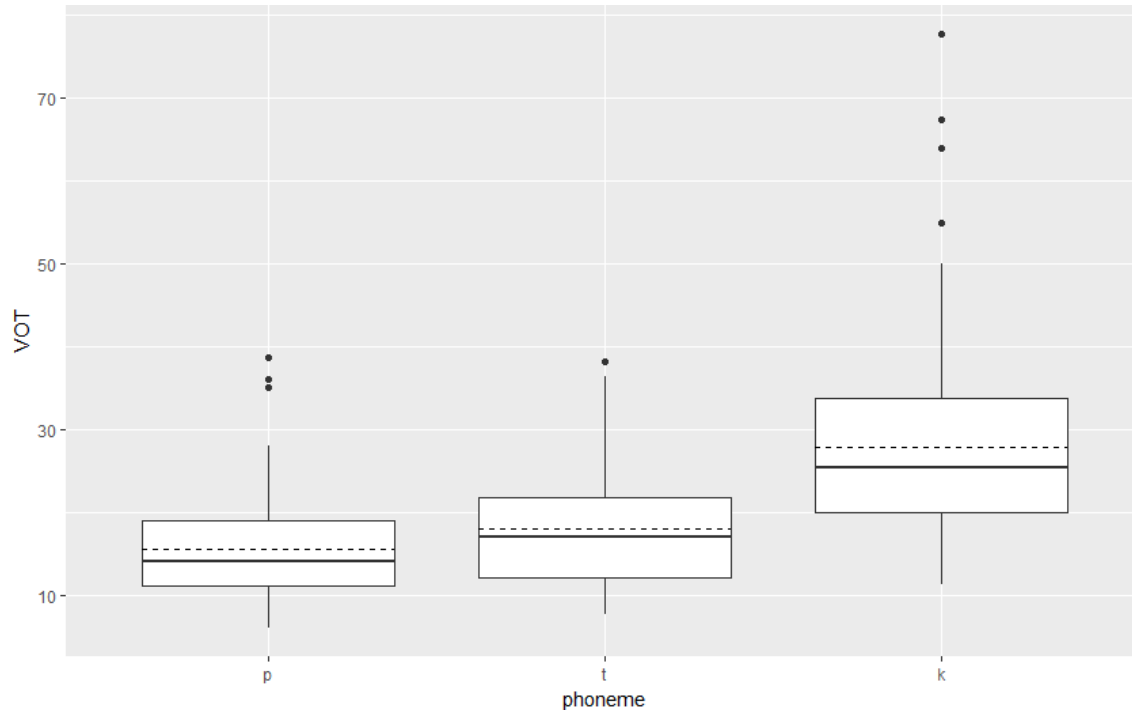
The L1 Spanish control group produced all three stops as short-lag, in line with earlier findings in the literature on the productions of the Spanish /p t k/ (Castañeda Vicente 1986, Rosner et al. 2010) (Table 4.51). The bilabial phoneme was produced with the shortest in VOT duration and the velar with the longest. A two-sample t-test revealed no statistical significance of any of the independent variables (stress $p < .111$, syllable type $p < .994$, word position $p < .752$), but the raw data shows that all three stops were produced with longer VOTs in stressed position. Not surprisingly, the L1 Spanish group yielded the highest number of tokens in the narrative task where all speakers, with one exception, produced at least 10 tokens of each stop (speaker S4 produced seven tokens of /k/). All participants pronounced all three segments as short-lag and in each speaker's individual results the bilabial segment has the shortest VOT and the velar segment the longest. The individual results, as well as the group outcome, both display

considerably small standard deviations, signaling that the data points are closely clustered around the mean, which makes this a very reliable data set.

Table 4.51. Mean VOT values (ms) in Spanish produced by the L1 Spanish control group in the narrative task

Phoneme	Mean / SD	Mean / SD by stress	Mean / SD by syllable type	Mean / SD by word position	Total tokens
/p/	15.6 / 6.5	stressed (t<47): 16.5 / 6.3	open (t<74): 14.5 / 6.1	initial (t<77): 15.4 / 6.5	100
		unstressed (t<53): 14.7 / 6.6	closed (t<26): 18.6 / 6.6	internal (t<23): 16.3 / 6.5	
/t/	18 / 7.1	stressed (t<25): 18 / 7.4	open (t<45): 16.8 / 6.3	initial (t<17): 20.4 / 8.3	70
		unstressed (t<45): 18 / 7.1	closed (t<25): 20.1 / 8.1	internal (t<53): 17.2 / 6.6	
/k/	27.9 / 10.8	stressed (t<29): 28.9 / 11.2	open (t<119): 28.3 / 11.2	initial (t<95): 27.6 / 10.2	148
		unstressed (t<119): 27.6 / 10.7	closed (t<29): 26.2 / 9.1	internal (t<53): 28.2 / 11.8	

Figure 4.66. Mean VOT values (ms) in Spanish produced by the L1 Spanish control group in the narrative task



As in the narrative task, all three stops in the picture-naming task were produced as short-lag (Table 4.52). The bilabial /p/ was pronounced with the shortest VOT, while the velar /k/ was

produced with the longest VOT value. A two-sample t-test revealed stress ($p < .0143$) to be statistically significant, while syllable type ($p < .143$) and word position ($p < .967$) showed no effect on the VOT. The stops /p/ and /t/ were produced with longer VOTs in unstressed position, while /k/ displays longer VOTs in opposite context.

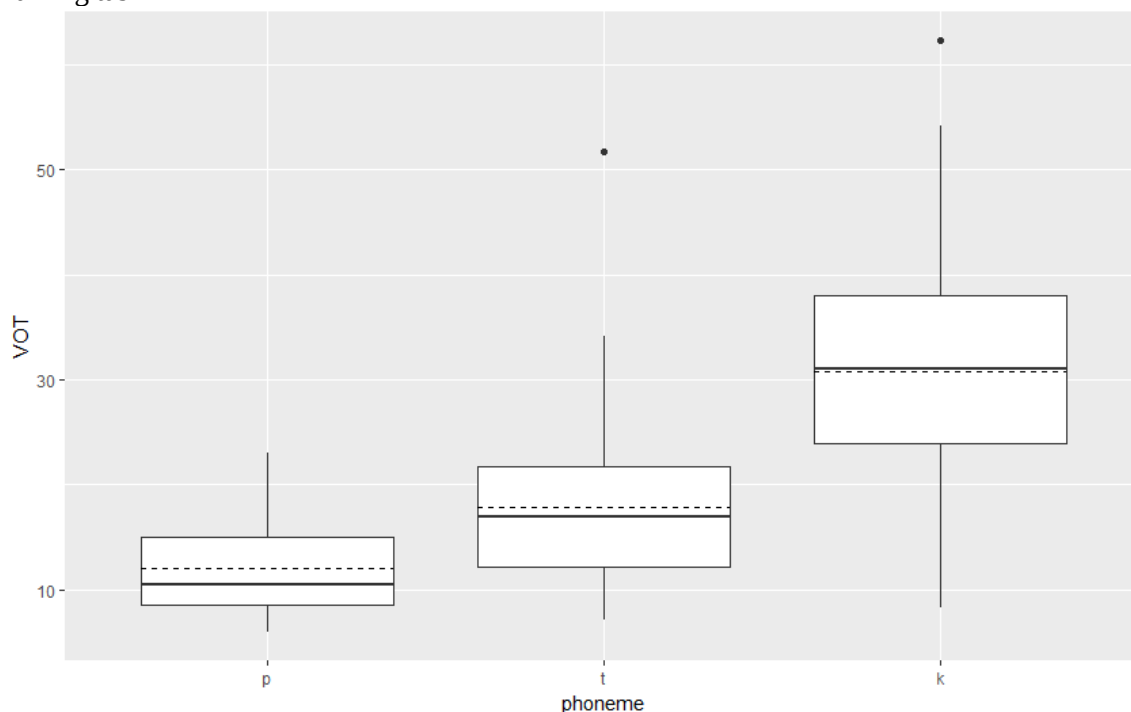
When looking at the standard deviation values, the velar /k/ shows the greatest variation in the data points distribution out of the three segments. However, as in the narrative task, the standard deviations in the picture-naming task, both in the group and in the individual results, are smaller than in other speaker groups' data sets, indicating less variation in the data.

Table 4.52. Mean VOT values (ms) in Spanish produced by the L1 Spanish control group in the picture-naming task

Phoneme	Mean / SD	Mean / SD by stress*	Mean / SD by syllable type	Mean / SD by word position	Total tokens
/p/	12 / 4.5	stressed (t<14): 10.3 / 4.1	open (t<24): 11.9 / 4.8	initial (t<29): 12 / 4.5	29
		unstressed (t<15): 13.6 / 4.5	closed (t<5): 12.3 / 3	internal (t<0): NA	
/t/	17.8 / 7.7	stressed (t<15): 17.2 / 7.1	open (t<54): 17.8 / 8.1	initial (t<30): 19.9 / 8.7	67
		unstressed (t<52): 18 / 7.9	closed (t<13): 18 / 6.4	internal (t<37): 16.1 / 6.5	
/k/	30.8 / 10.2	stressed (t<6): 35.5 / 10.7	open (t<53): 31.3 / 10.4	initial (t<37): 30.5 / 10.6	58
		unstressed (t<52): 30.3 / 10.2	closed (t<5): 25.9 / 7.2	internal (t<21): 31.4 / 9.8	

Significant at the $\alpha < 0.05$ level

Figure 4.67. Mean VOT values (ms) in Spanish produced by the L1 Spanish control group in the picture-naming task



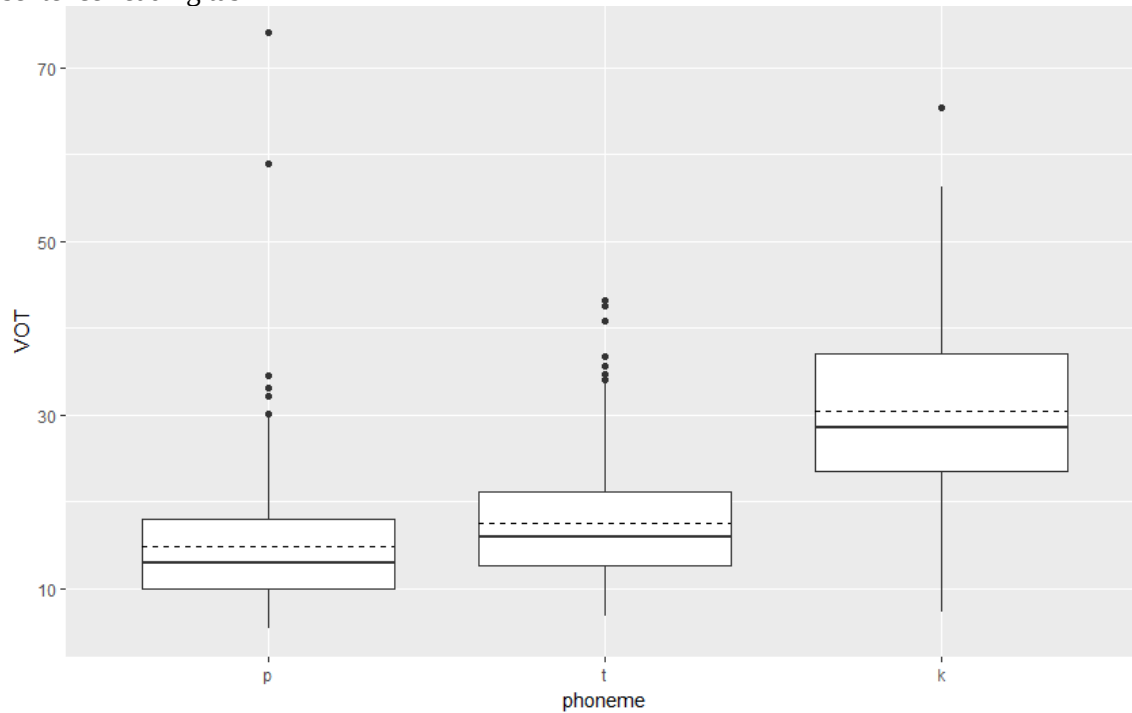
Once again, the L1 Spanish control group produced all three voiceless stops as short-lag in the sentence-reading task, where the velar segment is the longest and the bilabial stop is the shortest in VOT duration (Table 4.53). A two-sample t-test revealed no statistical significance of any of the independent variables (stress $p < .446$, syllable type $p < .0595$, word position $p < .239$) in the sentence-reading task, but the raw data shows that all three stops have longer VOT values in closed syllables. All speakers display relatively small standard deviations in the individual results, with very few exceptions, signaling a clustering of data points close to the means.

Table 4.53. Mean VOT values (ms) in Spanish produced by the L1 Spanish control group in the sentence-reading task

Phoneme	Mean / SD	Mean / SD by stress	Mean / SD by syllable type	Mean / SD by word position	Total tokens
/p/	14.9 / 8.1	stressed (t<84): 13.8 / 8.7	open (t<174): 14.7 / 8.2	initial (t<109): 14.9 / 9.2	183
		unstressed (t<99): 15.8 / 7.4	closed (t<9): 17.2 / 5.9	internal (t<74): 14.8 / 6.1	
/t/	17.5 / 7.2	stressed (t<83): 16.7 / 7.4	open (t<204): 17.5 / 7	initial (t<85): 17.8 / 7.4	219
		unstressed (t<136):	closed (t<15):	internal (t<134):	

		18 / 7.1	18.3 / 9.7	17.3 / 7.1	
/k/	30.4 / 9.7	stressed (t<71): 33.9 / 10.5	open (t<150): 30.2 / 9.7	initial (t<70): 30 / 8.8	165
		unstressed (t<94): 27.8 / 8.1	closed (t<15): 32.4 / 10.4	internal (t<95): 30.7 / 10.4	

Figure 4.68. Mean VOT values (ms) in Spanish produced by the L1 Spanish control group in the sentence-reading task



As in the previous tasks, all three voiceless stops were produced with short-lag VOT values in the nonce words reading task (Table 4.54). Interestingly, the dental stop was produced with the shortest mean VOT, while the velar stop has the longest VOT duration. However, the difference between the mean VOT values of the bilabial and the dental segments is very small (0.4 ms). A two-sample t-test showed that all three independent variables were significant (stress $p < .00108$, syllable type $p < .000302$, word position $p < .0459$). The stops /p/ and /t/ display longer VOTs in unstressed position, while /k/ does so in stressed position. However, there is only one token of /k/ in the stressed syllable context and that token is also an outlier, making it difficult to draw a definitive conclusion. The phonemes /t/ and /k/ have longer VOTs in open

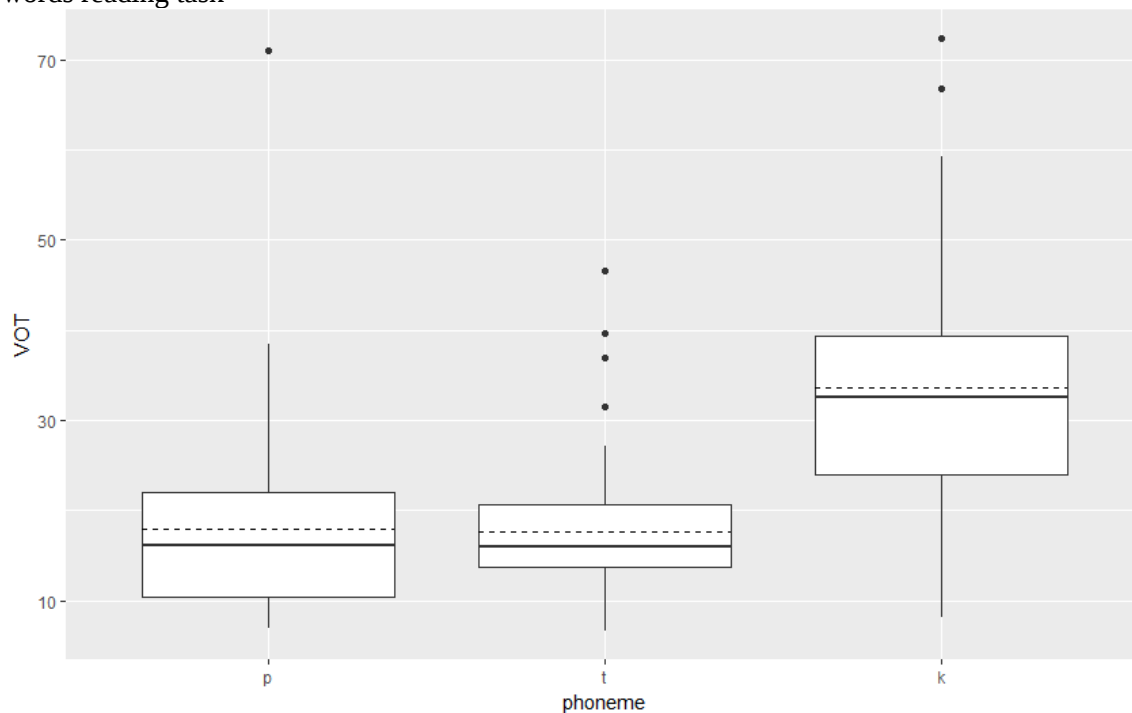
syllables and word-initial positions, while /p/ only appears in closed syllables and displays longer VOT values in word internal position.

Table 4.54. Mean VOT values (ms) in Spanish produced by the L1 Spanish control group in the nonce words reading task

Phoneme	Mean / SD	Mean / SD by stress*	Mean / SD by syllable type*	Mean / SD by word position*	Total tokens
/p/	18 / 11.1	stressed (t<14): 12.5 / 4.7	open (t<0): NA	initial (t<30): 17 / 7.3	45
		unstressed (t<31): 20.4 / 12.3	closed (t<45): 18 / 11.1	internal (t<15): 19.8 / 16.5	
/t/	17.6 / 6.7	stressed (t<26): 16.2 / 6.1	open (t<11): 18.3 / 5.9	initial (t<40): 19.7 / 8.3	94
		unstressed (t<68): 18.1 / 6.9	closed (t<83): 17.5 / 6.8	internal (t<54): 16.1 / 4.8	
/k/	33.6 / 12.7	stressed (t<1): 72.3 / NA	open (t<14): 38 / 13.6	initial (t<29): 34.2 / 13.7	44
		unstressed (t<43): 32.7 / 11.4	closed (t<30): 31.6 / 12	internal (t<15): 32.4 / 11.1	

Significant at the $\alpha < 0.05$ level

Figure 4.69. Mean VOT values (ms) in Spanish produced by the L1 Spanish control group in the nonce words reading task

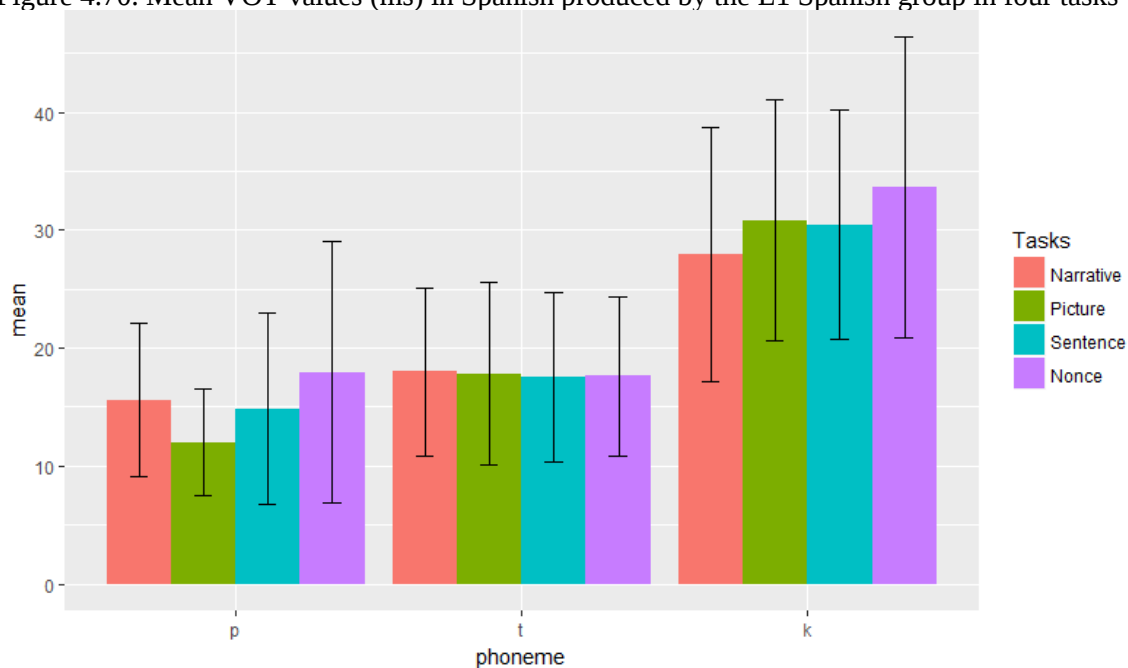


4.3.4.1.1 Summary

Figure 4.70 summarizes the mean VOT values of /p t k/ produced by the L1 Spanish control group in all four tasks. The picture-naming task yielded the shortest VOT value for /p/, the sentence-reading task generated the shortest VOT value for /t/, and the narrative task showed the shortest VOT for /k/. The nonce words reading task yielded the longest VOT measurements for /p/ and /k/ and the narrative task did so for /t/.

A Linear Mixed Effects Model revealed that task type had a statistically significant effect on the VOT values for /p/ ($p < .0101$) and /k/ ($p < .008746$), but not /t/ ($p < .5726$). By looking at Figure 4.71, it is evident that task formality increased VOT values of both /p/ and /k/, while it did not affect the VOT of /t/. This finding reflects the trend observed in the Spanish vowel analyses, where the L1 Spanish speakers' performance becomes less target-like as tasks become less natural.

Figure 4.70. Mean VOT values (ms) in Spanish produced by the L1 Spanish group in four tasks



4.3.4.2 L1 English control group

The L1 English control group produced a total of 995 tokens of Spanish /p t k/. 114 productions were analyzed in the narrative task, 131 in the picture-naming task, 566 in the sentence-reading task, and 184 in the nonce words reading task.

The group means indicate that the L1 English speakers produced all three voiceless stops with long-lag VOT, which supports earlier findings in the literature on the production of /p t k/ by L1 English L2 Spanish learners (Díaz-Campos and Lazar 2003, Díaz-Campos 2006, González-Bueno 1997, Zampini 1998) (Table 4.55). However, by looking at the standard deviation of the means, it is evident that the data points were spread out over a wide range of values, meaning there is a considerable variation in the production of the segments. The bilabial /p/ was produced with the shortest VOT value, while the velar /k/ was pronounced with the longest VOT, which reflects the relationship between the place of articulation of the L1 Spanish control group's results. Figure 4.72 summarizes the mean VOTs of the L1 English control group and compares them to the L1 Spanish control group's results. All three stops were produced with longer VOTs in stressed ($p < .0297$) and word-initial positions ($p < 9.13 \times 10^{-6}$), which also were shown to be statistically significant in a two-sample t-test.

The individual speaker results demonstrate that nearly all speakers, with one exception, produced all three Spanish stops with long-lag VOTs. When looking at the token distribution, the Spanish narration task yielded a more balanced elicitation of /p t k/ among the speakers than the English narration task with only a few exceptions. For example, one of the participants produced only one instance of /k/ and two instances of /t/. Also, another speaker produced only three tokens of /t/.

Table 4.55. Mean VOT values (ms) in Spanish produced by the L1 English control group in the narrative task

Phoneme	Mean / SD	Mean / SD by stress*	Mean / SD by syllable type	Mean / SD by word position*	Total tokens
/p/	52.5 / 27.1	stressed (t<24): 53.5 / 27.6	open (t<34): 54.5 / 25.9	initial (t<30): 54.9 / 29.4	45
		unstressed (t<21): 51.4 / 27.1	closed (t<11): 46.1 / 30.8	internal (t<15): 47.7 / 21.9	
/t/	57.7 / 30.6	stressed (t<8): 58.9 / 29.4	open (t<23): 53.6 / 34.5	initial (t<15): 76.6 / 27.2	33
		unstressed (t<25): 57.3 / 31.6	closed (t<10): 67 / 45.7	internal (t<18): 41.9 / 24	
/k/	58.1 / 36.6	stressed (t<16): 79.9 / 43.8	open (t<29): 52.5 / 32.6	initial (t<18): 79.3 / 41.2	36
		unstressed (t<20): 40.7 / 15.4	closed (t<7): 81.2 / 45.7	internal (t<18): 37 / 10.7	

*significant at the $\alpha < 0.05$ level

Figure 4.71. Mean VOT values (ms) in Spanish produced by the L1 English control group in the narrative task

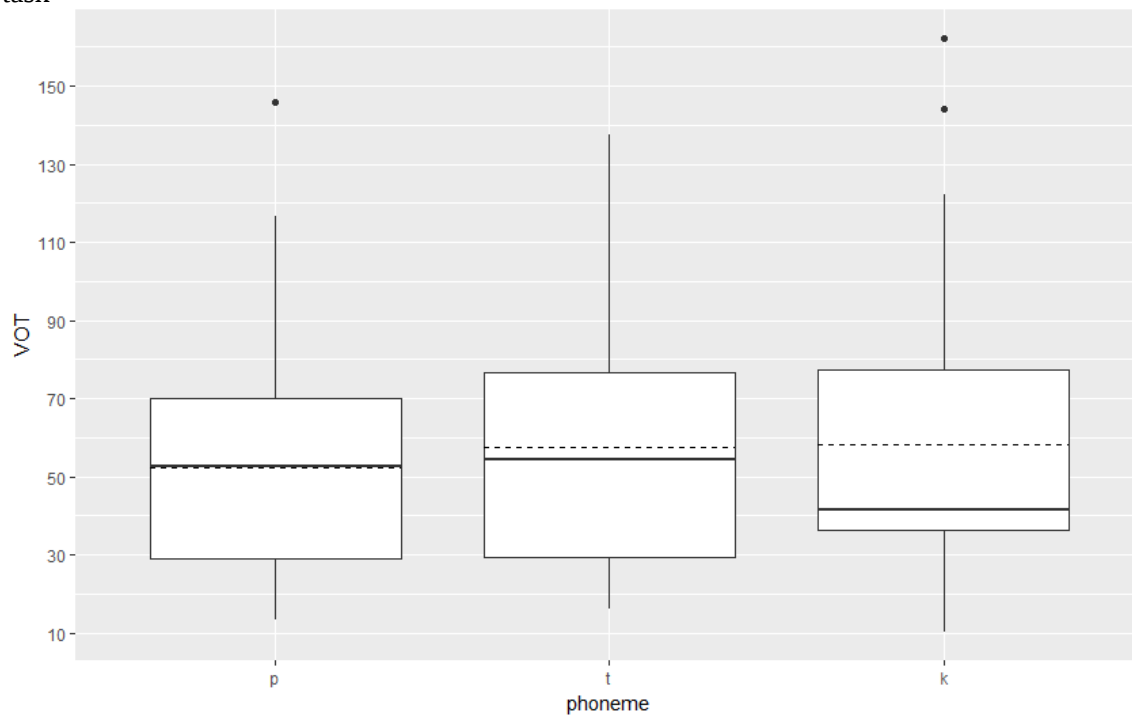
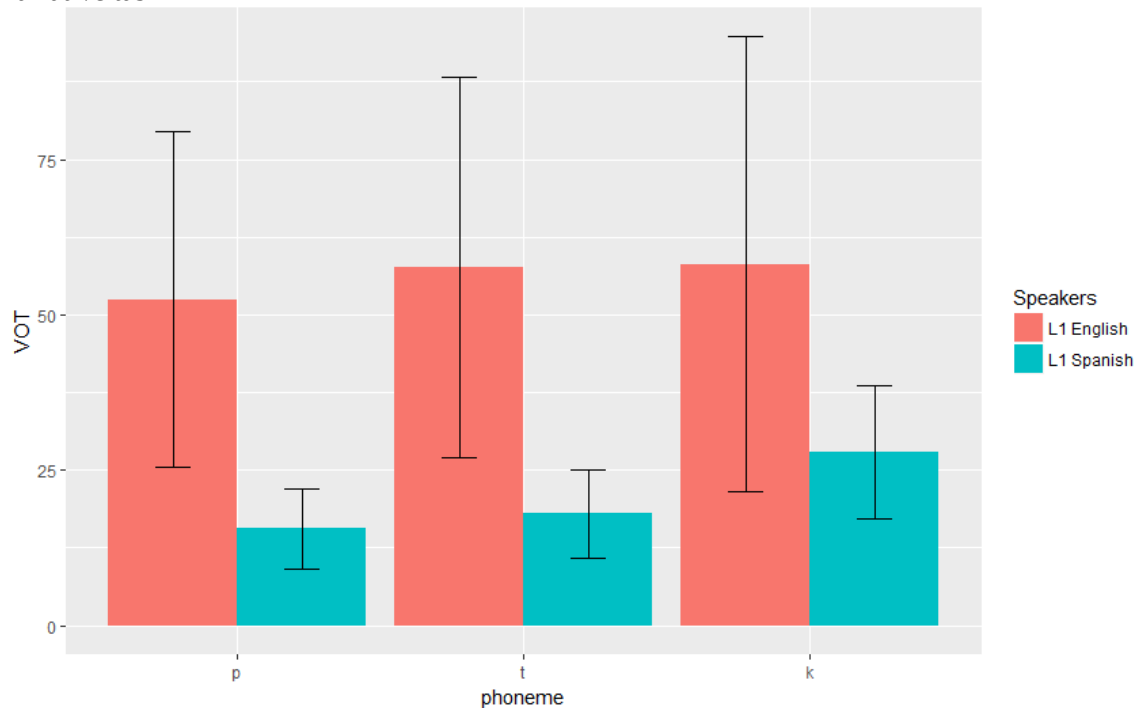


Figure 4.72. Mean VOT (ms) values produced by the L1 English and L1 Spanish control groups in the narrative task



The three Spanish voiceless stops /p t k/ were produced with long-lag mean VOT values by the L1 English L2 Spanish control group, which is in line with the previous findings in the literature (Díaz-Campos and Lazar 2003, Díaz-Campos 2006, González-Bueno 1997, Zampini 1998) (Table 4.56). All three stops displayed very similar VOT values, with /p/ and /t/ sharing the exact same mean. In the picture-naming task, the velar segment was produced with the shortest VOT value out of the three stops, but the difference between the mean of /k/ and the means of /p/ and /t/ is very small (1.3 ms). This relationship between the place of articulation and mean VOT values differs from the relationship displayed by L1 Spanish speakers. A comparison of the mean VOT values produced by the L1 English speakers task and the results of the L1 Spanish control group in the picture-naming task can be viewed in Figure 4.74. As in the narration task, all three segments were produced with longer VOTs in stressed ($p < .00107$) and word-initial positions ($p < .0028$) (/p/ had no tokens in word internal position), which were

shown to be significant independent variables by a two-sample t-test. The standard deviations in the individual results are considerably lower than in the previous task, indicating the data points are more closely clustered around the mean, making this a reliable data set.

Table 4.56. Mean VOT values (ms) in Spanish produced by the L1 English control group in the picture-naming task

Phoneme	Mean / SD	Mean / SD by stress*	Mean / SD by syllable type	Mean / SD by word position*	Total tokens
/p/	55.8 / 27	stressed (t<14): 68.2 / 27.4	open (t<23): 53 / 25.4	initial (t<28): 55.8 / 27	28
		unstressed (t<14): 43.4 / 20.8	closed (t<5): 68.6 / 33.5	internal (t<0): NA	
/t/	55.8 / 27.6	stressed (t<10): 64.8 / 27.4	open (t<41): 56.3 / 26.1	initial (t<28): 61.2 / 28.9	51
		unstressed (t<41): 53.6 / 27.5	closed (t<10): 53.6 / 34.4	internal (t<23): 49.2 / 24.9	
/k/	54.5 / 20.8	stressed (t<5): 75.9 / 30.1	open (t<47): 54.1 / 21.5	initial (t<32): 62.9 / 20.8	52
		unstressed (t<47): 52.2 / 18.6	closed (t<5): 57.8 / 14.5	internal (t<20): 42.6 / 14.6	

*significant at the $\alpha < 0.05$ level

Figure 4.73. Mean VOT values (ms) in Spanish produced by the L1 English speakers in the picture-naming task

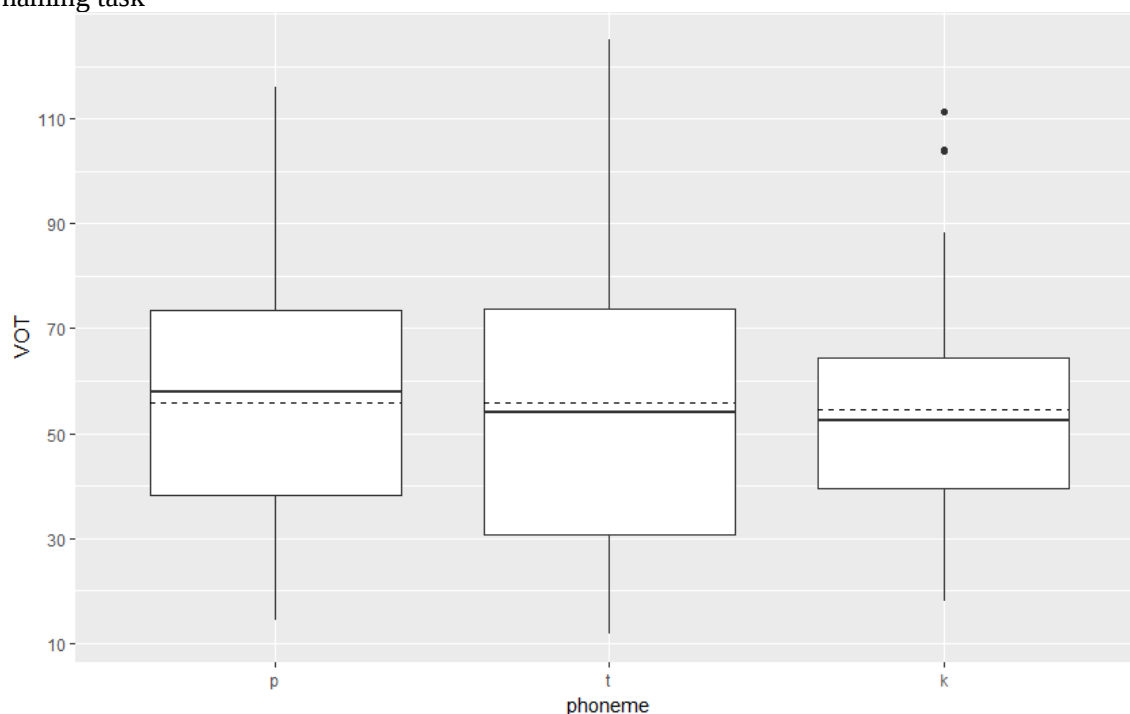
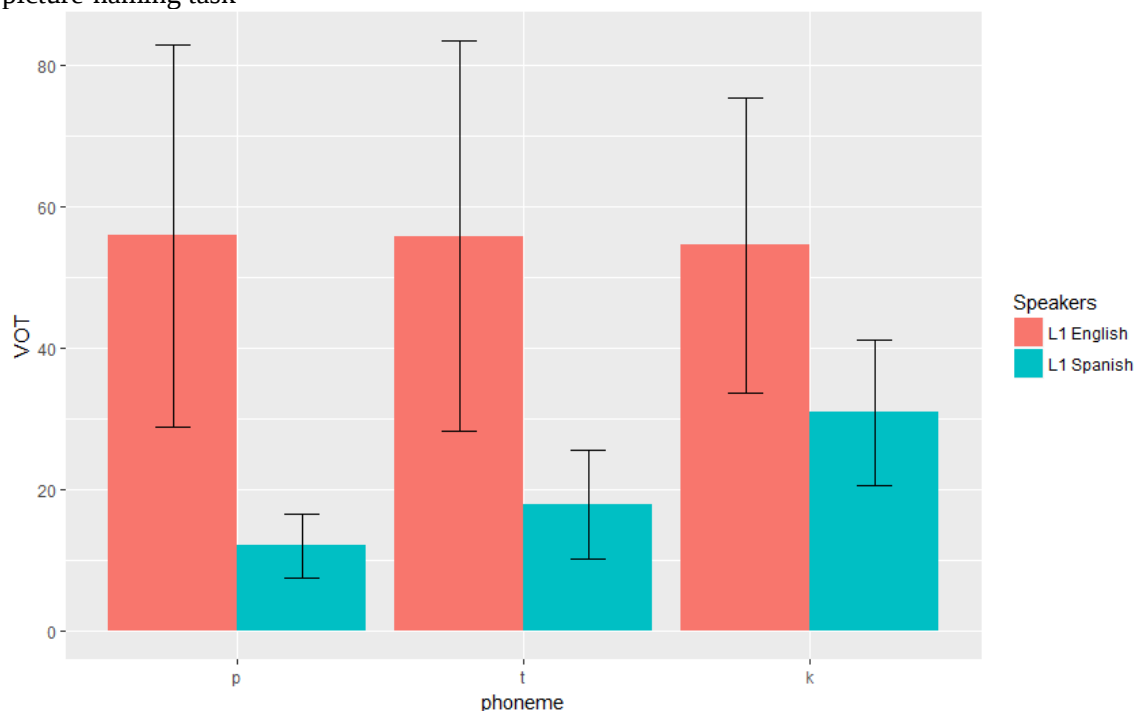


Figure 4.74. Mean VOT (ms) values produced by the L1 English and L1 Spanish control groups in the picture-naming task



As with the previous two tasks, the L1 English L2 Spanish learner group produced the Spanish /p t k/ with long-lag mean VOT values in the sentence-reading task (Table 4.57). However, when these values are compared to the ones discovered in the narrative and the picture-naming tasks, they are approximately 10 ms shorter (/p/ and /t/ measurements). In this task, the velar segment was produced with the longest VOT duration, while the bilabial had the shortest duration, mirroring the results of the L1 Spanish speakers. Figure 4.76 summarizes the mean VOT productions of the L1 English speakers and compares them to the L1 Spanish speakers' results. A two-sample t-test revealed both stress ($p < 5.62 \times 10^{-6}$) and word position ($p < 1.31 \times 10^{-9}$) to be very significant, but showed no effect of syllable type ($p < .681$). Once again, reflecting the findings in the previous two tasks, all segments display longer VOTs in stressed and word-initial positions. The individual speaker results reveal more short-lag productions than the previous two tasks. One participant produced /p/ with a VOT of 23 ms, and another speaker produced /p/ and /t/ with VOTs of 22.9 ms and 25.6 ms, respectively, and also displays a VOT

mean for the velar stop that is close to the short-lag category (35.5 ms). The rest of the participants produced the three stops with long-lag VOTs. The standard deviations of the individual results indicate more variation in the data than was seen in the narrative and the picture-naming tasks.

Table 4.57. Mean VOT values (ms) in Spanish produced by the L1 English control group in the sentence-reading task

Phoneme	Mean / SD	Mean / SD by stress*	Mean / SD by syllable type	Mean / SD by word position*	Total tokens
/p/	41.5 / 27	stressed (t<82): 43.4 / 29.3	open (t<174): 41.5 / 27	initial (t<110): 45.1 / 24.5	182
		unstressed (t<100): 39.9 / 24.9	closed (t<8): 40.7 / 28.1	internal (t<72): 35.9 / 29.7	
/t/	47 / 26.7	stressed (t<85): 56.2 / 29.1	open (t<205): 47.2 / 26.5	initial (t<85): 59 / 27.5	220
		unstressed (t<135): 41.2 / 23.4	closed (t<15): 44.4 / 30.2	internal (t<135): 39.4 / 23.3	
/k/	54.2 / 28.3	stressed (t<69): 62.1 / 26.6	open (t<149): 53.8 / 27.9	initial (t<70): 64.5 / 28.6	164
		unstressed (t<95): 48.4 / 28.2	closed (t<15): 58.3 / 32.3	internal (t<94): 46.5 / 25.6	

*significant at the $\alpha < 0.05$ level

Figure 4.75. Mean VOT values (ms) in Spanish produced by the L1 English speakers in the sentence-reading task

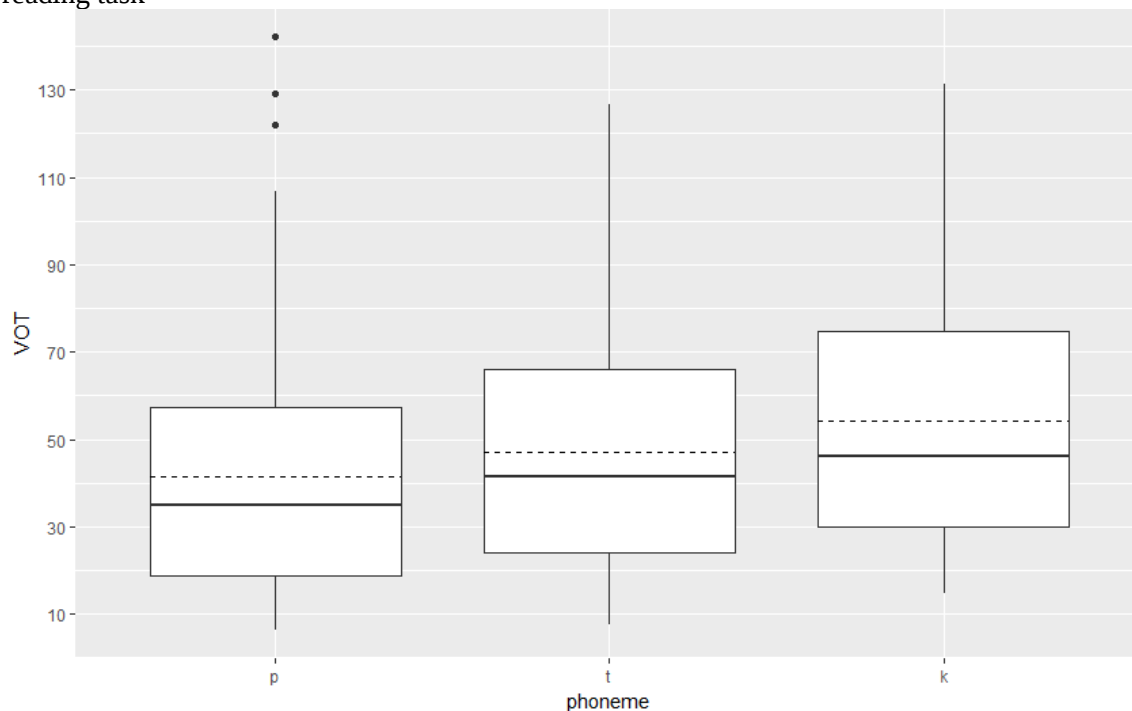
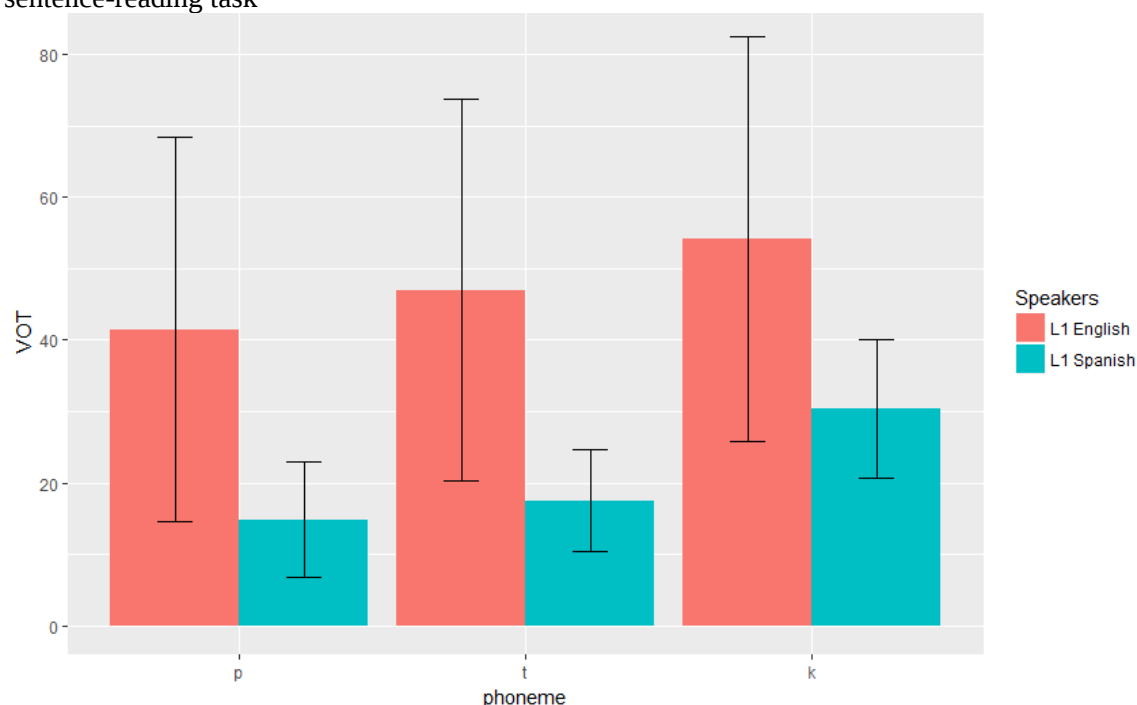


Figure 4.76. Mean VOT (ms) values produced by the L1 English and L1 Spanish control groups in the sentence-reading task



In the final task, the Spanish voiceless stops were once again produced as long-lag (Table 4.58). Interestingly, the bilabial segment displays the longest VOT duration, while the velar segment the shortest. The mean VOT productions of the L1 English and L1 Spanish speakers can be viewed in Figure 4.78. A two-sample t-test revealed statistical significance of word position ($p < 2.52 \cdot 10^{-6}$), but showed no effect of stress ($p < .0576$) and syllable type ($p < .106$). Both /t/ and /k/ have greater VOTs in word-initial position, while /p/ has a longer VOT value in word internal position. When looking at the standard deviations of the individual means, the distribution of the data resembles that of the previous task, where data points appear spread out over a wider range of values, signaling greater variation in the data.

Table 4.58. Mean VOT values (ms) in Spanish produced by the L1 English speakers in the nonce words reading task

Phoneme	Mean / SD	Mean / SD by stress	Mean / SD by syllable type	Mean / SD by word position*	Total tokens
/p/	60.5 / 29	stressed (t<15): 70.1 / 33.3	open (t<45): 60.5 / 29	initial (t<30): 60.2 / 25.4	45
		unstressed (t<30):	closed (t<0):	internal (t<15):	

		55.7 / 25.9	NA	61.2 / 36.2	
/t/	56.2 / 29.7	stressed (t<29): 61.6 / 25.3	open (t<83): 55.5 / 29.9	initial (t<41): 69.2 / 26.3	95
		unstressed (t<65): 53.8 / 31.4	closed (t<11): 61 / 29.5	internal (t<53): 46.1 / 28.5	
/k/	55.8 / 22.5	stressed (t<1): 42.4 / NA	open (t<31): 49.8 / 21.4	initial (t<29): 66.7 / 18.6	45
		unstressed (t<44): 56.1 / 22.7	closed (t<14): 69.1 / 19.5	internal (t<16): 36 / 13.9	

*significant at the $\alpha < 0.05$ level

Figure 4.77. Mean VOT values (ms) in Spanish produced by the L1 English speakers in the nonce words reading task

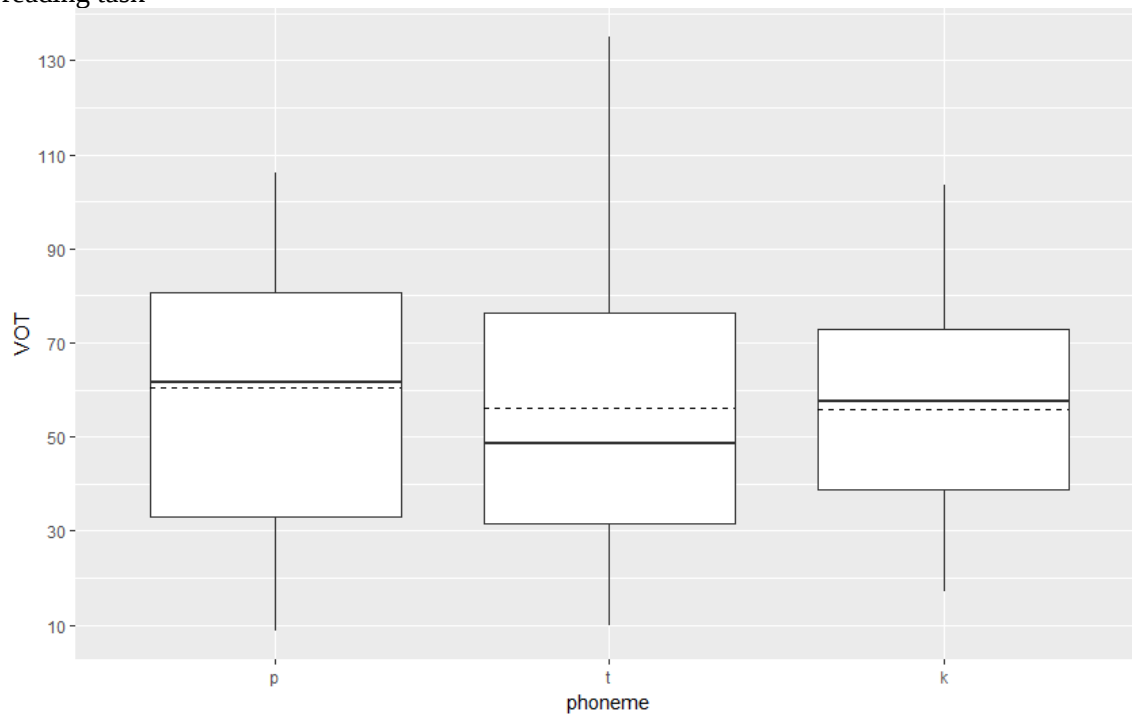
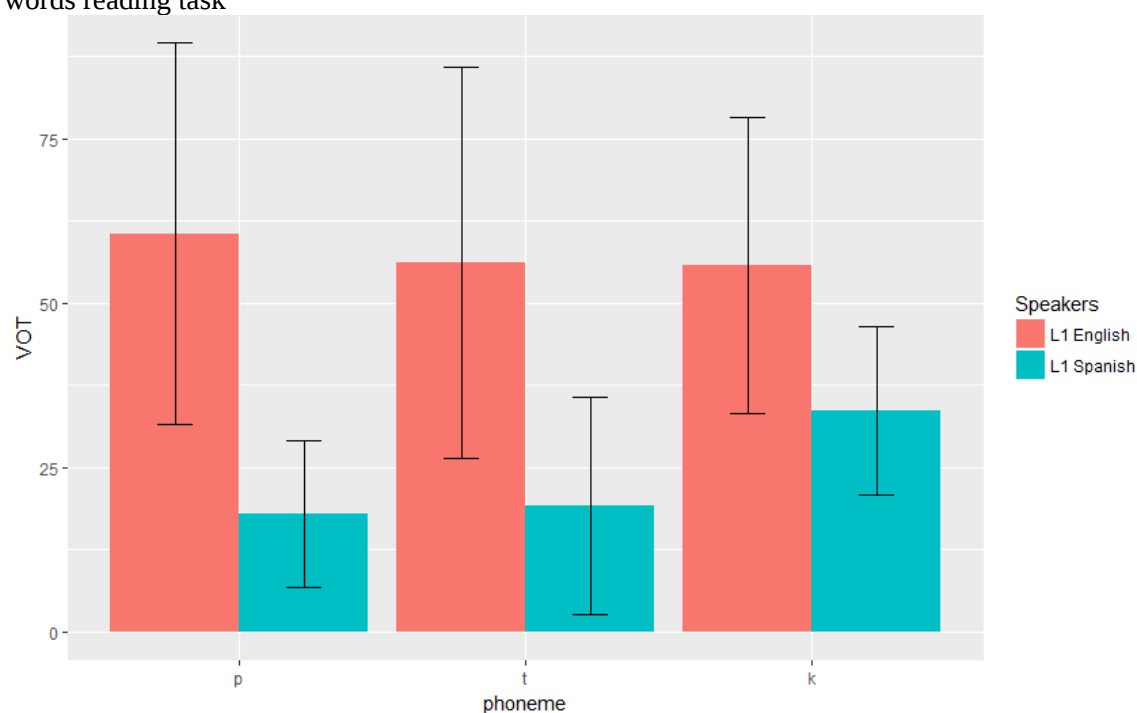


Figure 4.78. Mean VOT (ms) values produced by the L1 English and L1 Spanish speakers in the nonce words reading task



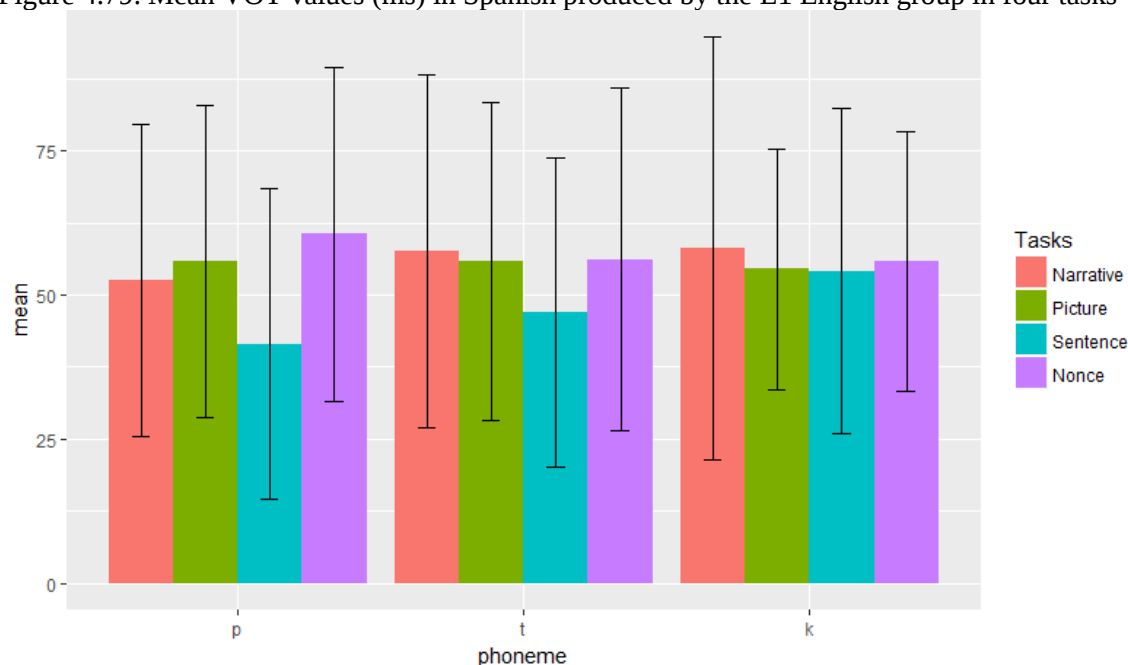
4.3.4.2.1 Summary

Figure 4.79 summarizes the Spanish voiceless stop productions by the L1 English control group across all four tasks. From the graph, it can be seen that the sentence-reading task yielded the shortest VOT values in all three stops, while the nonce word reading task induced the longest VOT in /p/, and the narrative task caused the longest VOT productions in /t/ and /k/. As can be seen from the standard deviation indicators, the variation in the data is large, which was shown to be a common feature of the L2 and L3 Spanish learners' data.

A Linear Mixed Effects Model was run to determine the significance of task on the VOT of each phoneme. Task type was shown to be statistically significant for /p/ ($p < 2.415 \times 10^{-7}$) and /t/ ($p < 0.0003193$), but showed no effect on the production of /k/ ($p < .5429$). Unlike with the L1 Spanish speakers' results, the L1 English control group's data does not illustrate a clear pattern between task formality and VOT values. However, the fact that all three stops have the shortest

VOTs in the sentence-reading task may indicate that this is the most familiar task for this group of speakers, who are more familiar with reading in their L2 than actively speaking it. This issue will be addressed in greater detail in the next chapter.

Figure 4.79. Mean VOT values (ms) in Spanish produced by the L1 English group in four tasks



4.3.4.3 Ukrainian HSs

The Ukrainian HSs produced 1,199 tokens of Spanish voiceless stops. 162 appeared in the narrative task, 142 in the picture-naming task, 673 in the sentence-reading task, and finally, 222 in the nonce words reading task.

The Ukrainian HSs produced all three voiceless stops with short-lag mean VOTs (/p/ - 18.6 ms, /t/ - 20.5 ms, /k/ - 31.5), in line with the previous finding in the literature on Spanish voiceless stops (Castañeda Vicente 1986, Lisker and Abramson 1964, Rosner et al. 2010) (Table 4.59). The bilabial segment has the shortest VOT, while the velar stop has the longest VOT measurement, which reflects the L1 Spanish control group's distribution. For a visual comparison of the Ukrainian HSs' VOT values in the narrative task to the control groups' results,

one can reference Figure 4.81. The Ukrainian HSs' standard deviations of the means signal that the group's data is more closely clustered around the mean and is not as spread out as it appears in the Ukrainian and English narrative tasks. A two-sample t-test revealed statistical significance of word position ($p < .0222$), while stress ($p < 0.34$) and syllable type ($p < .531$) showed no statistical effect. All three stops were produced with longer VOTs in word-initial positions.

Table 4.59. Mean VOT values (ms) in Spanish produced by the Ukrainian HSs in the narrative task

Phoneme	Mean / SD	Mean / SD by stress	Mean / SD by syllable type	Mean / SD by word position*	Total tokens
/p/	18.6 / 20.5	stressed (t<24): 18.7 / 7.7	open (t<38): 18 / 7.1	initial (t<35): 19.2 / 6.8	46
		unstressed (t<22): 18.5 / 6.1	closed (t<8): 21.4 / 5.9	internal (t<11): 16.8 / 7.3	
/t/	20.5 / 11.4	stressed (t<21): 22 / 13.6	open (t<24): 21.8 / 13.3	initial (t<7): 25.5 / 13.5	51
		unstressed (t<30): 19.6 / 9.7	closed (t<27): 19.4 / 9.5	internal (t<44): 19.7 / 11	
/k/	31.5 / 10.8	stressed (t<25): 34.8 / 13.8	open (t<51): 31.2 / 11.5	initial (t<48): 31.5 / 9.1	65
		unstressed (t<40): 29.5 / 7.9	closed (t<14): 32.7 / 7.5	internal (t<17): 31.5 / 14.9	

*significant at the $\alpha < 0.05$ level

Figure 4.80. Mean VOT values (ms) in Spanish produced by the Ukrainian HSs in the narrative task

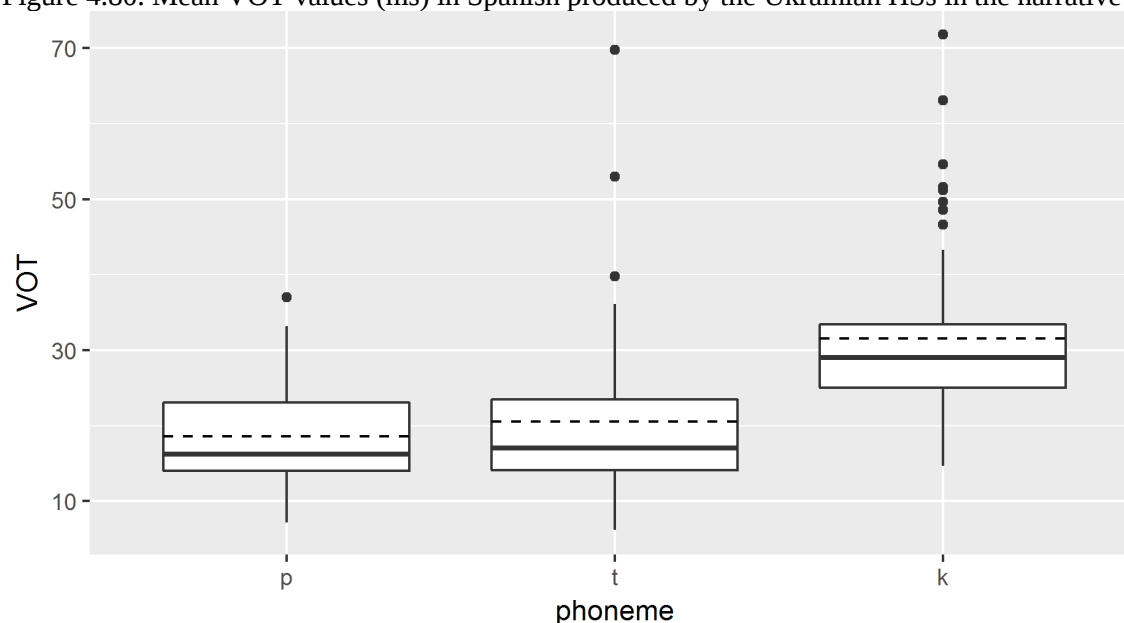
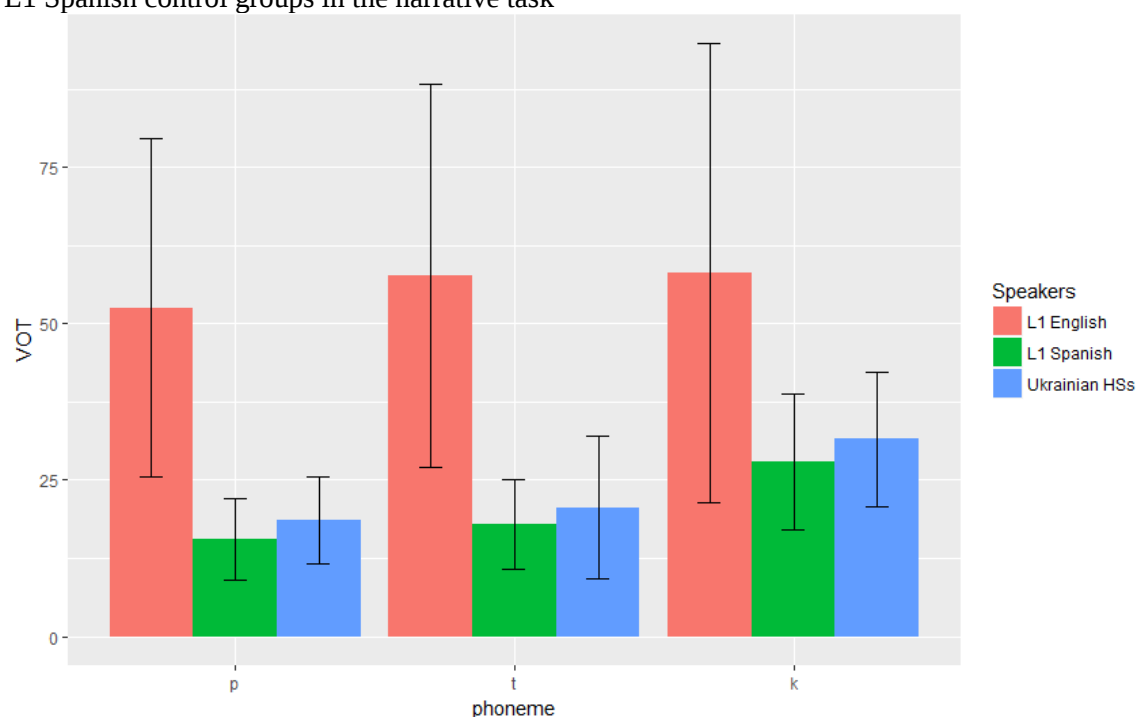


Figure 4.81. Mean VOT (ms) values in Spanish produced by the Ukrainian HSs and the L1 English and L1 Spanish control groups in the narrative task



As in the narrative task, all three stops in the picture-naming task were produced as short-lag, in line with the finding in the literature on Spanish /p t k/ (Castañeda Vicente 1986, Lisker and Abramson 1964, Rosner et al. 2010) (Table 4.60). Once again, the bilabial segment shows the shortest VOT value, while the velar stop displays the longest VOT, thus patterning with the L1 Spanish control group's distribution. For a comparison of the Ukrainian HSs' VOT data in the picture-naming task to the control groups' results, one should reference Figure 4.83. A two-sample t-test was conducted to determine statistical significance of the independent variables, and word stress proved to be statistically significant ($p < .0373$), while syllable type ($p < .687$) and word position ($p < .754$) showed no effect. The stops /p/ and /k/ have longer VOTs in stressed position, while /t/ shows longer VOT in unstressed position. The raw data also indicates that all three phonemes have longer VOTs in word-initial. The lower standard deviations in the

group data set across categories signal that the data points are in close proximity to the mean and are not as spread out as the data points in the Ukrainian and English data sets.

Table 4.60. Mean VOT values (ms) in Spanish produced by the Ukrainian HSs in the picture-naming task

Phoneme	Mean / SD	Mean / SD by stress*	Mean / SD by syllable type	Mean / SD by word position	Total tokens
/p/	15.24 / 13.2	stressed (t<16): 15.9 / 15.8	open (t<19): 15.8 / 14.4	initial (t<25): 15.2 / 13.2	25
		unstressed (t<9): 14.1 / 7.2	closed (t<6): 13.4 / 9.4	internal (t<0): NA	
/t/	20.1 / 11.3	stressed (t<12): 18.3 / 7.4	open (t<48): 20.1 / 12.1	initial (t<32): 21.4 / 13.4	58
		unstressed (t<46): 20.6 / 12.1	closed (t<10): 20 / 6.3	internal (t<26): 18.5 / 7.9	
/k/	30.4 / 11.5	stressed (t<6): 31.2 / 14.8	open (t<53): 29.8 / 10.8	initial (t<37): 31.6 / 12.1	59
		unstressed (t<53): 30.3 / 11.2	closed (t<6): 35.7 / 16.7	internal (t<22): 28.4 / 10.3	

*significant at the $\alpha < 0.05$ level

Figure 4.82. Mean VOT values (ms) in Spanish produced by the Ukrainian HSs in the picture-naming task

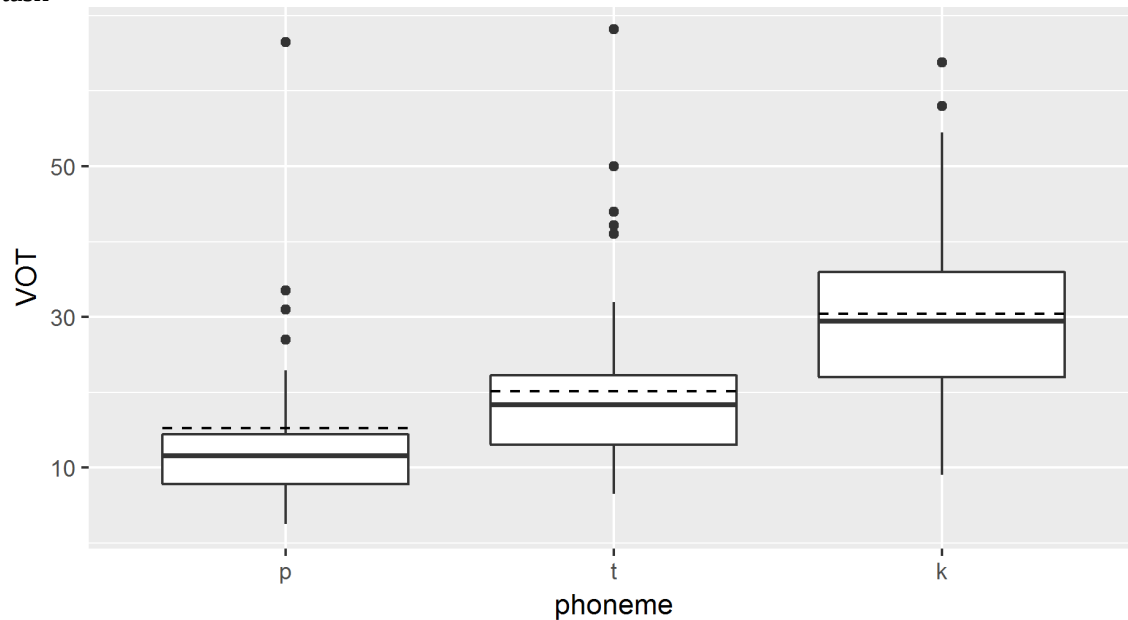
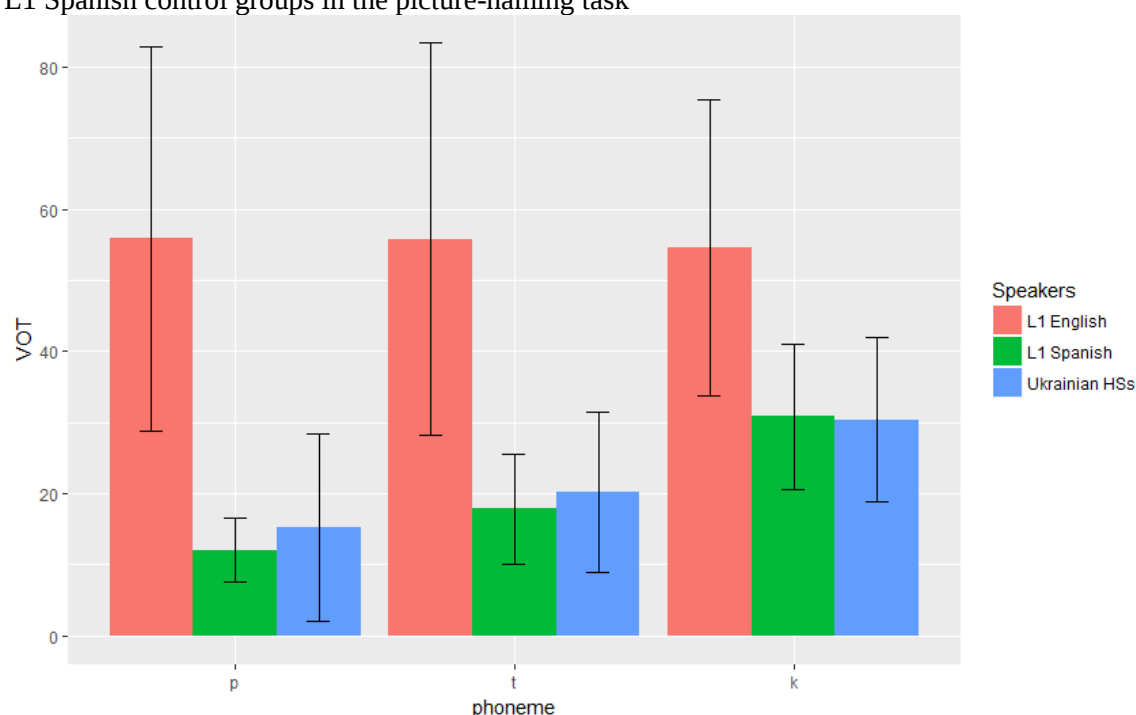


Figure 4.83. Mean VOT (ms) values in Spanish produced by the Ukrainian HSs, and the L1 English and L1 Spanish control groups in the picture-naming task



Once again, the Ukrainian HS group produced all three stops with a short-lag mean VOT in the sentence-reading task, supporting earlier findings in the literature on Spanish voiceless stops and modeling the L1 Spanish control group's distribution (Table 4.61). Refer to Figure 4.85 for a comparison of the Ukrainian HSs' VOT values in the sentence-reading task to the control groups' results. The relatively small standard deviations of the overall group means signal that the data points are clustered around the mean, providing a more reliable data set. A two-sample t-test revealed no statistical significance of any of the independent variables (stress $p < .736$, syllable type $p < .272$, word position $p < .0888$). While nothing is significant, the raw numbers show that all three stops have longer VOT values in closed syllables and in word-initial position.

Table 4.61. Mean VOT values (ms) in Spanish produced by the Ukrainian HSs in the sentence-reading task

Phoneme	Mean / SD	Mean / SD by stress*	Mean / SD by syllable type	Mean / SD by word position	Total tokens

/p/	20.3 / 10.2	stressed (t<97): 19.1 / 9.7	open (t<206): 20.3 / 10.3	initial (t<131): 20.9 / 10.8	215
		unstressed (t<118): 21.4 / 10.6	closed (t<9): 20.4 / 9.9	internal (t<84): 19.4 / 9.3	
/t/	19.7 / 9.6	stressed (t<100): 19.1 / 8.5	open (t<244): 19.7 / 9.7	initial (t<102): 21.6 / 11	262
		unstressed (t<162): 20 / 10.3	closed (t<18): 19.6 / 9.5	internal (t<160): 18.5 / 8.5	
/k/	33.5 / 13.1	stressed (t<84): 34.6 / 11.4	open (t<178): 33.4 / 13.4	initial (t<83): 34.9 / 15.3	196
		unstressed (t<112): 32.7 / 14.3	closed (t<18): 35 / 10.7	internal (t<113): 32.6 / 11.3	

Figure 4.84. Mean VOT values (ms) in Spanish produced by the Ukrainian HSs in the sentence-reading task

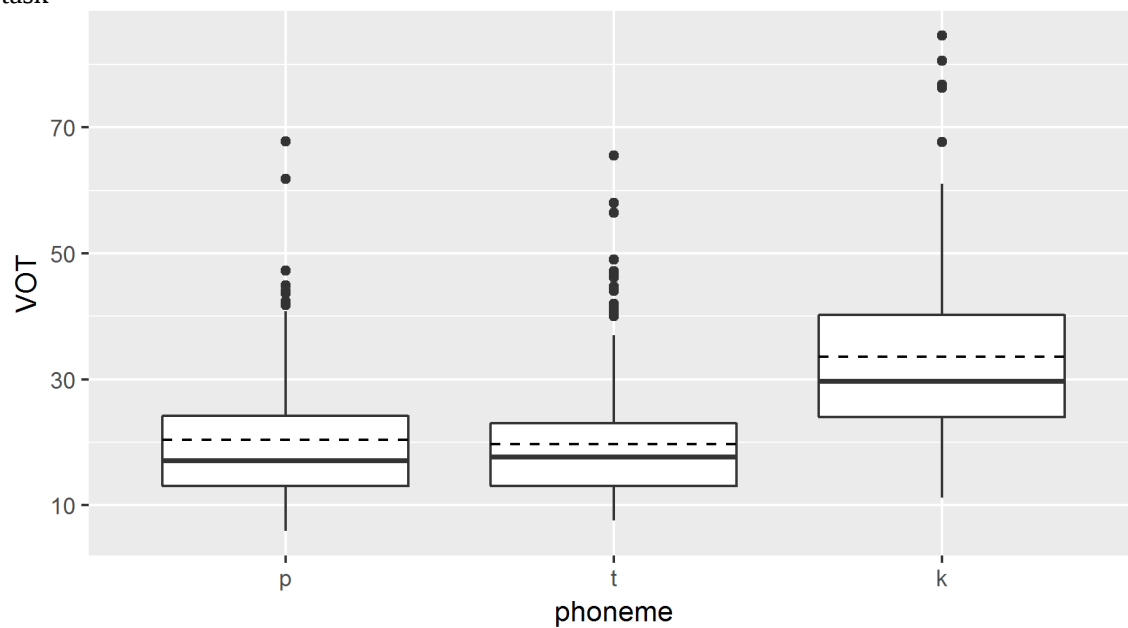
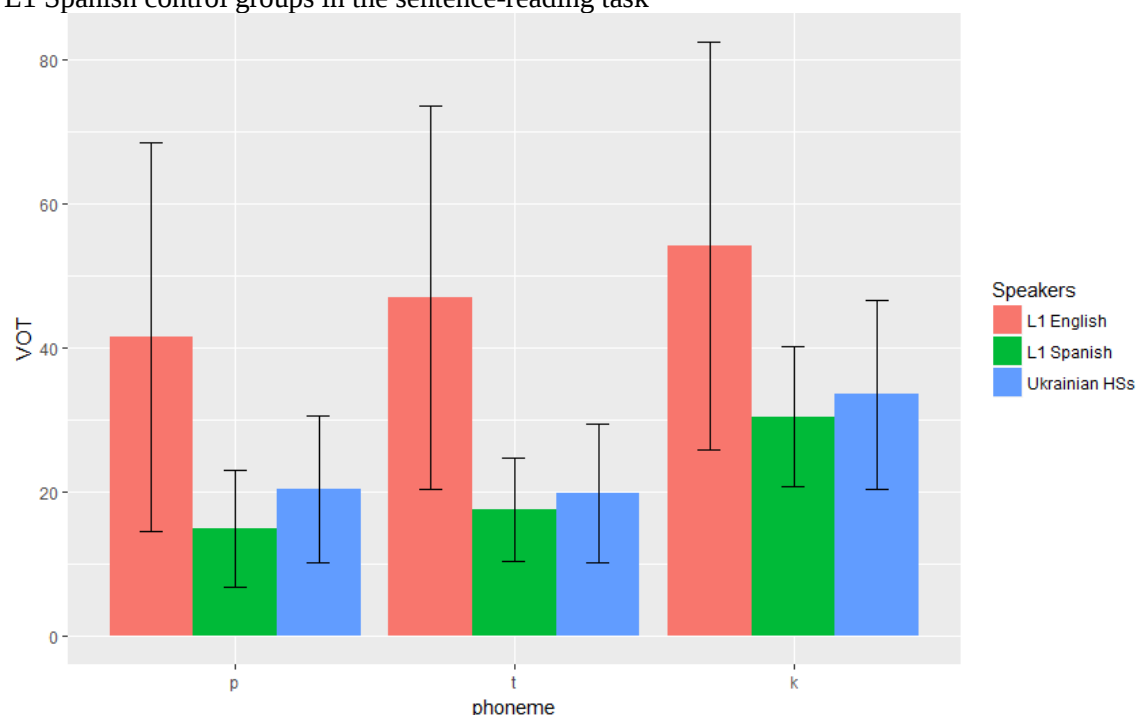


Figure 4.85. Mean VOT (ms) values in Spanish produced by the Ukrainian HSs and the L1 English and L1 Spanish control groups in the sentence-reading task



In the final task, the group's mean VOT values once again fall in the short-lag VOT category, as they did in the previous three tasks (Table 4.62). The difference, however, is that the segment with the shortest VOT value in this task is the dental /t/ and not the bilabial /p/, a result that differentiates from the L1 Spanish group distribution. Figure 4.87 provides a visual comparison of the Ukrainian HSs' VOT data in the nonce words reading task to the control groups' results. As in the previous tasks, the velar /k/ display the longest VOT value out of the three stops. When looking at the independent variables, a two-sample t-test confirmed statistical significance of word position ($p < .00254$) and showed no effect of stress ($p < .334$) and syllable type ($p < .0975$), with all three stops displaying longer VOT values in word-initial position.

Table 4.62. Mean VOT values (ms) in Spanish produced by the Ukrainian HSs in the nonce words reading task

Phoneme	Mean / SD	Mean / SD by stress	Mean / SD by syllable type	Mean / SD by word position*	Total tokens
/p/	25.2 / 15.4	stressed (t<18): 23.5 / 17.6	open (t<54): 25.2 / 15.4	initial (t<36): 26.4 / 15.7	54

		unstressed (t<36): 26 / 14.3	closed (t<0): NA	internal (t<18): 22.8 / 15	
/t/	23.6 / 15.7	stressed (t<32): 23.2 / 16.1	open (t<102): 23.4 / 16.1	initial (t<48): 26.5 / 16.7	114
		unstressed (t<82): 23.8 / 15.6	closed (t<12): 25.7 / 11.2	internal (t<66): 21.5 / 14.6	
/k/	31.4 / 10.8	stressed (t<2): 45.4 / 33.3	open (t<36): 30.6 / 11.6	initial (t<36): 33.8 / 11.3	54
		unstressed (t<52): 30.9 / 9.6	closed (t<18): 33 / 9.2	internal (t<18): 26.6 / 8.3	

*significant at the $\alpha < 0.05$ level

Figure 4.86. Mean VOT values (ms) in Spanish produced by the Ukrainian HSs in the nonce words reading task

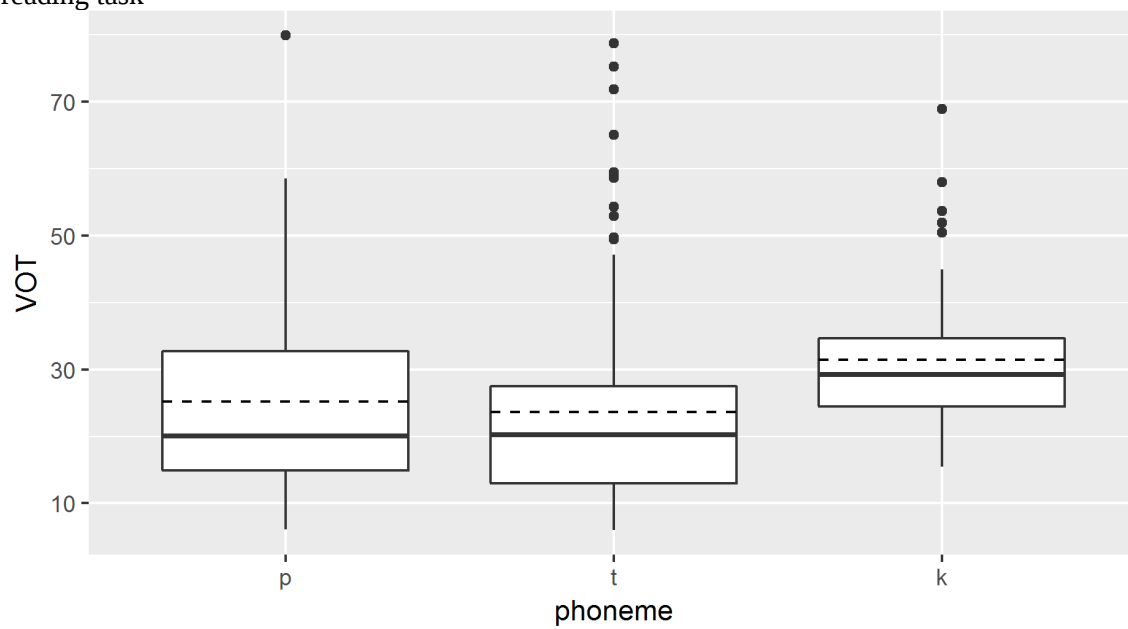
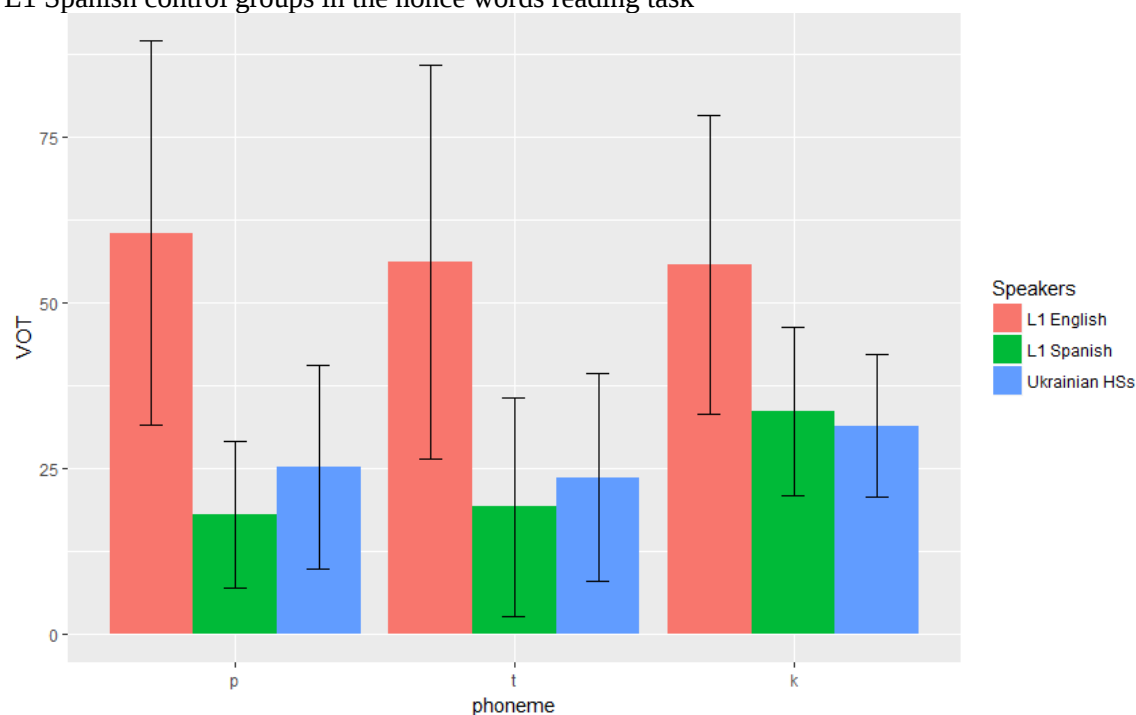


Figure 4.87. Mean VOT (ms) values in Spanish produced by the Ukrainian HSs and the L1 English and L1 Spanish control groups in the nonce words reading task

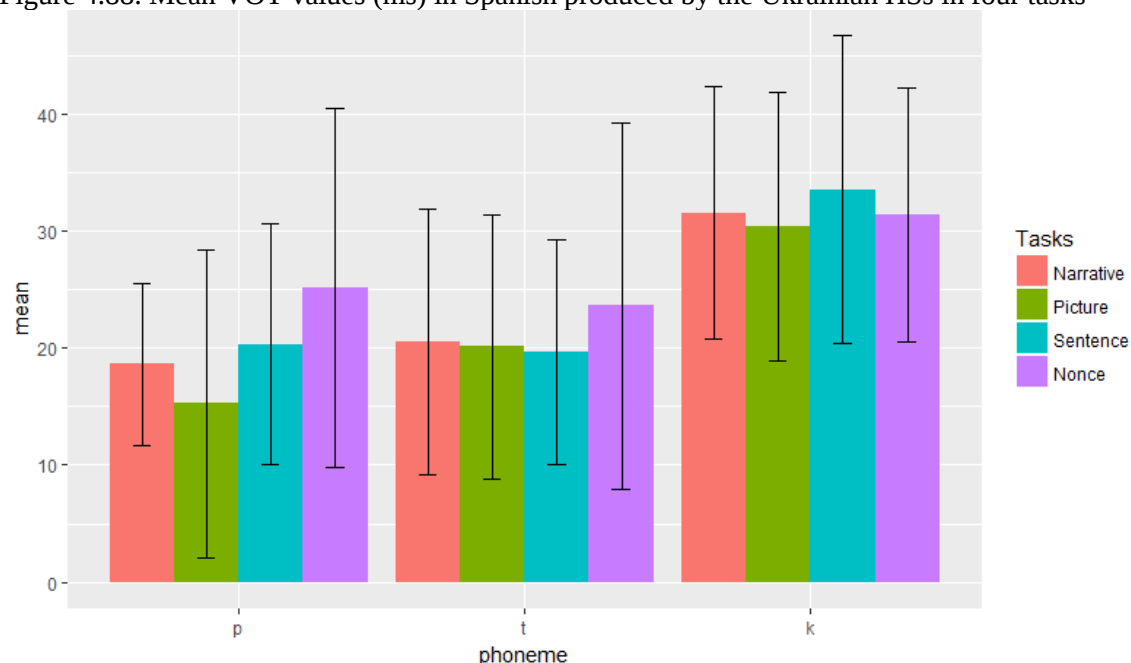


4.3.4.3.1 Summary

Figure 4.88 summarizes the mean VOT values of Spanish stops produced by the Ukrainian HSs in all four tasks. The phonemes /p/ and /k/ display the shortest VOT values in the picture-naming task, while /t/ has the shortest VOT duration in the sentence-reading task. Once again, both the bilabial and the dental phonemes show the longest VOT values in the nonce word reading task, while /k/ displays the longest VOT in the sentence-reading task.

A Linear Mixed Effects Model was conducted to determine the statistical significance of task on the VOT of each individual phoneme, revealing statistical significance of task type on the VOT of /p/ ($p < 3.41 \times 10^{-5}$) and /t/ ($p < .002798$). The task design did not have a statistically significant effect on the production of /k/ ($p < .2379$). The raw data results corroborate the statistical findings signaling that as task formality increases, /p/ and /t/ also show an increase in the VOT.

Figure 4.88. Mean VOT values (ms) in Spanish produced by the Ukrainian HSs in four tasks



4.3.4.4 Polish HSs

A total of 2,121 productions of /p t k/ were analyzed in the Polish HSs' data: 232 in the narrative task, 263 in the picture-naming task, 1,223 in the sentence-reading task, and 403 in the nonce words reading task.

The group results reveal that the Polish HSs produced the bilabial segment as short-lag, but the dental and the velar segments as long-lag in the narrative task (Table 4.63). This outcome places the Polish HSs between the results of the Ukrainian HSs group, who produced all three segments as short-lag, and the results of the L1 English control group, who produced all three segments as long-lag. Figure 4.90 provides a visual comparison of the Polish HSs' VOT data in the narrative task to the control groups' results. A two-sample t-test showed no effect of stress ($p < .108$) and syllable type ($p < .543$) on VOT values, but proved word position ($p < .000985$) to be statistically significant. All stops display longer VOTs in word-initial position.

The amount of variation in the data sets is different for each speaker. For instance, four speakers show greater distribution of the data points away from the mean, while the standard deviations of the rest of the speakers' data show less variation and more clustering of the data points around the means.

Table 4.63. Mean VOT values (ms) in Polish produced by the Polish HSs in the narrative task

Phoneme	Mean / SD	Mean / SD by stress	Mean / SD by syllable type	Mean / SD by word position*	Total tokens
/p/	28.6 / 17.9	stressed (t<31): 30 / 17.1	open (t<44): 27.9 / 18.3	initial (t<49): 30.7 / 19	65
		unstressed (t<34): 27.3 / 18.7	closed (t<21): 30.1 / 17.3	internal (t<16): 22.3 / 12.3	
/t/	42.7 / 22.6	stressed (t<19): 52.8 / 26	open (t<62): 41 / 21.9	initial (t<23): 51.8 / 23.7	73
		unstressed (t<54): 39.2 / 20.3	closed (t<11): 52.1 / 24.8	internal (t<50): 38.5 / 21	
/k/	53.6 / 25.8	stressed (t<38): 56.8 / 24.3	open (t<68): 53.5 / 26.8	initial (t<63): 59.4 / 27.9	94
		unstressed (t<56): 51.3 / 26.8	closed (t<26): 53.7 / 23.5	internal (t<31): 41.7 / 15.6	

*significant at the $\alpha < 0.05$ level

Figure 4.89. Mean VOT values (ms) in Polish produced by the Polish HSs in the narrative task

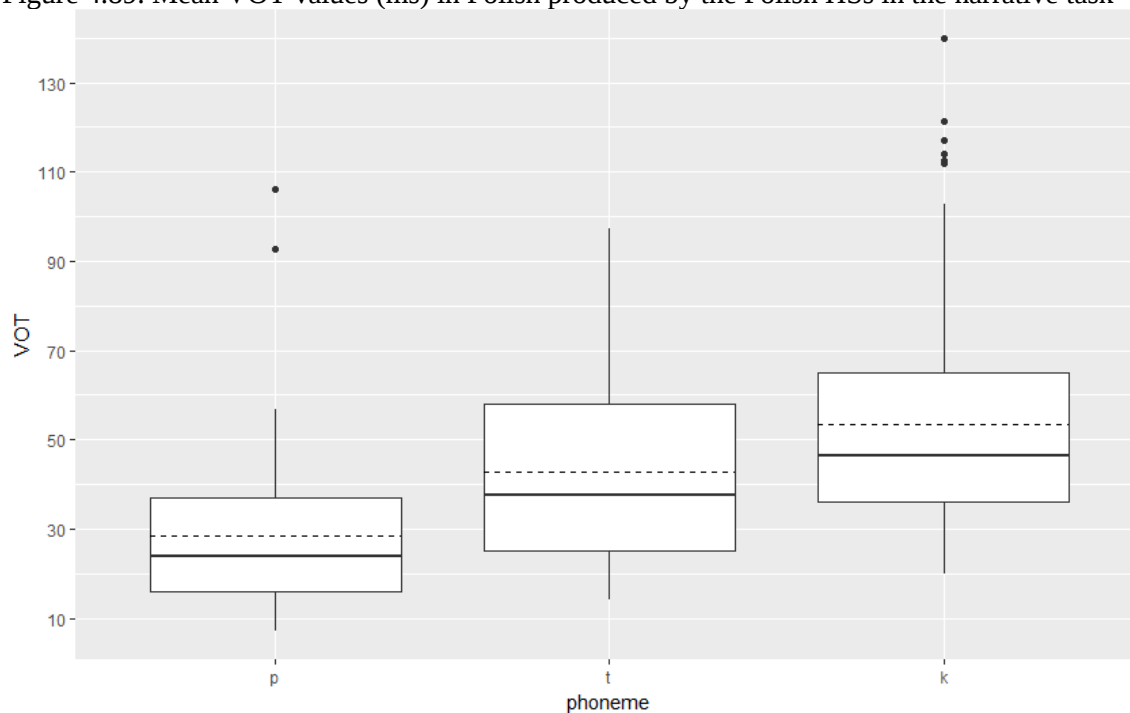
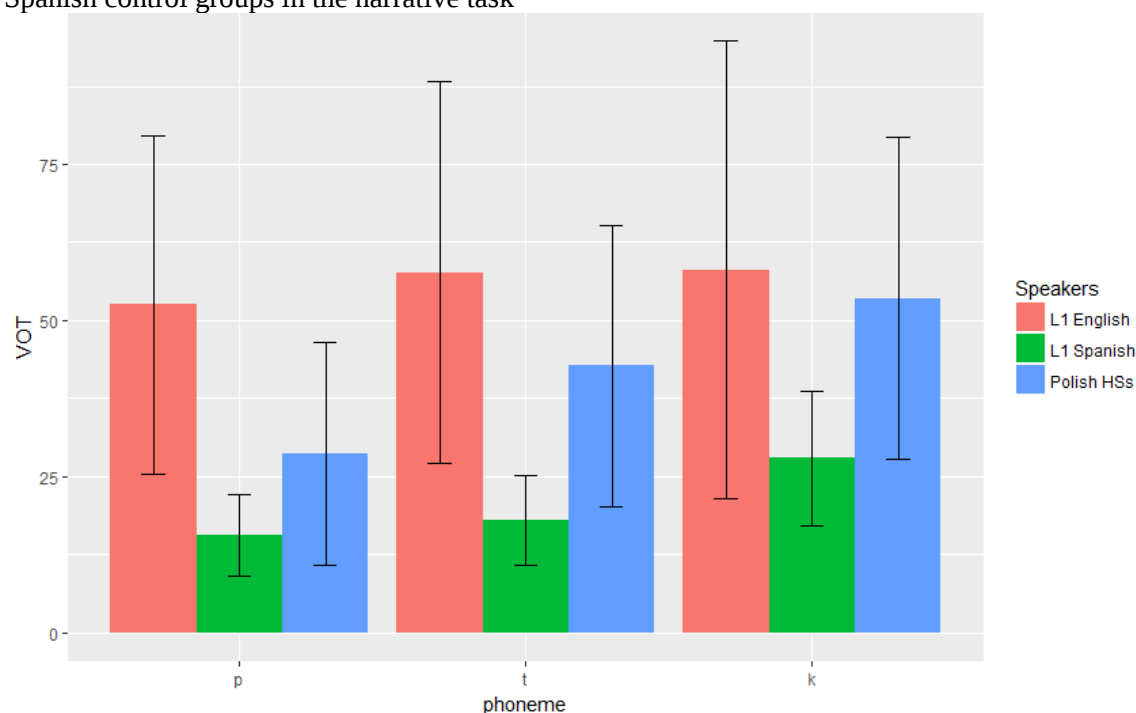


Figure 4.90. Mean VOT (ms) values in Spanish produced by the Polish HSs and the L1 English and L1 Spanish control groups in the narrative task



Similar to the narrative task, the Polish HSs produced /p/ as short-lag, and /t/ and /k/ as long-lag in the picture-naming task, placing their outcome between the Ukrainian HSs and the L1 English speakers' data results (Table 4.64). The relationship between the place of articulation and VOT resembles the one reflected in the L1 Spanish data where the bilabial segment had the shortest VOT and the velar segment the longest. The visual comparison of the Polish HSs' VOT data to the control groups' results in the picture-naming task can be referenced in Figure 4.92. A two-sample t-test was conducted to determine the statistical significance of the independent variables. Word position ($p < .0233$) was shown to be significant, while stress ($p < .497$) and syllable type ($p < .561$) had no effect on VOT. All three stops display longer VOT duration in word-initial positions.

Since the picture-naming task was a more controlled elicitation, the speakers produced a relatively similar number of tokens, with only one exception (one participant produced only one

/p/ token). When looking at the standard deviations in the individual results, they are generally higher than in the previous task, signaling greater variation in the data.

Table 4.64. Mean VOT values (ms) in Polish produced by the Polish HSs in the picture-naming task

Phoneme	Mean / SD	Mean / SD by stress	Mean / SD by syllable type	Mean / SD by word position*	Total tokens
/p/	29.6 / 23	stressed (t<25): 29.8 / 24.6	open (t<28): 29.8 / 25	initial (t<39): 29.9 / 23.3	40
		unstressed (t<15): 29.3 / 20.9	closed (t<12): 29.1 / 18.3	internal (t<1): 20.2 / NA	
/t/	37.2 / 23.3	stressed (t<22): 40 / 27.5	open (t<90): 36.8 / 22.1	initial (t<58): 40.8 / 24.9	112
		unstressed (t<90): 36.6 / 22.3	closed (t<22): 39.2 / 28.2	internal (t<54): 33.5 / 21.1	
/k/	45 / 19.8	stressed (t<10): 51.5 / 20.3	open (t<99): 45.2 / 19.8	initial (t<65): 49.9 / 19.8	111
		unstressed (t<101): 44.3 / 19.7	closed (t<12): 43.1 / 20.9	internal (t<46): 38 / 17.8	

*significant at the $\alpha < 0.05$ level

Figure 4.91. Mean VOT values (ms) in Polish produced by the Polish HSs in the picture-naming task

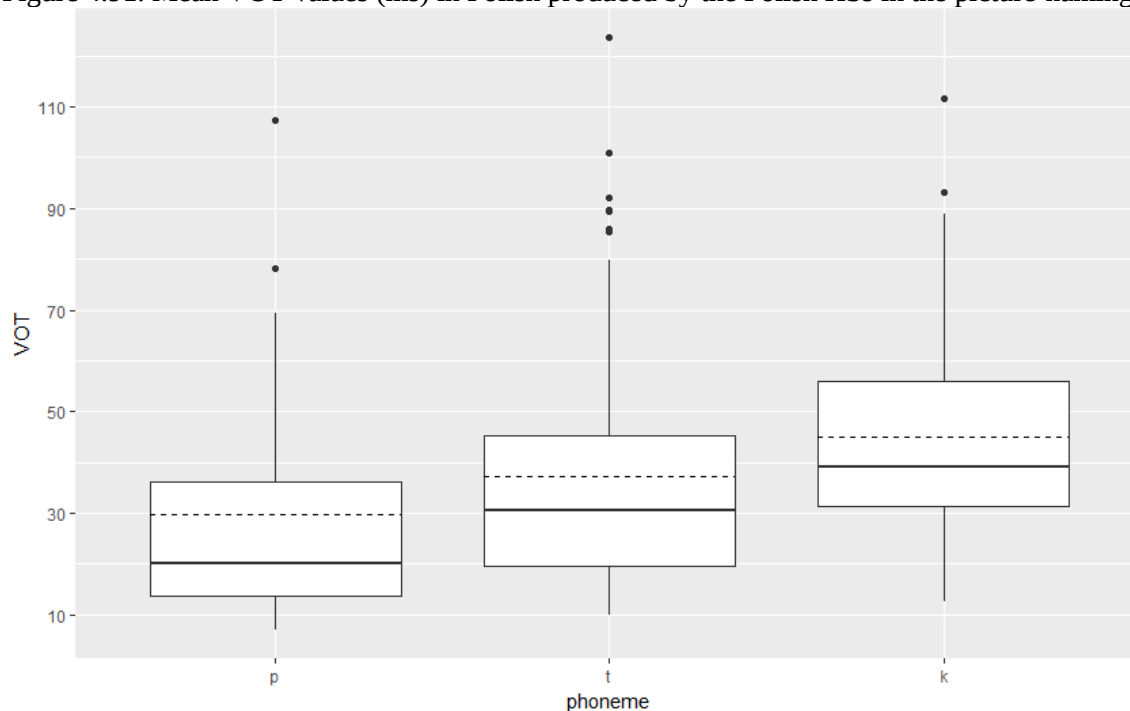
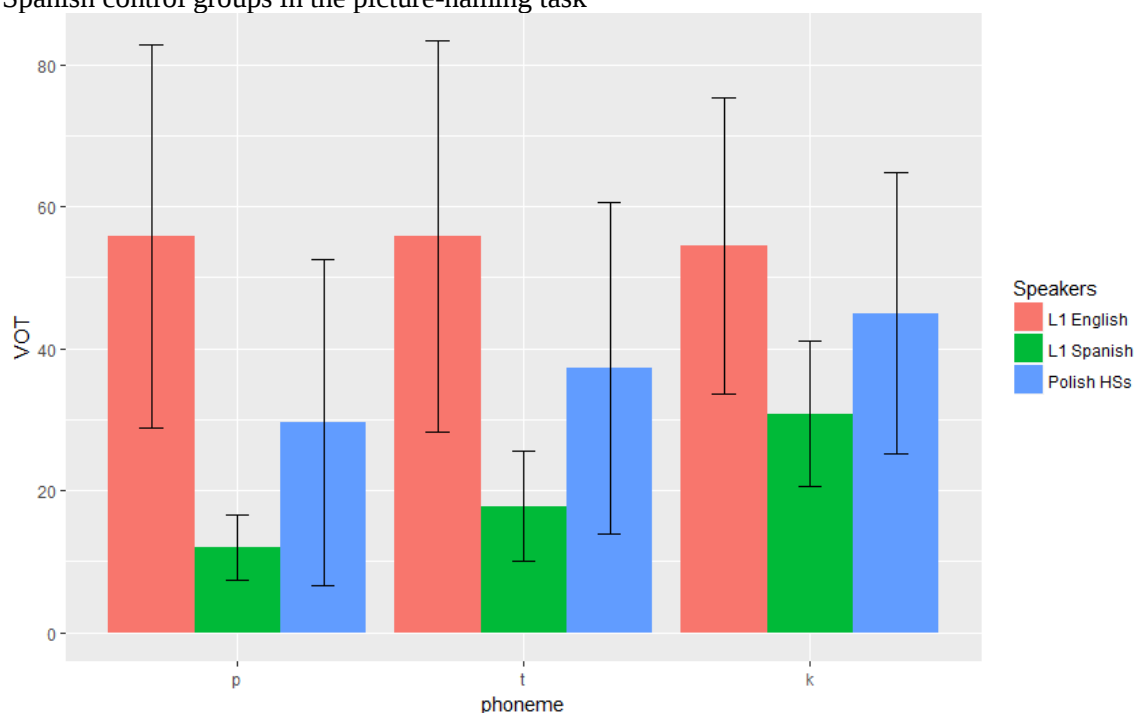


Figure 4.92. Mean VOT (ms) values in Spanish produced by the Polish HSs and the L1 English and L1 Spanish control groups in the picture-naming task



The group results reveal that the three stops were produced as long-lag in the sentence-reading task (Table 4.65). However, the values displayed for the bilabial and the dental segments (33.7 ms and 33.2 ms, respectively) were close to the short-lag category. The velar segment was produced with the longest VOT duration, and the dental segment with the shortest. However, the difference between the VOTs of /t/ and /p/ is very small (0.5 ms). A visual comparison of the Polish HSs' VOT data to the control groups' results in the sentence-reading task can be referred to in Figure 4.94. A two-sample t-test was conducted and revealed that stress ($p < .0128$) is statistically significant and word position ($p < 2.04 \times 10^{-8}$) is very significant, while syllable type ($p < .633$) showed no statistically significant effect on the VOT values. The segments /t/ and /k/ display longer VOTs in stressed position, while /p/ does so in the opposite context. All three stops were produced with longer VOT values in word-initial position.

Table 4.65. Mean VOT values (ms) in Polish produced by the Polish HSs in the sentence-reading task

Phoneme	Mean / SD	Mean / SD by stress*	Mean / SD by syllable type	Mean / SD by word position*	Total tokens
/p/	33.7 / 19.4	stressed (t<185): 33.4 / 19.9	open (t<379): 33.7 / 19.5	initial (t<239): 34.6 / 19.7	401
		unstressed (t<216): 34 / 19	closed (t<22): 34.3 / 17.3	internal (t<162): 32.5 / 18.9	
/t/	33.2 / 18.6	stressed (t<183): 36.3 / 20	open (t<440): 33 / 18.4	initial (t<185): 39.7 / 20.5	472
		unstressed (t<289): 31.2 / 17.4	closed (t<32): 35.1 / 20.7	internal (t<287): 29 / 15.9	
/k/	49.4 / 22.1	stressed (t<150): 51.8 / 22.3	open (t<319): 49.7 / 22.1	initial (t<148): 55.3 / 22.6	350
		unstressed (t<200): 47.6 / 21.9	closed (t<31): 46.5 / 22.1	internal (t<202): 45.1 / 20.8	

*significant at the $\alpha < 0.05$ level

Figure 4.93. Mean VOT values (ms) in Polish produced by the Polish HSs in the sentence-reading task

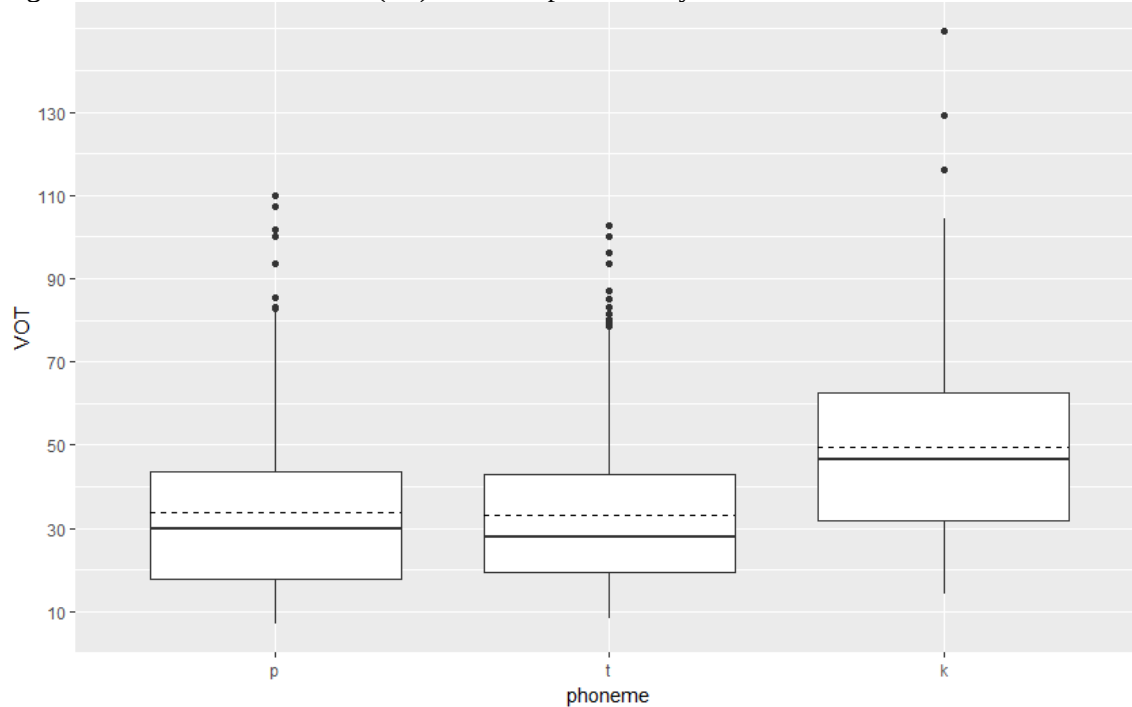
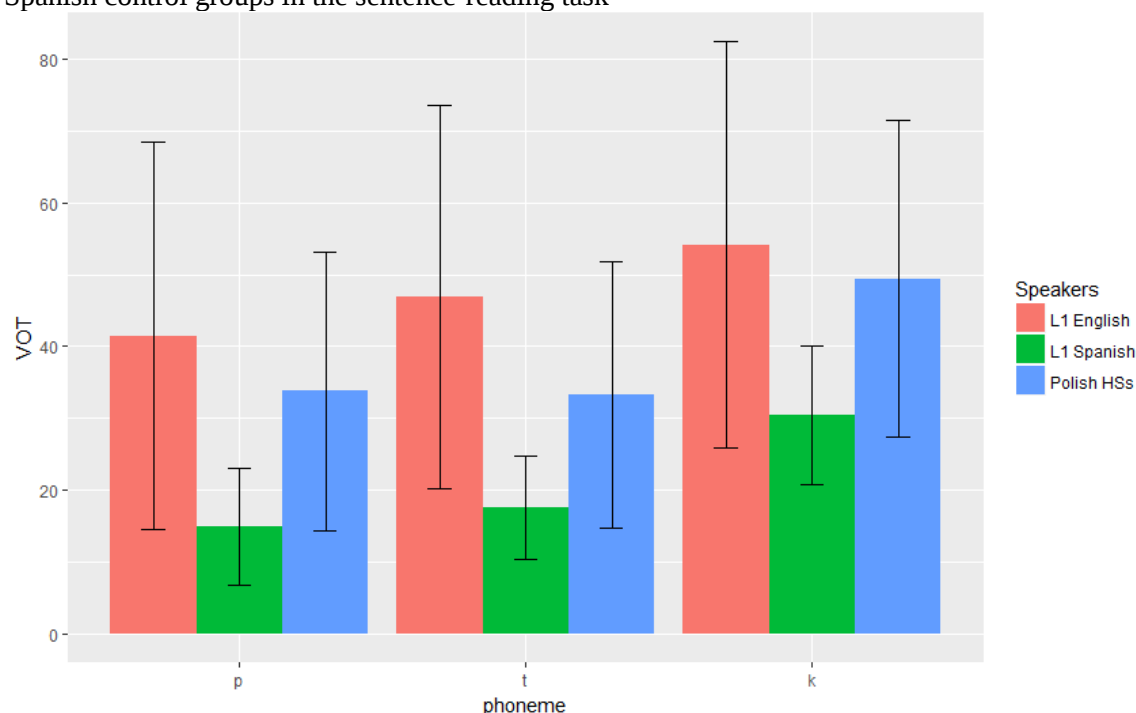


Figure 4.94. Mean VOT (ms) values in Spanish produced by the Polish HSs and the L1 English and L1 Spanish control groups in the sentence-reading task



Finally, as in the previous three tasks, the voiceless stops in the nonce words reading task were produced as long-lag (Table 4.66). However, the mean VOT of /t/ is very close to the short-lag category. Similar to the sentence-reading task, the segment /k/ was produced with the longest VOT, while /t/ was produced with the shortest VOT duration. The difference, however, between the VOTs of /p/ and /t/ is greater than in the previous task (7.2 ms). A comparison of the VOT durations produced by the Polish HSs group and the control groups can be referenced in Figure 4.96. A two-sample t-test reveals that both syllable type ($p < .00284$) and word position ($p < 2 \times 10^{-16}$) are very significant, while stress ($p < .755$) had no effect on the VOT. The segments /t/ and /k/ have longer VOTs in closed syllable context, while /p/ shows longer VOT durations in open syllable positions (the bilabial segment has no tokens in the closed syllable category). Finally, all three stops display longer VOT values in word-initial position.

Table 4.66. Mean VOT values (ms) in Polish produced by the Polish HSs in the nonce words reading task

Phoneme	Mean / SD	Mean / SD by stress	Mean / SD by syllable type*	Mean / SD by word position*	Total tokens
/p/	39.6 / 22.7	stressed (t<33): 35 / 21.9	open (t<100): 39.6 / 22.7	initial (t<67): 44.3 / 22.6	100
		unstressed (t<67): 41.9 / 23	closed (t<0): NA	internal (t<33): 30.1 / 20	
/t/	32.2 / 18.8	stressed (t<56): 37.3 / 21.3	open (t<183): 31.7 / 19	initial (t<86): 40.3 / 20.1	206
		unstressed (t<150): 30.3 / 17.5	closed (t<23): 35.9 / 17.3	internal (t<120): 26.4 / 15.5	
/k/	44.8 / 19	stressed (t<12): 46.4 / 16.7	open (t<64): 41.8 / 19.7	initial (t<66): 50.9 / 18	97
		unstressed (t<85): 44.6 / 19.4	closed (t<33): 50.8 / 16.3	internal (t<31): 31.9 / 14.3	

*significant at the $\alpha < 0.05$ level

Figure 4.95. Mean VOT values (ms) in Polish produced by the Polish HSs in the nonce words reading task

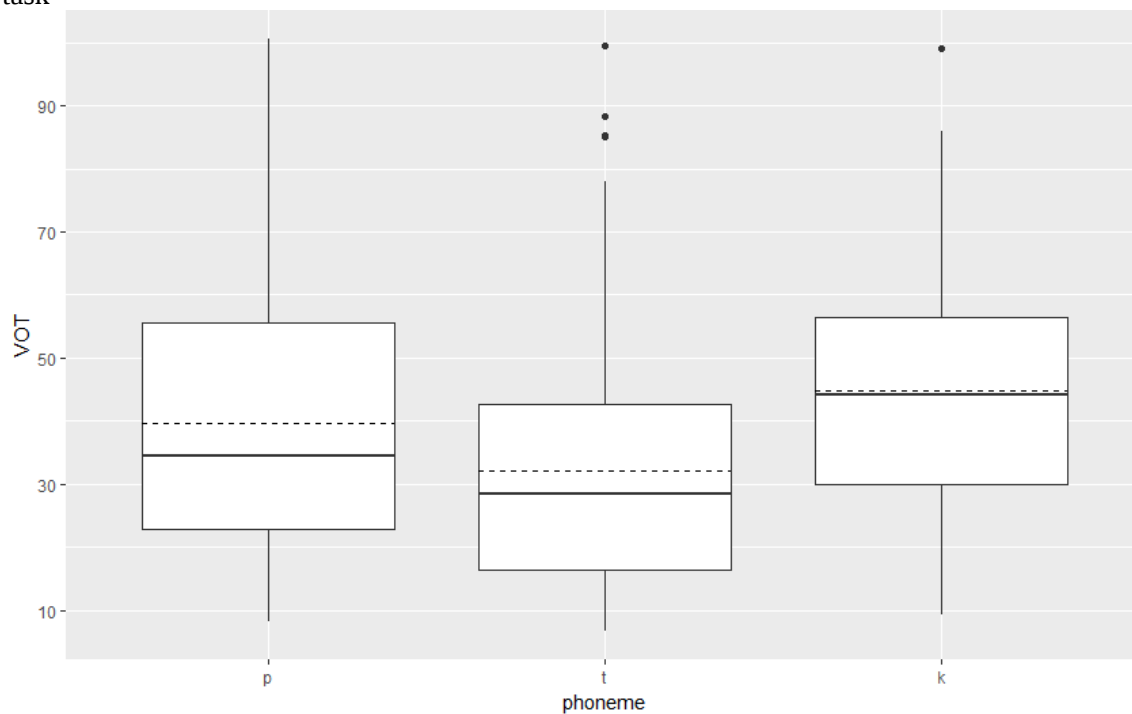
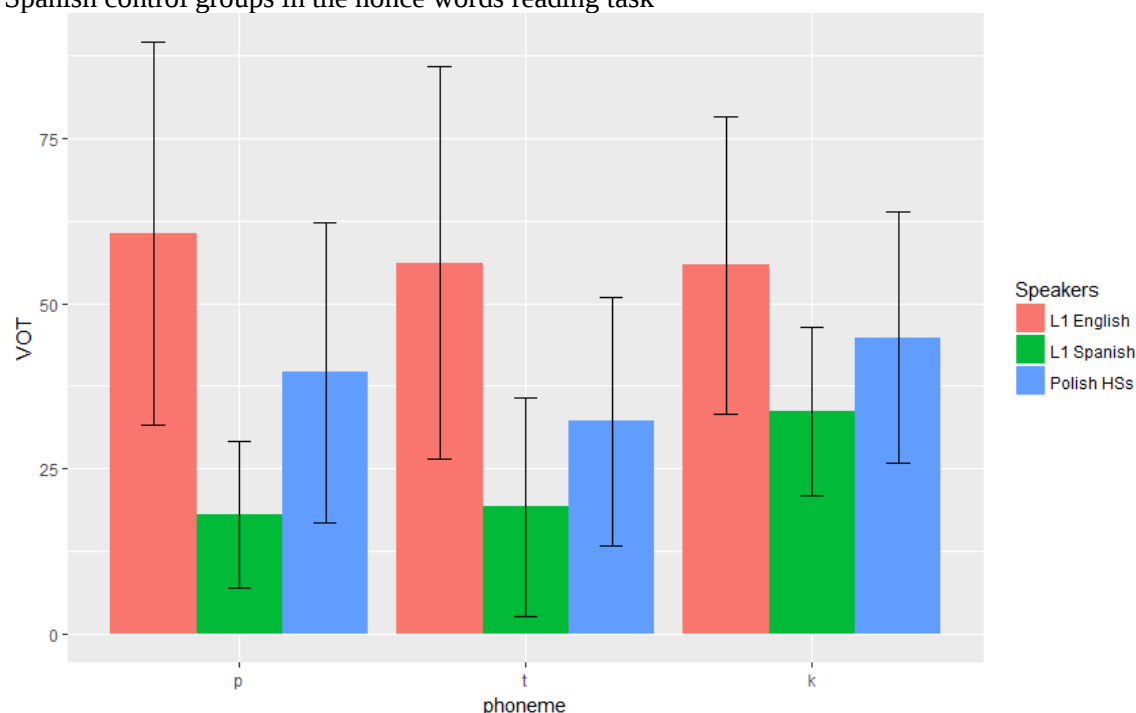


Figure 4.96. Mean VOT (ms) values in Spanish produced by the Polish HSs and the L1 English and L1 Spanish control groups in the nonce words reading task

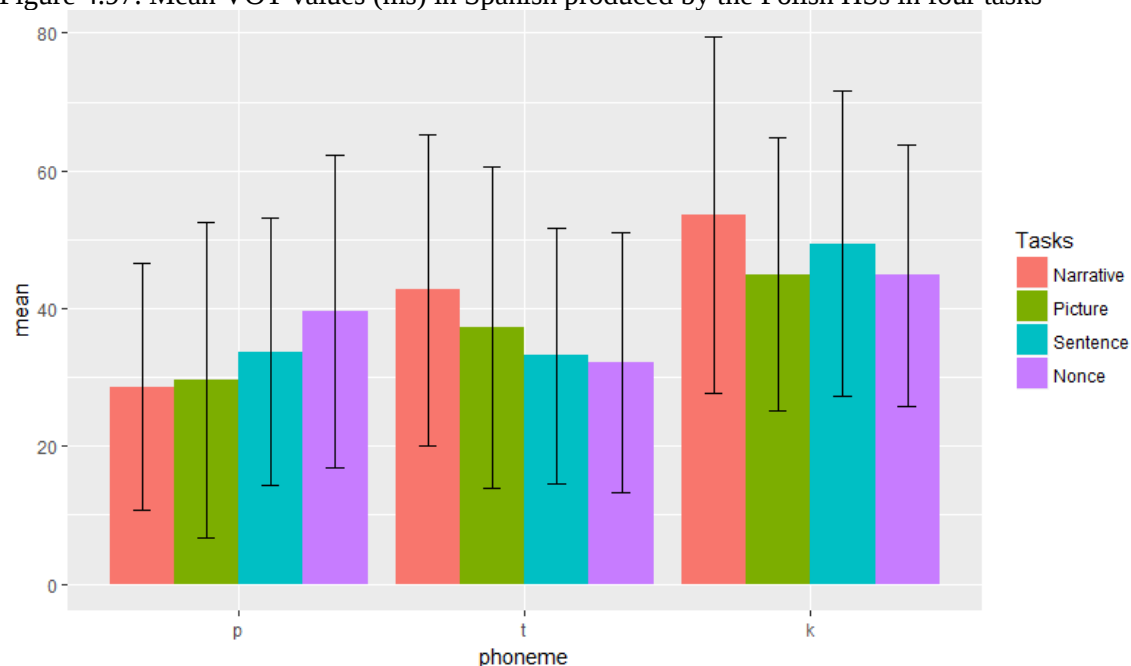


4.3.4.4.1 Summary

Figure 4.97 summarizes the voiceless stop productions by the Polish HSs in all four tasks. The bilabial segment was produced with the shortest VOT duration in the narrative task, and the dental and the velar segments displayed the shortest VOT measurements in the nonce words reading task. Interestingly, the phoneme /p/ showed the longest VOT duration in the nonce words reading task, while /t/ and /k/ had the longest VOT values in the narrative task.

A Linear Mixed Effects Model was fitted and revealed that task type had a statistically significant effect on all three phonemes (/p/: $p < .002483$, /t/: $p < 4.616 \times 10^{-7}$, /k/: $p < 0.0009222$). While /p/ shows a clear increase in VOT as task becomes more formal and /t/ decreases in VOT as elicitation become more controlled, the relationship between task formality and VOT for /k/ is not very clear.

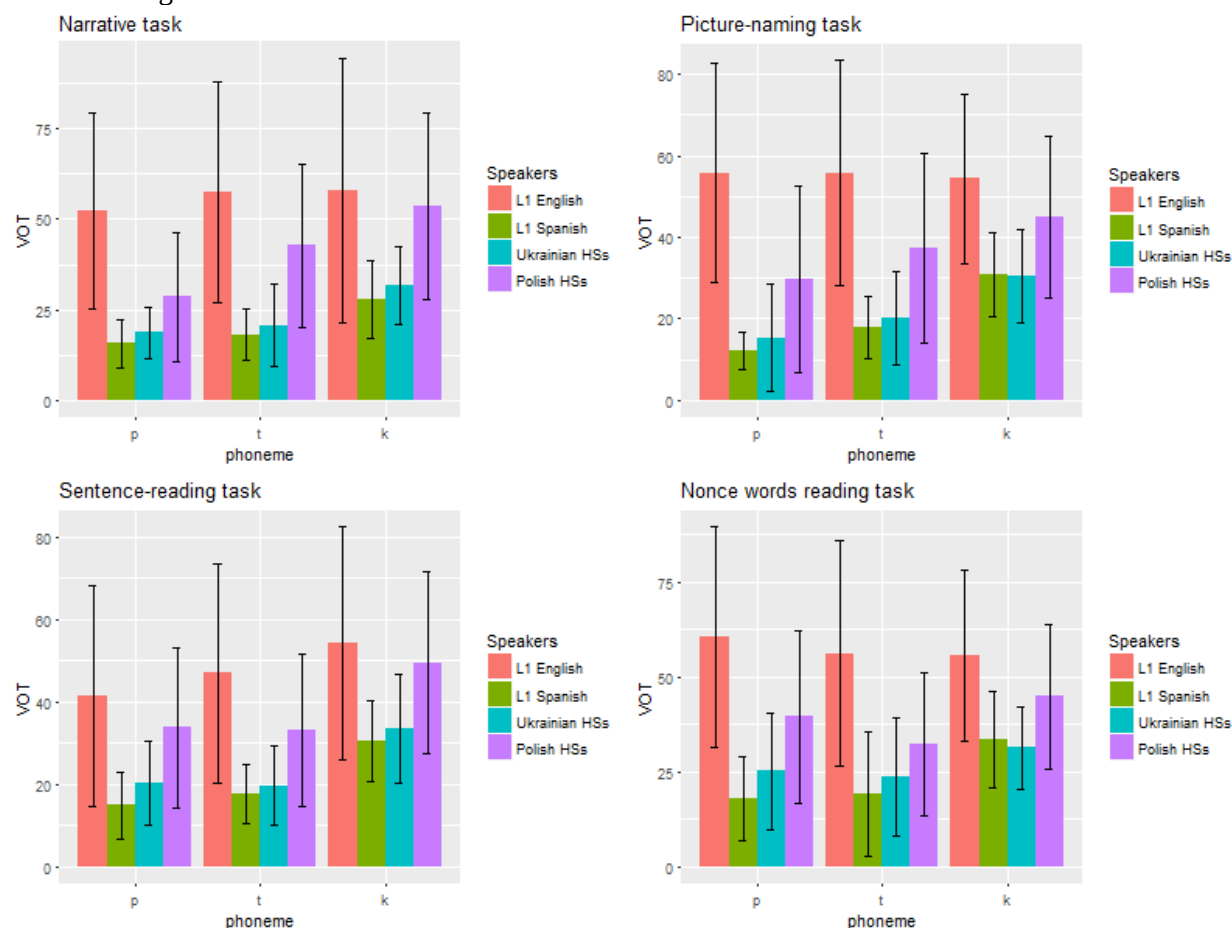
Figure 4.97. Mean VOT values (ms) in Spanish produced by the Polish HSs in four tasks



4.3.5 Summary of the Spanish voiceless stops productions

Figure 4.98 summarizes the productions of the Spanish /p t k/ by the Ukrainian HSs, the Polish HSs, and L1 English and L1 Spanish control groups in the narrative, picture-naming, sentence-reading, and nonce words reading tasks. The L1 Spanish control group produced the lowest VOT values in all four tasks among the four speaker groups with two exceptions. In the picture-naming task and the nonce words reading task, the Ukrainian HSs displayed the lowest VOT values for the velar segment /k/. The Ukrainian HSs demonstrated the second lowest VOT values after the L1 Spanish control group, followed by the Polish HSs. The L1 English control produced all segments in all four tasks with the longest VOT durations among the four speaker groups.

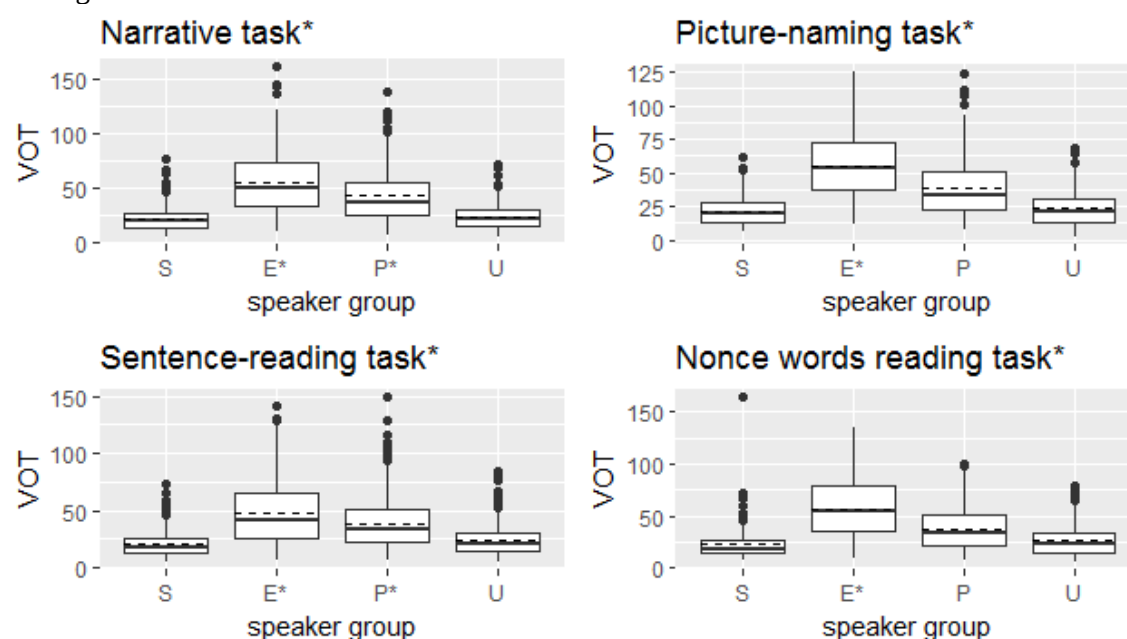
Figure 4.98. Mean VOT (ms) values in Spanish produced by the Ukrainian HSs, the Polish HSs and the L1 English and L1 Spanish control groups in the narrative, picture-naming, sentence-reading and nonce words reading tasks



The mean VOT measurements were subjected to a Linear Mixed Effects Model where *phoneme* and *speaker group* were included as fixed effect and *individual speaker* as random effect, in order to determine whether there were any statistically significant differences between the acoustic means of the four groups of speakers. Figure 4.99 provides a graphical representation of the /p t k/ productions by the four groups of speakers, where the results are grouped by task, but not by phoneme. The test revealed that the productions of the four groups were significantly different in all four tasks (narrative: $p < 3.618 \cdot 10^{-5}$, picture-naming: $p < .0005493$, sentence-reading: $p < .0004193$, nonce words reading: $p < 0.000005$). A closer examination of the four groups of participants via post-hoc pairwise comparisons with a

Bonferroni adjustment revealed that the L1 English control group's results are significantly different from those of the L1 Spanish speakers in all four tasks (narrative: $p < 8.15 \cdot 10^{-6}$, picture-naming: $p < .000557$, sentence-reading: $p < .000537$, nonce words reading: $p < 5.79 \cdot 10^{-6}$). The following are the differences between the average means of the L1 Spanish and L1 English speakers: 38.4 ms (narrative), 33.4 ms (picture-naming), 26.9 ms (sentence-reading), and 34.9 ms (nonce words reading). The Polish HSs significantly differ from the L1 Spanish base in the narrative ($p < .00707$) and sentence-reading ($p < 0.015996$) tasks, where the differences between the means of the L1 Spanish base and the Polish HSs equal 21.9 ms and 17.5 ms, respectively. The Ukrainian HSs' productions, on the other, do not differ significantly from those of the L1 Spanish control group in any of the tasks, approximating them the closest.

Figure 4.99. Productions of the Spanish /p t k/ by the Ukrainian HSs, the Polish HSs, and the L1 English and L1 Spanish control groups in the narrative, picture-naming, sentence-reading and nonce words reading tasks



4.3.6 Summary of the main findings from the voiceless stops analyses

The following list summarizes the main discoveries in the Ukrainian, Polish, English, and Spanish voiceless stops produced by the Ukrainian and Polish HSs, as well as L1 English and L1 Spanish speakers.

- The Ukrainian HSs produced the Ukrainian voiceless stops as short-lag, according to the Ukrainian norm.
- The Polish HSs produced the Polish bilabial and dental segments as short-lag, but the velar segment was produced as long-lag, following the Polish norm in the pronunciation of /p/ and /t/, but not /k/.
- Both the Ukrainian and the Polish HSs produced the English voiceless stops as long-lag, displaying results that are closer to the L1 English base than the production of the L1 Spanish control group. Linguistic context did not play a statistically significant role in any of the productions.
- The Ukrainian HSs produced all three Spanish voiceless stops as short-lag in all four tasks, mimicking the L1 Spanish control group's results, who also produced /p t k/ as short-lag in the four tasks. Consequently, the Ukrainian HSs' results approximated the L1 Spanish base the closest, more so than the L1 English control group and the Polish HSs.
- The Polish HSs produced the Spanish /p/ as short-lag in the narrative, picture-naming, and sentence reading tasks, and /t/ as short-lag in sentence and nonce words reading tasks. The rest of the segments were produced as long-lag, showing evidence of transfer from both the heritage and the dominant languages.
- The L1 English speakers produced the Spanish /p t k/ as long-lag in all four tasks, showing clear evidence of transfer from English.

- The relationship between task formality and VOT varied between the four groups. The L1 Spanish speakers displayed an increase in VOT for /p/ and /k/, Ukrainian HSs did so for /p/ and /t/, and the Polish HSs only for /p/. The L1 English group, however, showed no cleared relationship between task formality and VOT values.
- The L1 English participants and the Polish HSs showed a significant effect of word position in all four tasks, but the other two groups did not show consistent significance of any of the independent variables.

4.4 Voiced stops

Each subsection of this unit contains a table that provides the overall RI means, means associated with independent variables, standard deviations, and token counts of the group results. Each section also contains a figure that provides a graphical representation of the group's RI measurements. Two-sample t-tests are utilized to establish the significance of the independent variables (i.e., stress, word position, syllable type) and Linear Mixed Effects Models, along with pairwise comparisons with a Bonferroni adjustment, are used to compare the estimated RI means of the four speaker groups.

4.4.1 Ukrainian voiced stops

A total of 116 productions of /b/ and /d / were analyzed. As described in Chapter 2, the Ukrainian voiced velar /g/ mainly appears in loan words and is not as common in Ukrainian words as its debuccalized counterpart, the glottal fricative /ɦ/. Due to its generally reduced use in Ukrainian, the velar /g/ does not appear in the Ukrainian HSs' data. Unlike the voiceless stops, the voiced stops do not undergo the process of palatalization before the front vowel /i/, and therefore, no tokens followed by /i/ were excluded from the analyses.

Since in Ukrainian voiced stops do not undergo weakening in intervocalic position as they do in Spanish, they were expected to be produced as voiced stops. However, the results demonstrate that both /b/ and /d/ were produced with lower RI means than was expected, indicating weakening of intervocalic stops in Ukrainian (Table 4.67). The bilabial segment undergoes a greater degree of weakening than the dental segment. A two-sample t-test was conducted to determine the statistical significance of stress, syllable type, and word position. The results revealed that stress was statistically significant ($p < .005$), while syllable type ($p < .977$) and word position ($p < .329$) showed no significant effect on RI. The two phonemes are less lenited in stressed position and show less constriction in unstressed context.

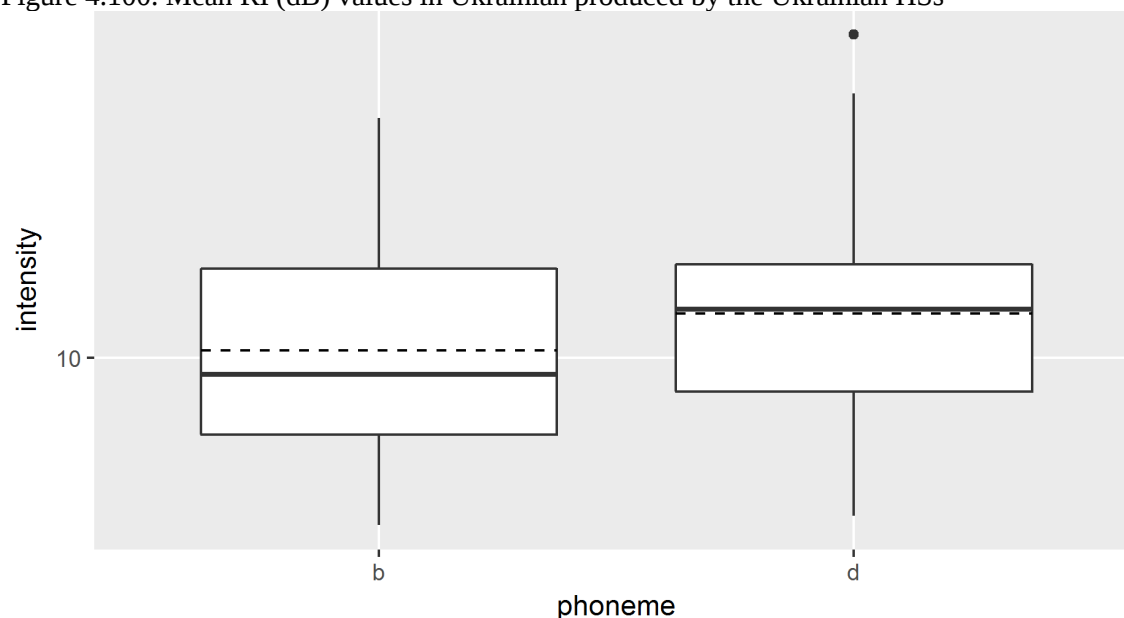
The data set has no outliers and the distribution of the tokens among the speakers is uniform. Negative VOT measurements of voiced stops were taken only in the cases where the voiced stop phonemes were produced as true stops and were not lenited. It was also only measured in instances where the audio quality was the highest. In the Ukrainian HSs' data, negative VOT measurements were taken in the following data sets: U1, U4, U5, and U6. Speakers U1, U4, and U6 show evidence of true voicing of the Ukrainian voiced stops by producing pre-voicing in instances when the segment was produced as a stop. Speaker U4 produced one segment (/d/) as a true voiced stop and two segments (/d/) with short-lag VOTs (i.e., English-like), which signal a lack of true voicing in those instances.

Table 4.67. Mean RI (dB) values in Ukrainian produced by the Ukrainian HSs

Phoneme	Mean / SD	Mean / SD by stress*	Mean / SD by syllable type	Mean / SD by word position	Total tokens
/b/	10.4 / 5.3	stressed (t<37): 11.4 / 5.2	open (t<41): 10.4 / 5.3	initial (t<24): 11 / 5.1	56
		unstressed (t<19): 8.4 / 5.1	closed (t<15): 10.5 / 5.6	internal (t<32): 9.9 / 5.5	
/d/	12.3 / 5.6	stressed (t<45): 13.1 / 5.3	open (t<45): 12.5	initial (t<22): 13.1 / 5.9	60
		unstressed (t<15): 10.2 / 6	closed (t<15): 12.2 / 6.1	internal (t<38): 12 / 5.4	

*significant at the $\alpha < 0.05$ level

Figure 4.100. Mean RI (dB) values in Ukrainian produced by the Ukrainian HSs



4.4.2 Polish voiced stops

A total of 179 productions of /b d g/ were analyzed (Table 4.68). As with the voiceless stop, no tokens that appear before the front vowel /i/ needed to be excluded, since they showed no evidence of palatalization. As was the case with Ukrainian voiced stops, Polish /b d g/ were expected to be produced as stops, since they do not undergo intervocalic weakening. However, the three voiced stops were produced with evidence of some degree of weakening and not as clear stops. The dental segment is the most lenited out of the three stops and the velar segment undergoes the least amount of weakening. A two-sample t-test revealed no statistical significance of either stress ($p < .051$), syllable type ($p < .112$) or word position ($p < .0799$). However, the raw data reveals less weakening of the three stops in stressed and word-initial contexts.

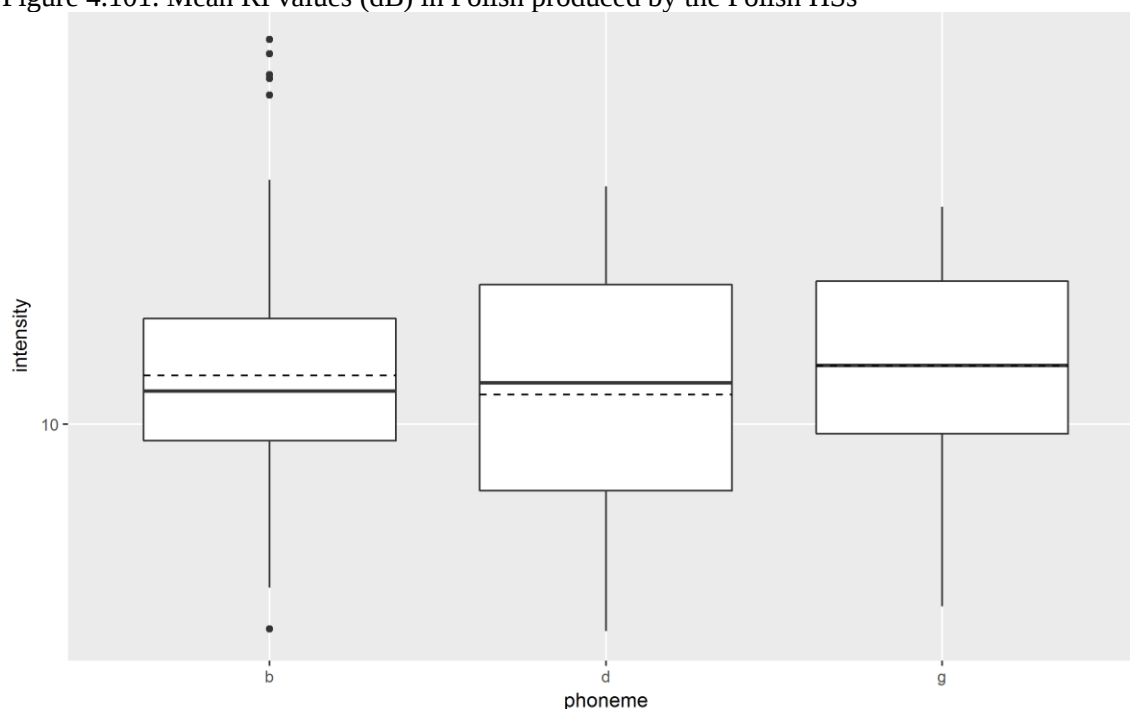
The data set does not have any outliers and the distribution of the tokens is rather uniform with some exceptions. The speakers show a comparable level of lenition, demonstrating a lesser degree of weakening in Polish than the Ukrainian HSs group in Ukrainian. Finally, negative

VOT measurements were taken for speakers P1, P3, P4, P5, P6, P7, P9, P10, and P11. All nine speakers show evidence of true voicing, in line with findings in the literature (Newlin-Łukowicz 2014, Ringen and Kulikov 2012).

Table 4.68. Mean RI (dB) values in Polish produced by the Polish HSs

Phoneme	Mean / SD	Mean / SD by stress	Mean / SD by syllable type	Mean / SD by word position	Total tokens
/b/	12.4 / 5.5	stressed (t<66): 12.8 / 5.3	open (t<70): 13.1 / 5.8	initial (t<65): 12.9 / 5.4	111
		unstressed (t<45): 11.8 / 5.7	closed (t<41): 11.1 / 4.6	internal (t<46): 11.6 / 5.5	
/d/	11.4 / 5.4	stressed (t<11): 14.1 / 4.7	open (t<22): 11.2 / 5.9	initial (t<13): 13.3 / 5.5	36
		unstressed (t<25): 10.3 / 5.4	closed (t<14): 11.9 / 4.8	internal (t<23): 10.4 / 5.2	
/g/	12.8 / 4.9	stressed (t<4): 16 / 2.7	open (t<31): 12.8 / 5	initial (t<2): 16 / 1	32
		unstressed (t<28): 12.4 / 5	closed (t<1): 12.8 / NA	internal (t<30): 12.6 / 5	

Figure 4.101. Mean RI values (dB) in Polish produced by the Polish HSs



4.4.3 English voiced stops

A total of 495 productions of the English voiced stops were analyzed. All four speaker groups (L1 English, L1 Spanish, Ukrainian HSs, Polish HSs) completed the narration task in English and the results are presented for each speaker group individually.

4.4.3.1 L1 English control group

The L1 English control group produced a total of 70 tokens of /b d g/ in the English narrative task (Table 4.69). Due to a limited number of tokens, the distribution of productions in the L1 English speakers' data is not uniform and certain categories have no tokens, such as the unstressed and syllable open categories for the phoneme /g/ and the word internal category for the phoneme /d/. As was described in Chapter 2, the voiced stops /b d g/ do not undergo intervocalic weakening in English. However, the group results of the L1 English speakers show evidence of lenition in the production of voiced stops, with /d/ displaying the lowest RI values, a finding which is not in line with the usual production of English voiced stops. A two-sample t-test was conducted to determine the statistical significance of the independent variables. Syllable type ($p < .00416$) was shown to be significant, while stress ($p < .0751$) and word position ($p < .226$) showed no effects. All three stops show less weakening in stressed position. The raw data also reveal a smaller degree of weakening in word-initial and closed syllable positions for all three stops.

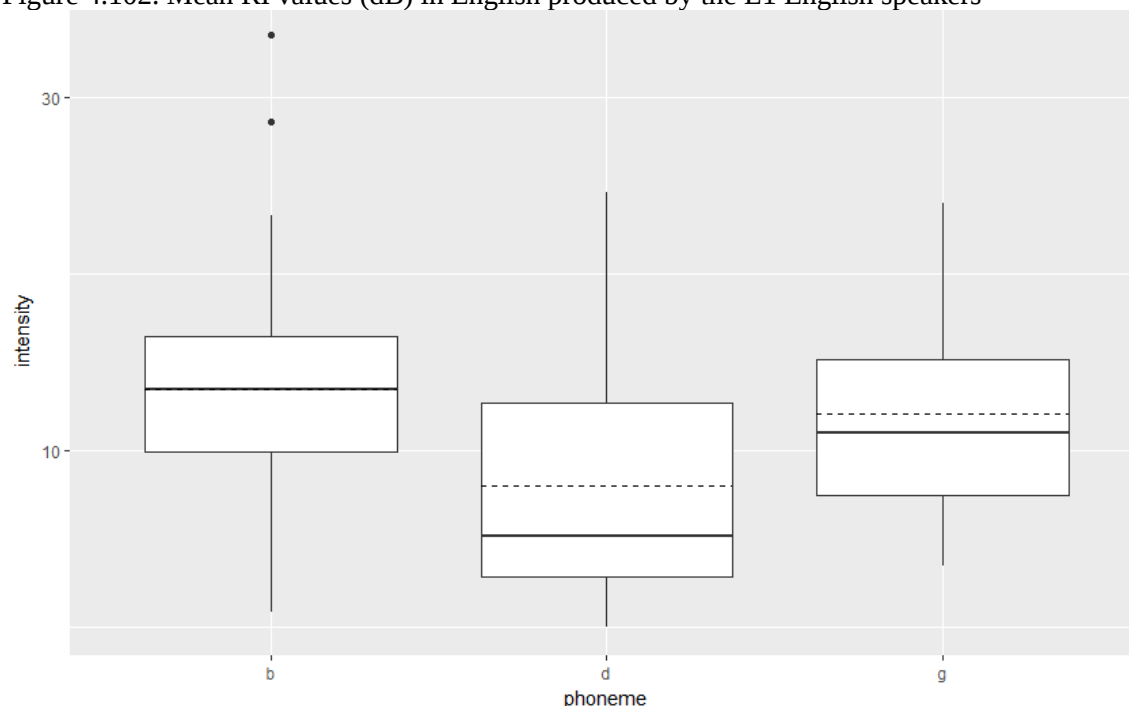
The VOT measurements of the voiced stops were recorded for all five speakers. Speakers E1 and E5 show evidence of true voicing of the phoneme /b/ in instances when it was produced as a stop. The rest of the speakers (E2, E3, E4) produced the voiced stops with short-lag, showing no evidence of true voicing, in line with earlier findings in the literature on English (Lisker and Abramson 1964).

Table 4.69. Mean RI values (dB) in English produced by L1 the English speakers

Phoneme	Mean / SD	Mean / SD by stress	Mean / SD by syllable type*	Mean / SD by word position	Total tokens
/b/	13.4 / 6.4	stressed (t<27): 15 / 5.1	open (t<17): 9.7 / 5.9	initial (t<43): 13.7 / 6.6	48
		unstressed (t<21): 11.3 / 7.4	closed (t<31): 15.4 / 5.8	internal (t<5): 10.9 / 4.5	
/d/	8 / 7.6	stressed (t<7): 9.9 / 7.6	open (t<2): 1.4 / 2	initial (t<9): 8 / 7.6	9
		unstressed (t<2): 1.4 / 2	closed (t<7): 9.9 / 7.6	internal (t<0): NA	
/g/	12.1 / 5.8	stressed (t<13): 12.1 / 5.8	open (t<0): NA	initial (t<10): 13.3 / 6	13
		unstressed (t<0): NA	closed (t<13): 12.1 / 5.8	internal (t<3): 8 / 2.8	

*significant at the $\alpha < 0.05$ level

Figure 4.102. Mean RI values (dB) in English produced by the L1 English speakers



4.4.3.2 L1 Spanish control group

A total of 115 productions of /b d g/ were analyzed in the L1 Spanish speaker' English narrative task (Table 4.70). The L1 Spanish speakers produced more tokens in the English narrative task than the L1 English control group, which contributes to a more uniform distribution of tokens among the five speakers. The L1 Spanish control group produced the three

voiced stops with less lenition in English than the L1 English control group. Figure 4.104 provides L1 Spanish speakers' RI means together with those of the L1 English group. The alveolar segment is the most lenited, while the bilabial segment is the least weakened. A two-sample t-test revealed word position ($p < .00421$) to be statistically significant, but showed no effect of stress ($p < .831$) or syllable type ($p < .0737$) on RI. The three stops demonstrate less weakening in word-initial positions (/d/ and /g/ each have only two tokens in word internal position). The raw data also indicates that all three stops are less lenited in stressed position.

A negative VOT measurement was recorded for all participants in instances where the segments were produced as stops. All five speakers showed evidence of true voicing of the English /b d g/ in their data.

Table 4.70. Mean RI values (dB) in English produced by the L1 Spanish speakers

Phoneme	Mean / SD	Mean / SD by stress	Mean / SD by syllable type	Mean / SD by word position*	Total tokens
/b/	15.3 / 6.2	stressed ($t < 35$): 15.6 / 6.2	open ($t < 22$): 12.5 / 5	initial ($t < 62$): 15.8 / 6.2	70
		unstressed ($t < 35$): 15.1 / 6.4	closed ($t < 48$): 16.6 / 6.4	internal ($t < 8$): 11.7 / 5.9	
/d/	13.4 / 8.9	stressed ($t < 16$): 13.9 / 8.8	open ($t < 2$): 15 / 17.4	initial ($t < 17$): 14.2 / 8.6	18
		unstressed ($t < 2$): 9.6 / 13.2	closed ($t < 16$): 13.2 / 8.4	internal ($t < 1$): 0.2 / NA	
/g/	15.1 / 5.5	stressed ($t < 27$): 15.1 / 5.5	open ($t < 2$): 15.7 / 9	initial ($t < 25$): 15.8 / 5	27
		unstressed ($t < 0$): NA	closed ($t < 25$): 15.1 / 5.4	internal ($t < 2$): 6.3 / 4.2	

*significant at the $\alpha < 0.05$ level

Figure 4.103. Mean RI values (dB) in English produced by the L1 Spanish speakers

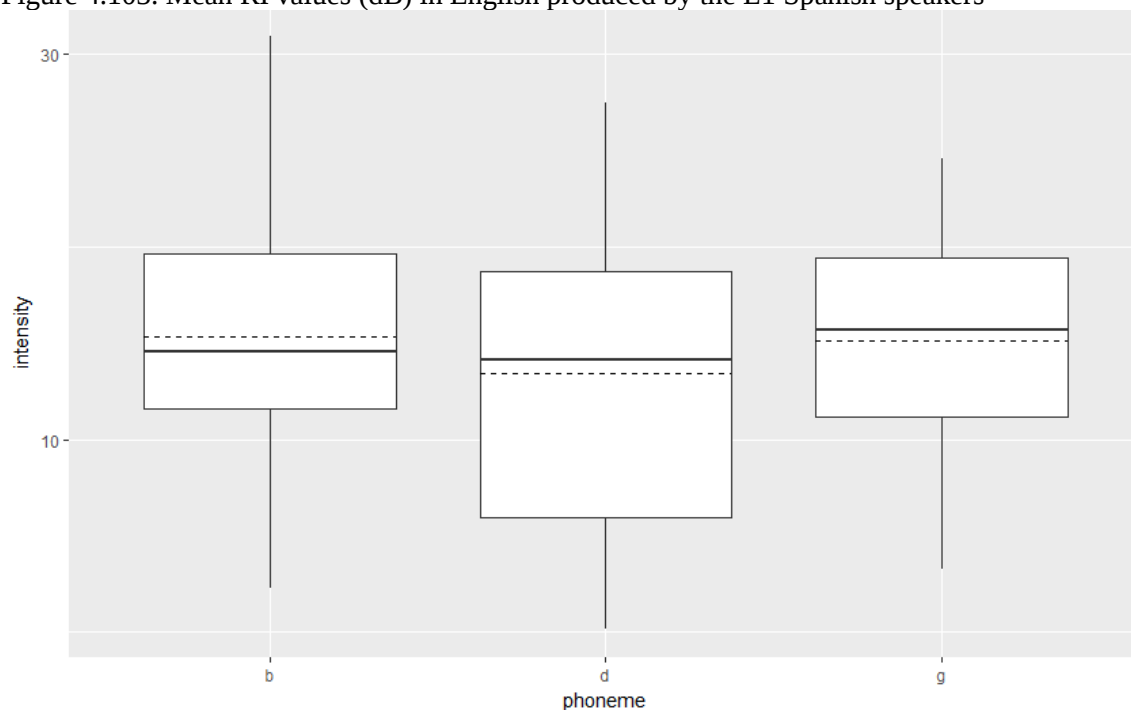
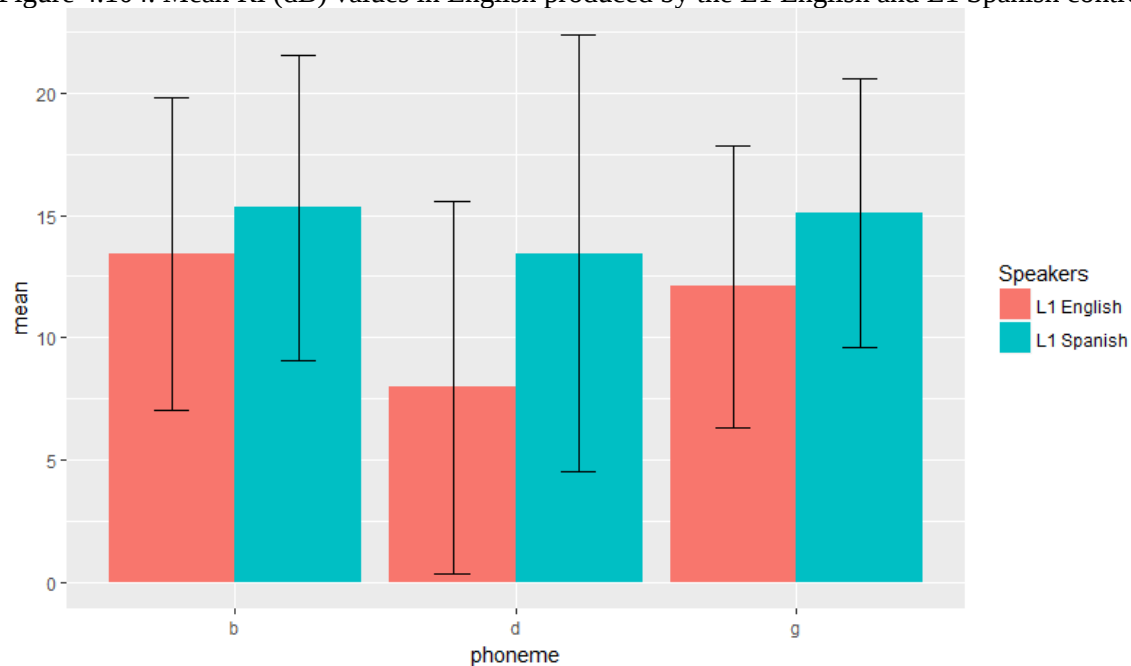


Figure 4.104. Mean RI (dB) values in English produced by the L1 English and L1 Spanish control groups



4.4.3.3 Ukrainian HSs

The Ukrainian HSs produced a total of 108 voiced stop tokens in the English narration task (Table 4.71). The Ukrainian HSs speakers' results show that the bilabial and the velar

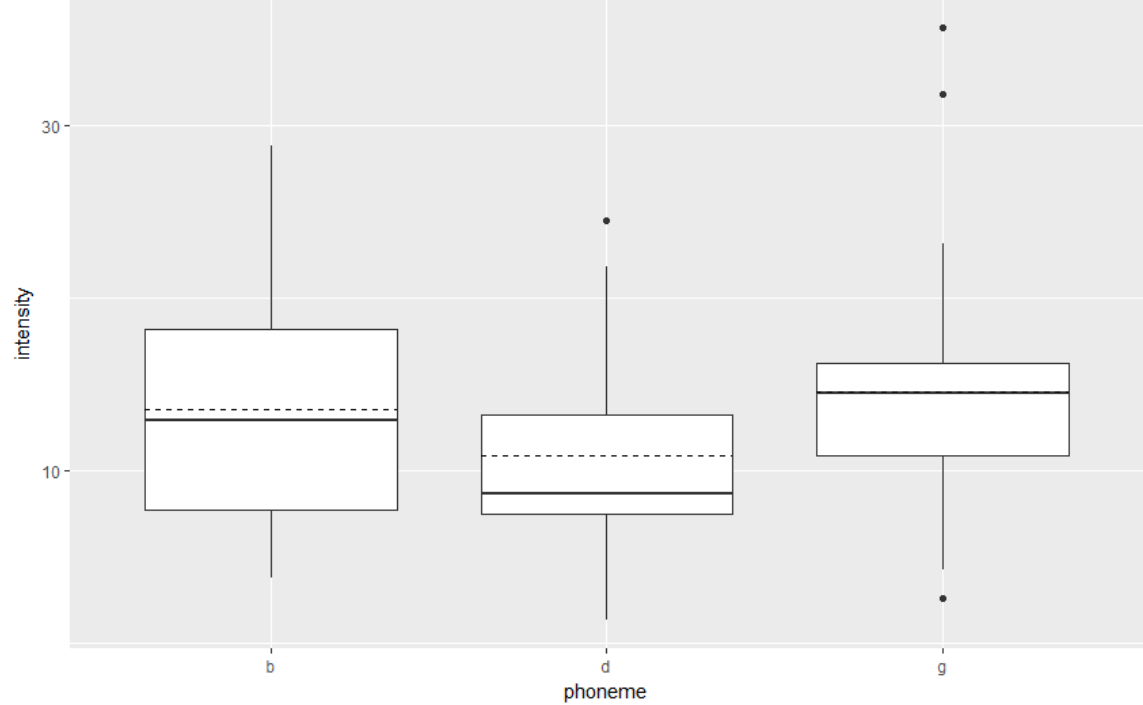
segments were produced with intermediate RI values and that the alveolar segment shows the greatest amount of weakening. The mean intensities of the Ukrainian HSs are greater than the mean intensities produced by the L1 English speakers, but lesser than those of the L1 Spanish control group. Unlike the control groups, who showed the least weakening in the production of /b/, the Ukrainian HSs group produced /g/ with the highest RI. Figure 4.106 provides a comparison between the Ukrainian HSs mean RI measurements and the RI means of the L1 English and L1 Spanish control groups. A two-sample t-test showed no statistical significance of any of the independent variables (stress $p < .321$; syllable type $p < .429$; word position $p < .103$). However, the raw data indicates that all three voiced stops undergo less weakening in stressed and word-initial positions.

VOT measurements were recorded in the data of speakers U2, U3, U4, and U6; speaker U2 produced all stops as short-lag, and speakers U3 and U6 show evidence of true voicing of the English stops. Speaker U4 displays the most interesting results by producing nine out of 18 stops as short-lag and nine segments as true-voiced stops.

Table 4.71. Mean RI values (dB) in English produced by the Ukrainian HSs

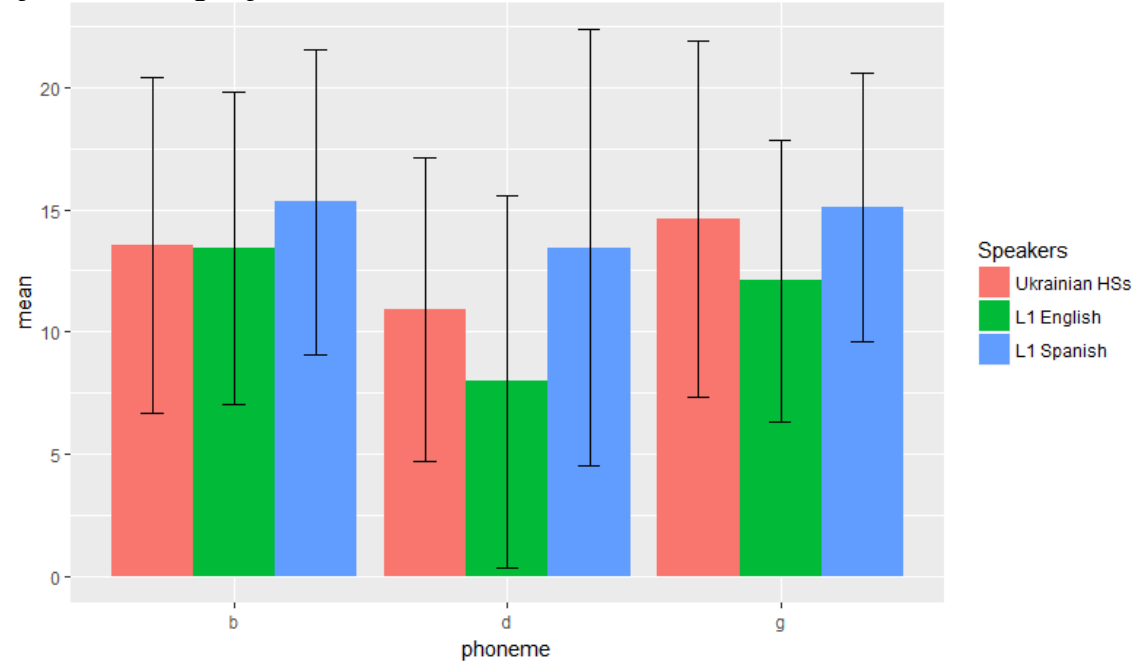
Phoneme	Mean / SD	Mean / SD by stress	Mean / SD by syllable type	Mean / SD by word position*	Total tokens
/b/	13.5 / 6.9	stressed (t<37): 13.7 / 7.1	open (t<16): 12 / 6.6	initial (t<58): 13.6 / 6.8	61
		unstressed (t<24): 13.5 / 6.6	closed (t<45): 14.1 / 6.9	internal (t<3): 12.1 / 9.6	
/d/	10.9 / 6.2	stressed (t<18): 11.9 / 6.3	open (t<0): NA	initial (t<18): 11.9 / 6.3	22
		unstressed (t<4): 6.6 / 3.6	closed (t<22): 10.9 / 6.2	internal (t<4): 6.6 / 3.6	
/g/	14.6 / 7.3	stressed (t<24): 15.1 / 7	open (t<0): NA	initial (t<19): 15.5 / 6	25
		unstressed (t<1): 2.6 / NA	closed (t<16): 12 / 6.6	internal (t<6): 11.9 / 10.6	

Figure 4.105. Mean RI values (dB) in English produced by the Ukrainian HSs



Figure

4.106. Mean RI (dB) values in English produced by the Ukrainian HSs, and the L1 English and L1 Spanish control groups



4.4.3.4 Polish HSs

A total of 202 productions of /b d g/ were analyzed in the Polish HSs data (Table 4.72).

Similar to the Ukrainian HSs results, the Polish HSs produced the English bilabial and velar

segments with intermediate RI values and the dental segment as the most lenited segment out of the three stops. Also, mimicking the Ukrainian HSs results, but distinct from the control groups' outcomes, is that /g/ was produced with the highest RI value, while /d/ displays the lowest RI. Figure 4.108 provides a comparison between the Polish HSs' mean RI measurements and the RI means of the L1 English and L1 Spanish control groups. A two-sample t-test revealed that both stress ($p < .0198$) and syllable type ($p < .0263$) are statistically significant, while word position ($p < .318$) had no effect on RI. All three stops are least lenited in stressed position. The segments /b/ and /d/ show less weakening in closed syllables, while /g/ does so in open syllables (/d/ has only one token in closed syllable context).

VOT measurements were recorded for speakers P1, P2, P3, P5, P7, P10, and P11; participants P1, P5, P7, P10, and P11 show evidence of true voicing by producing the stop segments with negative VOT values, speaker P2 produced the stop segments with short-lag VOT values, and finally, the participant P3 produced nine out of the 20 phonemes as short-lag and 11 segments as pre-voiced.

Table 4.72. Mean RI (dB) values in English produced by the Polish HSs

Phoneme	Mean / SD	Mean / SD by stress*	Mean / SD by syllable type*	Mean / SD by word position	Total tokens
/b/	14.5 / 7	stressed (t<65): 16.1 / 6.4	open (t<38): 11.4 / 6.6	initial (t<111): 14.8 / 6.9	116
		unstressed (t<51): 12.6 / 7.2	closed (t<78): 16.1 / 6.6	internal (t<5): 9.2 / 5.2	
/d/	10.8 / 5.4	stressed (t<36): 11.2 / 4.8	open (t<1): 3.8 / NA	initial (t<39): 11.6 / 5.1	44
		unstressed (t<8): 9 / 7.8	closed (t<43): 11 / 5.4	internal (t<5): 5 / 3.9	
/g/	15 / 6.3	stressed (t<42): 15 / 6.3	open (t<4): 17.6 / 2.4	initial (t<29): 14.3 / 6.1	42
		unstressed (t<0): NA	closed (t<38): 14.8 / 6.6	internal (t<13): 16.7 / 6.7	

*significant at the $\alpha < 0.05$ level

Figure 4.107. Mean RI values (dB) in English produced by the Polish HSs

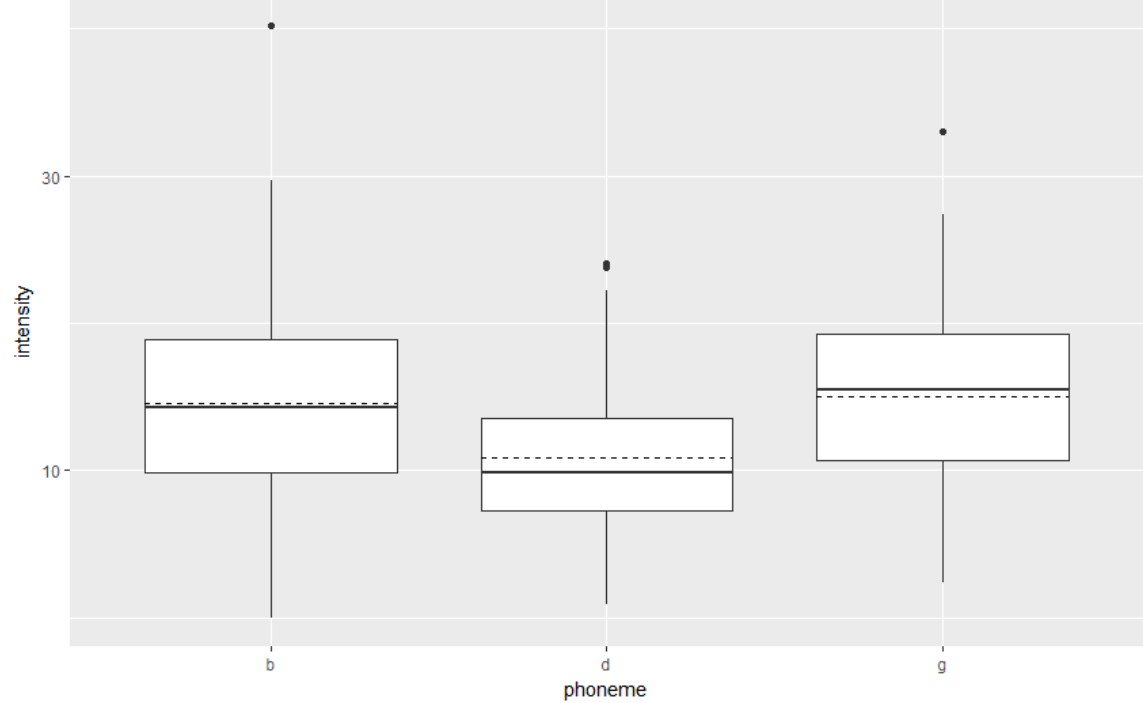
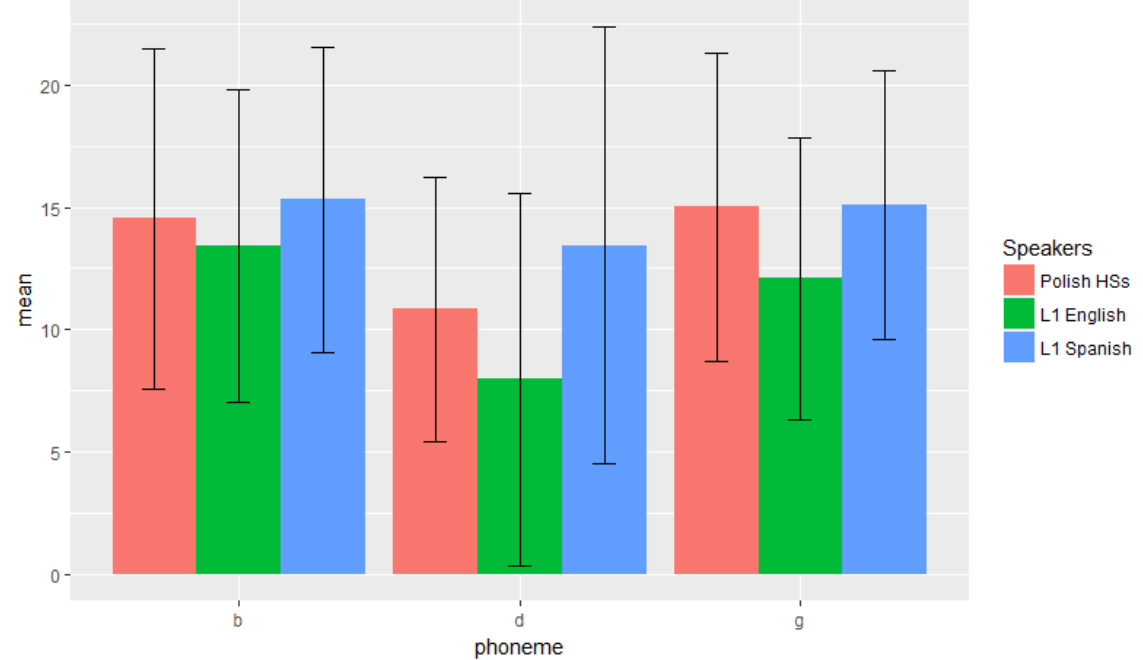


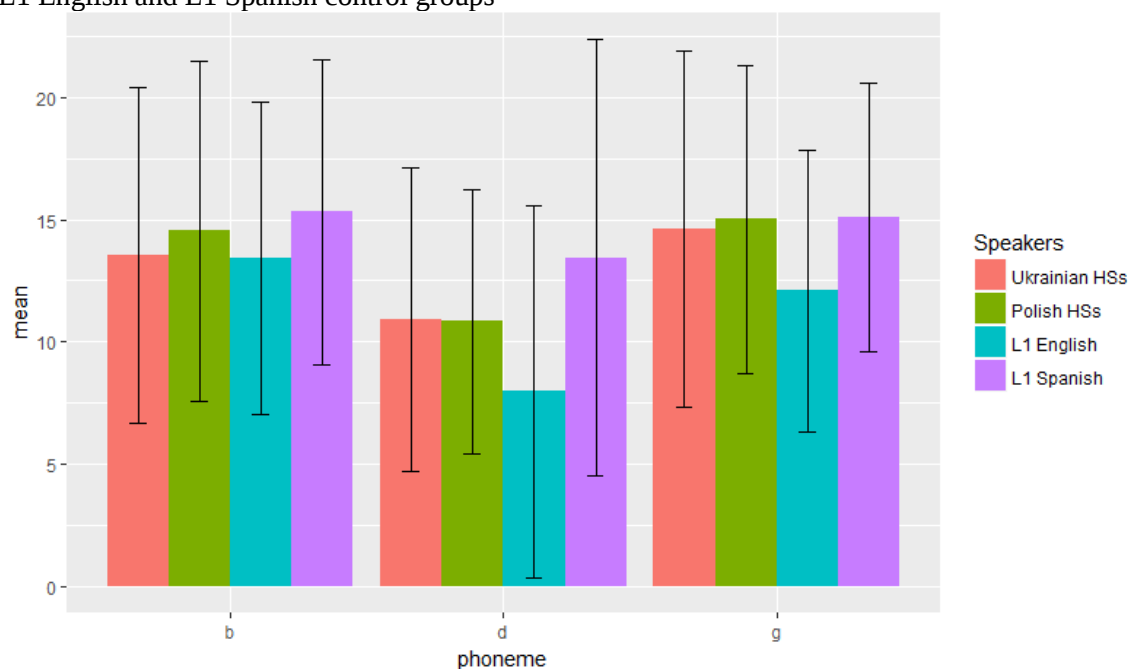
Figure 4.108. Mean RI (dB) values in English produced by the Polish HSs and the L1 English and L1 Spanish control groups



4.4.3.5 Summary

Figure 4.109 summarizes the English voiced stop productions in the narrative task by the Ukrainian HSs, the Polish HSs and the L1 English and L1 Spanish control groups. As can be seen from the graph, the L1 Spanish control group showed the least weakening in the production of the English voiced stops. Interestingly, the L1 English control group showed the greatest degree of lenition of the English /b d g/, while the L1 Spanish speakers produced the least weakened voiced stops. The Ukrainian and the Polish HSs' results are rather similar and are closer to those of the L1 Spanish control group.

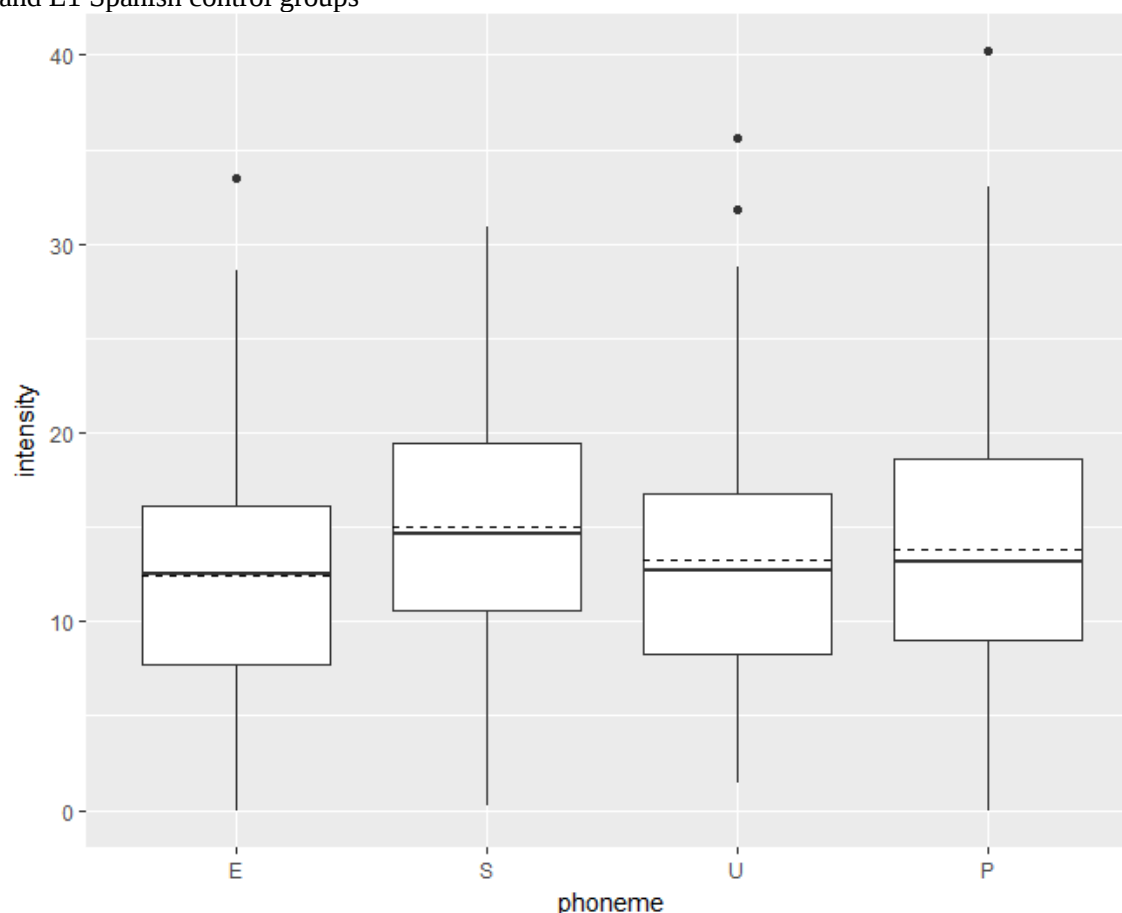
Figure 4.109. Mean VOT values (ms) in English produced by the Ukrainian HSs, the Polish HSs and the L1 English and L1 Spanish control groups



A Linear Mixed Effects Model was fitted to the mean RI measurements where *phoneme* and *speaker group* were included as fixed effect and *individual speaker* acted as random effect to determine whether there are any statistically significant differences between the acoustic means of the four groups of speakers. The test revealed no statistically significant difference in the

mean RI productions between the four groups ($p < .6319$). Figure 4.110 summarizes the mean intensities produced by the four speaker groups.

Figure 4.110. Productions of the English /b d g/ by the Ukrainian HSs, the Polish HSs, and the L1 English and L1 Spanish control groups



4.4.4 Spanish voiced stops

The Spanish voiced stops section is arranged into four parts, presenting each speaker group's data in the following order: L1 Spanish control group, L1 English control group, Ukrainian HSs, and Polish HSs. All four speaker groups completed four tasks in Spanish. Each speaker group section presents the results of each task in the order they were administered during the elicitation process: the narrative task, the picture-naming task, the sentence-reading task, and finally, the nonce words reading task. In this order, the results from the least controlled tasks are presented first and the most controlled tasks' outcomes are presented last.

4.4.4.1 L1 Spanish control group

A total of 848 productions of /b d g/ were analyzed in the L1 Spanish control group's data set. The narrative task yielded 107 tokens, the picture-naming task had 125 tokens, the sentence-reading task yielded 471 productions, and finally, the nonce words reading task yielded a total of 145 productions.

The L1 Spanish speakers produced all three intervocalic Spanish voiced stops with very low RI means, which evidence approximant realizations, in line with previous findings in the literature (Carrasco et al. 2012, Eddington 2011, Hualde 2005, Morgan 2010) (Table 4.73). However, it is important to note that the standard deviation values are high, signaling variation in the data. The velar /g/ is the most lenited stop, while the bilabial /b/ is the least weakened segment. A two-sample t-test was conducted, revealing statistical significance of both syllable type ($p < .0109$) and word position ($p < .005540$), while showing no effect of stress ($p < .273$) on RI. All three stops are more lenited in open syllables. The segments /b/ and /d/ weaker in word internal position and /g/ appears more lenited in word-initial position. However, there is only one /g/ token in word-initial position, which makes it difficult to draw a definitive conclusion. Finally, the raw data reveals that all three stops are more weakened in unstressed position.

VOT measurements were recorded in the data sets of speakers S1, S3, and S4. All instances of /b d g/ that were produced as stops showed pre-voicing, supporting earlier findings in the literature on the true-voice nature of the Spanish voiced stops (Lisker and Abramson 1964).

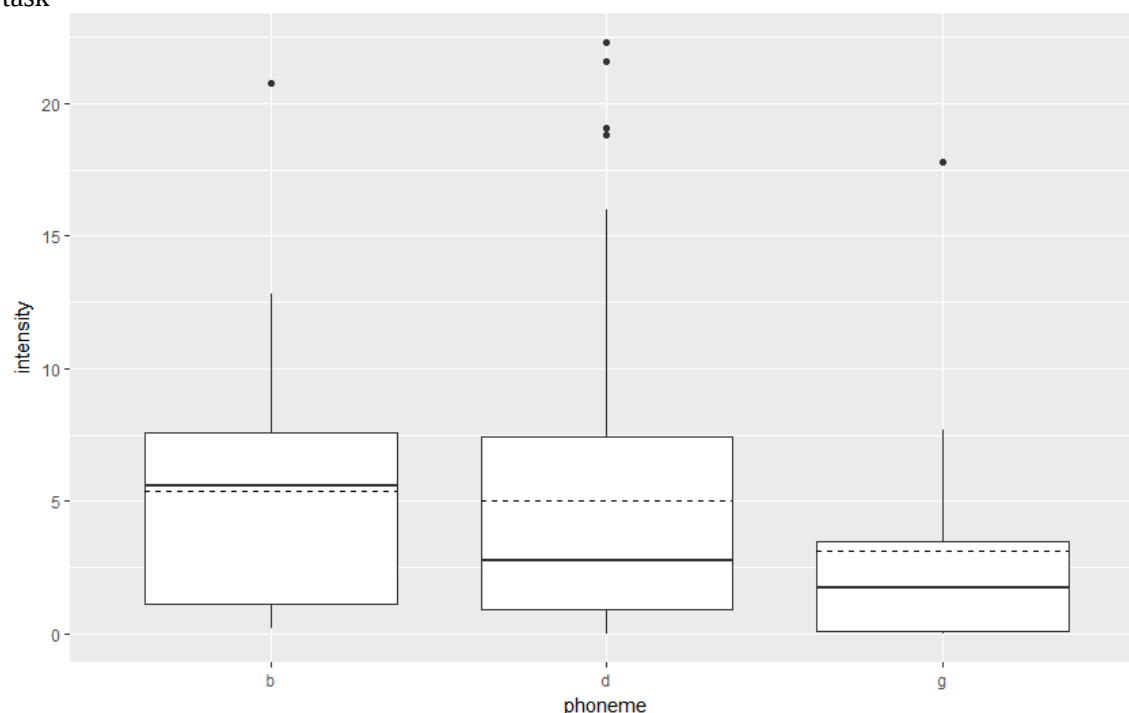
Table 4.73. Mean RI (dB) values in Spanish produced by the L1 Spanish control group in the narrative task

Phoneme	Mean / SD	Mean / SD by stress	Mean / SD by syllable type*	Mean / SD by word position*	Total tokens
/b/	5.4 / 4.6	stressed ($t < 19$): 6.4 / 4.8	open ($t < 18$): 4.9 / 5.3	initial ($t < 18$): 5.5 / 4.9	29
		unstressed ($t < 10$):	closed ($t < 11$):	internal ($t < 11$):	

		3.4 / 3.5	6.1 / 3.1	5.2 / 4.2	
/d/	5 / 5.9	stressed (t<18): 5.3 / 5.3	open (t<48): 3.9 / 4.7	initial (t<39): 6.6 / 6.7	62
		unstressed (t<44): 4.9 / 6.1	closed (t<14): 9 / 7.8	internal (t<23): 2.4 / 2.8	
/g/	3.1 / 4.6	stressed (t<7): 3.5 / 6.4	open (t<9): 2.7 / 2.9	initial (t<1): 2.2 / NA	16
		unstressed (t<9): 2.8 / 2.9	closed (t<7): 3.7 / 6.4	internal (t<15): 3.2 / 4.7	

*Significant at the $\alpha < 0.05$ level

Figure 4.111. Mean RI (dB) values in Spanish produced by the L1 Spanish control group in the narrative task



The three stops in the picture-naming task were produced with low RI values (Table 4.74). As in the narrative task, the bilabial segment is the least lenited out of the three stops; however, this time the dental segment is the most weakened stop. Similar to the narrative task, the high standard deviation values indicate variation in the data and more spread out data points away from the means. A two-sample t-test revealed that word position ($p < .0133$) is statistically significant, while stress ($p < .338$) and syllable type ($p < .815$) showed no statistical effect on syllable. The dental /d/ is more weakened in word internal position, while /g/ is more lenited in word-initial position. The bilabial /b/ has no tokens in word internal position. As in the previous

task, the raw data indicates that all three voiced stops show the most weakening in unstressed position.

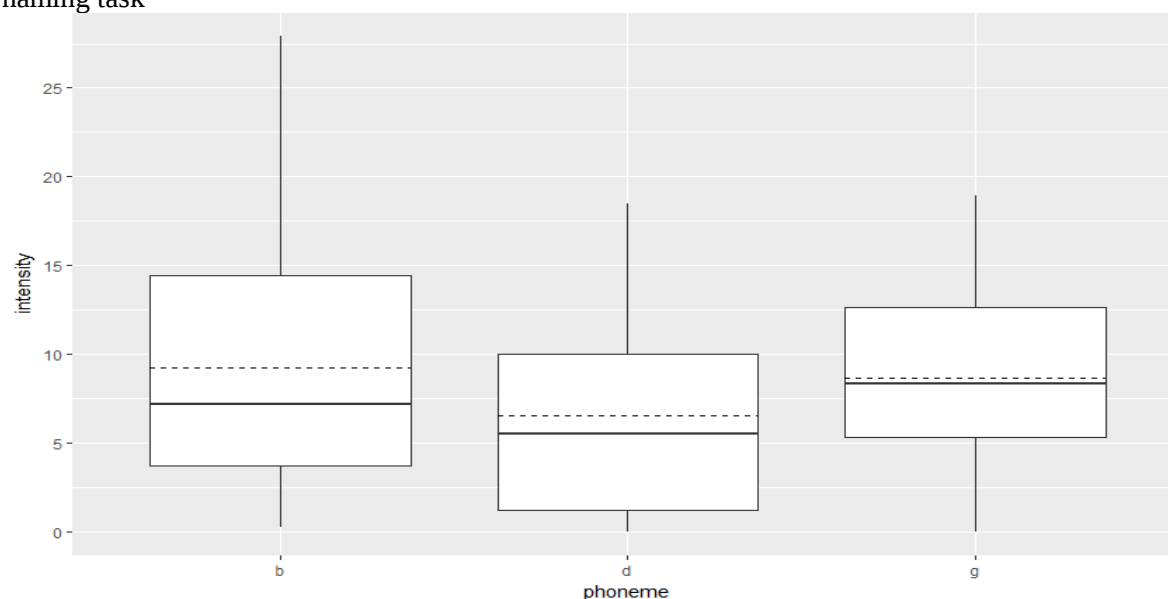
VOT measurements were recorded for speakers S1 and S4, showing evidence of pre-voicing in the segments that were pronounced as stops.

Table 4.74. Mean RI (dB) values in Spanish produced by the L1 Spanish control group in the picture-naming task

Phoneme	Mean / SD	Mean / SD by stress	Mean / SD by syllable type	Mean / SD by word position*	Total tokens
/b/	9.2 / 6.7	stressed (t<15): 10.7 / 6.4	open (t<47): 9.3 / 6.7	initial (t<13): 13 / 7	29
		unstressed (t<37): 8.7 / 6.8	closed (t<5): 8.8	internal (t<0): NA	
/d/	6.5 / 5.6	stressed (t<19): 7 / 5.9	open (t<39): 6.3 / 5.5	initial (t<10): 8.3 / 6.3	44
		unstressed (t<25): 6.2 / 5.4	closed (t<5): 8.3 / 6.5	internal (t<34): 6 / 5.3	
/g/	8.6 / 5.1	stressed (t<10): 9.7 / 4.6	open (t<29): 8.6 / 5.1	initial (t<39): 8 / 6.2	29
		unstressed (t<19): 8.1 / 5.4	closed (t<0): NA	internal (t<29): 8.6 / 5.1	

*Significant at the $\alpha < 0.05$ level

Figure 4.112. Mean RI (dB) values in Spanish produced by the L1 Spanish control group in the picture-naming task



The three stops in the sentence-reading task were produced with fairly low RI means, with the dental segment displaying the lowest values (Table 4.75). As in the picture-naming task,

the dental /d/ segment is the most lenited out of the three stops. This time, however, /g/ is the least weakened segment out of the three stops. A two-sample t-test revealed that stress ($p < 2.01 \times 10^{-6}$) is very significant in this task, while syllable type ($p < .748$) and word position ($p < .141$) had no effect on RI. Mimicking the results of the two previous tasks, the three stops show more weakening in unstressed position.

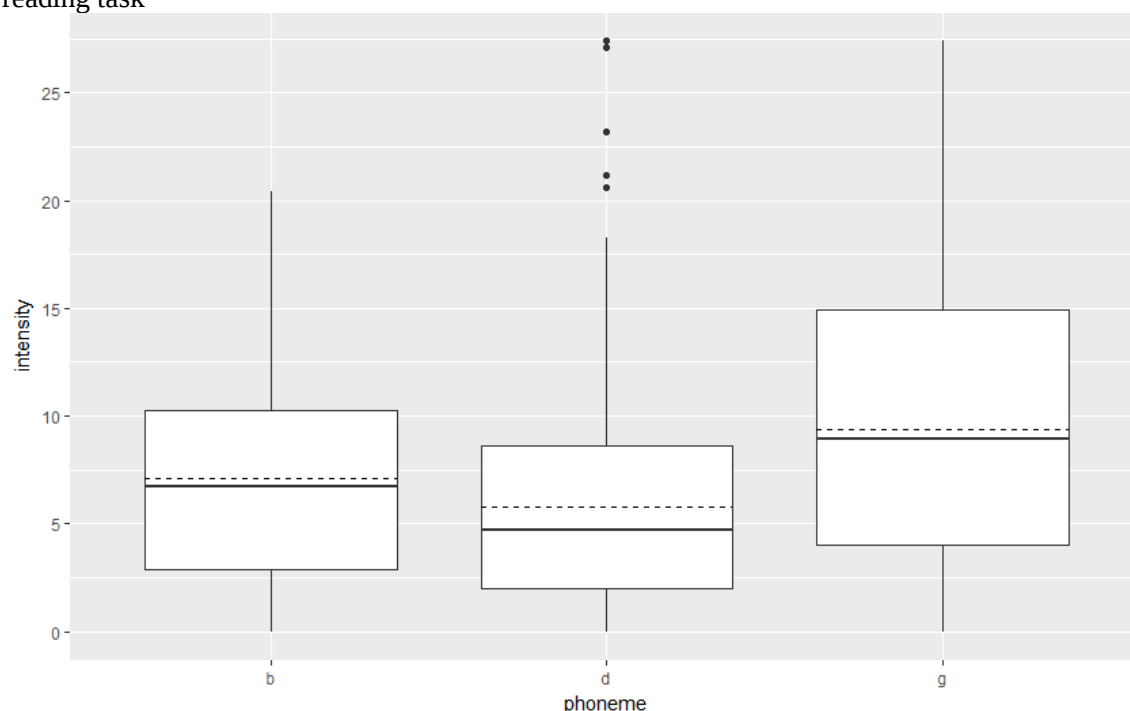
VOT measurements were recorded for all five speakers. The results revealed that all instances of stop like realizations of /b d g/ were produced with pre-voicing.

Table 4.75. Mean RI (dB) values in Spanish produced by the L1 Spanish control group in the sentence-reading task

Phoneme	Mean / SD	Mean / SD by stress*	Mean / SD by syllable type	Mean / SD by word position	Total tokens
/b/	7.1 / 5	stressed (t<108): 8.2 / 5.3	open (t<208): 7 / 5	initial (t<109): 6.5 / 4.8	227
		unstressed (t<119): 6.1 / 4.5	closed (t<19): 8 / 4.5	internal (t<118): 7.7 / 5.1	
/d/	5.8 / 5.4	stressed (t<55): 7.5 / 6.2	open (t<145): 6 / 5.5	initial (t<30): 8.8 / 7.3	160
		unstressed (t<105): 4.9 / 4.7	closed (t<15): 4.2 / 4	internal (t<130): 5.1 / 4.6	
/g/	9.4 / 6.7	stressed (t<40): 10.5 / 6.9	open (t<74): 9.5 / 6.7	initial (t<25): 10.9 / 7.5	84
		unstressed (t<44): 8.4 / 6.4	closed (t<10): 8.4 / 6.7	internal (t<59): 8.8 / 6.3	

*Significant at the $\alpha < 0.05$ level

Figure 4.113. Mean RI (dB) values in Spanish produced by the L1 Spanish control group in the sentence-reading task



In the nonce words reading task all three stops were produced with the overall highest RI values, indicating more closure (Table 4.76). Unlike in the previous three tasks, the dental segment shows the least amount of weakening in the nonce words reading elicitation, and the bilabial segment displays the most weakening out of the three stops. A two-sample t-test revealed that both stress ($p < 1.91 \cdot 10^{-6}$) and word position ($p < .017$) are statistically significant, while syllable type ($p < .499$) showed no effect on RI. All three phonemes are more lenited in unstressed and word internal positions.

VOT measurements were taken for instances where /b d g/ were produced as stops in the data sets of the speakers S1, S2, S4, and S5 and all four speakers showed evidence of pre-voicing.

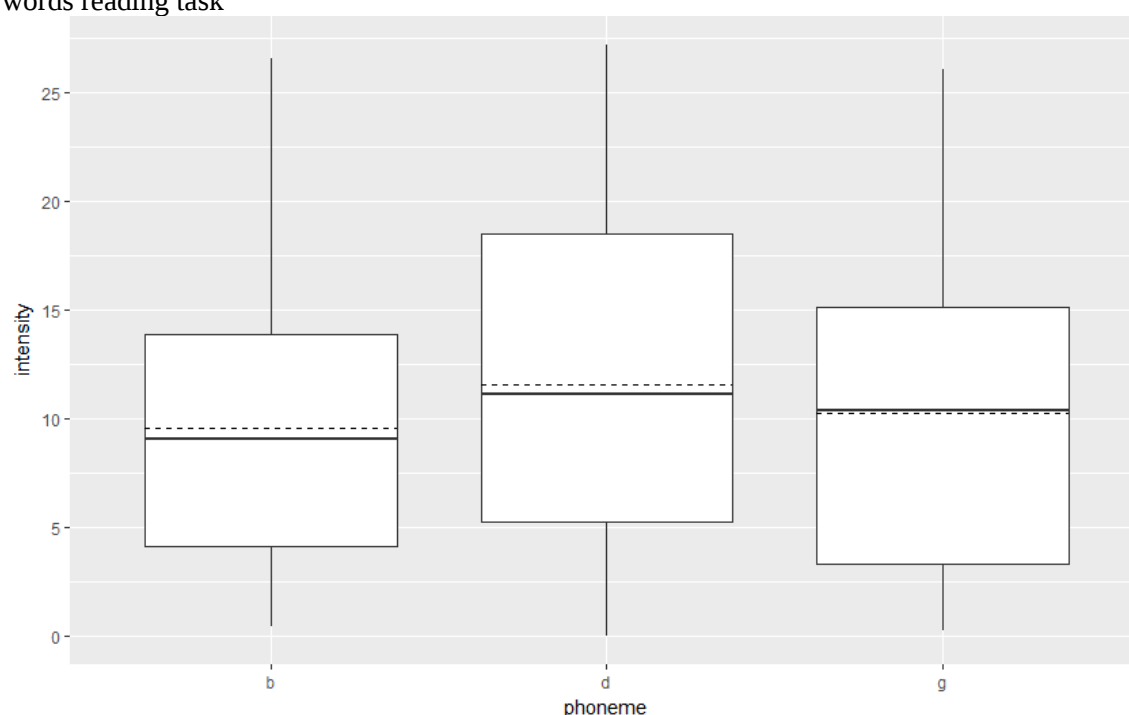
Table 4.76. Mean RI (dB) values in Spanish produced by the L1 Spanish control group in the nonce words reading task

Phoneme	Mean / SD	Mean / SD by stress*	Mean / SD by syllable type	Mean / SD by word position*	Total tokens
/b/	9.6 / 6.4	stressed (t<34):	open (t<50):	initial (t<15):	

		11.5 / 7	9.6 / 6.6	10.9 / 6.4	70
		unstressed (t<36): 7.7 / 5.3	closed (t<20): 9.4 / 6.2	internal (t<55): 9.2 / 6.5	
/d/	11.5 / 7.7	stressed (t<21): 13.8 / 6.6	open (t<20): 11.3 / 6.9	initial (t<10): 14.3 / 5.6	30
		unstressed (t<9): 6.2 / 7.5	closed (t<10): 12 / 9.3	internal (t<20): 10.1 / 8.3	
/g/	10.2 / 7	stressed (t<12): 15.7 / 7.1	open (t<35): 9.6 / 6.4	initial (t<15): 12.5 / 6.5	45
		unstressed (t<33): 8.2 / 5.9	closed (t<10): 12.4 / 8.8	internal (t<30): 9.1 / 7.1	

*Significant at the $\alpha < 0.05$ level

Figure 4.114. Mean RI (dB) values in Spanish produced by the L1 Spanish control group in the nonce words reading task



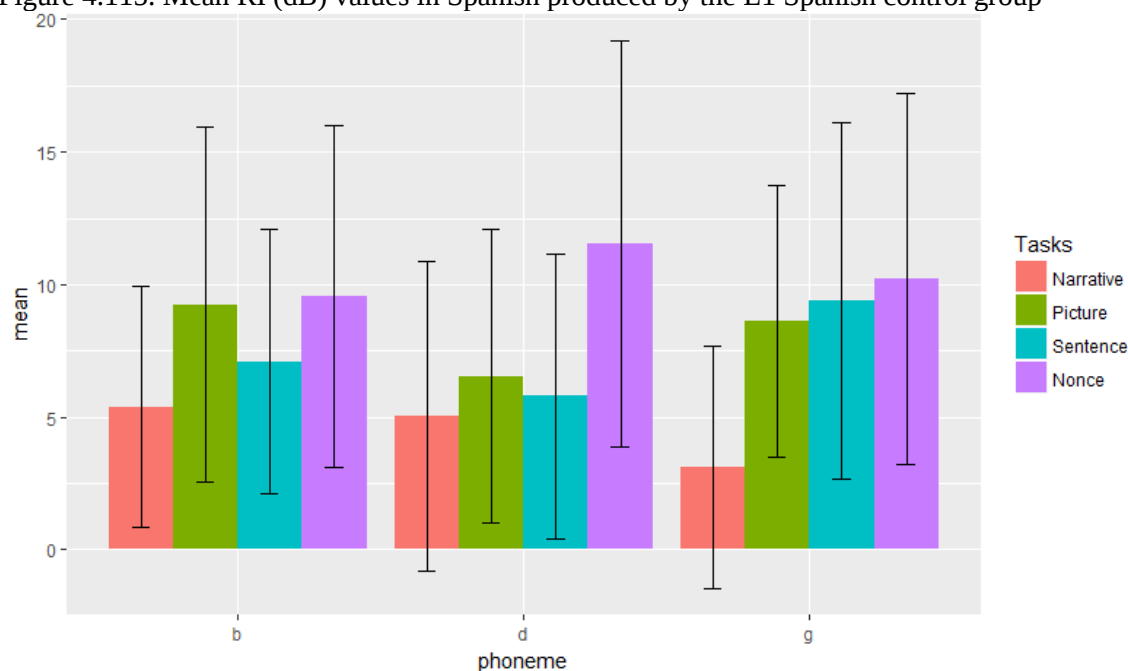
4.4.4.1.1 Summary

Figure 4.115 summarizes the mean RI values of the intervocalic Spanish /b d g/ produced by the L1 Spanish control group in the narrative, picture-naming, sentence-reading, and nonce words reading tasks. As can be seen from the graph, the relationship between the place of articulation and RI values is not uniform across the four tasks and each elicitation has a different distribution of the RI values among the three stops. Overall, the narrative task yielded the most lenited segments and the nonce words reading task produced the least lenited stops, supporting

earlier findings in the literature that show a greater degree of weakening in more natural elicitations (i.e., speaking) and less lenition in formal tasks (i.e., reading) (Rao 2014, 2015).

A Linear Mixed Effects Model was implemented to determine the statistical significance of task type on RI of each stop. The results reveal that task type was very significant for each phoneme: /b/ $p < 3.94 \times 10^{-10}$, /d/ $p < 4.18 \times 10^{-9}$, /g/ $p < .0001452$.

Figure 4.115. Mean RI (dB) values in Spanish produced by the L1 Spanish control group



4.4.4.2 L1 English control group

A total of 605 tokens of the Spanish voiced stops were analyzed in the L1 English control group's data: 54 tokens in the narrative task, 80 tokens in the picture-naming task, 334 tokens in the sentence-reading task, and finally, 137 tokens in the nonce words reading task.

The L1 English control produced half as many intervocalic instances of /b d g/ in the narrative task compared to the L1 Spanish control group, which explains why some speakers have only one token in certain categories. Due to the limited number of elicited tokens, it is difficult to make definitive assumptions. Nonetheless, we do see that the L1 English speakers

produced the Spanish dental /d/ with a fairly low RI mean, and the bilabial and the velar segments with slightly higher values, indicating more constriction (Table 4.77). The phoneme /d/ is the most lenited and the velar /g/ is the least weakened segment of the three stops. A comparison of the L1 English speakers' results to the L1 Spanish speakers' realizations can be viewed in Figure 4.117. A two-sample t-test revealed statistical significance of stress ($p < .0159$) on RI, but the other two independent variables (syllable type $p < .465$, word position $p < .221$) showed no effect. All three stops show a greater degree of lenition in unstressed position.

The VOT measurements of the segments that were produced as stops were recorded for all five speakers. Speakers E3 and E4 show no signs of pre-voicing in the Spanish narrative task and produced all instances of stops as short-lag. Speaker E1, on the other hand, pronounced the stop segments with pre-voicing. Speaker E2 produced two stops with short-lag VOT values and one instance of a stop segment with pre-voicing. Finally, speaker E5 produced five instances of stop segments as short-lag and two instances as true voice.

Table 4.77. Mean RI values (dB) in Spanish produced by the L1 English speakers in the narrative task

Phoneme	Mean / SD	Mean / SD by stress*	Mean / SD by syllable type	Mean / SD by word position	Total tokens
/b/	11.2 / 6.4	stressed (t<8): 14.8 / 4.5	open (t<5): 5.3 / 4.4	initial (t<0): NA	13
		unstressed (t<5): 5.3 / 4.4	closed (t<8): 14.8 / 4.5	internal (t<13): 11.2 / 6.4	
/d/	10.9 / 8	stressed (t<8): 13.7 / 6.1	open (t<23): 11.1 / 8.4	initial (t<20): 13.3 / 8.2	30
		unstressed (t<22): 9.8 / 8.4	closed (t<7): 10 / 4.5	internal (t<10): 6 / 4.6	
/g/	12.8 / 7.9	stressed (t<7): 13.9 / 8.7	open (t<2): 18.8 / 7.6	initial (t<5): 10.1 / 7.1	11
		unstressed (t<4): 10.8 / 7	closed (t<9): 11.4 / 7.7	internal (t<6): 15 / 8.4	

*significant at the $\alpha < 0.05$ level

Figure 4.116. Mean RI values (dB) in Spanish produced by the L1 English speakers in the narrative task

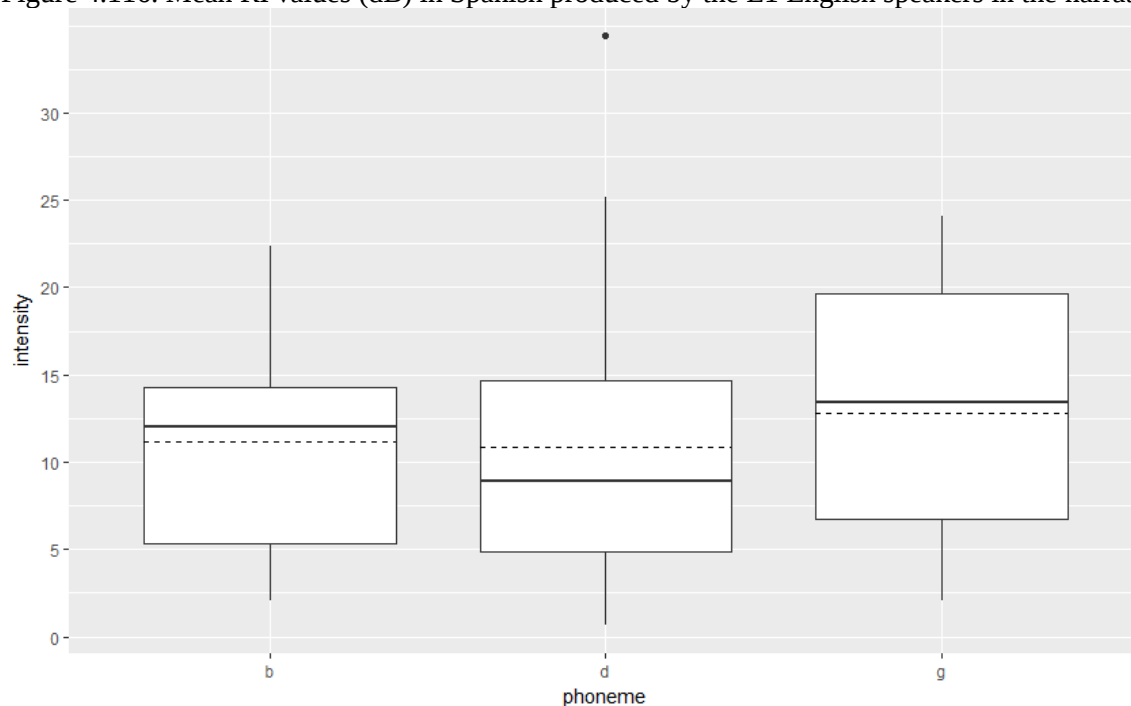
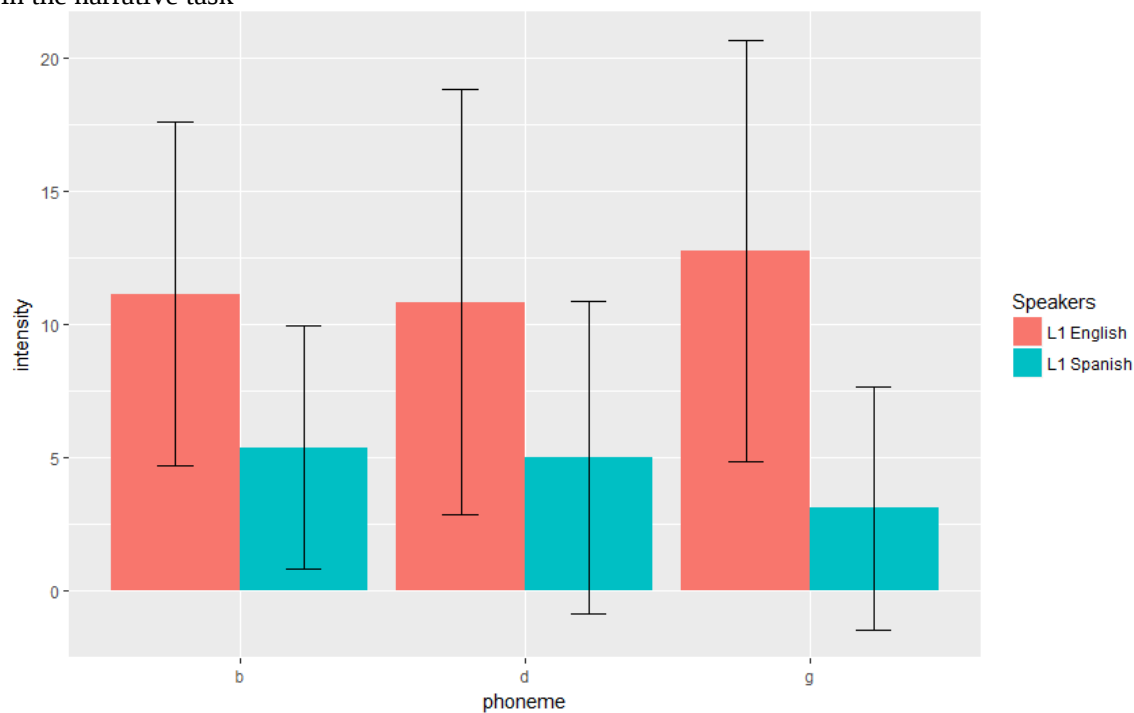


Figure 4.117. Mean RI (dB) values in Spanish produced by the L1 English and L1 Spanish control groups in the narrative task



The productions of /b d g/ in the picture-naming task showed the same pattern as in the narrative task, where /d/ was produced with the lowest RI (Table 4.77). As in the previous task,

/d/ was the most lenited segment and /g/ was the least weakened stop, which is again distinct from the L1 Spanish speakers' results. Figure 4.119 presents the L1 English control group's outcomes next to the L1 Spanish control group's results in the picture-naming task. A two-sample t-test was conducted and showed no effect of any of the independent variables (stress $p < .539$, syllable type $p < .405$, word position $p < .142$) on RI.

The VOT measurements of the stop-like realizations of /b d g/ were recorded for all five speakers. Participants E1, E2, and E4 showed evidence of pre-voicing in all productions of stops. Speaker E3 produced stop segments with short-lag VOT, lacking true voicing. Finally, speaker E5 produced two stops with pre-voicing and one stop with a short-lag VOT.

Table 4.78. Mean RI values (dB) in Spanish produced by the L1 English speakers in the picture-naming task

Phoneme	Mean / SD	Mean / SD by stress	Mean / SD by syllable type	Mean / SD by word position	Total tokens
/b/	11.8 / 4.3	stressed (t<11): 12.7 / 5.2	open (t<22): 12.1 / 4.6	initial (t<10): 12.9 / 5.2	26
		unstressed (t<15): 11.2 / 5.7	closed (t<4): 10.4 / 2.8	internal (t<16): 11.2 / 3.7	
/d/	9.2 / 4.7	stressed (t<16): 10.6 / 4.8	open (t<29): 9.4 / 4.7	initial (t<10): 12.8 / 4.4	34
		unstressed (t<18): 8 / 4.3	closed (t<5): 8.2 / 5.1	internal (t<24): 7.8 / 4	
/g/	12.7 / 10.7	stressed (t<6): 11.5 / 5.7	open (t<20): 12.7 / 10.7	initial (t<0): NA	20
		unstressed (t<14): 13.1 / 12.5	closed (t<0): NA	internal (t<20): 12.7 / 10.7	

Figure 4.118. Mean RI values (dB) in Spanish produced by the L1 English speakers in the picture-naming task

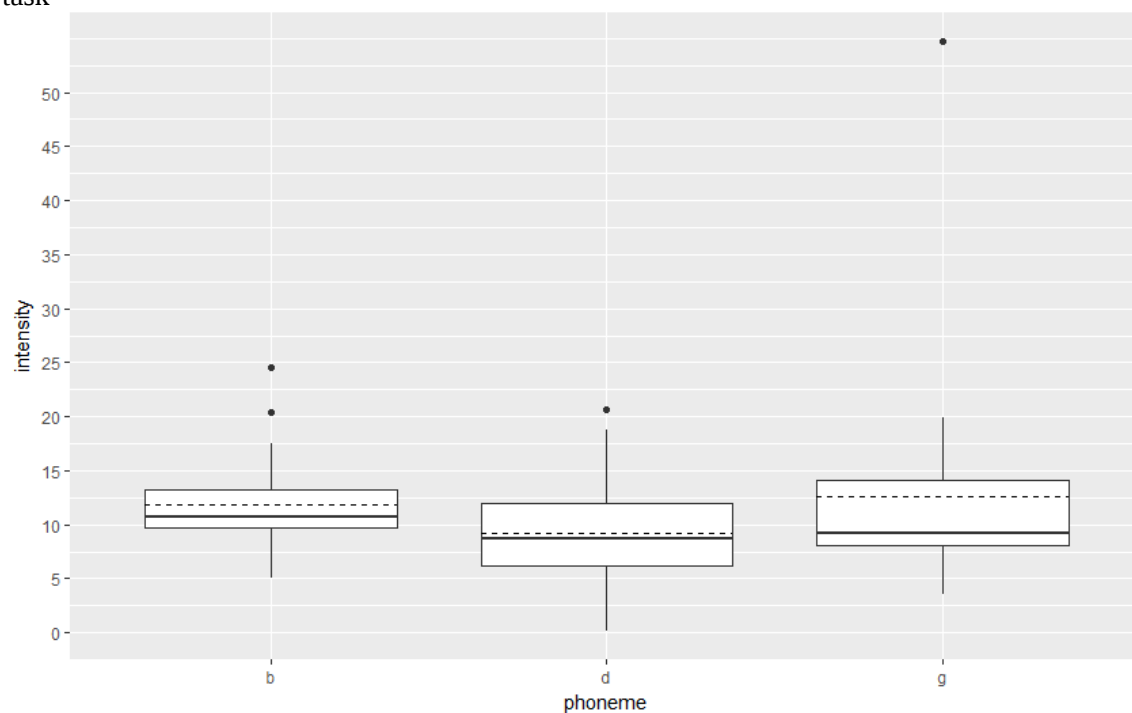
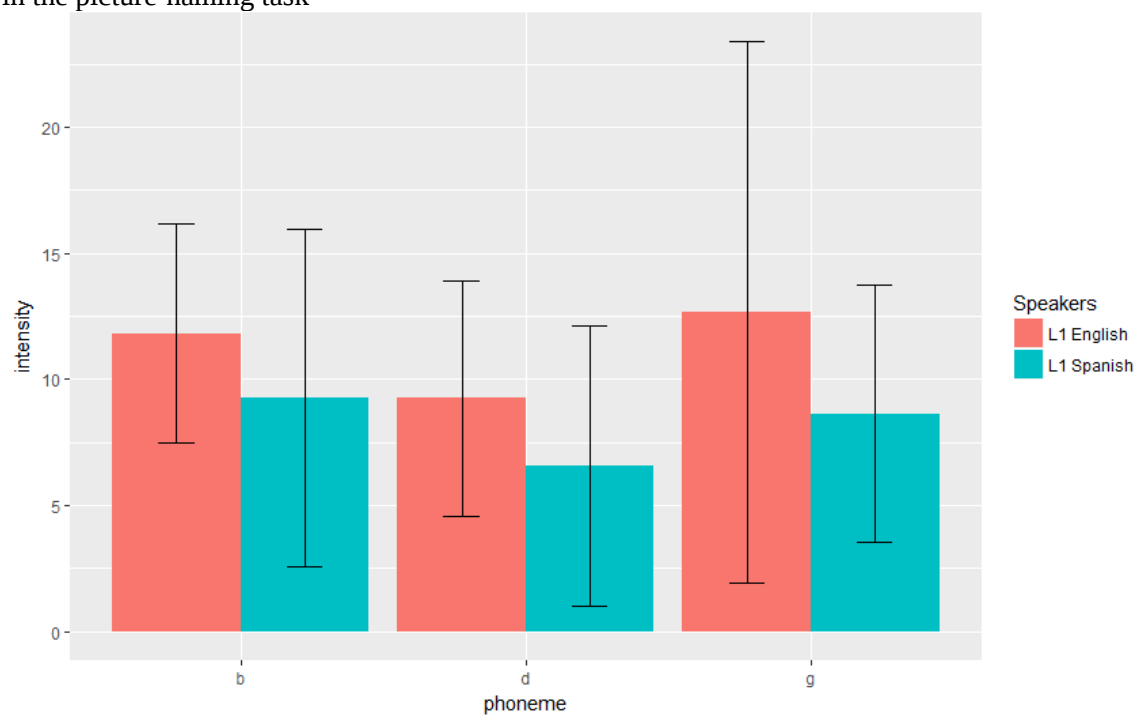


Figure 4.119. Mean RI (dB) values in Spanish produced by the L1 English and L1 Spanish control groups in the picture-naming task



In the sentence-reading task, the three voiced stops were produced with higher RI values than those seen in the previous two tasks (Table 4.79). As in the narrative and picture-naming

tasks, the dental segment is the most lenited of the three stops. However, in this task, the bilabial /b/ is the least weakened segment, contrasting with the L1 Spanish speakers' results where /g/ was the least lenited segment. For a comparison of the L1 English control group's results to the L1 Spanish control group's productions in the sentence-reading task, refer to Figure 4.121. A two-sample t-test was conducted and revealed that both stress ($p < 1.04 \cdot 10^{-5}$) and word position ($p < 3.32 \cdot 10^{-11}$) were very significant, while syllable type ($p < .732$) had no effect on RI. All three stops demonstrate more weakening in unstressed and word internal positions.

The aspect that stands out about the individual speaker results is an uneven distribution of /d/ tokens. It is due to the fact that some speakers, most notably participants E2 and E4, transferred the intervocalic flapping feature from English and produced /d/ as a tap ([ɾ]). The VOT measurements of the stop-like realization were recorded for all five speakers. Participants E3, E4, and E5 all show evidence of true voicing by producing stops with negative VOT values. Informants E1 and E2 show evidence of both pre-voicing and short-lag realizations of stop segments. Speaker E1 produced eight stops as true voiced stops and eight stops as short-lag. Participant E2 pronounced 17 stops with negative VOT values and 18 stops with short-lag VOTs.

Table 4.79. Mean RI values (dB) in Spanish produced by the L1 English speakers in the sentence-reading task

Phoneme	Mean / SD	Mean / SD by stress*	Mean / SD by syllable type	Mean / SD by word position*	Total tokens
/b/	13.8 / 7.4	stressed (t<70): 14.7 / 7.4	open (t<105): 13.7 / 7.4	initial (t<40): 16.4 / 8.4	115
		unstressed (t<45): 12.3 / 7.3	closed (t<10): 15.1 / 7.4	internal (t<75): 12.4 / 6.5	
/d/	11.3 / 6.8	stressed (t<51): 13.9 / 6.3	open (t<120): 11.2 / 7	initial (t<26): 16.9 / 7.4	135
		unstressed (t<84): 9.7 / 6.6	closed (t<15): 11.7 / 4.9	internal (t<109): 9.9 / 5.9	
/g/	11.6 / 6.9	stressed (t<39): 18.2 / 6.6	open (t<74): 16.7 / 7.1	initial (t<25): 20.6 / 5.9	84
		unstressed (t<45):	closed (t<10):	internal (t<59):	

		15.2 / 6.9	16 / 4.4	14.9 / 6.6	
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*significant at the $\alpha < 0.05$ level

Figure 4.120. Mean RI values (dB) in Spanish produced by the L1 English speakers in the sentence-reading task

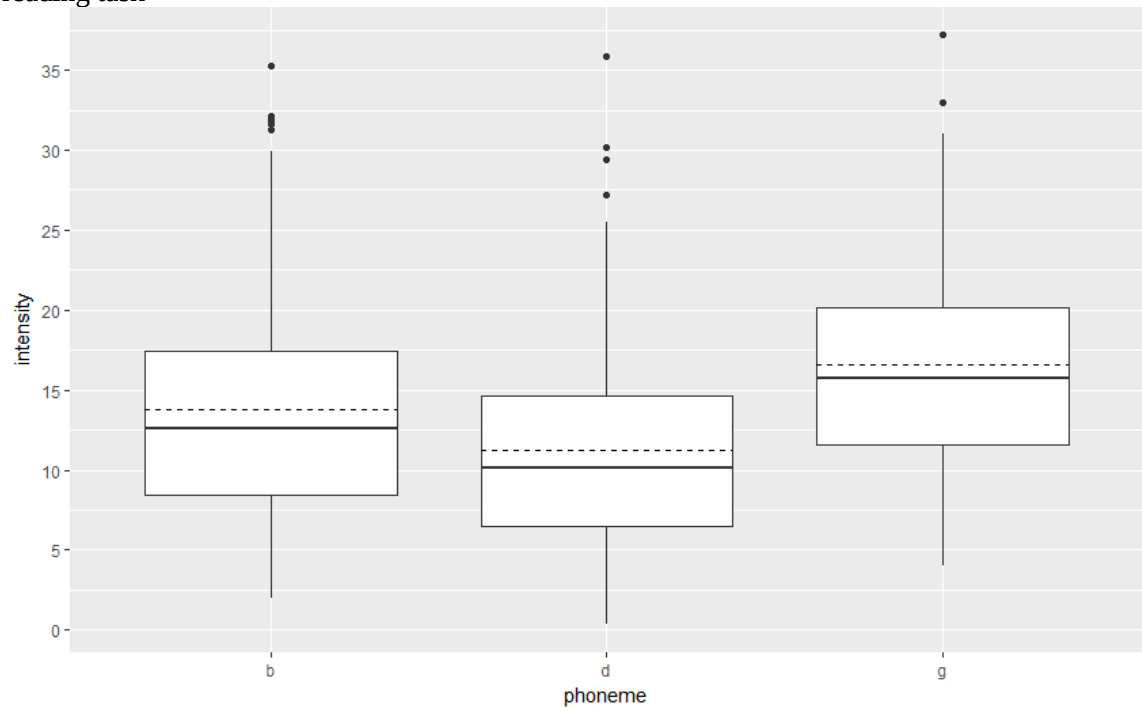
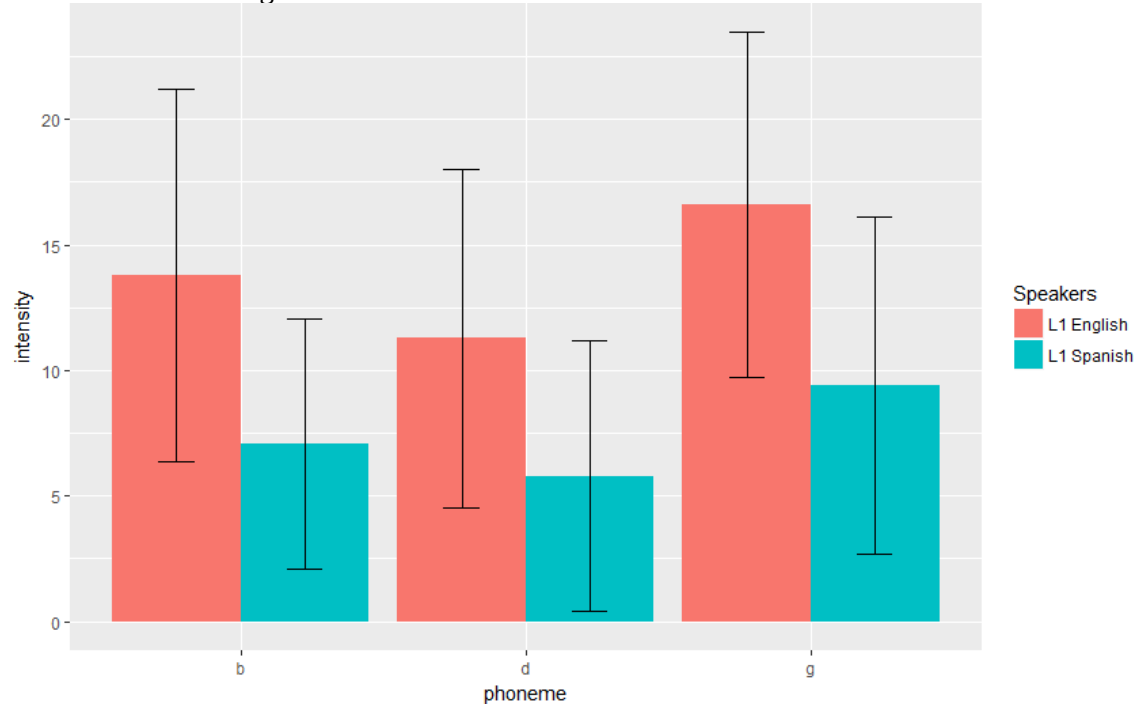


Figure 4.121. Mean RI (dB) values in Spanish produced by the L1 English and L1 Spanish control groups in the sentence-reading task



Finally, like in the L1 Spanish control group's outcomes, the nonce words reading task yielded the least lenition out of the four tasks in the L1 English control group's results (Table 4.80). Figure 4.123 displays a comparison of the L1 English and L1 Spanish control groups' results in the nonce words reading task. All three stops were produced with relatively high RI values. Interestingly, for the first time, the dental /d/ is the least weakened segment and /g/ the most lenited stop. A two-sample t-test confirmed that both stress ($p < .00203$) and word position ($p < 4.65 \times 10^{-7}$) were very significant, while syllable type ($p < .34$) had no effect on RI. As in the sentence-reading task, the three segments show a greater degree of weakening in unstressed and word internal positions.

The VOT measurements were recorded for all five speakers in instances where /b d g/ were produced as stops. Speakers E2, E3, and E4 produced all stop tokens as short-lag, lacking true voicing. Speakers E1 and E5 show evidence of true voicing in some stop realization and lack of voicing in other stops. Participant E1 produced seven stops with pre-voicing and seven stops with short-lag VOT, and informant E5 pronounced 12 stops with pre-voicing and seven stops with short-lag VOT.

Table 4.80. Mean RI values (dB) in Spanish produced by the L1 English speakers in the nonce words reading task

Phoneme	Mean / SD	Mean / SD by stress*	Mean / SD by syllable type	Mean / SD by word position*	Total tokens
/b/	16.4 / 7.4	stressed (t<35): 17.1 / 7.5	open (t<47): 17.2 / 8.2	initial (t<15): 22.9 / 4.4	66
		unstressed (t<31): 15.7 / 7.4	closed (t<19): 14.4 / 4.6	internal (t<51): 14.5 / 7.1	
/d/	18.5 / 5.9	stressed (t<21): 19.9 / 5.5	open (t<18): 19.6 / 6.1	initial (t<10): 21 / 4.6	27
		unstressed (t<6): 13.7 / 5.2	closed (t<9): 16.3 / 5.4	internal (t<17): 17.1 / 6.3	
/g/	15.9 / 6.9	stressed (t<11): 20.5 / 4.9	open (t<34): 15.3 / 7.2	initial (t<15): 19.6 / 5.5	44
		unstressed (t<33): 14.4 / 6.9	closed (t<10): 17.8	internal (t<29): 14 / 6.9	

*significant at the $\alpha < 0.05$ level

Figure 4.122. Mean RI values (dB) in Spanish produced by the L1 English speakers in the nonce words reading task

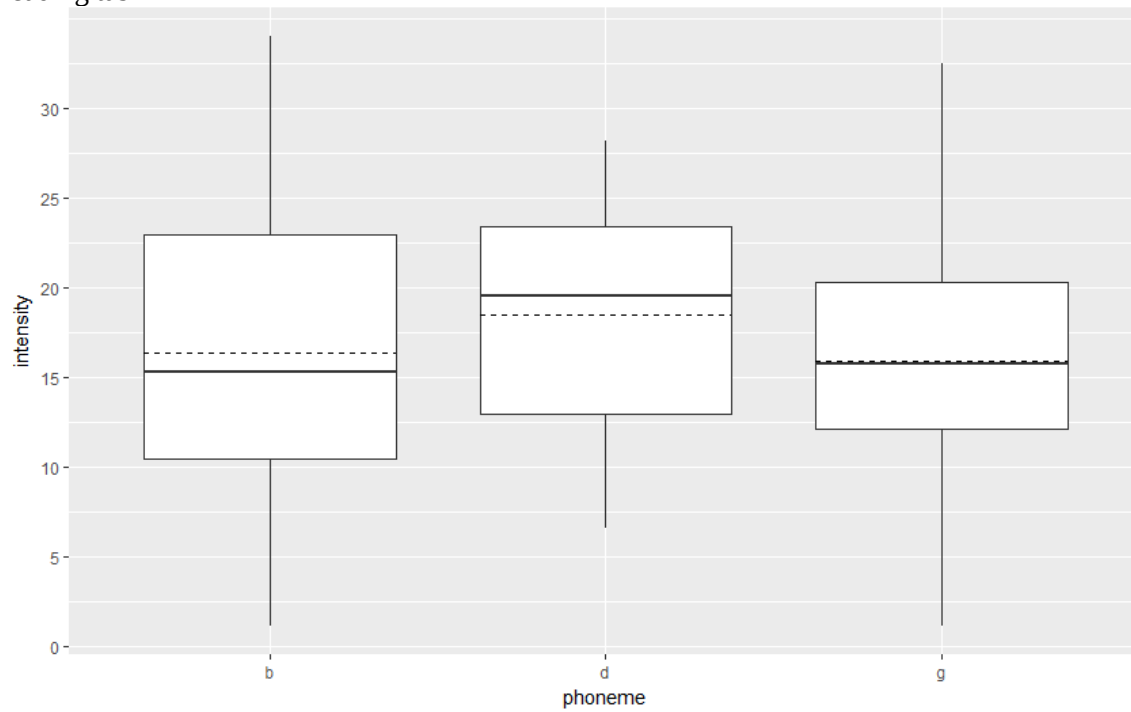
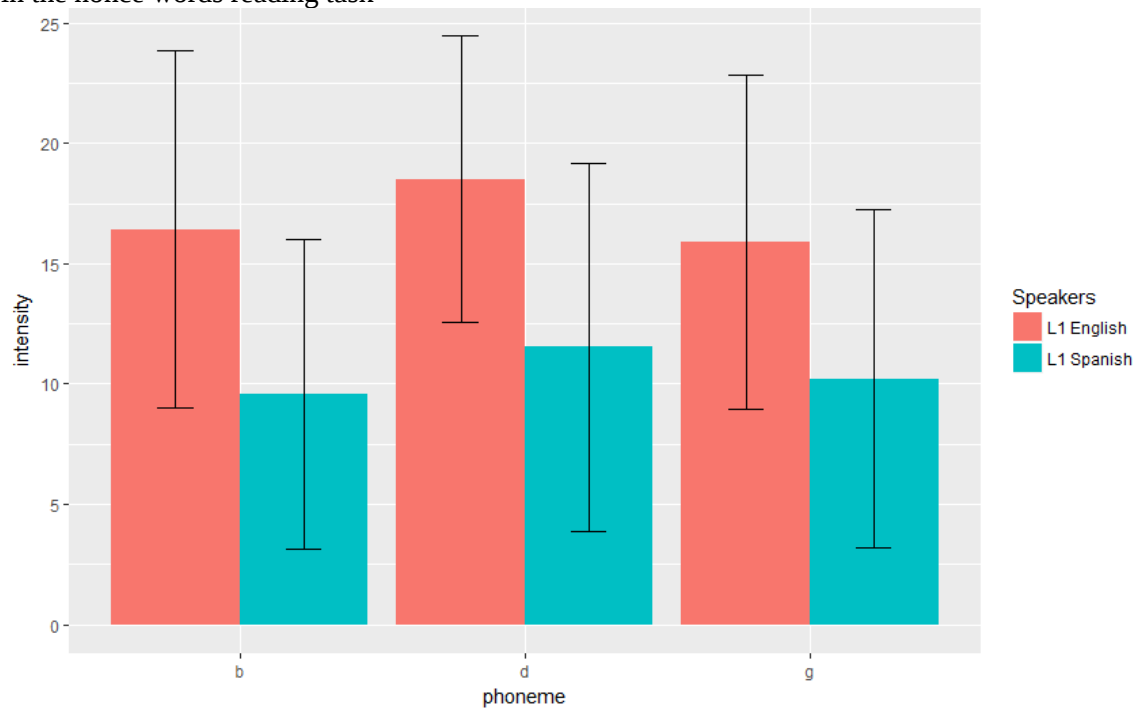


Figure 4.123. Mean RI (dB) values in Spanish produced by the L1 English and L1 Spanish control groups in the nonce words reading task

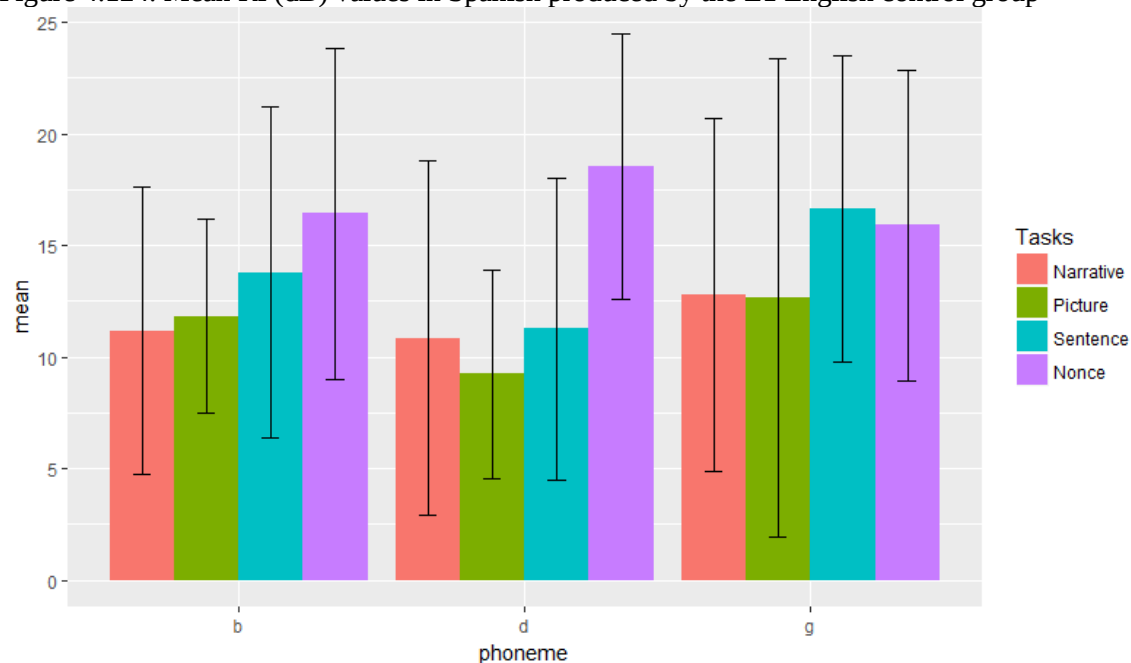


4.4.4.2.1 Summary

Figure 4.124 summarizes the production of the Spanish /b d g/ by the L1 English control group in the narrative, picture-naming, sentence-reading, and nonce words reading tasks. The segment /b/ showed the highest degree of lenition in the narrative task, while /d/ and /g/ experienced most weakening in the picture-naming task. The nonce words reading task yielded the most stop-like productions of /b/ and /d/, while /g/ experienced the least weakening in the sentence-reading task.

A Linear Mixed Effects Model was fitted to determine the statistical significance of task type on each phoneme. The results revealed that task type played a statistically significant role on the RI of all three stops: /b/ $p < .0005836$, /d/ $p < 5.122 \times 10^{-8}$, /g/ $p < .02017$. The raw data supports this finding, showing a clear relationship between task formality and the degree of lenition of /b d g/, with more weakening occurring in more natural tasks (narrative and picture-naming) as opposed to more controlled tasks (sentence and nonce words reading tasks).

Figure 4.124. Mean RI (dB) values in Spanish produced by the L1 English control group



4.4.4.3 Ukrainian HSs

The Ukrainian HSs produced a total of 762 /b d g/ tokens in the four tasks. 92 tokens were collected from the narrative task, 93 from the picture-naming task, 406 from the sentence-reading task, and finally, 171 from the nonce words reading task.

The Ukrainian HSs show evidence of weakening in the production of the three stops (Table 4.81). While HSs lenited /b d g/ to a lesser degree than the L1 Spanish speakers, they display consistently lower RI values than the L1 English control group. Similar to the L1 English control group, the Ukrainian HSs produced /d/ with the lowest mean RI value and /g/ with the highest value. A comparison between the Ukrainian HSs mean RI measurements and the RI means of the L1 English and L1 Spanish control groups can be found in Figure 4.126. A two-sample t-test showed that stress ($p < .00696$) was very significant, while syllable type ($p < .67$) and word position ($p < .738$) had no effect on RI in the narrative task. The segments /b/ and /g/ undergo more weakening in unstressed position, while /d/ does so in stressed position.

The VOT measurements of the stop-like productions of /b d g/ were in the data sets of the speakers U1, U2, U3, U4, and U6. All five speakers showed evidence of pre-voicing, signaling a true voice production of the Spanish /b d g/ segments.

Table 4.81. Mean RI values (dB) in Spanish produced by the Ukrainian HSs in the narrative task

Phoneme	Mean / SD	Mean / SD by stress*	Mean / SD by syllable type	Mean / SD by word position	Total tokens
/b/	8.1 / 4.9	stressed (t<17): 10 / 5.7	open (t<17): 6.9 / 4.1	initial (t<1): 9.2 / NA	34
		unstressed (t<17): 6.2 / 3.1	closed (t<17): 9.3 / 5.5	internal (t<33): 8.1 / 5	
/d/	8 / 4.5	stressed (t<7): 7.7 / 4.4	open (t<24): 8.1 / 3.9	initial (t<16): 8.5 / 4.8	31
		unstressed (t<24): 8.1 / 4.6	closed (t<7): 7.9 / 6.6	internal (t<15): 7.5 / 4.3	
/g/	9.7 / 5.8	stressed (t<16): 11.4 / 5.1	open (t<11): 11.2 / 6.4	initial (t<5): 7.2 / 6	27
		unstressed (t<11): 7.3 / 6	closed (t<16): 8.7 / 5.2	internal (t<22): 10.3 / 5.7	

*significant at the $\alpha < 0.05$ level

Figure 4.125. Mean RI values (dB) in Spanish produced by the Ukrainian HSs in the narrative task

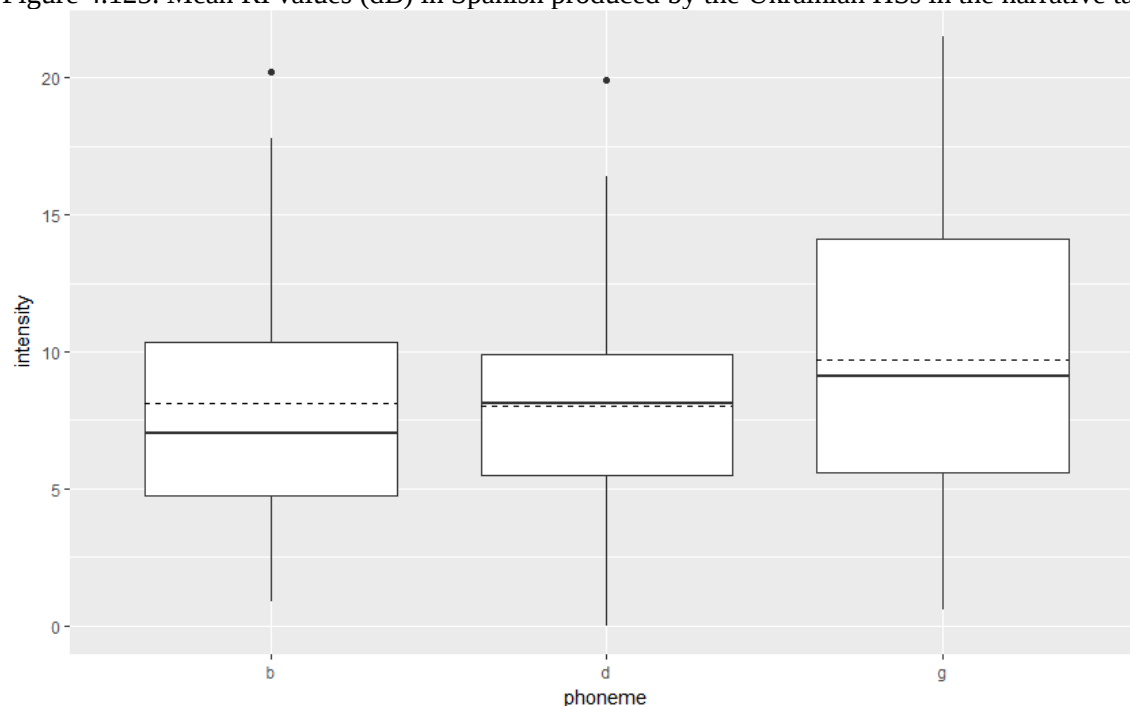
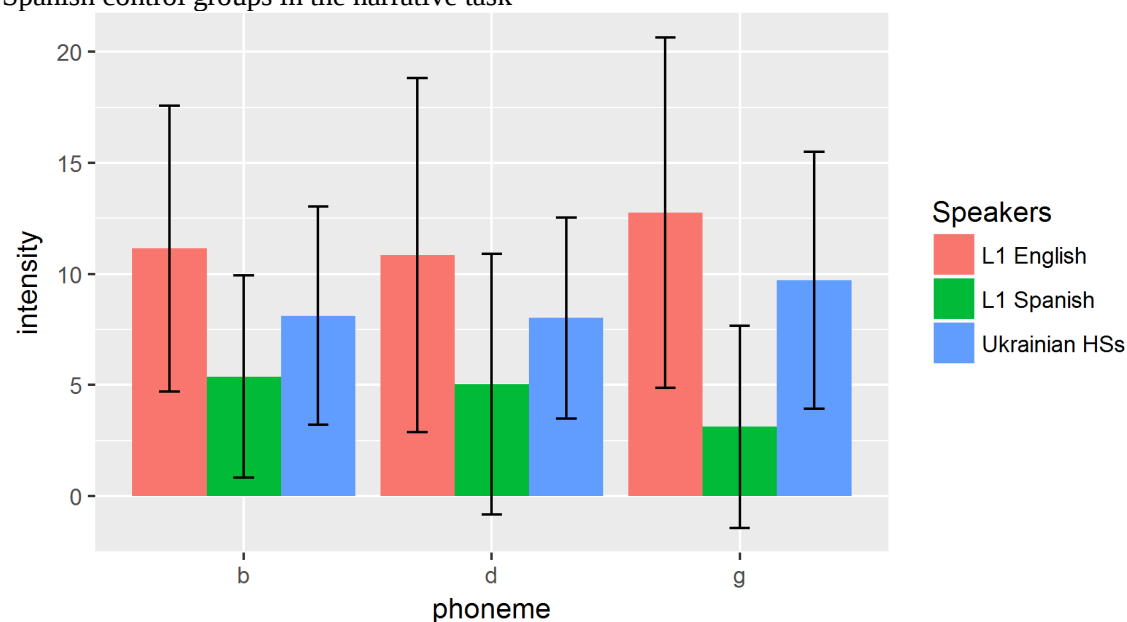


Figure 4.126. Mean RI (dB) values in Spanish produced by the Ukrainian HSs and the L1 English and L1 Spanish control groups in the narrative task



As in the narrative task, the Ukrainian HSs display consistently low RI values for /b d g/ in the picture-naming task, which are slightly higher than the ones produced by the L1 Spanish control group (except for /b/), but lower than the RI values of the L1 English control group

(Table 4.82). Unlike in the control groups' results, /g/ is the most weakened segment in the HSs data. The bilabial segment is produced with least lenition. Refer to Figure 4.128 to see a comparison between the Ukrainian HSs mean RI measurements and the RI means of the L1 English and L1 Spanish control groups. A two-sample t-test signaled that word position ($p < .000176$) was very significant, while stress ($p < .105$) and syllable type ($p < .818$) showed no statistically significant effects. Both /b/ and /d/ undergo more weakening in word internal position, while /g/ only has tokens in word internal position.

VOT measurements were recorded for stop-like realization of /b d g/ in all speakers' data set. All six participants showed evidence of pre-voicing in the production of Spanish stops, producing /b d g/ as true voice stops.

Table 4.82. Mean RI values (dB) in Spanish produced by the Ukrainian HSs in the picture-naming task

Phoneme	Mean / SD	Mean / SD by stress	Mean / SD by syllable type	Mean / SD by word position*	Total tokens
/b/	9.3 / 4.5	stressed (t<14): 10.1 / 4.8	open (t<28): 9.6 / 4.6	initial (t<10): 13.5 / 4.9	32
		unstressed (t<18): 8.6 / 4.3	closed (t<4): 6.9 / 3.3	internal (t<22): 7.3 / 2.7	
/d/	8.5 / 4.2	stressed (t<15): 10 / 2.5	open (t<34): 8.1 / 4.2	initial (t<9): 10.5 / 3.7	38
		unstressed (t<23): 7.5 / 4.8	closed (t<4): 11.2 / 3.7	internal (t<29): 7.8 / 4.2	
/g/	8.1 / 5.3	stressed (t<9): 8.1 / 5.5	open (t<23): 8.1 / 5.3	initial (t<0): NA	23
		unstressed (t<14): 8.2 / 5.4	closed (t<0): NA	internal (t<23): 8.1 / 5.3	

*significant at the $\alpha < 0.05$ level

Figure 4.127. Mean RI values (dB) in Spanish produced by the Ukrainian HSs in the picture-naming task

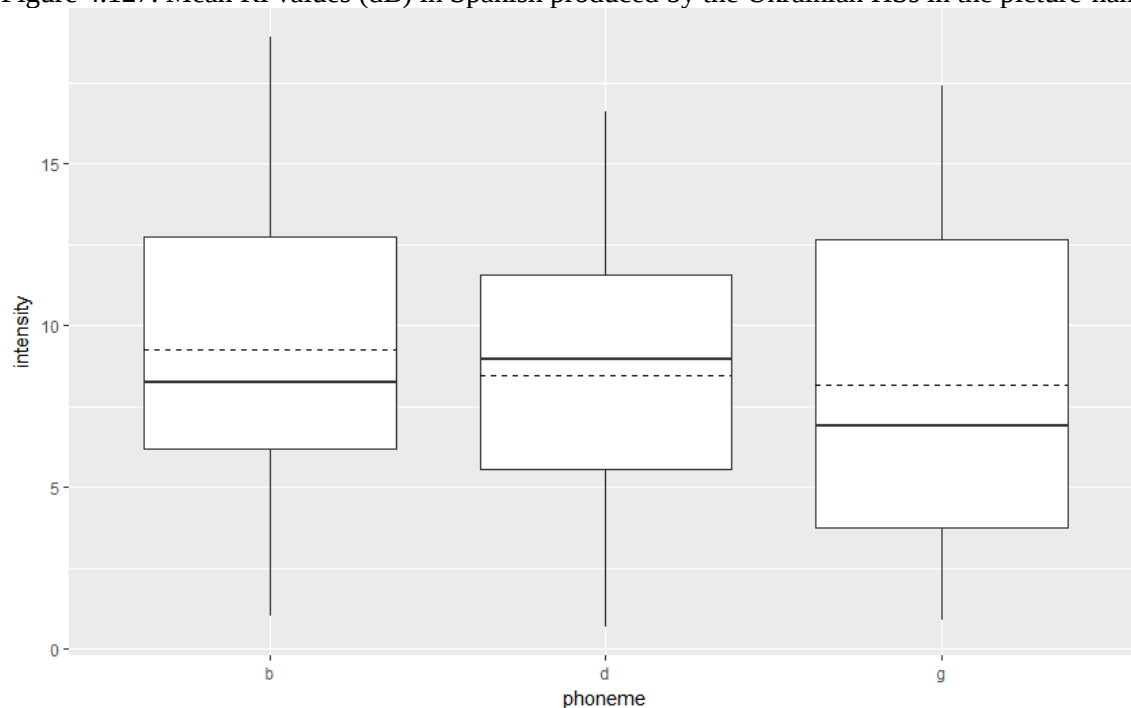
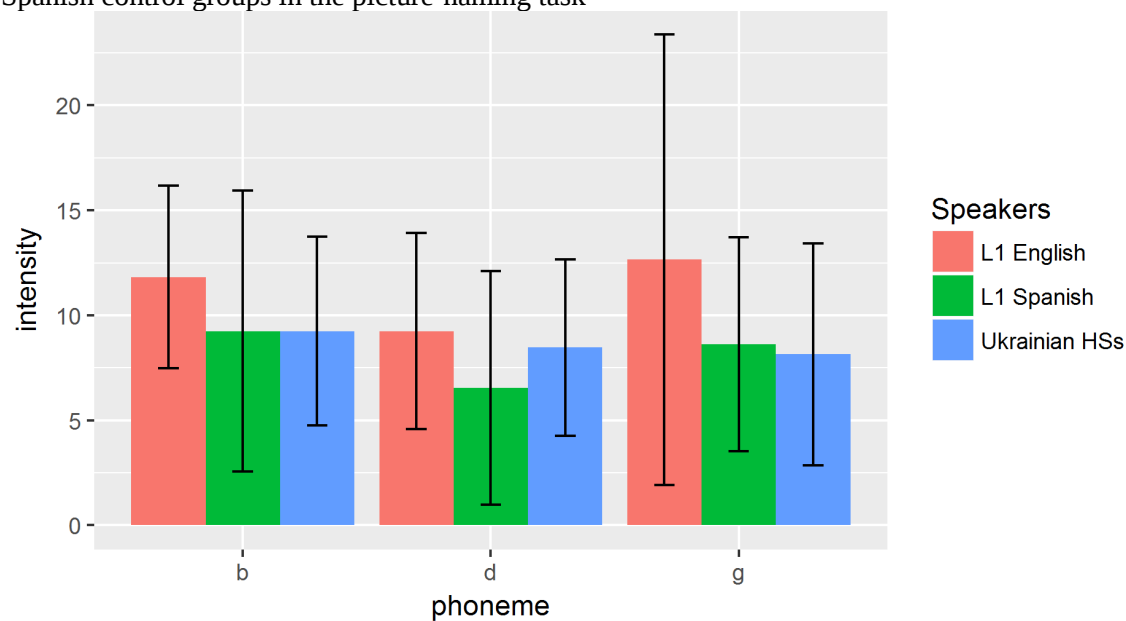


Figure 4.128. Mean RI (dB) values in Spanish produced by the Ukrainian HSs and the L1 English and L1 Spanish control groups in the picture-naming task



In the sentence-reading task, the segment /d/ is produced with the lower RI value, while /b/ and /g/ exhibit a higher degree of constriction (Table 4.83). This time, the Ukrainian HSs results are closer to the L1 English control groups' productions, but their RI values are still

lower. As in the narrative task, the dental stop is the most lenited and the velar segment shows the least amount of weakening, mirroring the L1 Spanish control group's outcome in the sentence-reading task. For a comparison of the Ukrainian HSs mean intensities to the control groups' results, refer to Figure 4.130. Both stress ($p < .00248$) and word position (1.67×10^{-10}) were shown to be very significant by a two-sample t-test, while syllable type ($p < .191$) had no effect on RI. All three segments experienced greater weakening in stressed and word internal positions. Finally, unlike with the L1 English control group's data, no /d/ tokens needed to be excluded from the data of the Ukrainian HSs due to intervocalic flapping.

The VOT measurements of the stop-like production of /b d g/ were recorded in the results of the speakers U1, U3, U4, U5, and U6. All five speakers produced the Spanish /b d g/ as true voiced, showing evidence of pre-voicing.

Table 4.83. Mean RI values (dB) in Spanish produced by the Ukrainian HSs in the sentence-reading task

Phoneme	Mean / SD	Mean / SD by stress*	Mean / SD by syllable type	Mean / SD by word position*	Total tokens
/b/	11.1 / 5.3	stressed (t<81): 11.4 / 5.4	open (t<125): 10.9 / 5.4	initial (t<48): 12.6 / 5.8	134
		unstressed (t<53): 10.5 / 5.3	closed (t<9): 13.3 / 4.4	internal (t<86): 10.2 / 4.9	
/d/	10 / 4.9	stressed (t<59): 11.5 / 4.6	open (t<167): 9.7 / 4.9	initial (t<30): 13.4 / 5.2	184
		unstressed (t<125): 9.3 / 4.9	closed (t<17): 12.4 / 4	internal (t<154): 9.3 / 4.6	
/g/	12.6 / 5.8	stressed (t<41): 13 / 6.1	open (t<81): 12.8 / 5.8	initial (t<25): 16.3 / 5.6	90
		unstressed (t<49): 12.2 / 5.6	closed (t<9): 10.1 / 5.8	internal (t<65): 11.1 / 5.3	

*significant at the $\alpha < 0.05$ level

Figure 4.129. Mean RI values (dB) in Spanish produced by the Ukrainian HSs in the sentence-reading task

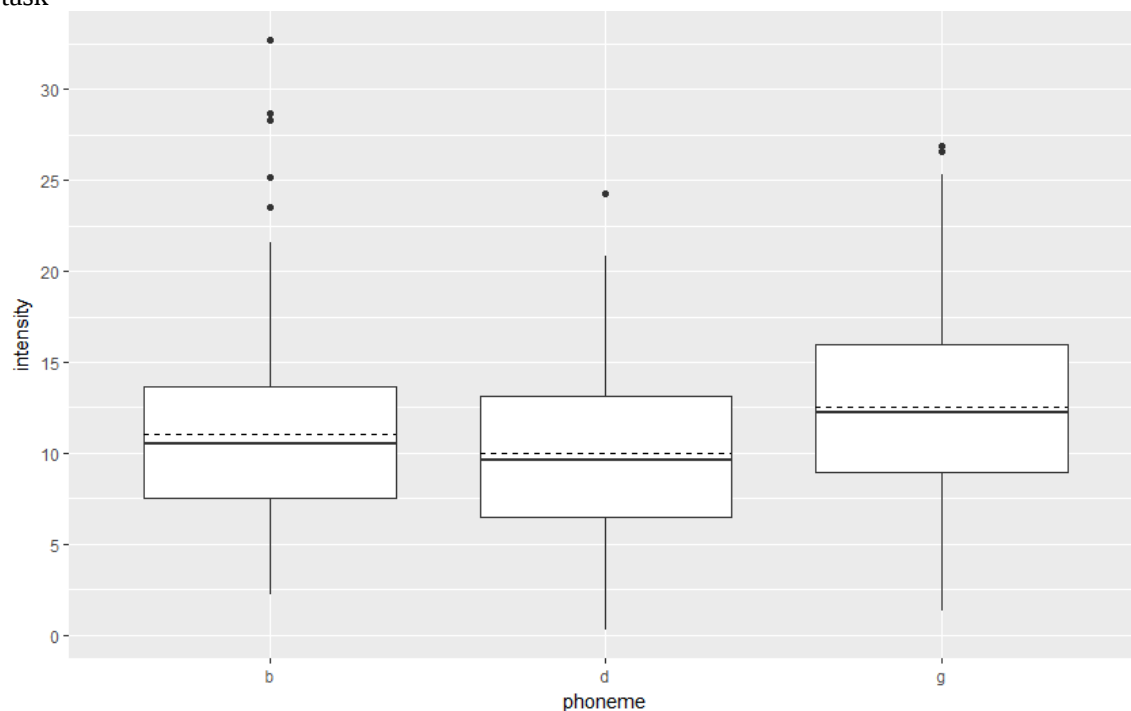
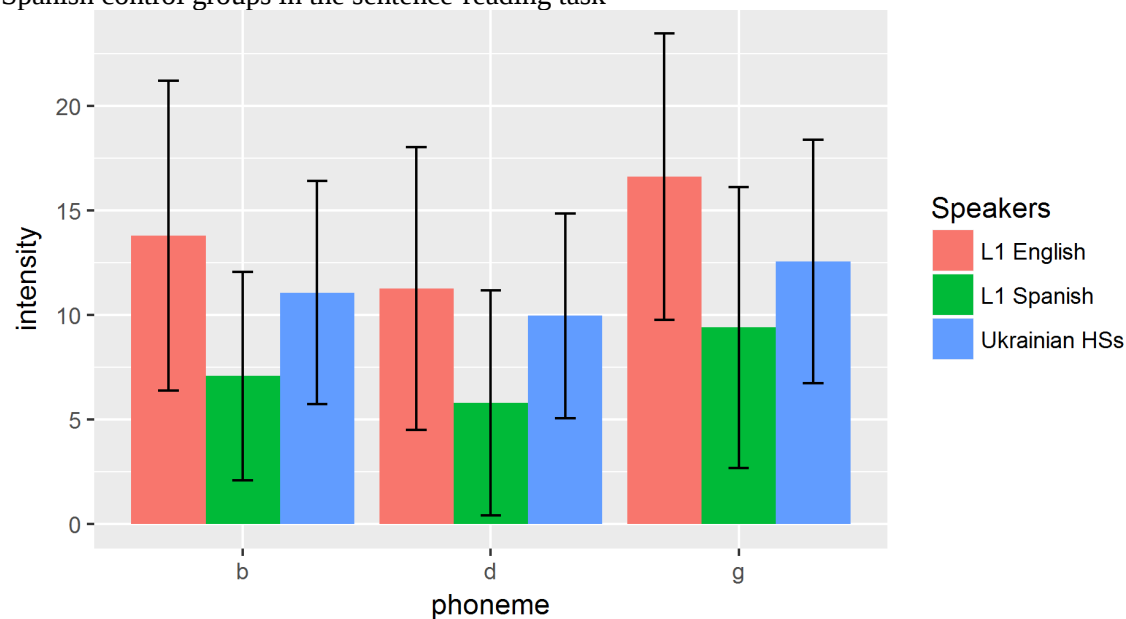


Figure 4.130. Mean RI (dB) values in Spanish produced by the Ukrainian HSs and the L1 English and L1 Spanish control groups in the sentence-reading task



Finally, all three segments in the nonce words reading task were produced with very similar RI values (Table 4.84). The RI values of /b d g/ in this task are higher than those observed in the previous three elicitations (with the exception of /g/, which displays the highest

RI in the sentence-reading task). The HSs' results are slightly higher than the ones of the L1 Spanish control group (except for /b/), but lower than the productions of the L1 English control group. As in the L1 English speakers' data, the velar was produced with the lower RI value. A comparison of the Ukrainian HSs mean RI values to the control groups' results can be viewed in Figure 4.132. All three independent variables (word position $p < .0265$) were shown to be statistically significant by a two-sample t-test, with stress ($p < .000534$) and word position ($p < 2.16 \times 10^{-14}$) being very significant. All three segments show more weakening in unstressed, closed syllables and word internal position.

A VOT measurements of the stop productions of /b d g/ was taken for all speakers. Participants U1, U3, U4, and U6 produced all stops with pre-voicing. Speaker U2 produced four stops as short-lag and three stops as true-voiced. Finally, informant U5 displays negative VOT values for 12 stops and produced only two stops as short-lag.

Table 4.84. Mean RI values (dB) in Spanish produced by the Ukrainian HSs in the nonce words reading task

Phoneme	Mean / SD	Mean / SD by stress*	Mean / SD by syllable type*	Mean / SD by word position*	Total tokens
/b/	12.7 / 6.8	stressed (t<44): 13.7 / 6.7	open (t<60): 13.5 / 6.8	initial (t<18): 19.4 / 6	84
		unstressed (t<40): 11.6 / 6.7	closed (t<24): 10.6 / 6.4	internal (t<66): 10.9 / 5.8	
/d/	12.7 / 6.5	stressed (t<25): 15.4 / 4.7	open (t<24): 13.9 / 6.8	initial (t<12): 17.5 / 4.2	36
		unstressed (t<11): 6.5 / 5.8	closed (t<12): 10.4 / 5.4	internal (t<24): 10.3 / 6.2	
/g/	12.5 / 7.2	stressed (t<12): 15.6 / 7.6	open (t<39): 12.8 / 7.6	initial (t<18): 18.4 / 5.4	51
		unstressed (t<39): 11.5 / 6.9	closed (t<12): 11.6 / 6.2	internal (t<33): 9.3 / 6	

*significant at the $\alpha < 0.05$ level

Figure 4.131. Mean RI values (dB) in Spanish produced by the Ukrainian HSs in the nonce words reading task

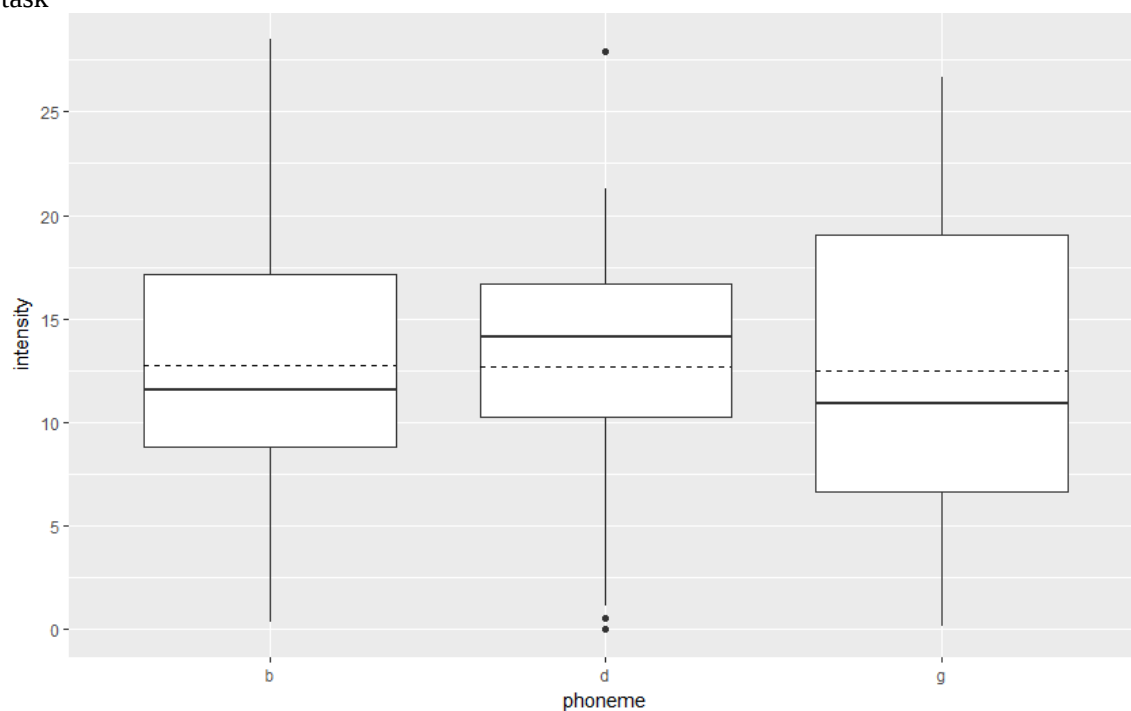
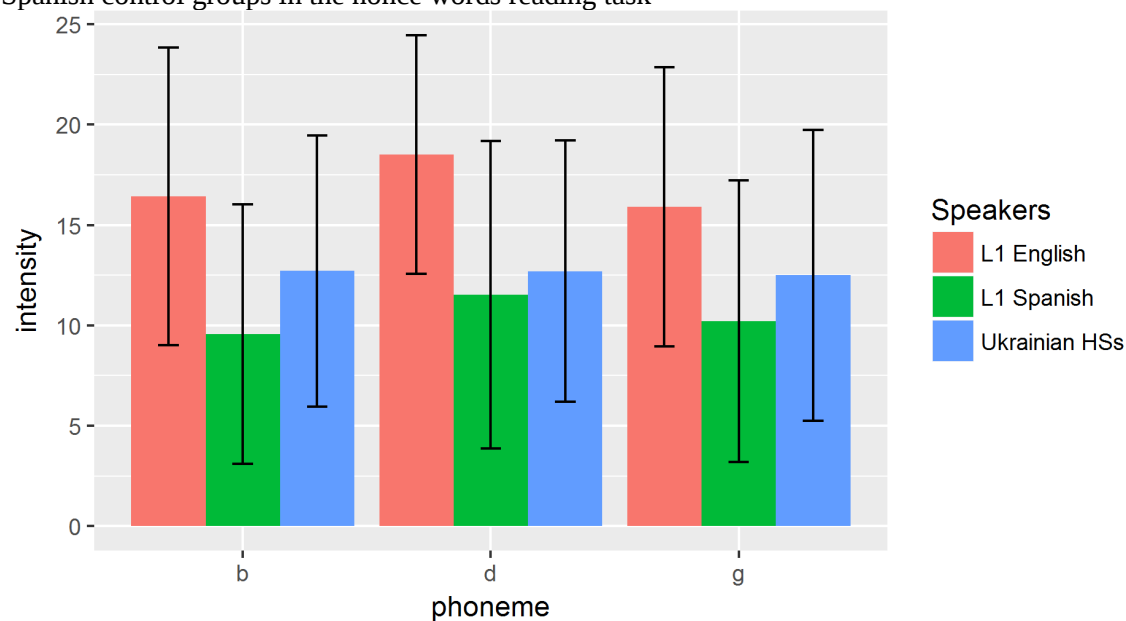


Figure 4.132. Mean RI (dB) values in Spanish produced by the Ukrainian HSs and the L1 English and L1 Spanish control groups in the nonce words reading task



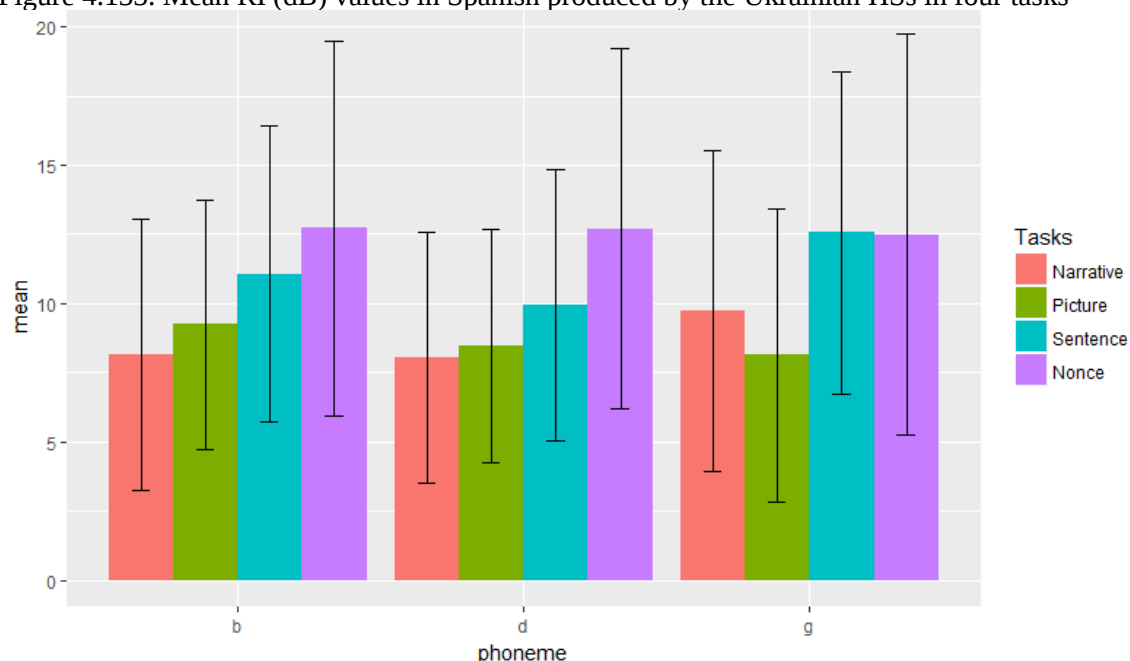
4.4.4.3.1 Summary

Figure 4.133 provides a summary of the Spanish /b d g/ productions by the Ukrainian HSs group in the narrative, picture-naming, sentence-reading, and nonce words reading tasks.

The segments /b/ and /d/ showed the most weakening in the narrative task and the velar /g/ segment was most lenited in the picture-naming task. The phonemes /b/ and /d/ were least lenited in the nonce words reading task and /g/ exhibited the least lenition in the sentence-reading task. However, the mean RI values for /g/ in the nonce words reading task is very close to the RI value in the sentence-reading elicitation (12.5 dB and 12.6 dB).

A Linear Mixed Effects Model was applied to the Ukrainian data and showed that task type played a statistically significant role in the productions of all three phonemes: /b/ $p < .00144$, /d/ $p < .0001311$, /g/ $p < .02379$. Similar to L1 English speakers' results, the raw data shows a clear relationship between task formality and lenition. The least formal tasks (narrative and picture-naming) yielded a greater degree of weakening, while the more controlled tasks (sentence and nonce words reading) caused a higher degree of constriction in the production of /b d g/.

Figure 4.133. Mean RI (dB) values in Spanish produced by the Ukrainian HSs in four tasks



4.4.4.4 Polish HSs

The Polish HSs produced a total of 1,313 /b d g/ tokens in the four tasks. 96 productions were analyzed in the narrative task, 148 in the picture-naming task, 756 in the sentence-reading task, and finally, 313 in the nonce words reading task.

In the narrative task, the Polish HSs produced /b/ and /d/ with mean RI values that are lower than those produced by the L1 English group, but higher than those of both the L1 Spanish control group and the Ukrainian HSs. Similar to the L1 English speakers' and the Ukrainian HSs' results, the dental segment is the most lenited out of the three stops and the velar stop exhibits the least amount of weakening in the Polish HSs data (Table 4.85). For a comparison of the mean RI values of the Polish HSs and the control groups, refer to Figure 4.135. A two-sample t-test revealed that none of the independent variables had a significant effect on RI (stress $p < .289$, syllable type $p < .283$, word position $p < .584$). The raw data shows that /b/ and /d/ display the same patterns in terms of RI values and the independent variables, while /g/ behaves differently than the other two stops.

The VOT measurements of the stop productions were recorded in the data sets of the speakers P1, P2, P4, P5, P6, P7, P8, and P11. All eight speakers show evidence of true voicing by producing the stop segments with negative VOT values.

Table 4.85. Mean RI (dB) values in Spanish produced by the Polish HSs in the narrative task

Phoneme	Mean / SD	Mean / SD by stress	Mean / SD by syllable type	Mean / SD by word position	Total tokens
/b/	9.7 / 6	stressed (t<26): 10.1 / 6	open (t<12): 9.5 / 7	initial (t<2): 15.7 / 11.8	38
		unstressed (t<12): 8.7 / 6	closed (t<26): 9.8 / 5.6	internal (t<36): 9.4 / 5.6	
/d/	9.4 / 4.9	stressed (t<18): 11.1 / 4.4	open (t<31): 9.2 / 4.4	initial (t<18): 10.9 / 4.4	36
		unstressed (t<18): 7.8 / 4.9	closed (t<5): 10.6 / 7.7	internal (t<18): 7.9 / 4.9	
/g/	14.5 / 4.1	stressed (t<10): 14.3 / 2.9	open (t<8): 14.6 / 4.3	initial (t<1): 8.9 / NA	22

		unstressed (t<12): 14.7 / 5	closed (t<14): 14.4 / 4.1	internal (t<21): 14.8 / 4	
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Figure 4.134. Mean RI (dB) values in Spanish produced by the Polish HSs in the narrative task

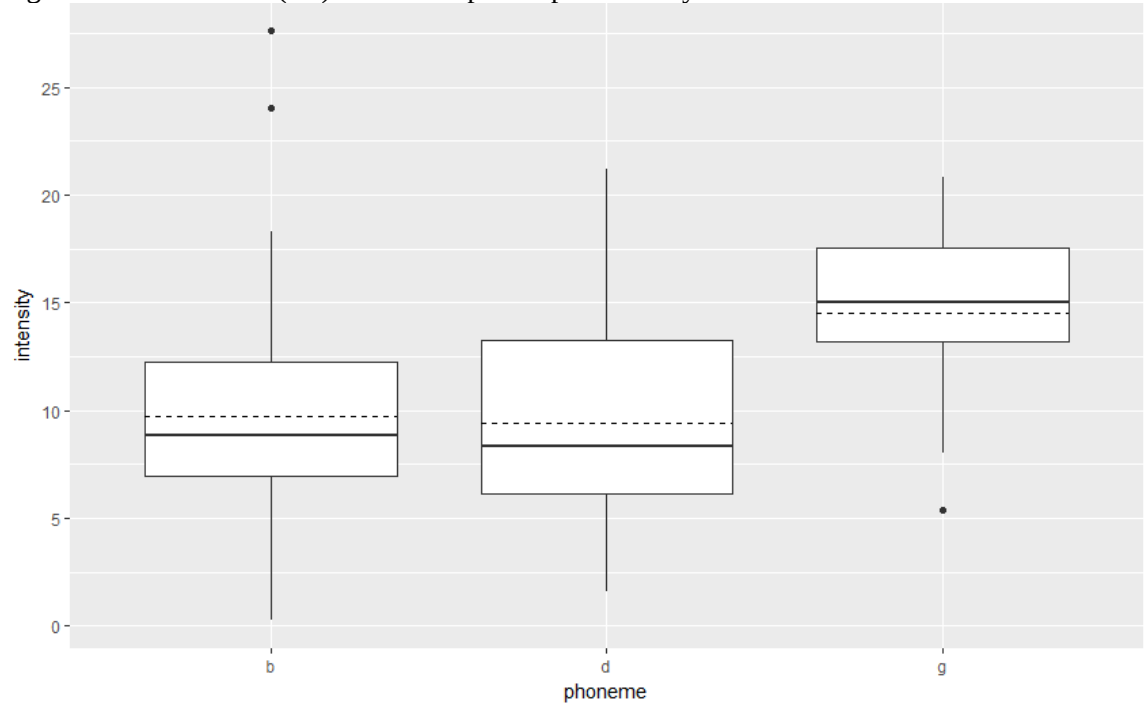
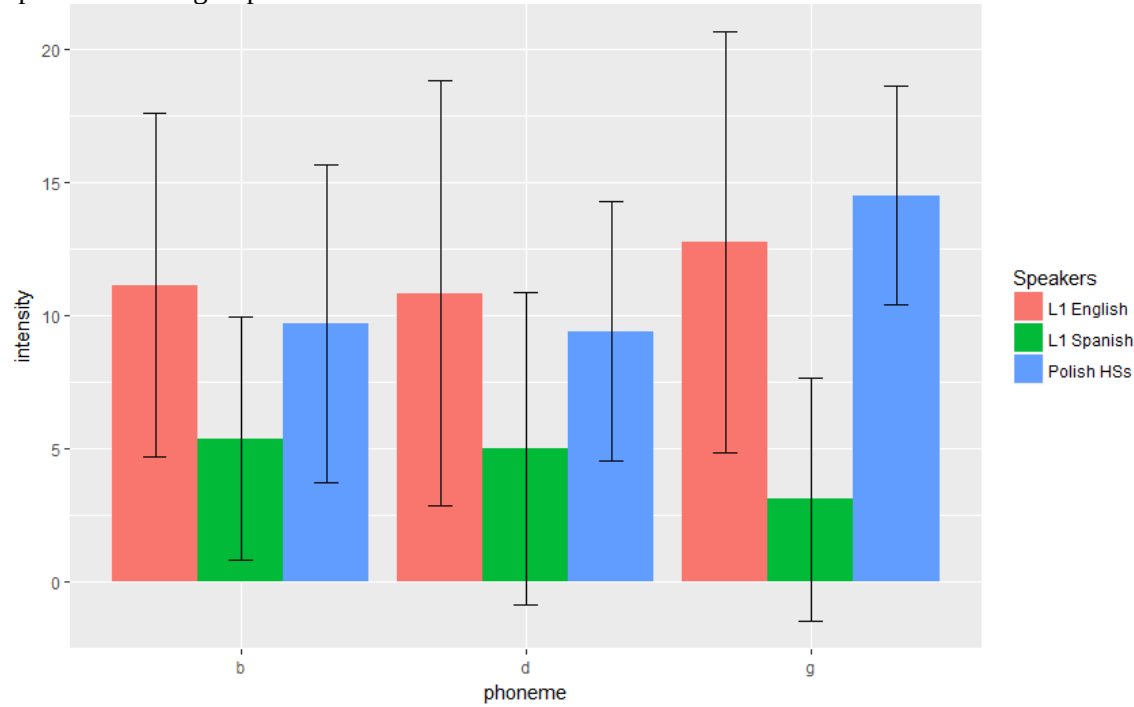


Figure 4.135. Mean RI (dB) values in Spanish produced by the Polish HSs and the L1 English and L1 Spanish control groups in the narrative task



The three stops in the picture-naming task were produced with mean RI values that indicate more closure than is observed in the narrative task (Table 4.86). As in the narrative task, /d/ shows the most weakening. This time, however, /b/ is the least lenited segment. This relationship between place of articulation and lenition reflects the one in the Ukrainian HSs' results for the picture-naming task. Out of the four speaker groups, the Polish HSs produced the least lenited /b/ and /d/ segments in this task. Figure 4.137 summarizes the Polish HSs' mean intensities and compares them to the productions of the control groups. A two-sample t-test showed that word position ($p < .00881$) was very significant, while stress ($p < .367$) and syllable type ($p < .71$) had no effect on RI.

The phoneme /b/ is more lenited in word internal position, while /d/ is more weakened in the opposite context. Meanwhile, /g/ has no tokens in word-initial position.

The VOT measurements of the instances of /b d g/ that were produced like stops were recorded for all eleven speakers. All but one speaker show evidence of true voicing by producing the stop segments with pre-voicing. The exceptional speaker, P6, however, produced four of the stop segments with short-lag VOT.

Table 4.86. Mean RI (dB) values in Spanish produced by the Polish HSs in the picture-naming task

Phoneme	Mean / SD	Mean / SD by stress	Mean / SD by syllable type	Mean / SD by word position*	Total tokens
/b/	12.7 / 6.1	stressed (t<26): 11.7 / 4.7	open (t<42): 13.6 / 6.2	initial (t<18): 16.1 / 6.6	52
		unstressed (t<26): 13.7 / 7.1	closed (t<10): 8.9 / 3.9	internal (t<34): 10.9 / 5	
/d/	11.1 / 4.7	stressed (t<25): 12.5 / 4.4	open (t<47): 10.5 / 4.5	initial (t<15): 10.8 / 3.8	58
		unstressed (t<33): 10 / 4.7	closed (t<11): 13.6 / 5.2	internal (t<43): 11.2 / 5	
/g/	11.3 / 3.8	stressed (t<14): 12.2 / 4.4	open (t<38): 11.3 / 3.8	initial (t<0): NA	38
		unstressed (t<24): 10.7 / 3.3	closed (t<0): NA	internal (t<38): 11.3 / 3.8	

*significant at the $\alpha < 0.05$ level

Figure 4.136. Mean RI (dB) values in Spanish produced by the Polish HSs in the picture-naming task

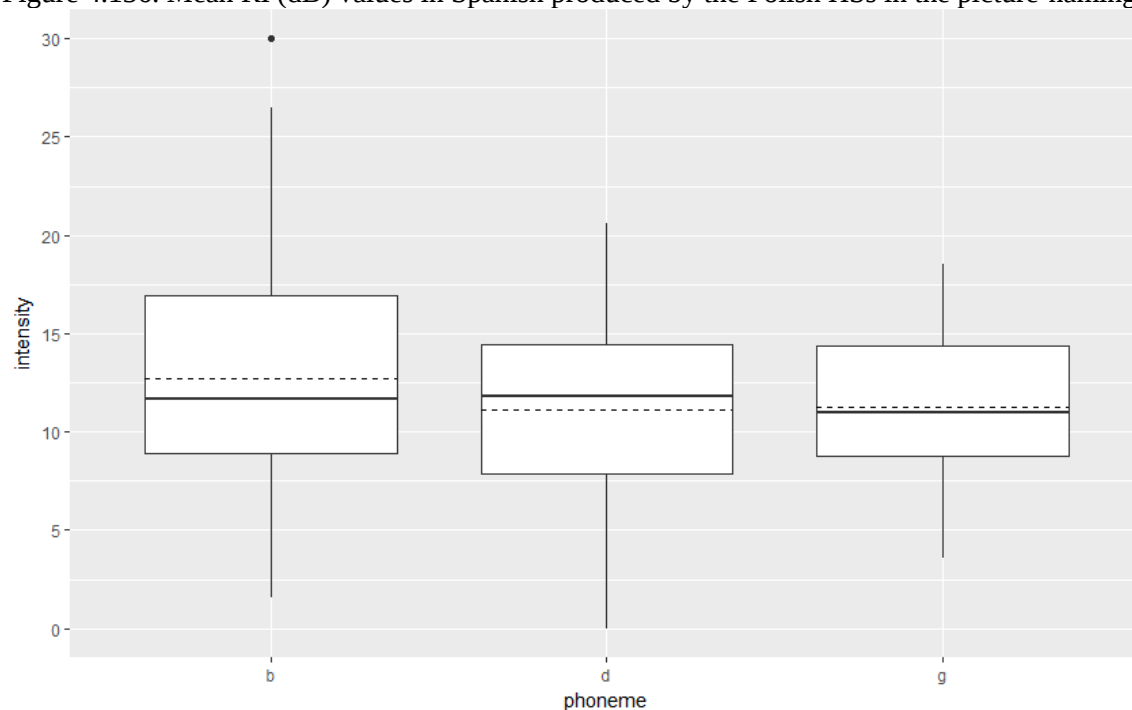
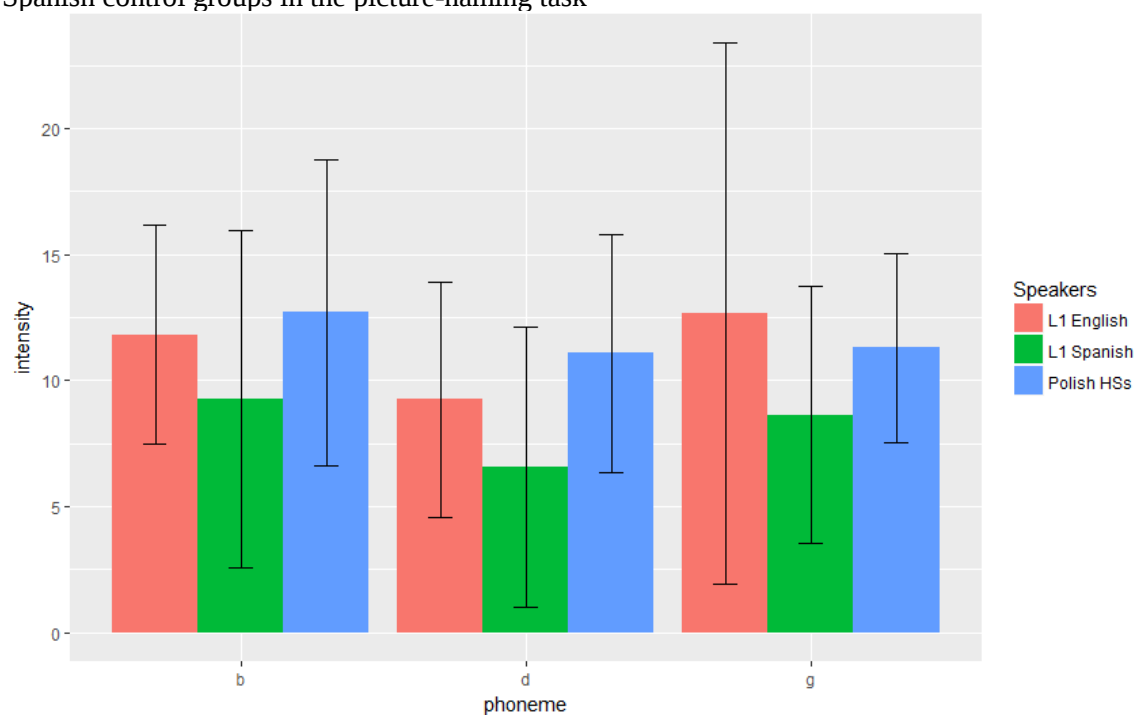


Figure 4.137. Mean RI (dB) values in Spanish produced by the Polish HSs and the L1 English and L1 Spanish control groups in the picture-naming task



The Spanish /b d g/ undergo less lenition in the sentence-reading task than in the previous two elicitations. The segment /d/ was lenited the most, while the phonemes /b/ and /g/ showed a

higher degree of constriction, indicating more closure (Table 4.87). As in the previous two elicitations, /d/ is the most weakened segment in the sentence-reading task. The least lenited segment in this task is the velar phoneme /g/. The Polish HSs produced the least lenited /b/ and /g/ segments out of the four groups of speakers and the mean RI of /g/ is very close to the L1 English group's realization. The mean RI values of the Polish HSs along with the L1 English and L1 Spanish control groups' realizations, can be viewed in Figure 4.139. According to a two-sample t-test, both stress ($p < 1.53 \cdot 10^{-5}$) and word position ($p < 2 \cdot 10^{-16}$) were very significant, while syllable type ($p < .911$) showed no effect on RI. All three segments display more weakening in unstressed and word internal positions.

Finally, VOT measurements of the stop segments were recorded for all speakers. Participants P1, P2, P3, P7, P8, P10, and P11 produced all stops with pre-voicing. Speakers P4, P5, P6, and P8 show evidence of pre-voicing, producing a total of 87 stops as true-voice, but also pronounced 14 stops with short-lag VOTs.

Table 4.87. Mean RI (dB) values in Spanish produced by the Polish HSs in the sentence-reading task

Phoneme	Mean / SD	Mean / SD by stress*	Mean / SD by syllable type	Mean / SD by word position*	Total tokens
/b/	14.4 / 6	stressed (t<154): 15.1 / 5.9	open (t<225): 14.3 / 6	initial (t<88): 16.6 / 6.1	247
		unstressed (t<93): 13.3 / 5.9	closed (t<22): 15.6 / 6	internal (t<159): 13.2 / 5.6	
/d/	12.7 / 5.8	stressed (t<108): 13.9 / 5.4	open (t<302): 12.8 / 5.9	initial (t<55): 16.7 / 5.3	333
		unstressed (t<225): 12.2 / 5.9	closed (t<31): 12.6 / 4.4	internal (t<278): 12 / 5.5	
/g/	16.5 / 6.5	stressed (t<77): 17.4 / 6.6	open (t<157): 16.8 / 6.5	initial (t<53): 19.2 / 6.1	176
		unstressed (t<99): 15.9 / 6.3	closed (t<19): 14.8 / 5.7	internal (t<123): 15.4 / 6.3	

*significant at the $\alpha < 0.05$ level

Figure 4.138. Mean RI (dB) values in Spanish produced by the Polish HSs in the sentence-reading task

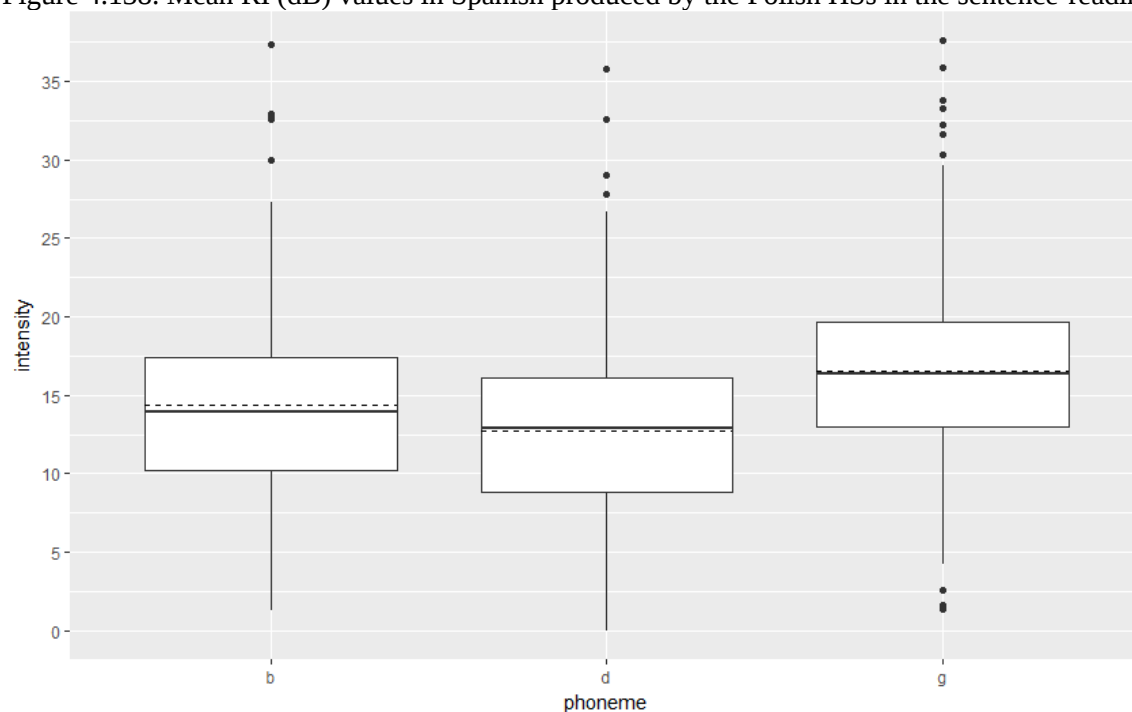
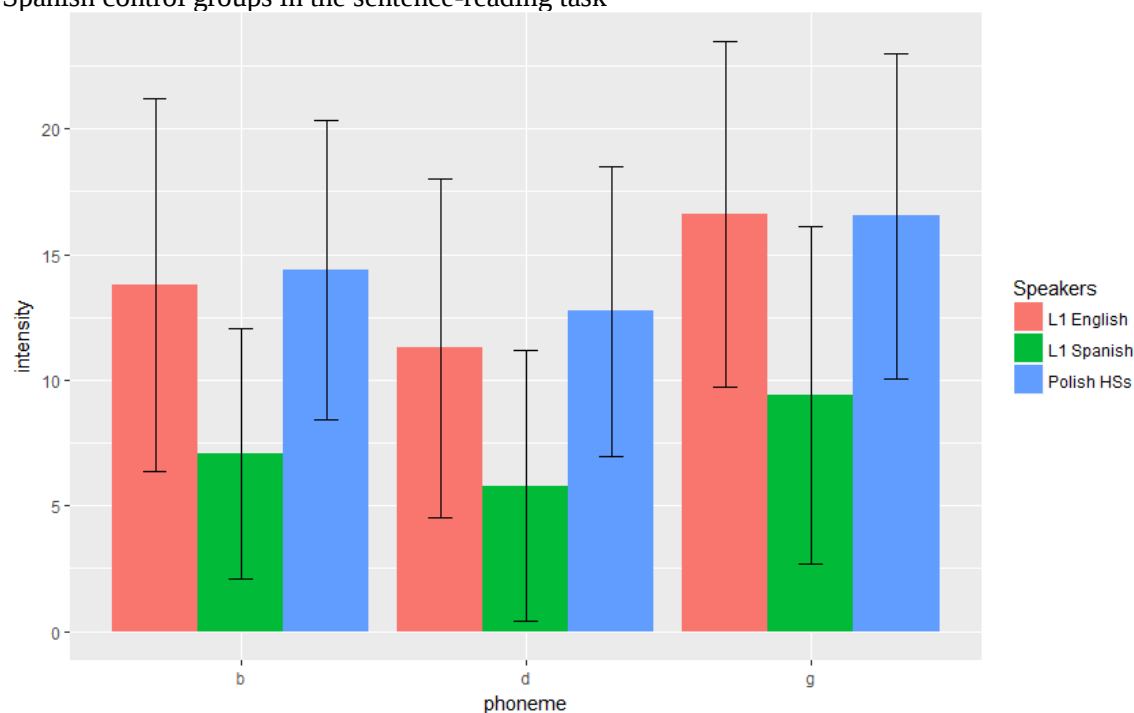


Figure 4.139. Mean RI (dB) values in Spanish produced by the Polish HSs and the L1 English and L1 Spanish control groups in the sentence-reading task



The three stops in the nonce words reading task display consistently high RI values (Table 4.88). Unlike in the previous three elicitations, the dental segment is the least lenited stop

in the nonce words reading task (reflecting the L1 Spanish control group's result), while the bilabial and the velar segments share the same mean RI. The Polish HSs produced mean RI values that are higher than those of the L1 Spanish group and Ukrainian HSs, but lower than the ones of the L1 English control group. Figure 4.141 summarizes the productions of the Polish HSs and provides a comparison with the values obtained from the control groups. All three independent variables were shown to be statistically significant by a two-sample t-test: stress ($p < .0083$), syllable type ($p < .000102$), word type ($p < 1.49 \cdot 10^{-10}$). All three phonemes demonstrate more weakening in unstressed, word internal positions and in closed syllables.

The VOT measurements of stop productions were recorded for all eleven speakers. The participants P1, P2, P4, P7, P8, P9, and P10 produced all stop segments with negative VOT values, showing evidence of true voicing of /b d g/. Participants P3, P5, P6, and P11, on the other hand, pronounced some stops as short-lag (a total of 32) and some stops as true voice (a total of 46).

Table 4.88. Mean RI (dB) values in Spanish produced by the Polish HSs in the nonce word reading task

Phoneme	Mean / SD	Mean / SD by stress*	Mean / SD by syllable type*	Mean / SD by word position*	Total tokens
/b/	15.9 / 7.4	stressed (t<78): 16.9 / 7.9	open (t<108): 16.9 / 7.1	initial (t<33): 19.7 / 7	153
		unstressed (t<75): 15 / 6.8	closed (t<45): 13.5 / 7.8	internal (t<120): 14.9 / 7.2	
/d/	16.5 / 7.5	stressed (t<53): 17.8 / 7.6	open (t<44): 18.3 / 7.5	initial (t<22): 21.6 / 6.8	65
		unstressed (t<12): 10.8 / 3.9	closed (t<21): 12.6 / 6	internal (t<43): 13.9 / 6.5	
/g/	15.9 / 6.5	stressed (t<21): 16.5 / 5.4	open (t<74): 16.3 / 6.8	initial (t<32): 19.5 / 6.3	95
		unstressed (t<74): 15.7 / 6.8	closed (t<21): 14.4 / 4.7	internal (t<63): 14.1 / 5.8	

*significant at the $\alpha < 0.05$ level

Figure 4.140. Mean RI (dB) values in Spanish produced by the Polish HSs in the nonce word reading task

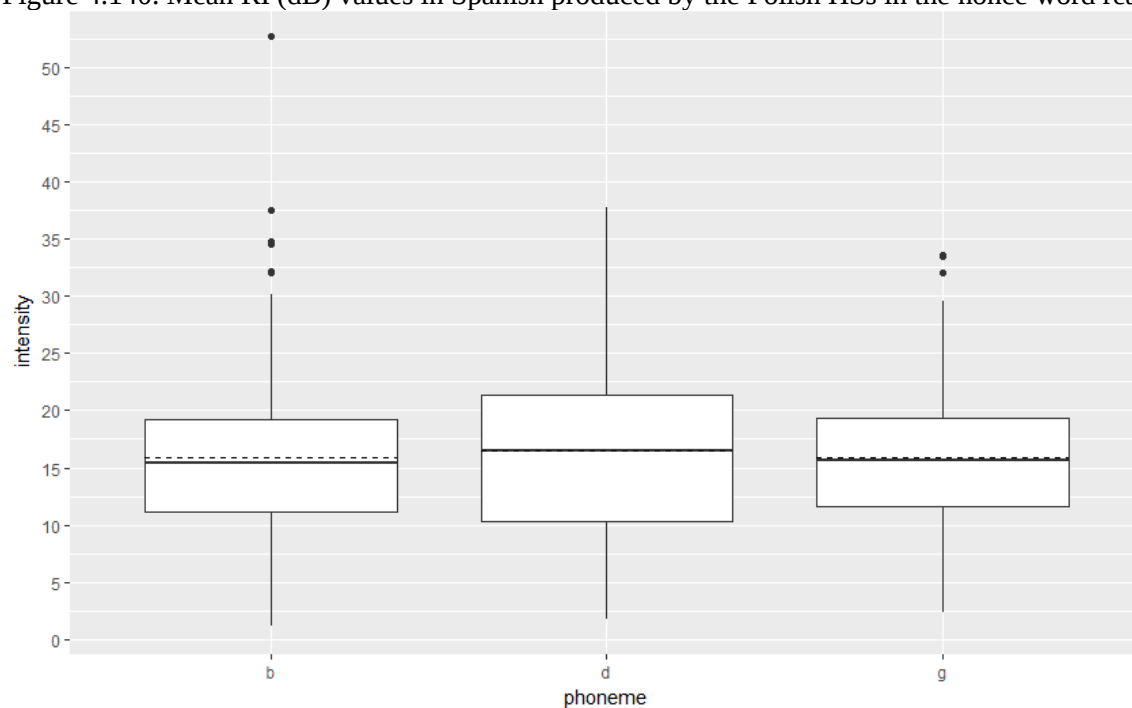
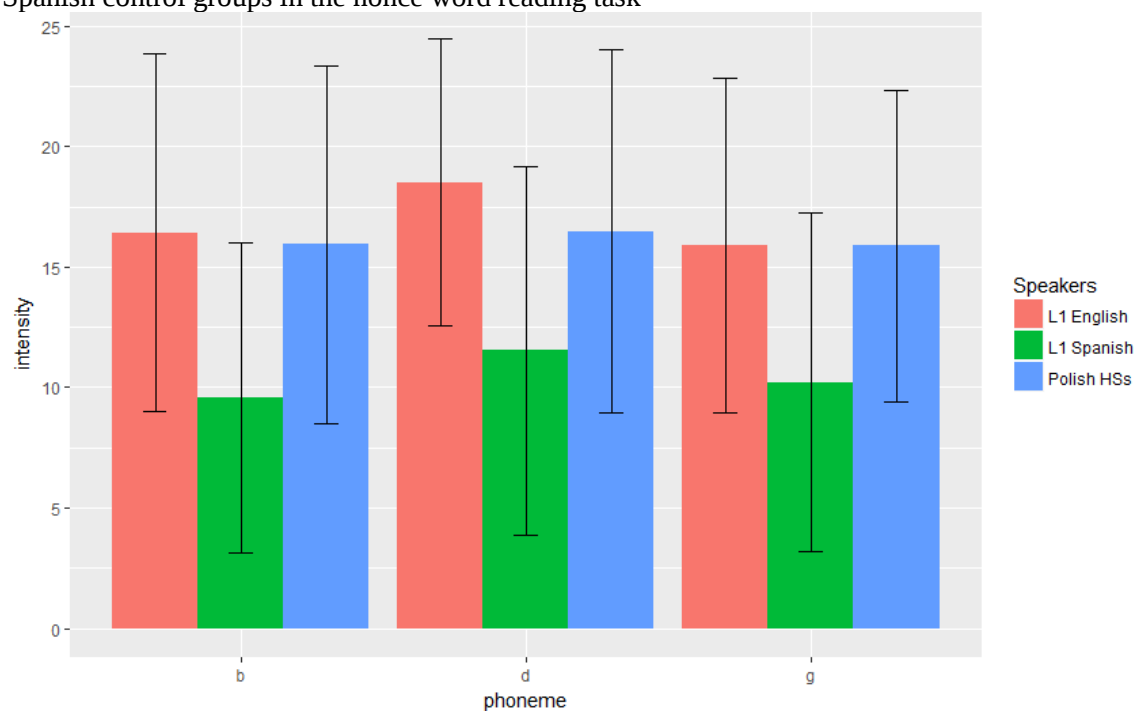


Figure 4.141. Mean RI (dB) values in Spanish produced by the Polish HSs and the L1 English and L1 Spanish control groups in the nonce word reading task

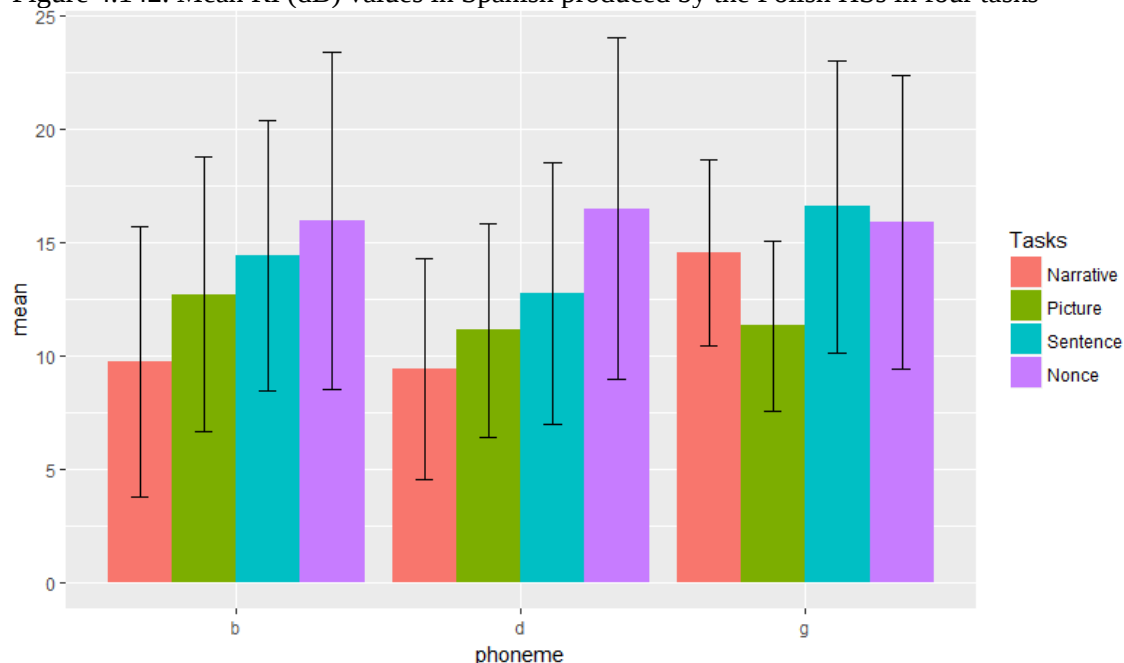


4.4.4.4.1 Summary

Figure 4.142 summarizes the Polish HSs' productions of the Spanish /b d g/ in the narrative, picture-naming, sentence-reading, and nonce words reading tasks. The phonemes /b/ and /d/ were most lenited in the narrative task, while the phoneme /g/ displayed the most weakening in the picture-naming task. The nonce words reading task yielded the least lenited /b/ and /d/ segments and the velar /g/ displayed the least amount of lenition in the sentence-reading task.

A Linear Mixed Effects Model was fitted to determine the statistical significance of task type on each phoneme. The results revealed that task type played a very significant role in the production of all three segments: /b/ $p < 3.14 \times 10^{-7}$, /d/ $p < 8.375 \times 10^{-10}$, /g/ $p < 3.204 \times 10^{-6}$. As with the previous groups' results, the raw data shows a clear correlation between lenition and task formality. All three stops displayed more weakening in least controlled tasks (narrative and picture-naming) and higher RI values in more formal tasks (sentence and nonce words reading tasks).

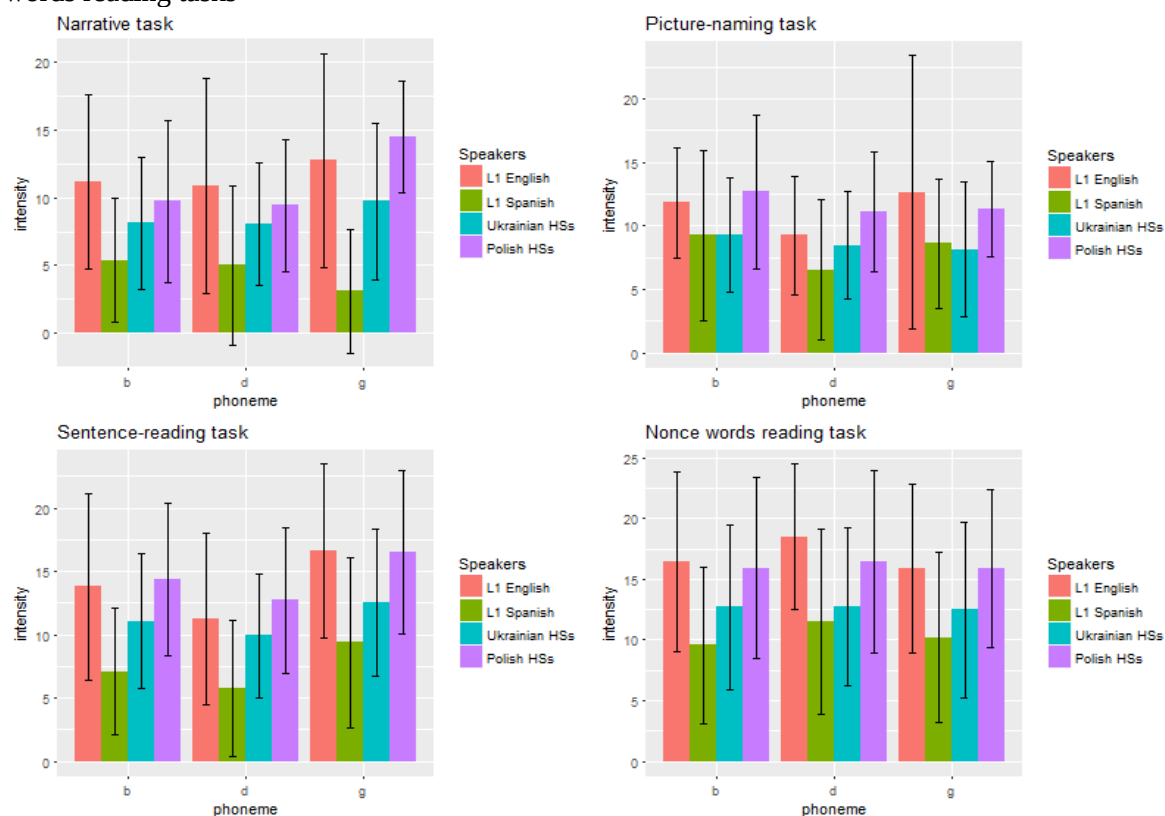
Figure 4.142. Mean RI (dB) values in Spanish produced by the Polish HSs in four tasks



4.4.5 Summary

Figure 4.143 summarizes the productions of the Spanish /b d g/ by the Ukrainian HSs, the Polish HSs, and the L1 English and L1 Spanish control groups in the narrative, picture-naming, sentence-reading and nonce words reading tasks. The L1 Spanish control group produced the most lenited segments in all four tasks with one exception; the Ukrainian HSs produced the most lenited /g/ in the picture-naming task. The L1 English control group, along with the Polish HSs group, showed the least degree of weakening in the four tasks. The Ukrainian HSs weakened more than the L1 English speakers and the Polish HSs, but not to the same extent as the L1 Spanish speakers. From the graphs, it can be seen that all four groups of speakers produced more weakening in least controlled tasks (the narrative and picture-naming elicitations) and less lenition in controlled tasks (the sentence and nonce words reading elicitations).

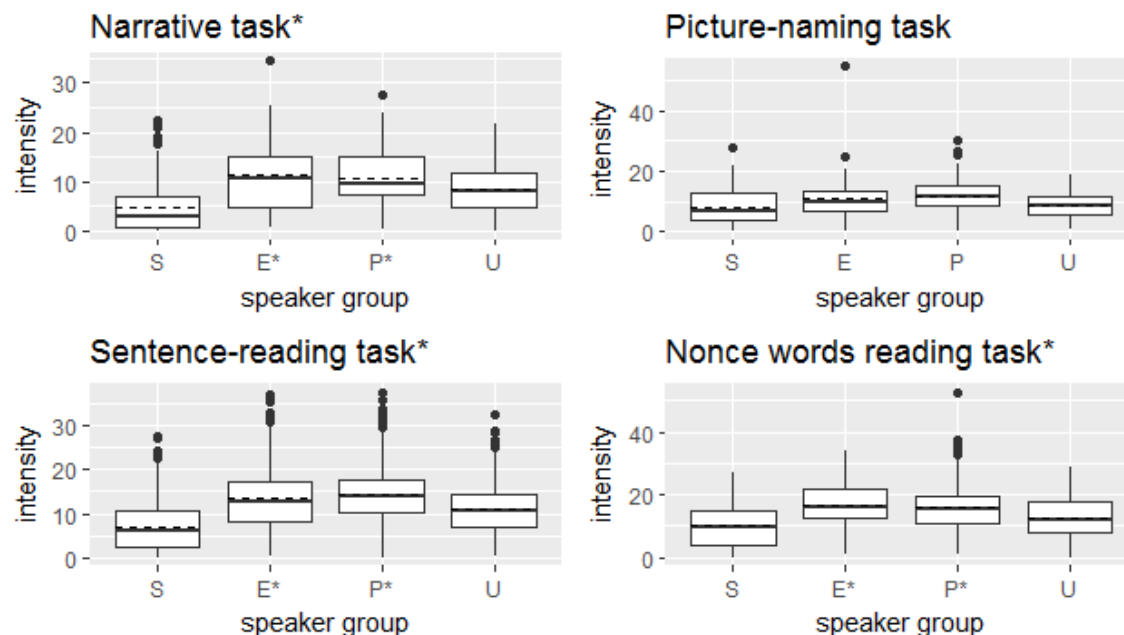
Figure 4.143. Mean RI (dB) values in Spanish produced by the Ukrainian HSs, the Polish HSs, and the L1 English and L1 Spanish control groups in the narrative, picture-naming, sentence-reading, and nonce words reading tasks



The mean RI measurements were submitted to a Linear Mixed Effects Model where *phoneme* and *speaker group* were included as fixed effect and *individual speaker* acted as random effect to determine whether there were any statistically significant differences between the acoustic means of the four groups of participants. The statistical results are presented below, individually for each task. Figure 4.144 provides a summary of the RI measurements of the four groups of speakers, grouping productions by task, but not by phoneme.

The test revealed that the productions of the four groups were significantly different in the narrative ($p < .0002762$), sentence-reading ($p < .0009761$), and nonce words reading tasks ($p < .03092$), but not in the picture-naming task ($p < .0878$). A closer examination of the four groups of participants via post-hoc pairwise comparisons with a Bonferroni adjustment revealed that the L1 English control group (narrative: $p < .000303$, 7 dB [difference between the average means of the L1 Spanish group and the L1 English group]; sentence-reading: $p < .008879$, 6.4 dB; nonce words reading: $p < .0987$, 6.5 dB) and the Polish HSs' (narrative: $p < .000132$, 6.4 dB; sentence-reading: $p < .000182$, 7.1 dB; nonce words reading: $p < .0657$, 5.8 dB) results were significantly different from the productions of the L1 Spanish control group in the three aforementioned tasks, while the Ukrainian HSs' realizations did not differ from those of the L1 Spanish base. Overall, the results reveal that the Ukrainian HSs' productions of /b d g/ are the closest to those of the L1 Spanish control group, with both groups displaying low RI values. The L1 English control group and the Polish HSs' productions differ the most from the L1 Spanish base, with both groups showing a higher degree of constriction in their production of /b d g/.

Figure 4.144. Productions of the Spanish /b d g/ by the Ukrainian HSs, the Polish HSs, and the L1 English and L1 Spanish control groups in the narrative, picture-naming, sentence-reading and nonce words reading tasks



4.4.6 Summary of the main findings from the voiced stop analyses

The following list presents the main findings in the analyses of the Ukrainian, Polish, English, and Spanish voiced stops produced by the Ukrainian and Polish HSs, as well as the L1 English and L1 Spanish control groups.

- The Ukrainian HSs do not follow the Ukrainian standard and display lenition of /b d g/ in intervocalic position in their HL.
- The Polish HSs also do not follow the Polish standard and show evidence of lenition of Polish voiced stops in intervocalic position.
- All four speaker groups show evidence of lenition in the production of the English voiced stops. The L1 Spanish participants produced the most constricted stops and the L1 English speakers the most lenited. The Ukrainian and Polish HSs display results that are more similar to those of the L1 English control group than the L1 Spanish control group.

The independent variables did not affect the RI values of the four groups in a consistent manner, with each group's production being significantly affected by different linguistic contexts.

- In the production of the Spanish voiced stops, the L1 Spanish speakers produced the most weakened segments, and the L1 English participants and the Polish HSs produced the most constricted stops. The Ukrainian HSs results approximated those of the L1 Spanish control group, showing a high degree of weakening. As with the English results, the significance of the linguistic context is inconsistent across the four groups. Task type effects were more significant for the degree of reduction than the effects of the specific independent variables.

4.5 Conclusion

This chapter covered several important discoveries in the production of Spanish vowels, and voiced and voiceless stops by the Ukrainian and Polish HSs, as well as the two control groups. Unstressed vowel reduction was found in the data sets of all four speaker groups in all four languages. Ukrainian HSs were shown to pattern more closely with the L1 Spanish speakers, while the Polish HSs more closely resembled the L1 English control group, particularly in the production of the voiced and voiceless stops. While in certain analyses the results were inconsistent in regard to linguistic context, phoneme, task formality, and speaker group, the overall findings still provide important implications regarding multilingual phonology and cross-linguistic influence in a trilingual context. These implications will be discussed in greater detail in the next chapter.

Chapter 5

Discussion and Conclusions

This final chapter of this dissertation examines the main findings of the current research with the aim of answering the general question that guided this study: How do HSs of Ukrainian and Polish acquire and produce L3 Spanish vowels, and voiceless and voiced stops? This chapter is divided into six main sections. The first section summarizes the key discoveries of the vowel analysis from the last chapter, answering the main research questions that guided this investigation, while also elaborating on specific findings and connecting them to earlier research on heritage phonology and L3 acquisition. The following two sections are dedicated to the discussion of the voiceless and voiced stops results. Based on the discussion of the three sound classes and the three research questions, concluding remarks on the contribution of the investigation are offered. The final two sections overview the limitations of this study and propose directions for future research. It is important to note that since this area of research is in its initial stages, the questions that this study raises are just as important as the results themselves.

5.1 Vowels

5.1.1 Main findings

The Ukrainian vowels produced by the Ukrainian HSs recruited for this study did not resemble the native standard described in the literature (Korunet 2004). Most of the vowels were centralized in stressed position and all vowels were reduced in unstressed context. Stress significantly affected tongue height, but not tongue backness. The Polish HSs, on the other hand, produced a Polish vowel space that greatly resembled the standard described in the literature (Jassem 2004). However, Polish vowels also displayed reduction in unstressed position. The

degree of reduction observed in the Polish HSs' data was considerably smaller than that of the Ukrainian HSs, but stress was significant for both tongue height and backness.

All four speaker groups produced English vowel spaces that vaguely resembled the standard described in the literature (Bradlow 1995). The differences between the estimated means of the four groups were not statistically significant for any of the measurements. However, there is clear evidence of unstressed vowel reduction in the productions of all four groups, with stress significantly affecting both tongue height and backness of all speakers, a practice that reflects standard American English (Delattre 1969).

The Spanish vowel analyses also revealed unstressed vowel reduction in all four speaker groups and in all four tasks. The L1 Spanish control group showed a clear correlation between task formality and reduction, producing most reduced segments in the most controlled task (i.e., nonce words reading) and the least reduced vowels in the least controlled task (i.e., narrative). However, the statistical analyses did not confirm task type to be significant for the rate of reduction of any vowel. Also, stress did not consistently affect either tongue height or backness. The L1 English speakers and the Ukrainian and Polish HSs showed no clear link between task formality and rate of reduction. Task type was statistically significant for the rate of reduction of some vowels in these three groups (L1 English speakers: /i/, /e/; Ukrainian HSs: /a/, /o/; Polish HSs: /i/, /e/, and /o/), but not all. The Ukrainian HSs' results did not reveal a consistent effect of stress on either tongue height or backness, but the results of the Polish HSs and the L1 English participants displayed greater consistency with stress affecting either one or both axis.

The statistical analyses revealed a significant difference in the production of F1 values by the four groups in the narrative task and F2 values in the sentence and nonce words reading tasks. The rate of dispersion and reduction was not shown to be significantly different between

the four speaker groups in any of the tasks. However, in individual group results, it was revealed that task type significantly affected the rate of dispersion of most vowels.

5.1.2 Will the speakers of this study transfer the dominant language's practice of unstressed vowel reduction to Spanish or will these HSs of Ukrainian and Polish perform in a more native-like manner when pronouncing unstressed vowels, potentially due to the influence of their HL knowledge?

The results of this study suggest that both the Ukrainian and Polish HSs rely on their dominant language in the production of unstressed vowels in Spanish, displaying reduction in unstressed context. The unstressed vowel centralization is observed in all four tasks in both groups, with one exception. The Polish HSs produced the unstressed /i/, /o/, and /u/ in the narrative task that appeared further away from the centroid than their stressed counterparts. This particular behavior might suggest that the participants relied on the HL, where the Polish HSs produced the Polish unstressed /i/, /i/, and /u/ further from the centroid than the stressed counterparts of these segments.

The evidence of transfer from the dominant language is not surprising when looking at the HL data, which also implies strong influence of English in the production of both Ukrainian and Polish vowels. The Ukrainian vowels showed stronger evidence of the effect of English phonology. For example, even the stressed Ukrainian vowels (/ɪ/, /ɛ/, /ɑ/, /u/) appeared more centralized in the vocalic space than what is observed in standard Ukrainian pronunciation. All vowels, except for /u/, were reduced in unstressed position, in particular, showing a significant degree of raising, with tongue height being significantly affected by stress. As was mentioned above, the Polish HSs displayed an interesting treatment of the Polish vowels where there was greater centralization of the stressed vowels rather than the unstressed. However, the other three

vowels (/ɛ/, /a/, /ɔ/) still displayed reduction in unstressed contexts, with stress significantly affecting both tongue height and backness. These findings support claims in the literature that prolonged contact with a language (in this case, English) can influence the underlying phonological rules of another language (in this case, Ukrainian and Polish), despite the latter language possibly being the one to which speakers were first exposed during childhood (Caramazza and Yeni-Komshian 1974, Ringen and Suomi 2012, Van Alphen and Smith 2004).

The English data strengthen the assumption regarding HSs' reliance on the dominant language. Both the Ukrainian and Polish HSs clearly exhibited unstressed vowel reduction in the production of English vowels. In fact, the Ukrainian HSs displayed Euclidean distances between the stressed and unstressed vowels that were the closest to those of the L1 English speakers, supporting the claim that when it comes to the production of the English vowels, Ukrainian HSs behave like L1 English speakers. The Polish HSs, on the other hand, produced Euclidean distances that were the furthest from the L1 English base, showing a smaller degree of unstressed vowel reduction in English. Nonetheless, there was still clear evidence of unstressed vowel centralization in the Polish HSs' data. The fact that both tongue height and backness were significantly affected by stress in the Ukrainian and Polish HSs' English vowel productions further indicates that the unstressed vowel reduction is a feature that is fully acquired and practiced by these two groups.

These findings in the HLs and the dominant language give strong support to Cabrelli Amaro's (2013) argument that phonological proficiency needs to be objectively tested in all languages when conducting L3 research because simply assuming that a participant is going to behave like a native speaker of a certain language is problematic, especially in the case of HSs.

By providing evidence from the HSs' HLs and English, my claim of the dominant language influence on the production of the unstressed L3 Spanish vowels is more substantially supported.

Overall, these results suggest that the Ukrainian and Polish HSs face the same challenges experienced by the L1 English speakers in the production of the Spanish vowels. The L1 English control group in this study, just like the HSs, showed evidence of unstressed vowel reduction in all four tasks. Interestingly, the F1 values produced by the L1 English participants were the closest to those of the L1 Spanish speakers, and stress did not significantly affect tongue height in three out of the four tasks. On the other hand, the F2 values, which are indicative of tongue backness, are different from the Spanish base and were significantly affected by stress in three out of the four tasks. Bradlow (1995) showed that the English vowels are more fronted than the Spanish vowels. This difference in the vocalic spaces of the two languages gives clues as to the type of transfer observed in the Spanish data from English and helps explain why the L1 English speakers produced more fronted Spanish vowels.

The vowel analysis also revealed unstressed vowel reduction in the productions of the L1 Spanish control group. Since the speakers recruited for this study all moved to the United States after completing their K-12 education in Mexico and reported utilizing Spanish often and intensely, it was predicted that these speakers were going to either avoid any unstressed vowel reduction or show a very small degree of it. The results confirmed that L1 Spanish participants centralized unstressed Spanish vowels in all four tasks, with evidence of either tongue height or tongue backness being significantly affected by stress in different tasks. The rate of vowel reduction in this group was generally smaller than that of the other three groups; nonetheless, it was consistently present in all four tasks. There are several factors that might have contributed to this outcome. First, it may be attributed to the speakers' variety of Spanish. Previous research

(Canellada de Zamora and Zamora Vicente 1960, Lope Blanch 1963) showed that unstressed vowel devoicing is a common practice in Mexican Spanish, during which vowels experience reduction in duration and devoicing, or are completely lost. While this process does not entail the change in vowel quality that is observed during unstressed vowel reduction in English, it is a weakening process that affects vowel stability. Other studies (e.g., Barajas 2014) also revealed that certain communities in Mexico (e.g., Colongo, Michoacán) practice vowel raising. In sum, it may be possible that the L1 Spanish speakers in this study were exposed to unstressed vowel reduction in their L1 variety when they still lived in Mexico, which could have played a role in the results observed in their Spanish data.

This interesting outcome may also be due to the L1 Spanish speakers' prolonged residence in the United States, as well as the speakers' high proficiency in L2 English. As mentioned earlier, prolonged contact with another language influences the features of the native language of the speakers, which is evident in the unstressed vowel reduction observed in the L1 Spanish speakers' data. A very recent study by Solon et al. (forthcoming) confirmed this observation by showing that native Spanish-speaking late bilinguals show vowel productions that are different from those of the monolingual Spanish speakers, indicating that even when a L2 is acquired later in life, it still can influence the L1 sound system.

From a theoretical standpoint, this finding also appears to support Flege's (1995) Speech Learning Model (SLM), which argues that L1 and L2 phonetic elements interact in a shared phonological space, influencing one another. If the two elements are perceived to be similar, then a new category is not formed for the L2 segment and instead, L1 and L2 categories assimilate, as was seen in Flege's (1987) study on the production of the English and French /t/ by bilingual speakers of those two languages. It is possible that the L1 Spanish speakers in this study

perceived unstressed vowels to be similar in both Spanish and English, which resulted in unstressed vowel reduction in Spanish. Moreover, the L1 Spanish speakers produced reduced unstressed vowels in English, showing that this English-specific feature is acquired by these speakers, supporting the claim of cross-linguistic influence. These results also go along with O'Rourke's (2010) findings, who showed that language contact (in this case, between Quechua and Spanish) and bilingualism can influence vowel quality. In her study, L1 Quechua late L2 Spanish learners behaved more like the L1 Spanish speakers, while native bilinguals of Quechua and Spanish (i.e., early L2 Spanish learners) produced more heterogeneous results, a finding that is also reflected in this investigation, where the late L2 English learners (i.e., L1 Spanish speakers) present comparable results to those of the L1 English speakers.

The L1 Spanish speakers' results provide additional support to Cabrelli Amaro's (2013) claim that L3 speakers should not be compared to monolingual speakers, who are navigating only one sound system. Comparing the HSs in this study to bilingual speakers allows for a better understanding of the cross-linguistic interactions in the phonological systems of the languages in question in a multilingual context and gives a glimpse into the end state of L3 acquisition of the experimental group. By testing bilingual L1 Spanish speakers alongside HSs, we were able to discover that when it comes to the production of vowels, language contact and dominance may potentially be playing a more significant role than order of acquisition.

5.1.3 What role would speech formality play in production and possible reduction of vowels /i e a o u/ in the speech of heritage Ukrainian and Polish speaking learners of Spanish?

The vowel analysis clearly indicates that task type influences the Ukrainian and Polish HSs' productions of the Spanish segments. The Ukrainian HSs' data reveal that task type was

significant in the production of F1 and F2 values, as well as vowel dispersion and unstressed vowel reduction for almost all Spanish vowels. All vowels' either F1 (/i/, /a/, /o/, /u/) or F2 (/e/, /a/, /o/) measurements were affected by task design, signaling that both tongue height and tongue backness depended on task formality. However, the data do not show that task type consistently affected one axis or the other. Four vowels (/e/, /a/, /o/, /u/) were affected by task type in terms of degree of dispersion. However, for the degree of reduction, task type was significant for only two vowels (/a/ and /u/). Ronquest (2016) discovered in her study that speech formality played an important role in the degree of dispersion and vowel duration in the speech of Spanish HSs. The author observed the greatest degree of dispersion and the longest vowels in a highly-controlled task, while conversational and semi-spontaneous tasks yielded the opposite results. The Ukrainian HSs' data mostly support Ronquest's claim, with /e/, /a/ and /u/ showing greater dispersion away from the centroid in more controlled tasks in comparison to less formal elicitations. When examining the distance between vowel pairs, vowel pairs /i/-/e/, /a/-/o/, and /o/-/u/ also appeared further away from each other in more controlled tasks (sentence and nonce words reading) than in less formal tasks (narrative and picture-naming), once again giving support to Ronquest's finding. It is interesting that task type was significant only in the rate of reduction of two vowels and that all segments experienced the most reduction in a semi-controlled task (picture-naming), as well as a highly-controlled (nonce words reading) task rather than the narrative task. This finding signals that the Ukrainian HSs tend to maintain vowel quality in unstressed position in conversational speech, but centralize unstressed vowels in more formal tasks, displaying a similar relationship between task formality and segment accuracy that is usually observed in the literature, as well as mimicking the L1 Spanish speakers' results. As was mentioned earlier, previous studies showed that language learners produced intervocalic

Spanish voiced stops more accurately in less controlled tasks than in more formal elicitations, in large part due to orthography (Rao 2014, 2015). Although there is not necessarily a direct link between orthography and vowel pronunciation, which can negatively influence production during a formal task, it appears that, similar to voiced stops, learners in this group are also less likely to produce target-like vowels during more controlled elicitations. Alternatively, the Ukrainian HS learners' proficiency level in Spanish might also help explain why their results are closer to those of the L1 Spanish control group, which also produced less reduction in spontaneous speech.

The Polish HSs' results provide even stronger support for the significance of task type in the production of F1 and F2 values, and Euclidean distances in Spanish. Task type significantly affected the F1 values of all five vowels and the F2 measurements of four vowels (/e/, /a/, /o/, /u/), showing a more consistent effect on both axes. It also influenced the degree of dispersion of all five vowels and the rate of reduction of three vowels (/i/, /e/, /o/). The Polish HSs' data also strongly support Ronquest's results regarding task formality and vowel dispersion. All five vowels appeared closer to the centroid in less controlled tasks (four vowels in the narrative task and one vowel [e/] in the picture-naming task) and further dispersed from the centroid in a highly controlled elicitation (nonce words reading). In addition, all vowel pairs appeared further away from each other in the most controlled tasks (sentence and nonce words reading) than in the narrative and picture-naming tasks. The relationship between task formality and the rate of unstressed vowel reduction in the Polish HSs' data is different than the one displayed by the Ukrainian HSs. Some of the vowels presented the same Euclidean distances between stressed and unstressed segments in several tasks; however, all vowels consistently showed greater reduction in the nonce words reading task, possibly signaling that not only are Spanish vowels

more reduced in the most highly controlled/least natural task, but also that unstressed vowel reduction may likely be a part of the speakers' productive grammars and is not merely a result of role-learning (lexicalization) for this group of speakers (Asherov et al. 2016). All vowels experienced a lower rate of reduction in the other three, less controlled tasks, most often in the sentence-reading task. Perhaps, the reason why the Polish HSs produced more native-like results in more a controlled task has to do with their language familiarity. Language learners, especially at lower and intermediate levels, tend to be more familiar with "less natural" uses of the language, such as reading and writing. It is possible that for language learners, as in the case of the Polish HSs learning Spanish, more controlled, reading tasks reflect more familiar uses of the language than less scripted tasks do, which might help explain why these speakers produced more target-like segments in formal tasks, where they avoided unstressed vowel reduction.

The two HS groups show similarities in the production of the Spanish vowels to both of the control groups. First, it is important to note that all four speaker groups produced the most reduced unstressed vowels in either the semi- or the highly-controlled task and not in spontaneous speech (narrative task). The L1 Spanish speakers (as well as the Ukrainian HSs) showed the smallest degree of reduction for most vowels in the narrative task, which for this group of speakers is the most familiar speech style. The L1 English participants and the Polish HSs, however, tended to reduce the least in either the picture-naming or the sentence-reading task, perhaps due to the speakers' familiarity with more controlled speech styles. The relationship between task formality and vowel dispersion of the Polish HSs is very similar to that of the L1 English participants, who also showed statistical significance of task type on the degree of dispersion of all vowels and support Ronquest's (2016) findings by displaying the most dispersed segments in the most controlled tasks (sentence and nonce words reading) in contrast

with the least formal elicitations where the segments are more closely clustered around the centroid. The L1 Spanish control group's dispersion results are closer to those of the Ukrainian HSs, where task type is significant for only three vowels (/a/, /o/, /u/). Generally, however, each vowel's Euclidean distance points to a greater dispersion in more controlled tasks, especially in comparison to the tasks where a smallest dispersion occurred. In terms of rate of reduction, the L1 English speakers and the Polish HSs' results coincide once again, with the L1 English participants also showing a significant relationship between the reduction of front segments and task formality. The L1 Spanish speakers' results, however, did not show task formality to be significant in the rate of reduction of any of the five vowels, which ultimately supports the general rule about the standard Spanish vowel pronunciation, which does not practice unstressed reduction in any context. Although the L1 Spanish speakers in this study reduce vowels in unstressed position, the rate of reduction is similar across all tasks and speech formality does not appear to increase it to a statistically significant rate.

Interestingly, when looking at the stressed vowel distribution, the L1 English speakers, along with the Ukrainian and Polish HSs displayed the most native-like Spanish vowel spaces in the nonce words reading task, where the overall shapes resemble the triangle that is typically associated with the Spanish vocalic space (Hualde 2005). The L1 Spanish speakers, on the other hand, centralized /u/ in the nonce words reading space, reflecting the general vowel shape displayed by all four speaker groups in the other three tasks. In terms of the unstressed vowel spaces, the Ukrainian and Polish HSs generally reflected the vowel shapes of the L1 Spanish speakers and not the L1 English participants in the narrative, picture-naming, sentence-reading task. In the nonce words reading task, the two HS groups differentiate from the two control groups, once again avoiding centralization of /u/. The nonce words task's results possibly

suggest that for the HSs in this study, centralization of /u/ is not part of their productive grammars, unlike for the L1 English and L1 Spanish participants recruited for this study. The fact that /u/ is centralized in the L1 Spanish speakers' speech is not very surprising. Harmegnies and Poch-Olivé (1992) showed that in Mexican variety of Spanish the vowels /i/, /e/, /o/, /u/ tend to cluster into a small acoustic space in spontaneous speech. The type of centralization observed in the Mexican dialect was not symmetrical or proportional, unlike in Peninsular Spanish, where vowels displayed "a proportional decrease in the size of the acoustic space" (Ronquest 2016, p. 277). It is possible that the nonce words reading task is signaling that for the L1 Spanish speakers recruited for this study, the centralization of /u/ is part of their productive grammars, as it is characteristic of all speech styles.

5.1.4 Do the results of the vowel analysis support one specific theoretical model of L3 acquisition: the Cumulative-Enhancement Model (CEM), the Multilingual Role Model (MRM), the Dynamic Systems Theory (DST), the Cognitive Chain Reaction Theory (CCRT), the L2 Status Factor Model, the Typological Primacy Model (TPM) or the Linguistic Proximity Model (LPM)?

Before answering this question, I will briefly revisit theoretical models of L3 acquisition to remind the reader of the main premises of each one. The CEM (Flynn et al. 2004) posits that neither the L1 or the L2 have a special status when it comes to the acquisition of additional languages. Prior languages can either be neutral or it is possible to observe transfer from both languages, but only when this it is facilitative since all non-facilitative transfer will be blocked. The MRM (Fernandes-Boëchat 2007), which is based on the CCRT (Fernandes-Boëchat and Siebeneicher Brito 2008), argues that it is the L2 that will exhibit the greatest influence on the L3 due to an involuntary link between the two languages, which are both classified as *foreign* in a

learner's mind. As a learner becomes more proficient in his or her L3, this link is severed, and the involuntary process of transfer is reduced. Similar to the MRM and the CCRT, the L2 Status Factor Model (Bardel and Falk 2007, 2012) also postulates that the L2 plays a more significant role than the L1 during L3 acquisition due to association of a foreignness factor, meaning the L2 and L3 are more cognitively connected. The DST (de Bot et al. 2007, van Geert 2008) views the multilingual brain as a complex system where language forms interconnected networks that constantly interact and change over time. Due to the dynamic nature of these interactions, it is not easy to predict which changes will take place; however, even the subtlest changes in internal and external factors will influence the acquisition of all languages in a learner's mind. The TPM (Rothman 2011, 2015) postulates that typology is the determining element in language transfer and not order of acquisition. It argues for an exclusive transfer (both facilitative and non-facilitative) from only one of the previously learned languages, whichever displays the closest structural similarity (or psychotypological similarity) to the L3. Finally, the LPM (Westergaard et al. 2016) predicts both facilitative and non-facilitative transfers from any of the previously learned languages. The transfer is triggered when L3 input displays an abstract structural similarity to the structures of one or both of the previously acquired languages. Therefore, it is possible to observe different learning patterns for different structural properties.

Before entering the discussion, it is very important to point out that the direct application of the MRM, the CCRT, and the L2 Status Factor Model will be challenging for this study. Since the HSs in this investigation do not consider English or their HL as completely *foreign*, it is difficult to determine which of these two languages is the L1 and which is the L2. Nearly all HSs in this study (with the exception of two participants) tested as English-dominant; however, most speakers reported learning the HL before English. This lack of correlation between the order of

acquisition and language dominance challenges the labeling procedure. Therefore, for the purposes of this study, I will follow Llama and López-Morelos' (2016) methodology, who treated both the HL and English (the dominant language) as two L1s, labeling English the second L1 in their study. The same practice is applied to this investigation as well, since it is difficult to classify either of the language as foreign for this group of HSs.

Overall, the results of this study appear to provide evidence for several theoretical models of L3 acquisition; however, they do not seem to support exclusively only one specific model across the entire study, which is an issue that will be addressed in the discussion that follows. Nonetheless, what the findings across this study do have in common is refuting of the CEM. As mentioned earlier, this model denies any non-facilitative transfer from either L1 or L2. However, in this study the results indicate that non-facilitative transfer did take place.

The vowel analysis results provide a very interesting case of a cross-linguistic influence taking place in the HSs' phonologies. The reason it is intriguing is because unstressed vowel reduction was discovered not only in the English data of Ukrainian and Polish HSs, where it was expected to be present, but also in the productions of Ukrainian and Polish vowels, where, according to the standards described in the literature, it should not be taking place. This finding signals that the HSs of this study do not actively practice the preservation of vowel quality in unstressed position in Ukrainian and Polish. As such, two vowel quality features (i.e., presence or absence of unstressed vowel reduction) we would predict to be competing with one another during L3 acquisition are actually not in conflict during this process. Instead, there is only one feature available to be transferred, which, in this case, is the presence of unstressed vowel reduction. Due to the merged nature of the feature in question in English, Ukrainian and Polish vowels, it is difficult to state that one particular L3 acquisition theory is at play, since the HL and

the dominant language are not providing two different and competing types of inputs. Instead, it appears that these results support Flege's (1995) SLM, which, as described previously, claims that a learner's phonologies are open to modifications and "that phonetic systems reorganize in response to sounds encountered in an L2 through the addition of new phonetic categories, or through the modification of old ones" (Flege 1995, p. 233). The Ukrainian and Polish HSs' results seem to imply that their HL vowel categories were modified due to increased contact with English. A similar conclusion was also proposed in Wrembel (2015b), where the L1 German L2 English L3 French speakers appeared to merge the voiceless stop categories for their L1 and L2, producing comparable VOT values in German and English. As in the present study, the author suggested that this outcome can be interpreted within the SLM framework.

Consequently, when acquiring L3 Spanish, the HSs in this study are in the same position as the L1 English L2 Spanish learners in that they only have one feature available, which is unstressed vowel reduction. Therefore, the presence of unstressed vowel reduction in the L3 Spanish data also appears to support the SLM. The results seem to suggest that the HSs, along with the L1 English participants, did not create a separate category for Spanish vowels, and as a result, unstressed Spanish vowels were processed in the same manner as English unstressed vowels, as a single phonetic category, thus perceptually linking the vowels of the two languages.

These findings once again highlight the importance of following appropriate methodological practices in L3 research and testing participants in all the language they speak. If the HSs in this investigation were not tested in their HL and English, the interpretation of the results would have been very different, and it would not have demonstrated the complexity of cross-linguistic influences in a sound system of a multilingual speaker. The results also emphasize the significance of including a bilingual or multilingual control group. For instance,

without testing the L1 Spanish speakers who had prolonged contact with L2 English, it would have been assumed that the HSs should be striving for the monolingual standard, avoiding all unstressed vowel reduction. However, the results of this study, especially of the late L2 learners of English (L1 Spanish speakers), appear to suggest that this monolingual standard may be a rather unrealistic goal for speakers who are English dominant and/or who have significant daily contact with English. Overall, the vowel results seem to suggest that contact and use of language is a stronger predictor of the final production stage than order of acquisition.

5.2 Voiceless stops

5.2.1 Main findings

The Ukrainian HSs produced all three Ukrainian voiceless stops as short-lag, following the native Slavic language norms described in the literature (Ringen and Kulikov 2010). The Polish HSs produced the Polish bilabial and dental voiceless stops as short-lag; however, the VOT value of the velar segment (36.9 ms) was slightly longer than the 30 ms cut-off line.

All four speaker groups produced the English voiceless stops as long-lag, following the native English norm described in the literature (Lisker and Abramson 1964, Nagy and Kochetov 2013). The L1 Spanish control group displayed shorter VOTs than the L1 English base. The Ukrainian and Polish HSs produced shorter VOTs than the L1 English speakers, but longer than the L1 Spanish participants. Statistical analyses revealed no significant difference in the VOT production of the four groups.

The L1 Spanish participants and the Ukrainian HSs produced the Spanish voiceless stops as short-lag in all four tasks. The Polish HSs produced a mix of short-lag and long-lag stops, while the L1 English speakers produced long-lag segments in all tasks. The statistical analyses revealed significant differences in the VOTs of the four groups in all four tasks. The Ukrainian

HSs consistently displayed the closest VOT values to the L1 Spanish base, while the L1 English speakers produced the most different values from the native base. The Polish HSs' values approximated those of the L1 English group closer than those of the L1 Spanish speakers. Task type was significant in the production of almost all stops (L1 Spanish speakers: /p, k/; L1 English speakers and Ukrainian HSs: /p, t/; Polish HSs: /p t k/). Generally, the L1 Spanish speakers and the Ukrainian HSs had longer VOTs in more formal tasks, while the L1 English speakers displayed shorter VOTs in more controlled tasks. The Polish HSs presented mixed results in terms of task effects.

5.2.2 Since Spanish and the two languages under investigation share the same short-lag feature, will the participants in this study be influenced by their knowledge of the HL sound system and produce the Spanish /p t k/ segments without aspiration or will they transfer the long-lag feature from English, their dominant language?

The Ukrainian HSs produced the Spanish /p t k/ without aspiration in all four tasks, potentially relying on the knowledge of their HL in the perception and production of short-lag stops instead in English. The Polish HSs, on the other hand, produced the bilabial segment without aspiration in the narrative, picture-naming and sentence-reading tasks, and the dental segment with a short-lag VOT in the sentence and nonce words reading task, while the rest of the segments in the four tasks were produced as long-lag, showing evidence of features of both the HL and the dominant language.

For the Ukrainian HSs, influence from the HL to Spanish is supported by the Ukrainian data. The Ukrainian HSs produced all three Ukrainian voiceless stops as short-lag. The English stops, on the other hand, were produced as long-lag by this group. The fact that the HSs did not transfer the English long-lag feature into Spanish nor the HL is very interesting, especially when

these results are compared to the vowel data, where we noted evidence of varying degrees of English vowel reduction being transferred not only to Spanish, but also to Ukrainian. This finding differentiates itself from the one in Llama and López-Morelo's (2016) study, who discovered a greater influence of the dominant language (English) and not the HL (Spanish) in the production of L3 French voiceless stops. At the same time, my finding supports Knightly et al.'s (2003) claim that the knowledge of HL phonology does not negatively affect dominant language production in HSs. The Ukrainian HSs produced the Ukrainian voiceless stops following the short-lag standard pronunciation, which did not affect their ability to produce the English stops according to the English long-lag norm.

Like the Ukrainian HSs, the Polish HSs also produced the Polish voiceless stops as short-lag, in line with the standard Polish pronunciation, and the English voiceless stops as long-lag. However, in the production of the Spanish /p t k/, there is a mix of short-lag and long-lag productions. This finding is similar to the one described in Zampini's (1998) study, who discovered that after explicit instruction, the L1 English L2 Spanish learners were producing /p/ with a considerably shorter VOT, while the VOT of the other two segments did not show a significant improvement. Since the Polish HSs tended to produce Spanish /t/ and /k/ according to the English long-lag pronunciation, it is possible that they are behaving like a typical L1 English L2 Spanish learner, acquiring the short-lag feature for /p/ faster than for the other two stops, instead of transferring the short-lag feature from Polish. This argument also goes along with Llama and López-Morelo's (2016) suggestion that the HSs may not only be relying on the dominant language, but may also be mimicking the values that they hear from their classmates, who serve as their main source of Spanish input, which makes their pronunciation more similar to that of L1 English speakers. The majority of the Polish HSs reported using Spanish most

frequently in a classroom setting, interacting with their instructor and fellow classmates, which may provide additional support to Llama and López-Morelo's claim. However, when looking at the production of the Spanish /p t k/ by the L1 English control group, who produced all three stops with long-lag VOT, this argument may not be completely valid. Alternatively, it is possible that the Polish HSs are perceiving /p/ and /t/ as structurally similar to Polish in certain speech contexts, while /k/ is perceived as structurally similar to English in all speech styles, an argument that will be addressed in greater detail in the next section.

The fact that the Ukrainian and Polish HSs behaved differently in the production of Spanish voiceless stops can be attributed to several factors. The first reason may be due to the speakers' different levels of proficiency in Spanish. Five out of six Ukrainian HSs recruited for this study demonstrated at least an intermediate level proficiency in their L3. Two of the participants, U2 and U6, are advanced speakers of Spanish. The Polish HS group, on the other hand, had four speakers (P1, P3, P4, P10) with a very low Spanish proficiency. Three of the speakers, P3, P4 and P10, could not form sentences during the narrative task and were only able to list words. As was shown by Hammarberg and Hammarberg (2005) and Wrembel (2009), the types of transfers observed during various stages of L3 acquisition are different, changing as speakers become more proficient L3 users. During the initial stages, there is a powerful influence of the L2, but as speakers become more proficient in their L3, this involuntary link between the preceding foreign language is broken. As was discussed in Chapter 2 and earlier in this chapter, in the case of the HSs, it is difficult to determine exactly which language is the L1 and which one is the L2 (considering that there is such a distinction). The only study that is available on the acquisition of L3 by HSs of a different language is Llama and López-Morelo (2016), which shows greater influence of the dominant language, and to my knowledge, there is no previous

research that examines HSs at different levels of L3 proficiency or learner development over time. Although my study does not aim to investigate HSs' development in L3 over time, it may provide clues as to what language plays a bigger role in the early stages of L3 production. Based on the evidence gathered from the Ukrainian and Polish HSs' voiceless stops data, it is possible that during the initial stages of L3 acquisition the HSs are more reliant on their dominant language, but once they become more proficient in Spanish, the link is severed. Nonetheless, without more research on HSs at different acquisitional stages of their L3, it is difficult to state with certainty whether the target-like production observed in the Ukrainian HSs' Spanish is due to experience and increased proficiency or whether it is due to reliance on the HL and familiarity with the short-lag feature. Alternatively, it is possible that both aspects are at play: the HSs' awareness of the short-lag features due to their experience with the HL presents an advantage and maybe they are more likely to perceive this similarity between the HL and the L3 as they become more proficient in the target language.

Another possible explanation for the discrepancy in the Ukrainian and Polish HSs' results are the HSs' ties with their HL communities. Hrycyna (2011) and Nagy and Kochetov (2013) showed that HSs who maintain strong ties with the HL community are likely to adjust to the language norms of the community. However, if there is no organized community, it may prevent HSs from using the HL outside of the household, which would allow them to maintain the HL norms that they learned from their family members. The Ukrainian HSs did not report having strong ties to the Ukrainian-speaking community in the United States, saying they only use their HL with family members. The Polish HSs, on the other hand, reported being involved in different Polish clubs, as well as being part of the Polish-speaking community in their hometowns. On average, the Polish HSs' VOT of the Polish stops was slightly greater than that

of the Ukrainian HSs in Ukrainian, which might signal different norms in their respective HL communities. If the Polish HSs are shifting to longer VOTs in Polish across generations, a change which was observed in Russian and Ukrainian-speaking communities in Toronto (Hrycyna 2011, Nagy and Kochetov 2013), this phenomenon may influence the speakers' VOT acquisition in other languages, as seen in the production of the Spanish stops in this study. However, since this investigation does not aim to study the community ties of the HSs, nor does it have the evidence to fully support this claim, this statement merely serves as a suggestion for a future research direction.

It is important to emphasize that neither the Ukrainian nor Polish HSs produced the longest VOT values in Spanish out of the four groups of speakers. It is, in fact, the L1 English control group that displayed the longest VOTs, which were also the most different from those of the L1 Spanish speakers (i.e., the estimated mean difference between the control groups was 38.4 ms). This outcome supports earlier findings in the literature showing that the production of the Spanish voiceless stops is generally problematic for L1 English L2 Spanish learners (Díaz-Campos and Lazar 2003, Díaz-Campos 2006, González-Bueno 1997, Zampini 1998).

Unlike in the Spanish vowel data, where the L1 Spanish speakers did not follow the monolingual standard, the L1 Spanish participants produced Spanish /p t k/ according to the short-lag norm and did not show evidence of influence from English, where all three voiceless stops were produced as long-lag by this group. This finding suggests that the L1 Spanish speakers in this study perceived the phonetic difference between the L1 and L2 voiceless stops and created a separate category for each language to maintain phonetic contrast in a common L1/L2 phonological space. This characteristic of the L1 Spanish control group supports Cabrelli-

Amaro's suggestion for using multilingual speakers as controls, as they provide a better understanding of the cross-linguistic influences in language learners' minds.

5.2.3 What role would task type play in production and the rate of aspiration of voiceless stops /p t k/ in the speech of heritage Ukrainian and Polish speaking learners of Spanish?

Task type was shown to affect the VOT values of the Spanish voiceless stops. In the Ukrainian HSs' data, it was significant in the production of /p/ and /t/, but not /k/. Since the Ukrainian HSs produced all three stops with short-lag VOTs in all four tasks, it is difficult to say that task type negatively affected the accuracy of the Spanish /p t k/. While the highest VOT values appeared in the most controlled tasks (sentence and nonce words reading), the difference was not very large in comparison to less controlled elicitations and it did not place any of the stops into the long-lag category. However, the results did show that as tasks become more formal, the Ukrainian HSs' VOTs increase, mimicking the L1 Spanish speakers' results, possibly indicating that for this group of speakers, speaking is the most natural and familiar speech style. Perhaps, this phenomenon once again relates to the speakers' proficiency level in Spanish, possibly signaling that as speakers become more proficient in their L3, speaking becomes the most natural speech style, while reading the most formal.

Task type was shown to be statistically significant for the production of all three stops in the Polish HSs' data. The relationship between task formality and VOT measurements is an interesting one. The bilabial segment displayed the shortest VOT value in the narrative task and the longest in the nonce words reading task, showing a gradual increase in VOT as task formality increases, mimicking the general trends seen in the L1 Spanish participants and Ukrainian HSs' data. The dental and the velar segments, on the other hand, had the shortest VOT values in the

nonce words reading task and the longest in the narrative task, displaying an inverse relationship in comparison to /p/. What is particularly intriguing is that /t/ was produced as a long-lag segment in the narrative task, but as a short-lag stop in the nonce words reading task, possibly suggesting that underlyingly, the dental segment may be classified as short-lag in the productive grammars of the Polish HSs. Although the velar stop is classified as long-lag in all four tasks, it generally displays a gradual decrease in VOT as tasks become more formal. Overall, this interesting finding seems to support Llama and López-Morelo's (2016) claim that heritage speaking learners of an L3 may be mimicking their L2 learning classmates' VOT productions, although in the productive grammars, the L3 segments may be classified differently for those speakers than for the L2 learners. The bilabial VOT in the nonce words reading task, however, signals that this segment might be underlyingly classified long-lag; however, as mentioned previously, the fact that in the narrative and picture-naming tasks /p/ is produced as short-lag may once again prove that the Polish HSs' are mimicking their classmates' productions, who as was shown by Zampini (1998), tend to acquire the bilabial segment the fastest. The dental and velar segments' results also seem to support an earlier claim that more familiar, controlled tasks yield more native-like productions than the less familiar, speaking task.

The Polish HSs' results once again coincide very closely with those of the L1 English speakers, who also produced the longest VOT for /p/ in the nonce words reading task, while /t/ and /k/ showed the longest values in the narrative tasks. The L1 English participants produced the shortest VOTs for all three stops in the sentence-reading task, giving additional support to the claim that this controlled task represents the most familiar speech style of these language learners, generating the most target-like results. However, unlike Polish HSs, the L1 English

control group produced the Spanish /p t k/ as long-lag in all four tasks, presenting clear evidence of transfer of the long-lag feature from the speakers' L1 regardless of task formality.

The Ukrainian HSs' results, on the other hand, approximate the results of the L1 Spanish control group, which produced all three stops as short-lag in the four tasks. The VOT values of /p/ and /k/, which were significantly affected by task type, show a clear correlation between task formality and VOT. As tasks become more formal, the L1 Spanish participants produce longer VOTs, showing that for this group of speakers, the spontaneous task is the most representative of the most familiar and naturalistic speech style for these speakers. However, as with the Ukrainian HSs, although the VOT tended to increase in more formal tasks, all stops were still produced as short-lag, suggesting that the short-lag feature is part of the productive Spanish grammar of these speakers. Although /t/ has the longest VOT in the narrative task, it is only slightly longer than the one observed in the other three tasks. Overall, the dental segment did not change its VOT value with task formality.

5.2.4 Do the results of the voiceless stop analysis support one specific theoretical model of L3 acquisition?

Unlike the vowel data, the voiceless stop analysis allows for an interpretation of the results within an L3 acquisition framework. Since the Ukrainian and Polish HSs produced short-lag stops in their HL and long-lag stops in English, signaling of an existence of two different phonetic categories for voiceless stops in the sound systems of these speakers, it is possible to clearly determine whether it is the HL or the dominant language that has a greater influence during the acquisition of L3 stops.

The data analysis revealed that the Ukrainian HSs produced the Spanish /p t k/ as short-lag in all four tasks. The Polish HSs, on the other hand, produced mixed results, pronouncing /p/

and /t/ as short-lag in some contexts, and producing the three stops as long-lag in other instances. Since there is evidence of transfer from both the HL and the dominant language, as well as a presence of both facilitative and non-facilitative influence in the results of the two groups, I believe that these findings shed light on the LPM. Solely looking at the Ukrainian HSs' results, it is possible to argue that they provide support for the TPM, which claims that speakers will exclusively transfer from a language that is typologically closer to the L3. However, the TPM only partially accounts for the Polish HSs' results, where transfer is seen not only from Polish, a language that is typologically closer to Spanish with regard to the three segment classes in question, but also from English, which is structurally different from Spanish when it comes to the production of these segment classes. On the other hand, the LPM, which argues that all previously learned languages are available throughout the L3 acquisition process and not just typologically similar languages, allows to account for the differences observed in the Ukrainian and Polish HSs' data. According to LPM, a cross-linguistic influence will take place when a linguistic property in the L3 input displays an abstract structural similarity to the structure of previously acquired languages. It is possible that the Ukrainian HSs perceived the L3 Spanish voiceless stops as structurally similar to the Ukrainian voiceless stops, which triggered the transfer of the short-lag feature from the HL. The Polish HSs, on the other hand, might have perceived /p/ and /t/ as typologically similar to Polish, while /k/ showed an abstract similarity to English, resulting in short-lag values for /p/ and /t/, but long-lag values for /k/.

In addition, it is also important to consider the differences in L3 proficiencies of the HSs recruited for this study. As was mentioned previously, the Ukrainian HS group included speakers that are more proficient in Spanish than the speakers in the Polish HS group. Odlin (1989) suggested that in learners of low proficiency levels we are more likely to observe negative

transfer, but as speakers become more proficient in their target language, we will observe more positive transfer, since learners at an advanced level are more likely to take advantage of their previous linguistic knowledge. Since the majority of the Polish HSs in this study are at a low proficiency level in L3 Spanish, Odlin's explanation might give insight as to why negative transfer is taking place in this particular group of speakers. However, it does not fully account for the positive transfer from the HL observed in this data set.

I believe that it is also crucial to consider the DST, which views cross-linguistic influence in multilingual acquisition as an extremely complex and dynamic process. Kopečková et al. (2016) propose that the DST model is more applicable for HSs learning an L3 than other models that are designed to explain the processes that take place during sequential language acquisition, since it utilizes conceptual vocabulary that allows for a better understanding of the changing degrees and directions of interactions between languages in a multilingual brain. Although it is difficult to predict the outcome, since even the subtlest changes will influence the language development of a speaker in all the languages that he or she knows, it is certain that a restructuring process will take place in all the languages involved and that one can expect considerable variability not only between different groups of speakers, but also within the same group of learners. As was described above, there are some significant differences between the Ukrainian and Polish HSs recruited for this study. The distinction that stands out the most is the variability in speakers' L3 proficiency levels, which is definitely one of the factors that could have influenced the final outcome. Certainly, there are also other differences between the two HS groups, as well as between individual speakers within those groups. This study most certainly aimed to recruit the most homogeneous group of speakers who share similar experiences in the acquisition of the three languages in question. While it does include speakers whose backgrounds

are comparable, it does not account for all possible variability. It is a very challenging task that would ideally be carried out in a longitudinal study where one is able to keep track of many more factors over time than a cross-section study, such as this one, is able to accomplish. Nonetheless, although this study lacks some information that could potentially account for all possible inter- and intra-group variability, the background information that is known, along with the results, which indicate variability between the groups, appear to provide evidence for the DST.

5.3 Voiced stops

5.3.1 Main findings

In the Ukrainian data, both /b/ and /d/ demonstrated intervocalic lenition and almost all speakers produced true-voiced stops. The Polish /b d g/ also lenited in intervocalic context and all Polish HSs showed evidence of true-voicing.

All four speaker groups produced lenited intervocalic stops in English. The L1 English control group displayed the greatest degree of lenition, followed by the Ukrainian HSs. The L1 Spanish speakers produced the most constricted stops and the Polish HSs' RI values fell between the measurements of the two control groups. The L1 English speakers mostly produced short-lag stops, with just a few instances of true-voicing. All L1 Spanish participants produced true-voiced stops. The Ukrainian and Polish HSs showed evidence of both short-lag and true-voiced productions. The statistical analyses revealed no significant difference in the mean RI values between the four groups of speakers.

The four groups of speakers showed at least some degree of lenition of the Spanish /b, d g/ in all four tasks. The L1 Spanish control group produced the most lenited segments in all elicitations and the Ukrainian HSs approximated their productions the closest. The L1 English speakers and the Polish HSs produced statistically different results from the L1 Spanish base,

consistently displaying higher RI values than the other two groups. The statistical analyses also revealed that the difference in the production of /b d g/ differed significantly in the narrative, sentence and nonce words reading tasks, but not in the picture-naming task among the four groups of speakers. Task type was shown to be statistically significant in the production of /b d g/ in all four speaker groups. All participants produced less lenited segments in more formal tasks and more weakened stops in less controlled tasks. Finally, all L1 Spanish participants, and almost all Ukrainian and Polish HSs produced true-voiced stops. The L1 English speakers, on the other hand, produced mixed results, displaying a greater ratio of short-lag productions in comparison to true-voiced realizations.

5.3.2 Will the participants of this study produce the voiced stops in Spanish with the pre-voicing that also exists in their HL, or will English, a language that lacks true voicing, interfere with the production of /b d g/ in Spanish?

As was mentioned in Chapter 4, VOT measurements were recorded only for instances of a stop-like production of /b d g/ and in cases where the audio quality was the highest. Therefore, in certain cases, there is no data available for some of the speakers. However, from the data that was gathered, we found evidence that most of the Ukrainian and Polish HSs produced pre-voiced Spanish voiced stops.

The Ukrainian HSs produced pre-voicing in all four tasks. The fact that most of the Ukrainian HSs produced the Spanish voiced stops as true-voiced is not surprising, since there is evidence of pre-voicing in the Ukrainian data, as well as the English data. Two speakers produced pre-voiced stops in English and one speaker a mix of true-voiced and short-lag stops, a feature that is not observed in standard English (Newlin-Łukowicz 2014). This finding suggests that the Ukrainian HSs may actually rely on their HL when producing phonetic features

associated with voiced stops rather than their dominant language; that is, similar voicing tendencies appear in all three of their languages. It is plausible to assume that the true-voiced features seen in all three languages is due to the HL influence since the dominant language results indicate that most speakers do not practice it in English. In addition, as will be discussed later, the nonce words reading task results seem to suggest that for most speakers true-voicing may likely be a part of their productive grammars, which implies that it was fully acquired by the Ukrainian HSs in their HL before they began learning the L3.

The majority of the Polish HSs also produced true-voiced Spanish /b d g/. Once again, this finding is not surprising, since all speakers (nine participants) whose data sets had negative VOT measurements showed evidence of pre-voicing in Polish. Moreover, five speakers produced true-voiced stops in English and one speaker displayed a mixed production (true-voiced and short-lag stops). As with the Ukrainian HSs, the Polish HSs' HL and dominant language data sets seem to suggest that it is the HL that impacts the true-voiced production of Spanish /b d g/. This influence also appears to extend to English, where some speakers produced true-voiced stops. It is possible to interpret true-voicing as the HL influence due to its presence in the speech of all HSs in Polish. Also, similar to the Ukrainian HSs, almost all Polish-speaking participants produced true-voicing or at least mixed results in the nonce words reading task, which may suggest that this feature was fully acquired in the HL, making it part of the speakers' productive grammars prior to learning Spanish.

Interestingly, the true-voiced production of the Spanish voiced stops is not only limited to the Ukrainian and Polish HSs' data. There is also evidence of pre-voicing in the English speakers' productions. The L1 English speakers' results definitely did not show as much pre-voicing as the HSs' data in the production of Spanish /b d g/; however, even a small amount of

true-voicing is intriguing, since initially it was predicted that these speakers were not going to produce any stops with pre-voicing. Furthermore, two speakers even displayed consistent pre-voicing in the production of English /b d g/, providing a fascinating case of cross-linguistic influence in bilingual speakers. These same two speakers also displayed mixed productions in the nonce words reading task, which may signal that true-voicing is possibly becoming part of their productive grammars.

Finally, not surprisingly, all L1 Spanish speakers whose data were analyzed for true-voicing showed evidence of pre-voicing of the Spanish stops. All five speakers also produced the English /b d g/ as true-voiced stops, showing a clear influence of Spanish on the production of English segments. This treatment of English voiced stops is interesting, considering that the L1 Spanish participants produced English vowels and voiceless stops according to the English standard without showing influence of the Spanish features, such as lack of unstressed vowel reduction and short-lag VOT. Perhaps these results indicate that for the L1 Spanish speakers in this study true-voicing remains the main distinguishing feature between voiced and voiceless stops. Since these participants produced the Spanish /p t k/ as short-lag, it may be that producing the English /b d g/ as short-lag instead of relying on true-voicing might interfere with the separation of these two sound classes. The fact that true-voicing of the Spanish stops appeared in the nonce words reading task also seems to suggest that this feature is part of the productive grammars of the speakers, making true-voicing an inherent feature of the voiced stops.

5.3.3 Will the experience of the Slavic language HS with the Spanish intervocalic lenition of voiced stops be similar to the experience of the L1 English L2 Spanish learner, since both the HLs and English do not have stop weakening in intervocalic position, or will

it be different, and possibly influenced by the shared pre-voiced nature of /b d g/ in the HLs and Spanish?

Both the Ukrainian and Polish HSs displayed intervocalic weakening in the production of the Spanish voiced stops. The Ukrainian HSs lenited /b d g/ in all four tasks, producing the most weakened segments in the narrative and picture-naming tasks, and the least weakened stops in the sentence and nonce words reading tasks, mirroring the L1 Spanish control groups' results, as well as supporting Rao's (2014, 2015) finding on the relationship between task formality and degree of lenition. In the narrative and sentence-reading tasks, the Ukrainian HSs lenited /b/ and /d/ the most, once again reflecting the L1 Spanish speakers' production and also supporting Eddington's (2011) claim that /b/ and /d/ experience a greater degree of lenition than /g/. In the other two tasks, however, /g/ was the most lenited segment. A possible reason why the Ukrainian HSs weaken the velar segment the most in those two tasks is due to the nature of this segment in Ukrainian. Since in Ukrainian, /g/ is very rarely utilized and is mostly replaced by /h/, which is a fricative segment, it may be the case that the Ukrainian HSs are more inclined to avoid a stop-like production of /g/. Overall, the Ukrainian HSs produced the second most lenited stops out of the four groups of speakers, approximating the L1 Spanish control group's results the most and without showing a statistically significant difference from them. Although the Ukrainian HSs' lenited production of the intervocalic stops in Spanish is slightly unexpected, considering that both the HL and the dominant languages do not practice intervocalic lenition, it is not entirely surprising when considering the Ukrainian and English data. The Ukrainian HSs displayed low RI values in the production of both Ukrainian and English voiced stops, indicating less closure than is typically expected in the standard production of /b d g/ in the two languages neither of which practices intervocalic lenition. However, a recent study by Bouavichith and Davidson

(2013) revealed that weakening of intervocalic voiced stops is not a completely uncommon practice in American English. The authors discovered that during a reading task, speakers lenited intervocalic voiced stops to approximants in cases where lenition occurred. Stress was shown to play the most significant role, a finding which does not coincide with the present study, where stress was only significant for the degree of lenition of the English stops in the results of the Polish HSs, but not in the speech of other participants. The authors also found that /d/ and /g/ lenited the most in comparison to /b/, which was also observed to be the case in the current study in the productions of the L1 English speakers, as well as L1 Spanish participants. Most intriguingly, Bouavichith and Davidson noticed that higher frequency words were more frequently produced with approximant-like realizations. Since the participants of this study were only asked to complete the narrative task in English, it is possible to assume that they were inclined to utilize frequent words in their speech during this spontaneous elicitation, which possibly explains the higher degree of intervocalic lenition in the results than was initially expected. Most certainly, more research needs to be done to determine just how common intervocalic lenition is in the Ukrainian HSs' HL and English, investigating various speech styles, as well as words of different frequencies. If it happens to be the case that the Ukrainian HSs actively practice intervocalic lenition in their HL and the dominant language, then it can possibly explain why this feature was not challenging for them to acquire in their L3.

The Polish HSs' Spanish data also provide evidence of intervocalic weakening in all four tasks, with the least controlled tasks displaying the smallest degree of constriction. The Polish HSs showed the greatest degree of weakening in the production of /d/ in the narrative, picture-naming and sentence-reading tasks, reflecting the L1 Spanish control group's results. However, in the nonce words reading task, it is the bilabial and the velar segments that are the most lenited.

Although the Polish HSs presented evidence of lenition of Spanish voiced stops, the degree of weakening approximated more closely the L1 English control group's results rather than the L1 Spanish speakers' productions. In fact, the Polish HSs produced the least lenited segments out of the four groups of speakers in the picture and sentence-reading tasks, also displaying significantly different RI values from those of the L1 Spanish base in three out of the four tasks.

The fact that the Polish HSs produced less lenited Spanish segments than the Ukrainian HSs speakers is also not surprising when considering the Polish and English data of these participants. While the Polish HSs showed evidence of intervocalic stop weakening in the HL and the dominant language, it is not as great as the one observed in the Ukrainian HSs' data. In fact, the Polish HSs produced more constricted English voiced stops than the L1 English control group, displaying the second highest RI values out of the four groups of speakers (the L1 Spanish speakers produced the least lenited English segments).

The voiced stops results reflect the outcome observed in the voiceless stops data, where the Ukrainian HSs approximate the L1 Spanish speakers' productions the most and the Polish HSs show a greater resemblance to the L1 English participants' results than those of the L1 Spanish participants. The Ukrainian HSs' results clearly show that the production of intervocalic weakening of the Spanish stops does not present a great challenge for this group of speakers. The L1 English participants and the Polish HSs' results, on the other hand, support earlier findings in the literature, which show this particular feature of Spanish to be challenging for a typical English-speaking learner of Spanish (González-Bueno 1995, Menke and Face 2009, Zampini 1994). Nonetheless, it is also important to note that while the L1 English speakers and the Polish HSs' /b d g/ productions were the furthest from the L1 Spanish base, their results still showed some degree of weakening, especially in less controlled tasks. This outcome shows that although

these two groups do not display as much weakening as the L1 Spanish speakers, they are also not producing all instances of intervocalic /b d g/ as stops, which is usually assumed to be the typical production of the Spanish /b d g/ by English-speaking learners. Although the Ukrainian and Polish HSs produced different results, there is one aspect where the two groups coincide. Both of the HS groups avoided transferring the intervocalic flapping feature from English to Spanish and produced all instances of intervocalic /d/ as dental segments and not as alveolar taps. The L1 English speakers, on the other hand, produced a significant number of intervocalic /d/ as taps in Spanish, especially in the sentence-reading task, showing clear transfer from their L1.

As was mentioned in the voiceless stops discussion, it is possible to attribute the difference in the Ukrainian and Polish HSs' production to the speakers' proficiency levels in Spanish. As was discussed previously, the Ukrainian HSs in this study are generally more proficient in Spanish than the Polish HSs, which may signal that they are relying less on their dominant language and are instead displaying results that are expected from speakers at higher acquisitional stages of Spanish.

5.3.4 What role would task type play in production and possible lenition of voiced stops /b d g/ in the speech of heritage Ukrainian and Polish speaking learners of Spanish?

The voiced stops data provide very strong evidence of the effect of speech style on the production of the Spanish /b d g/. In all four speaker groups' data sets, task type played a statistically significant role in the production of all three segments, confirming that different speech styles influence the rate of intervocalic stop lenition.

The Ukrainian HSs showed a very strong correlation between task formality and the rate of weakening, especially in the production of /b/ and /d/. The two segments underwent the smallest degree of constriction in the narrative task and as elicitations became more formal, the

rate of constriction gradually increased, resulting in the most constricted stops in the nonce words reading task. The velar segment also showed lower RI means in the conversational and semi-controlled tasks, with most weakening taking place in the picture-naming task, while the controlled elicitations display higher values, with the most constricted production occurring in the sentence-reading task. This relationship reflects the patterns observed in the Ukrainian HSs' productions of the Spanish vowels and voiceless stops, where speakers display the most target-like results in the most natural tasks, mimicking the L1 Spanish speakers' productions. In addition, this finding is in line with Rao's (2014, 2015) conclusion that controlled reading tasks yield less intervocalic weakening than spontaneous speaking tasks. In addition to being the most formal task, which due to its controlled nature yielded the most constricted stops, the nonce words reading task may also imply that underlyingly, a high degree of intervocalic weakening is not part of the productive grammars of the Ukrainian HSs. Perhaps, the consistently low RI values observed in the narrative task are due to lexicalization, with speakers showing greater weakening in most frequently used words that they had the greatest exposure to as language learners. In terms of true-voicing, the nonce words reading task results may also be suggesting that true-voicing is part of the speakers' productive grammars with four participants producing only true-voiced stops and two speakers showing mixed productions.

The Polish HSs displayed higher RI values than the Ukrainian HSs in all four tasks, however, the relationship between task formality and intervocalic weakening is exactly the same as the one observed in the Ukrainian HS group. The bilabial and dental segments had the lowest RI values in the narrative task, which gradually increased as tasks become more formal, with the highest RI values occurring in the nonce words reading task. The relationship between task formality and the production of /g/ is also identical to the one seen in the Ukrainian HSs' data.

These results once again confirm earlier findings in the literature on the relationship between task formality and RI values of the Spanish intervocalic /b d g/. This finding, however, is slightly different from the one observed in the Polish HSs' vowels and voiceless stops data, where more target-like productions tended to occur in more formal tasks. As was suggested previously, perhaps the words that the speakers produced in the narrative task are more frequently used by the participants and therefore, are more familiar to them, making lenition a more inherent feature of the speaking task. As in the Ukrainian HSs' results, the nonce words reading task RI means appear to imply that intervocalic weakening may not form a part of the Polish HSs' productive grammars, suggesting that the lenition observed in the narrative task is in fact a process of role-learning rather than a feature of the speakers' productive grammars. The nonce words reading task also appears to suggest that true-voicing may be a part of the speakers' productive grammars, with seven speakers producing only true-voiced stops and four speakers producing mixed results.

The Ukrainian and Polish HSs' task effects coincide more closely with the patterns observed in the L1 English control group's results. As the Polish HSs, the L1 English participants produced more constricted stops across all tasks. However, the relationship between task formality and RI values for /b/ and /g/ is identical to the one observed in the other two groups. The dental segment was produced with the lowest RI in the picture-naming task and the highest in the nonce words reading task, which still confirms that less controlled tasks yield more lenited segments. As with the Polish HSs, the relationship between task formality and target-like productions in the voiced stops data is different from the one observed with vowels and voiceless stops, where higher formality yielded more target-like results. This finding, along with the nonce words reading task results, which displayed the highest RI means, may be indicating that lenition

is not part of the L1 English speakers' productive grammars and perhaps suggesting that for the pronunciation of the Spanish voiced stops, word frequency and lexicalization play an important role, maybe more so than in the production of vowels and voiceless stops. However, further research is needed to support this claim. Interestingly, unlike with the HS groups, the nonce words reading task results seem to imply that for the L1 English speakers, true-voicing may actually not be a part of the productive grammar, since no speakers produced purely pre-voiced stops. Two speakers showed mixed results signaling that this feature may be becoming part of their productive grammars, but for all other speaker the true-voiced stops observed in the other three tasks may be due to other processes, such as lexicalization.

Overall, all three language learner groups reflect the L1 Spanish speakers' relationship between task formality and the rate of lenition. The L1 Spanish speakers produced the most weakened stops in the narrative task and the least lenited segments in the nonce words reading task, supporting earlier findings in the literature, as well as reflecting the speakers' general tendencies regarding task formality that were also observed in the pronunciation of vowels and /p t k/. While the RI means of the L1 Spanish speakers in the nonce words reading task were the highest, they are still the lowest among the four groups of speakers, signaling that intervocalic lenition is likely a part of these speakers' productive grammars. The nonce words reading task also suggests that true-voicing is a part of the speakers' underlying grammar, with all participants producing pre-voiced segments.

5.3.5 Do the results of the voiced stop analysis support one specific theoretical model of L3 acquisition?

The case of true-voicing is very similar to that of the unstressed vowel reduction. As in the vowel data, the Ukrainian and Polish HSs' HL and their dominant language results do not

provide clear evidence of the existence of two separate phonetic categories for the classification of voiced stops. The speakers of the two HS groups produced true-voiced stops in their HL (except for one Ukrainian HS who produced a mix of short-lag and true-voiced stops), signaling that the Ukrainian and Polish voiced stops are assigned one true-voiced phonetic category. The dominant language results, however, do not clearly indicate that there exists a short-lag phonetic category in the sound systems of all speakers to classify the English voiced stops. The majority of Ukrainian and Polish HSs produced both HL and dominant language /b d g/ as true-voiced, indicating that there is a single phonetic category for the HL and English voiced stops.

Therefore, similar to the vowels data, these results are difficult to interpret within a L3 acquisition theoretic framework, since there is not enough evidence to indicate that all speakers have two separate phonetic categories that can act as competing suppliers during the acquisition of L3 voiced stops. Instead, these findings seem to support Flege's SLM, signaling that for most speakers, a new phonetic category was not established for the dominant language voiced stops, as they were likely not perceived to be phonetically different from the HL segments. Since the majority of the HSs appear to have only one true-voiced feature available in their sound systems, that is the feature that has the highest change of being transferred. The Spanish /b d g/ results appear to support this claim.

The case of intervocalic lenition is an interesting one due to the unpredicted results in the heritage and dominant languages of the HSs. Initially, no intervocalic weakening was expected to take place in Ukrainian, Polish and English. However, the two HS groups produced relatively low RI means in their two languages, indicating less closure than was initially expected. As was mentioned previously, recent studies have shown that intervocalic weakening of voiced stops is not an entirely uncommon practice in American English, which explains the presence of

weakening in the dominant language results. However, to my knowledge, there are no studies that investigate intervocalic weakening of /b d g/ in the speech of monolingual Ukrainian and Polish speakers. Therefore, it is difficult to say whether this practice is also present to some degree in the HLs in question or if the lenition observed in Ukrainian and Polish of the HSs is due to prolonged contact with English. Generally, however, the degree of weakening in the HL data is greater than that of the dominant language, except for /d/, which is more lenited in English, in line with the results reported in Bouavichith and Davidson (2013). While the fact that the HSs produced lenited voiced stops in their HLs and English is unexpected, it is not surprising that there are no two separate categories for the classification of the intervocalic stops. The HLs and English were predicted to have comparable results in the production of intervocalic /b d g/, since the two languages are aligned in their treatment of these segments in intervocalic position.

Given that there are no two separate categories, as with the cases of unstressed vowel reduction and true-voicing, an application of a L3 acquisition theory is somewhat problematic in this circumstance, since there are no two clearly distinct competing features than can be transferred to L3. However, as mentioned earlier, Ukrainian and Polish RI values were generally lower than the English means, which can help indicate whether the Spanish /b d g/ are more HL-like or English-like. As was discussed previously, the Ukrainian HSs consistently display low RI values in Spanish. In the narrative, picture-naming, and sentence-reading tasks the RI means are lower than those produced in both Ukrainian and English. In the nonce words reading task, the RI means fall between the Ukrainian and English values. This distribution of the results signals that the Ukrainian HSs are not particularly relying on either of their two languages, but instead, are displaying productions that are closer to the Spanish standard described in the literature and observed in the results of the L1 Spanish control group. As was discussed previously, the fact

that the Ukrainian HSs are producing native-like results may be due to their proficiency level in the L3, which is more advanced than that of the Polish HS group. The nonce words reading task results may also be implying that in this group of speakers a stop-like production may not be part of their productive grammars. Instead, it is possible that the productive feature is the one that favors some amount of lenition in intervocalic position. The Polish HSs, on the other hand, produced more varied results. For instance, in the narrative task the RI values are lower than the means recorded in Polish and English (except for the Spanish /g/), and in the picture-naming task, the RI values are closer to those of the Polish data than those of the English data. In sentence and nonce words reading tasks, however, the RI means are closer to those of English than Polish (except for /d/). Unlike with the Ukrainian HSs, the nonce words reading task results appear to imply that a higher level of constriction of the voiced stops in intervocalic position may be part of the productive grammars of these speakers.

Due to the general lack of reliance on one particular language in the Ukrainian HSs' data and the variability in the results of the Polish HSs, the findings appear to shed light on the DST. As described in the DST, the outcome of intervocalic voiced stop productions was not easily predictable for any of the languages in this study. In addition, the HSs also demonstrated a great degree of intergroup as well as intragroup variability, possibly caused by different external and internal factors, which are able to influence the development of all the languages involved. While the results of the voiced stop analysis do not allow us to claim that either of the HLs, English or both languages is/are responsible for the L3 results, they show that L3 acquisition is an extremely complicated and often unpredictable process, thus giving support to the DST, which emphasizes the complexity of the interconnected networks in the dynamic system that is the multilingual brain.

5.4 Conclusions

The purpose of this study was to describe the acquisition of L3 Spanish vowels, and voiceless and voiced stops by the HSs of Ukrainian and Polish while considering the effect of speech style and the claims of various theoretical models of L3 acquisition. Several conclusions can be drawn from the results of this investigation.

First, the findings indicate that the HSs of this study do not exclusively rely on either their HL or the dominant language during the acquisition of L3 Spanish. Most importantly, the results suggest that for certain features, the HSs do not have two separate phonetic categories to classify HL and dominant language segments. Instead, as observed in cases of unstressed vowel reduction, true-voicing and intervocalic lenition, the HS participants appear to rely on a single phonetic category that processes the segments of both languages. Therefore, for these particular features, the HL and the dominant language are not competing, and the speakers have only one feature to transfer. The case of voiceless stops, however, is different, since the HSs have two separate phonetic categories in their sound systems. The results show that the Ukrainian HSs rely on their HL in the production of the L3 Spanish voiceless stops, while the Polish HSs rely on both the HL and English when producing the L3 Spanish /p t k/.

A second important finding of this research is that speech style plays a significant role on the production of the Spanish voiceless and voiced stops, and a lesser role on the production of the Spanish vowels. Task type did not affect in a consistent manner either tongue height or backness, nor the degree of unstressed vowel reduction, but it was significant for the degree of dispersion for almost all vowels in the productions of the four groups. Speech style also played a significant role in the production of voiceless stops. However, the relationship between speech formality and VOT was not uniform across the four groups. Finally, speech style had the greatest

effect on the production of voiced stops, significantly affecting all three stops in the production of all four groups. All speakers displayed a general tendency of producing most lenited stops in least formal tasks and more constricted segments in more controlled elicitations.

A third conclusion which can be drawn from this study is that the findings do not support only one specific L3 acquisition theory, but instead, shed light on several L3 acquisition models, as well as a L2 speech acquisition framework. The voiceless stops results suggest that the HSs of this study are guided by the LPM, relying on both the HL and the dominant language as sources of influence. However, unstressed vowel reduction, true-voicing, and intervocalic lenition suggest that the SLM is at play. Most importantly, the data shed light on the DST, which helps to account for the inter-group, as well as intra-group variation.

Overall, the results of this study demonstrate that L3 acquisition is a very complex process, the outcomes of which are not easily predictable. By examining four languages, three different sound classes, four separate speech styles, as well as four distinct speaker groups, this investigation was able to demonstrate that it is problematic to account for all L3 acquisition processes by only relying on one theoretical model. Instead, it is essential to consider several theories and frameworks to account for all cross-linguistic influences taking place during the acquisition of L3 by heritage speaking learners.

This study makes several contributions to the field of phonetics and phonology, as well as the study of language contact and multilingualism. First, it allowed us to establish a comparison between languages that have never been examined together in this particular combination – Ukrainian, Polish, English and Spanish. It sheds light on the development of Slavic HSs, a population of speakers that is continuously growing in the US, and provides critical information about the development of their sound systems as L3 learners. In particular, this study described

unstressed vowel reduction, VOT values of voiceless stops, and voicing and the degree of lenition of voiced stops in the productions of Ukrainian and Polish HSs in four languages, which will allow future research in Ukrainian and Polish or other Slavic languages to have a point of reference. Finally, this study, although just the first step towards more extensive research on Ukrainian and Polish, and Ukrainian and Polish HSs, is able to provide better insight into other Slavic languages, as well as their influence on the acquisition of Spanish and other Romance languages.

5.5 Limitations of Present Study and Directions for Future Research

As with any study, this investigation has some limitations. The novelty of this study has contributed to some of the limitations, which I hope will serve to inform future research that will continue to advance the fields of HLs and L3 acquisition. The most notable one is a small number of participants recruited for this study, specifically, the number of Ukrainian HSs – a group, which consists of only six speakers. A small sample size is often associated with low statistical power, which can prevent us from properly estimating and modeling the population we sample from. In addition, the Ukrainian HSs recruited for this study form a more heterogeneous group than the Polish HSs, who share a more similar background, including similar levels of linguistic competency in the L3. While the diversity of the Ukrainian HS group reflects the general composition of the Ukrainian speaking population in the United States, combining a diverse body of speakers in a small group complicates the interpretation of the findings since, as shown by the DST, each external and internal experience of a speaker can significantly influence language development. Therefore, for the sake of consistency and a more precise interpretation of the results, it is advisable to recruit a larger and more homogeneous group of speakers in future studies. Also, Pascual y Cabo and Rothman (2012) pointed out that the type of HL input

received by HSs varies due to cross-generational differences, attrition and other effects of language contact that are not experienced by monolingual speakers, which certainly contributes to different HL norms in this group of speakers. Therefore, it will be very informative to also test parents of HSs to see how contact with the dominant language has affected the use of their native tongue (or possibly their HL), which could have been transferred to their children.

Some may interpret the number of participants in the two control groups as a limitation as well. However, this study did not intend to recruit a large number of L1 English and L1 Spanish speakers, since there is already a generous body of literature describing in great detail these speakers' productions and developments in English and Spanish. The fact that the L1 Spanish participants did not behave like monolingual Spanish speakers in some instances may also be labeled a limitation. Nonetheless, as stated previously, recruiting bilingual speakers was imperative for this investigation, following Cabrelli Amaro's (2013) suggestion, who showed that multilingual control groups serve as a better comparison for L3 learners and the types of cross-linguistic influences that they experience. It is true that even late Spanish-English bilinguals differ from Spanish monolinguals (Solon et al. forthcoming), but it serves as additional evidence to show that L3 learners should not be compared to monolingual speakers whose L1 does not go through any changes due to an introduction of an additional language.

When recruiting control groups, it is also very important to consider the variety of the speakers' L1 and collect thorough background information on participants' community practices. For instance, the L1 Spanish speakers recruited for this study are speakers of Mexican Spanish, which is known for its variation in unstressed vowel realizations. Understanding whether these speakers' communities have been exposed to a certain production over generations will better

inform researchers about participants' frequent L1 phonological trends and their potential influences on other languages.

An absence of a native Ukrainian and Polish control group is another shortcoming of this study. Due to a very limited amount of recent literature on the Polish sound system and an even smaller number of studies on Ukrainian, at times it is difficult to say whether certain processes discovered in this study are only inherent to the HSs of these two languages or if they are part of the standard Ukrainian and Polish sound systems. Including a bilingual or a trilingual control group of native Ukrainian and Polish speakers in future studies would provide a comparison point for the HS groups, as well as inform the cross-linguistic process taking place in the native Ukrainian and Polish speaking bilingual or multilingual participants' sound systems. Also, when recruiting Ukrainian and Polish native speakers to serve as controls, it will be important to choose participants that are from the same geographical regions as the HSs. This process will help account for any dialectal variation that may be present in the speech of the two groups of speakers.

The methodology employed in this study allowed us to collect data in various speech styles. However, due to the spontaneous nature of the narrative task and the controlled characteristic of the sentence-reading task, the number of tokens collected in the highly controlled task is considerably larger than that of the uncontrolled elicitation. As mentioned earlier, a small sample size is often linked to low statistical power, which can make extrapolation to larger populations more difficult. It can also create complications in the form of comparing a small sample size to a larger sample size, since one of the sides provides a limited account. To remedy this limitation, it is advisable to include an additional spontaneous elicitation in the

future investigations, in order to gather a larger token count that will be more comparable to the data sets of controlled tasks.

In future investigations, it will also be beneficial to control the order in which data for each language are elicited. For example, half of the HSs can be asked to perform a task in their HL right before eliciting data in their L3, while the other half can be asked to complete a task in their DL before moving on to their L3. Triggering different language modes before collecting data in the HSs' L3 can provide insightful information regarding cross-linguistic influences. In addition, experimenting with the order of L3 tasks (e.g., asking half of the participants to begin with informal elicitations, while the other half begins with controlled tasks) can be informative in terms of speech style effects on production.

The following study provides a cross-sectional sample, which highlights the HSs development in L3 in apparent time, not real time. Consequently, any developmental stages that learners go through over time may be blurred due to the cross-sectional design. As was shown by previous research, the types of transfers that occur during L3 acquisition change as speakers become more proficient in the language and a longitudinal study of a small group of HS learners of an L3 would allow for an observation of such transformations over time. Alternatively, a future study could include several groups of HSs at various developmental stages of L3 – beginning, intermediate, and advanced – and observe the differences in L3 productions of speakers at different proficiency levels.

This study only focused on production, but it would also be very informative to observe the perception abilities of the HS learners of an L3 in future investigations. Earlier studies showed that perception stabilizes earlier than production (Flege 1995, Kim 2011, 2016). Investigating the perceptual skills of L3 learners can provide further insight into their

developmental stages and deepen the understanding of cross-linguistic processes taking place in multilingual sound systems. In addition, including a group of expert judges who can assess the foreign accent of L3 learners could provide insight as to whether the L3 learners are more HL-accented or English-accented. This judgment test could further inform the types of transfers taking place during L3 acquisition and help determine how HSs' L3 accent is perceived by native or highly-proficient speakers of the L3.

Furthermore, since L3 learners' development is guided not only by internal experiences, but also by external factors, it is important to study in detail the speakers' backgrounds, particularly the HS communities that they may belong to. It was shown by previous studies (Hrycyna 2011, Nagy and Kochetov 2013) that HS communities are highly diverse, and each group may have their own language norms, which may also be undergoing generational shifts. Therefore, it would be highly beneficial in the future studies to carefully examine the HSs' communities in order to have a better understanding of their language practices, which may be close to the norms of native speakers of those language or, on the contrary, differentiate greatly from standard productions.

Finally, vowels, and voiced and voiceless stops are three of many sound classes that make up a phonological system. By looking at other sounds, such as rhotics, as well as examining these segments in various phonological contexts, would allow for a more complete depiction of HS learners of L3 Spanish. In addition, studies with HSs have pointed to the importance of investigating suprasegmental features (i.e., stress, rhythm, intonation) as they also differentiate the HSs from the monolingual speakers and L2 learners, which may influence their acquisition of these features in L3. These features could form the basis of analysis for future studies.

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Appendix A

Materials

A.1a Language history questionnaire for Ukrainian HSs

Place of birth: _____

Place of birth of your parents/grandparents: _____

If resided in Ukraine, where and how long in each place? _____

Where and how long in each place have you lived in the United States? _____

How many times have you visited Ukraine? When and for how long? _____

What do you consider to be your first language? _____

What do you consider to be your second language? _____

What do you consider to be your third language? _____

Have you learned Spanish before? _____

At what age did you start learning Spanish? _____

How many semesters/years of classes have you had in Spanish (primary school through university)? List the classes you have taken. _____

Have you studied and/or lived abroad in a Spanish speaking country? If yes, when, where and how long? _____

In an average week, what percentage of the time do you use Spanish? _____

In what environments (school/work/home) and with whom
(friends/family/coworkers/instructors/classmates) do you use Spanish? _____

On a scale from 0 (not well at all) to 6 (very well), how well do you speak Spanish? _____

On a scale from 0 (not well at all) to 6 (very well), how well do you understand Spanish? _____

On a scale from 0 (not well at all) to 6 (very well), how well do you read Spanish? _____

On a scale from 0 (not well at all) to 6 (very well), how well do you write Spanish? _____

Have you taken any phonology or phonetics courses in any of the languages that you know? If
yes, what kind, when and where? _____

A.1b Language history questionnaire for Polish HSs

Place of birth: _____

Place of birth of your parents/grandparents: _____

If resided in Poland, where and how long in each place? _____

Where and how long in each place have you lived in the United States? _____

How many times have you visited Poland? When and for how long? _____

What do you consider to be your first language? _____

What do you consider to be your second language? _____

What do you consider to be your third language? _____

Have you learned Spanish before? _____

At what age did you start learning Spanish? _____

How many semesters/years of classes have you had in Spanish (primary school through university)? List the classes you have taken. _____

Have you studied and/or lived abroad in a Spanish speaking country? If yes, when, where and how long? _____

In an average week, what percentage of the time do you use Spanish? _____

In what environments (school/work/home) and with whom

(friends/family/coworkers/instructors/classmates) do you use Spanish? _____

On a scale from 0 (not well at all) to 6 (very well), how well do you speak Spanish? _____

On a scale from 0 (not well at all) to 6 (very well), how well do you understand Spanish? _____

On a scale from 0 (not well at all) to 6 (very well), how well do you read Spanish? _____

On a scale from 0 (not well at all) to 6 (very well), how well do you write Spanish? _____

Have you taken any phonology or phonetics courses in any of the languages that you know? If
yes, what kind, when and where? _____

A.2a Bilingual language profile for Ukrainian HSs

Bilingual Language Profile: English-Ukrainian

We would like to ask you to help us by answering the following questions concerning your language history, use, attitudes, and proficiency. This survey was created with support from the Center for Open Educational Resources and Language Learning at the University of Texas at Austin to better understand the profiles of bilingual speakers in diverse settings with diverse backgrounds. The survey consists of 19 questions and will take less than 10 minutes to complete. This is not a test, so there are no right or wrong answers. Please answer every question and give your answers sincerely. Thank you very much for your help.

I. Biographical Informations

Name _____		Today's Date ____/____/____										
Age _____	☐ Male / ☐ Female	Current place of residence: city/state _____ country _____										
Highest level of formal education: <table border="0"> <tr> <td>☐ Less than high school</td> <td>☐ High school</td> <td>☐ Some college</td> </tr> <tr> <td>☐ College (B.A., B.S.)</td> <td>☐ Some graduate school</td> <td>☐ Masters</td> </tr> <tr> <td>☐ PhD/MD/JD</td> <td>☐ Other: _____</td> <td></td> </tr> </table>				☐ Less than high school	☐ High school	☐ Some college	☐ College (B.A., B.S.)	☐ Some graduate school	☐ Masters	☐ PhD/MD/JD	☐ Other: _____	
☐ Less than high school	☐ High school	☐ Some college										
☐ College (B.A., B.S.)	☐ Some graduate school	☐ Masters										
☐ PhD/MD/JD	☐ Other: _____											

Please cite as :

Birdsong, D., Gertken, L.M., & Amengual, M. *Bilingual Language Profile: An Easy-to-Use Instrument to Assess Bilingualism*. COERLL, University of Texas at Austin. Web. 20 Jan. 2012. <<https://sites.la.utexas.edu/bilingual/>>.

II. Language history

In this section, we would like you to answer some factual questions about your language history by placing a check in the appropriate box.

1. At what age did you **start learning** the following languages?

English

☐ Since birth ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☐ 12 ☐ 13 ☐ 14 ☐ 15 ☐ 16 ☐ 17 ☐ 18 ☐ 19 ☐ 20+

Ukrainian

☐ Since birth ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☐ 12 ☐ 13 ☐ 14 ☐ 15 ☐ 16 ☐ 17 ☐ 18 ☐ 19 ☐ 20+

2. At what age did you **start to feel comfortable** using the following languages?

English

☐ As early as I can remember ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☐ 12 ☐ 13 ☐ 14 ☐ 15 ☐ 16 ☐ 17 ☐ 18 ☐ 19 ☐ 20+ ☐ not yet

Ukrainian

☐ As early as I can remember ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☐ 12 ☐ 13 ☐ 14 ☐ 15 ☐ 16 ☐ 17 ☐ 18 ☐ 19 ☐ 20+ ☐ not yet

3. How many years of **classes (grammar, history, math, etc.)** have you had in the following languages (primary school through university)?

English

☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☐ 12 ☐ 13 ☐ 14 ☐ 15 ☐ 16 ☐ 17 ☐ 18 ☐ 19 ☐ 20+

Ukrainian

☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☐ 12 ☐ 13 ☐ 14 ☐ 15 ☐ 16 ☐ 17 ☐ 18 ☐ 19 ☐ 20+

4. How many years have you spent in a **country/region** where the following languages are spoken?

English

☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☐ 12 ☐ 13 ☐ 14 ☐ 15 ☐ 16 ☐ 17 ☐ 18 ☐ 19 ☐ 20+

Ukrainian

☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☐ 12 ☐ 13 ☐ 14 ☐ 15 ☐ 16 ☐ 17 ☐ 18 ☐ 19 ☐ 20+

5. How many years have you spent in a **family** where the following languages are spoken?

English

☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☐ 12 ☐ 13 ☐ 14 ☐ 15 ☐ 16 ☐ 17 ☐ 18 ☐ 19 ☐ 20+

Ukrainian

☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☐ 12 ☐ 13 ☐ 14 ☐ 15 ☐ 16 ☐ 17 ☐ 18 ☐ 19 ☐ 20+

6. How many years have you spent in a **work environment** where the following languages are spoken?

English

☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☐ 12 ☐ 13 ☐ 14 ☐ 15 ☐ 16 ☐ 17 ☐ 18 ☐ 19 ☐ 20+

Ukrainian

☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☐ 12 ☐ 13 ☐ 14 ☐ 15 ☐ 16 ☐ 17 ☐ 18 ☐ 19 ☐ 20+

III. Language use

In this section, we would like you to answer some questions about your language use by placing a check in the appropriate box. Total use for all languages in a given question should equal 100%.

7. In an average week, what percentage of the time do you use the following languages **with friends**?

English	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Ukrainian	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Other languages	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%

8. In an average week, what percentage of the time do you use the following languages **with family**?

English	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Ukrainian	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Other languages	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%

9. In an average week, what percentage of the time do you use the following languages **at school/work**?

English	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Ukrainian	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Other languages	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%

10. When you talk to yourself, how often do you **talk to yourself** in the following languages?

English	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Ukrainian	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Other languages	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%

11. When you count, how often do you **count** in the following languages?

English	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Ukrainian	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Other languages	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%

IV. Language proficiency

In this section, we would like you to rate your language proficiency by giving marks from 0 to 6.

12. a. How well do you speak **English**? 0=not well at all 6=very well
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6
- b. How well do you speak **Ukrainian**?
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6
13. a. How well do you understand **English**?
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6
- b. How well do you understand **Ukrainian**?
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6
14. a. How well do you read **English**?
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6
- b. How well do you read **Ukrainian**?
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6
15. a. How well do you write **English**?
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6
- b. How well do you write **Ukrainian**?
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6

V. Language attitudes

In this section, we would like you to respond to statements about language attitudes by giving marks from 0-6.

16. a. I feel like myself when I speak **English**. 0=disagree 6=agree
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6
- b. I feel like myself when I speak **Ukrainian**.
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6
17. a. I identify with an **English-speaking** culture.
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6
- b. I identify with a **Ukrainian-speaking** culture.
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6
18. a. It is important to me to use (or eventually use) **English** like a native speaker. ☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6
- b. It is important to me to use (or eventually use) **Ukrainian** like a native speaker. ☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6
19. a. I want others to think I am a native speaker of **English**. ☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6
- b. I want others to think I am a native speaker of **Ukrainian**. ☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6

A.2b Bilingual language profile for Polish HSs

Bilingual Language Profile: English-Polish

We would like to ask you to help us by answering the following questions concerning your language history, use, attitudes, and proficiency. This survey was created with support from the Center for Open Educational Resources and Language Learning at the University of Texas at Austin to better understand the profiles of bilingual speakers in diverse settings with diverse backgrounds. The survey consists of 19 questions and will take less than 10 minutes to complete. This is not a test, so there are no right or wrong answers. Please answer every question and give your answers sincerely. Thank you very much for your help.

I. Biographical Informations

Name _____		Today's Date ____/____/____										
Age _____	☐ Male / ☐ Female	Current place of residence: city/state _____ country _____										
Highest level of formal education: <table border="0"> <tr> <td>☐ Less than high school</td> <td>☐ High school</td> <td>☐ Some college</td> </tr> <tr> <td>☐ College (B.A., B.S.)</td> <td>☐ Some graduate school</td> <td>☐ Masters</td> </tr> <tr> <td>☐ PhD/MD/JD</td> <td>☐ Other: _____</td> <td></td> </tr> </table>				☐ Less than high school	☐ High school	☐ Some college	☐ College (B.A., B.S.)	☐ Some graduate school	☐ Masters	☐ PhD/MD/JD	☐ Other: _____	
☐ Less than high school	☐ High school	☐ Some college										
☐ College (B.A., B.S.)	☐ Some graduate school	☐ Masters										
☐ PhD/MD/JD	☐ Other: _____											

Please cite as :

Birdsong, D., Gertken, L.M., & Amengual, M. *Bilingual Language Profile: An Easy-to-Use Instrument to Assess Bilingualism*. COERLL, University of Texas at Austin. Web. 20 Jan. 2012. <<https://sites.la.utexas.edu/bilingual/>>.

II. Language history

In this section, we would like you to answer some factual questions about your language history by placing a check in the appropriate box.

1. At what age did you **start learning** the following languages?

English

☐ Since birth ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☐ 12 ☐ 13 ☐ 14 ☐ 15 ☐ 16 ☐ 17 ☐ 18 ☐ 19 ☐ 20+

Polish

☐ Since birth ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☐ 12 ☐ 13 ☐ 14 ☐ 15 ☐ 16 ☐ 17 ☐ 18 ☐ 19 ☐ 20+

2. At what age did you **start to feel comfortable** using the following languages?

English

☐ As early as I can remember ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☐ 12 ☐ 13 ☐ 14 ☐ 15 ☐ 16 ☐ 17 ☐ 18 ☐ 19 ☐ 20+ ☐ not yet

Polish

☐ As early as I can remember ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☐ 12 ☐ 13 ☐ 14 ☐ 15 ☐ 16 ☐ 17 ☐ 18 ☐ 19 ☐ 20+ ☐ not yet

3. How many years of **classes (grammar, history, math, etc.)** have you had in the following languages (primary school through university)?

English

☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☐ 12 ☐ 13 ☐ 14 ☐ 15 ☐ 16 ☐ 17 ☐ 18 ☐ 19 ☐ 20+

Polish

☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☐ 12 ☐ 13 ☐ 14 ☐ 15 ☐ 16 ☐ 17 ☐ 18 ☐ 19 ☐ 20+

4. How many years have you spent in a **country/region** where the following languages are spoken?

English

☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☐ 12 ☐ 13 ☐ 14 ☐ 15 ☐ 16 ☐ 17 ☐ 18 ☐ 19 ☐ 20+

Polish

☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☐ 12 ☐ 13 ☐ 14 ☐ 15 ☐ 16 ☐ 17 ☐ 18 ☐ 19 ☐ 20+

5. How many years have you spent in a **family** where the following languages are spoken?

English

☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☐ 12 ☐ 13 ☐ 14 ☐ 15 ☐ 16 ☐ 17 ☐ 18 ☐ 19 ☐ 20+

Polish

☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☐ 12 ☐ 13 ☐ 14 ☐ 15 ☐ 16 ☐ 17 ☐ 18 ☐ 19 ☐ 20+

6. How many years have you spent in a **work environment** where the following languages are spoken?

English

☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☐ 12 ☐ 13 ☐ 14 ☐ 15 ☐ 16 ☐ 17 ☐ 18 ☐ 19 ☐ 20+

Polish

☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11 ☐ 12 ☐ 13 ☐ 14 ☐ 15 ☐ 16 ☐ 17 ☐ 18 ☐ 19 ☐ 20+

III. Language use

In this section, we would like you to answer some questions about your language use by placing a check in the appropriate box. Total use for all languages in a given question should equal 100%.

7. In an average week, what percentage of the time do you use the following languages **with friends**?

English	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Polish	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Other languages	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%

8. In an average week, what percentage of the time do you use the following languages **with family**?

English	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Polish	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Other languages	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%

9. In an average week, what percentage of the time do you use the following languages **at school/work**?

English	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Polish	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Other languages	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%

10. When you talk to yourself, how often do you **talk to yourself** in the following languages?

English	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Polish	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Other languages	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%

11. When you count, how often do you **count** in the following languages?

English	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Polish	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Other languages	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%

IV. Language proficiency

In this section, we would like you to rate your language proficiency by giving marks from 0 to 6.

12. a. How well do you speak **English**? 0=not well at all 6=very well
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6
 b. How well do you speak **Polish**?
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6
13. a. How well do you understand **English**?
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6
 b. How well do you understand **Polish**?
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6
14. a. How well do you read **English**?
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6
 b. How well do you read **Polish**?
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6
15. a. How well do you write **English**?
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6
 b. How well do you write **Polish**?
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6

V. Language attitudes

In this section, we would like you to respond to statements about language attitudes by giving marks from 0-6.

16. a. I feel like myself when I speak **English**. 0=disagree 6=agree
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6
 b. I feel like myself when I speak **Polish**.
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6
17. a. I identify with an **English-speaking** culture.
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6
 b. I identify with a **Polish-speaking** culture.
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6
18. a. It is important to me to use (or eventually use) **English** like a native speaker.
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6
 b. It is important to me to use (or eventually use) **Polish** like a native speaker.
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6
19. a. I want others to think I am a native speaker of **English**.
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6
 b. I want others to think I am a native speaker of **Polish**.
☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6

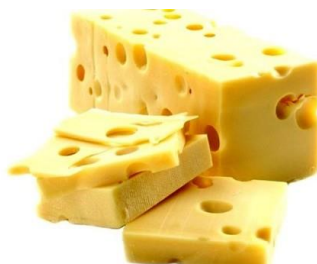
A.3 Narrative task

<https://www.youtube.com/watch?v<BVmkNuNeGhc>

The short-animated film utilized in the narrative task depicts a young and well-off woman who continuously runs into an unknown man, who appears to be homeless, at her bus stop. In the beginning the man and the woman do not like each other, but with time, they develop a friendship, until the man mysteriously disappears.

A.4 Picture-naming task

The following images were utilized in the picture-naming task during which the participants had to name the items they saw depicted on the photos using a carried phrase “*Yo digo _____.*”





A.5 Sentence-reading task

1. Habla tagalo con un hablante nativo.
2. El puré de papa me da dolor de estómago.
3. Se llama gabarro a un tumor inflamatorio.
4. Nunca peco porque soy una persona muy religiosa.
5. Muchas cavernas tienen túneles que van a otras direcciones.
6. El horrible dolor de cabeza no me deja dormir.
7. Como la pera con la boca bien abierta.
8. Quiero comprar ropa nueva para vestir a la moda.
9. Compramos el billete para viajar a Cuba mañana.
10. Mi hermano debe decir a papá que tiene malas notas.
11. Todavía no estás acabado con la carta.
12. Mi tía de Misuri dice poco, pero hace mucho.
13. Vamos a una boda en Perú la semana que viene.
14. El chico tímido tiene una risa bonita.
15. Como un taco pequeño y bebo cacao para el desayuno.
16. Muestra tu cara cobarde para, por fin, resolver este problema.
17. Mi padre tuvo dos hoteles en Gabón hace cinco años.
18. Mi mamá vio un pavo vivo por primera vez en su vida.
19. Me como solo un bocado porque no tengo hambre.
20. Tengo un vívido recuerdo de mi cariñosa abuela.
21. Este tacón está roto porque bailaste demasiado.
22. María toca la guitarra cada día en la escuela.

23. Él debe trabajar mucho para poder comprar un anillo de rubí para su novia.
24. Pedro tiene una vaca lechera y un gato negro en su finca.
25. El abogado no sabe jugar ningún deporte americano.
26. Usamos nuestro voto como la herramienta más potente para lograr un cambio.
27. Ve a la bodega y roba un par de botellas de cava.
28. Siempre me puedes pedir todo lo que necesites.
29. En clase leímos "David y el pepino gigante" que es un drama infantil muy interesante.
30. Cuando compro rímel siempre pago con mi tarjeta de crédito.
31. Es parte de mi rutina mirar una película cada fin de semana.
32. Heredó una hermosa gaveta del siglo dieciocho.
33. Ayer rompí el dedo y el codo mientras jugaba al futbol americano.
34. Este bobo no sabe nada de turismo ecológico en Costa Rica.
35. Tiene una granja de bovino lechero.
36. Antes era tabú decir algo de dopado deportivo, pero ahora no lo es.
37. Nunca tuve el más mínimo problema con ese estudiante.
38. Pienso que el piperigallo y el tulipán son las flores más bonitas de este jardín.
39. Nuestra vida siempre ha sido puro teatro.
40. La gripe es un desastre total y todavía no hay vacuna contra esta enfermedad.
41. Voy a hacerle vudú terrible a mi jefa porque ella pega furiosamente a sus empleados.
42. Encontramos una toga roja y una bota negra en su cuarto.
43. Está con el dogal al cuello.
44. En un rato vamos a cantar el coro de esta canción.
45. Se da el nombre raga al género musical de India.

46. Lara trabaja como gogó para vigilar a su novio en los clubes.
47. La ley vigente no permite echar un gapo en la calle.
48. Es una lástima que José dude que Sara rompiera su cadera la noche pasada.
49. El pueblo godo no tuvo ni una gota de paciencia con sus enemigos.
50. Mi tío es un hombre botado y es muy dado a ayudar a otras personas.
51. Has llegado al tope mi amigo y ya no puedo soportar que lleves la misma bata cada día.
52. ¿Puedes pintar al duco este picú viejo, por favor?
53. El que no tiene virtud no está bajo la tutela de nuestro padre.
54. Asegúrate de que todo esté bien pulido y que no quede una sola viruta de madera en el suelo.
55. A este petimetre le gusta comer el budín los sábados por la mañana.
56. Ponme un culín de vino en mi copa dorada, por favor.
57. Escucha a este ruletero porque es muy picudo y conoce bien la ciudad.
58. El brillante lucero que está en el cielo puede vulnerar la pupila de tu ojo.
59. En este vivero podemos encontrar numerosos tubérculos para examinar.
60. Tengo culillo del bubute que encontramos en tu cama.
61. El hermoso Cupido tiene pelo rubicundo largo y ojos azules.
62. Escribió "rúbrica" mal porque le falta una vocal en esta palabra.
63. Admiro tu apego a las reglas y no dejar pasar por la vadera a cualquier carruaje.
64. Este pitufo va a marcar un hito porque hace promesas a tutiplén a todos los ciudadanos.

A.6 Nonce words reading task

1. Yo digo desa para ti.
2. Yo digo lula para ti.
3. Yo digo noca para ti.
4. Yo digo paba para ti.
5. Yo digo tana para ti.
6. Yo digo rela para ti.
7. Yo digo gaga para ti.
8. Yo digo beta para ti.
9. Yo digo tupa para ti.
10. Yo digo dota para ti.
11. Yo digo fadola para ti.
12. Yo digo galefa para ti.
13. Yo digo mabina para ti.
14. Yo digo piluca para ti.
15. Yo digo tiroga para ti.
16. Yo digo bochaca para ti.
17. Yo digo piraga para ti.
18. Yo digo tibana para ti.
19. Yo digo gafula para ti.
20. Yo digo chufal para ti.
21. Yo digo posal para ti.
22. Yo digo soserol para ti.
23. Yo digo súbal para ti.
24. Yo digo tesora para ti.
25. Yo digo laburon para ti.
26. Yo digo mateba para ti.
27. Yo digo medín para ti.
28. Yo digo catosín para ti.
29. Yo digo bibon para ti.
30. Yo digo mítabusa para ti.
31. Yo digo pítabel para ti.
32. Yo digo tortina para ti.
33. Yo digo quetá para ti.
34. Yo digo lempega para ti.
35. Yo digo musá para ti.
36. Yo digo potorná para ti.
37. Yo digo tágul para ti.
38. Yo digo filor para ti.
39. Yo digo tandagal para ti.
40. Yo digo contabal para ti.
41. Yo digo jansoda para ti.
42. Yo digo corpulin para ti.
43. Yo digo compesil para ti.
44. Yo digo cabadon para ti.

Appendix B

Individual speaker results

B.1 Vowels

B.1.1 Ukrainian vowels

Table B.1. Mean frequencies (Hz) in Ukrainian by individual Ukrainian HS

Speaker	Phoneme	(F1) Mean/SD	(F2) Mean/SD	Total tokens
U1	/i/	410.7 / 27.4	2318.4 / 596.4	16
	/ɪ/	547.9 / 75.5	1766.8 / 293.5	28
	/ɛ/	510.5 / 82.5	1906.8 / 145.6	11
	/ɑ/	672.6 / 128.3	1428.5 / 282.4	56
	/ɔ/	497.4 / 80.4	1366.1 / 392.7	47
	/u/	459.2 / 66.3	1112.5 / 247.2	14
U2	/i/	384.2 / 30.8	2178.3 / 567	12
	/ɪ/	514.6 / 70.8	1853.3 / 129.2	16
	/ɛ/	508.7 / 66.8	1744.7 / 251.3	10
	/ɑ/	739.2 / 132.5	1603 / 296.7	37
	/ɔ/	528.7 / 105.8	1562.4 / 274.5	36
	/u/	445.8 / 32.5	1349.8 / 413.4	11
U3	/i/	390.2 / 62.7	2142 / 309.6	10
	/ɪ/	552.4 / 98.9	1814.7 / 125.6	8
	/ɛ/	544 / 75.9	1982.1 / 203.9	10
	/ɑ/	709.2 / 115.6	1665.5 / 294.4	31
	/ɔ/	579.3 / 113.6	1572.5 / 367.4	28
	/u/	501.5 / 81.4	1560.3 / 293.4	10
U4	/i/	411.7 / 50.7	2606.7 / 2606.6	24
	/ɪ/	537.1 / 87.8	1906.4 / 181.9	30
	/ɛ/	595.4 / 146.6	2007.5 / 262.1	35
	/ɑ/	717.3 / 177.8	1772.6 / 281.9	62
	/ɔ/	572.4 / 146.6	1540.7 / 255	49
	/u/	465.3 / 73.1	1260.9 / 429.3	25
U5	/i/	429.2 / 41.3	2572.3 / 250.5	20
	/ɪ/	554 / 48.2	2024 / 219.9	15
	/ɛ/	591.6 / 17.6	2042.5 / 302.6	2
	/ɑ/	678.7 / 121.9	1729.7 / 194.8	37
	/ɔ/	531.9 / 87.9	1549.8 / 369.5	37
	/u/	551.8 / 52	1490.5 / 513.2	11
U6	/i/	377.2 / 28.6	2302.1 / 281.1	22
	/ɪ/	481.6 / 54.1	1738.7 / 353.9	21
	/ɛ/	492.1 / 76.2	1822.8 / 220.7	10
	/ɑ/	614.7 / 107.5	1593.9 / 268.7	43
	/ɔ/	463.4 / 81.4	1663 / 355.7	40
	/u/	458 / 57.3	1658 / 313.3	13

B.1.2 Polish vowels

Table B.2. Mean frequencies (Hz) in Polish by individual Polish HS

Speaker	Phonem e	(F1) Mean/SD)	(F2) Mean/SD	Total tokens
P1	/i/	424.3 / 42.4	2350.3 / 369.3	17
	/i/	500.8 / 29.7	1746.1 / 114.6	13
	/ε/	533.9 / 59.8	1802.8 / 225.9	19
	/a/	641.6 / 64.9	1563.8 / 157	42
	/ɔ/	577.9 / 72.7	1391.5 / 187.2	22
	/u/	464.3 / 45.6	1348.6 / 267.7	9
P2	/i/	398.6 / 76.5	2178.8 / 233.8	10
	/i/	526 / 50.5	1614.2 / 257.4	20
	/ε/	518.5 / 72.6	1765.1 / 173.7	36
	/a/	643.9 / 58.1	1497.5 / 205.3	51
	/ɔ/	546.9 / 64.3	1237.5 / 147.4	40
	/u/	438.4 / 57.9	1087.9 / 223.5	13
P3	/i/	468.3 / 82	2565.1 / 194.6	24
	/i/	549.9 / 65.9	1944.5 / 159.7	21
	/ε/	626.6 / 75.6	1996.3 / 215.7	20
	/a/	755.4 / 53	1670.3 / 247.6	37
	/ɔ/	652.4 / 85	1258.9 / 312.5	36
	/u/	395.6 / 104.7	921.2 / 61.3	5
P4	/i/	422.9 / 43	2467.8 / 147.2	15
	/i/	498.9 / 49.9	1767.8 / 232.2	13
	/ε/	531.3 / 112.9	1879.7 / 136.8	13
	/a/	674.4 / 91.6	1587.5 / 146.5	18
	/ɔ/	550.2 / 83.5	1501.7 / 173.1	18
	/u/	404.9 / 22.2	1121.5 / 309.8	8
P5	/i/	472 / 34.4	2312 / 403.5	11
	/i/	538.1 / 63.8	1517.2 / 619.3	10
	/ε/	574.4 / 71.1	1960.3 / 212.2	16
	/a/	686.1 / 65.4	1612.9 / 361.8	27
	/ɔ/	610.6 / 89.2	1319.2 / 483.9	30
	/u/	NA	NA	0
P6	/i/	388.5 / 40.5	2567.2 / 171.7	9
	/i/	433.1 / 106.7	1698.7 / 448.6	8
	/ε/	501.8 / 109.6	2159.5 / 286.2	20
	/a/	755.5 / 107.6	1764.5 / 172	29
	/ɔ/	547.9 / 124.2	1351 / 327.8	21
	/u/	426.4 / 77.2	1250.5 / 459.1	7
P7	/i/	397.3 / 34.3	2512.5 / 280	13
	/i/	465.8 / 80	1821.6 / 322.9	11
	/ε/	521.7 / 51.9	1939.7 / 317.3	14
	/a/	656.2 / 59.8	1587.8 / 130.6	25
	/ɔ/	569 / 74	1303.2 / 209.9	18
	/u/	406.7 / 10.4	1370.1 / 155.3	2
P8	/i/	417.7 / 61.3	2092.5 / 387.7	6
	/i/	533.4 / 108.9	1992.6 / 196	9

	/ɛ/	608.7 / 153.8	1952.6 / 259.3	17
	/a/	802.3 / 76.6	1687.9 / 179.2	34
	/ɔ/	743.4 / 88.8	1434 / 333.1	16
	/u/	579.4 / 101	1608.8 / 456.4	4
P9	/i/	390.1 / 41.9	2192.8 / 254.3	5
	/i/	479.6 / 35.5	1766 / 163.9	6
	/ɛ/	547.3 / 44.5	1749.5 / 239.5	17
	/a/	642.1 / 77.1	1484.3 / 247.5	33
	/ɔ/	572.4 / 74.9	1379.9 / 278.9	21
	/u/	552.8 / 75.5	1278.9 / 354	4
P10	/i/	462.7 / 51.1	2244.5 / 491.7	19
	/i/	504.7 / 77.5	1980.1 / 294.6	17
	/ɛ/	569.9 / 73.3	2001.2 / 294.4	18
	/a/	751.7 / 92.2	1508.3 / 248.4	43
	/ɔ/	617.6 / 76.2	1288 / 269	37
	/u/	463.8 / 29.1	1443 / 359.2	8
P11	/i/	326.1 / 37.5	2199.1 / 264.8	5
	/i/	290.4 / 48	2157.4 / 385.8	5
	/ɛ/	522.6 / NA	1935.6 / NA	1
	/a/	590.3 / 141.3	1373.3 / 254.2	9
	/ɔ/	395.9 / 18.7	891.7 / 90.5	4
	/u/	334.4 / 30.9	1317.3 / 548	5

B.1.3 English vowels

Table B.3. Mean frequencies (Hz) in English by individual L1 English speaker

Speaker	Phoneme	(F1) Mean/SD	(F2) Mean/SD	Total tokens
E1	/i/	383.3 / 54.7	1886.1 / 224.3	17
	/ e /	520.2 / NA	1892.3 / NA	1
	/ɪ/	312.8 / 69.7	2109.1 / 158.4	5
	/ɛ/	621.4 / 92.5	1637.3 / 207.6	11
	/æ/	636.6 / 91.3	1798 / 118.1	8
	/ɑ/	797.3 / 108.3	1591.6 / 154.7	3
	[ə]	426.7 / 90.4	1794.7 / 270.8	21
	/ʌ/	623.5 / 151.4	1667.7 / 548.7	8
	/ɔ/	706.7 / 95.4	1433.7 / 475.7	8
	/o/	598.7 / 36.2	1166.5 / 57.1	3
	/ʊ/	558.5 / NA	1380.2 / NA	1
	/u/	378.1 / 18.5	1660.3 / 310.5	3
E2	/i/	475.7 / 88.3	2019.8 / 401.4	14
	/ e /	500.7 / 45.2	2322.5 / 35.2	3
	/ɪ/	605.6 / 74.5	1550.4 / 237.5	5
	/ɛ/	712.2 / 61	1782.7 / 292.2	9
	/æ/	777.8 / 116.3	1740.9 / 216	4
	/ɑ/	862.1 / 87.7	1405 / 375.1	5
	[ə]	506.2 / 93.6	1806 / 431.7	11
	/ʌ/	706.8 / 78.2	1484.5 / 305.3	9
	/ɔ/	NA	NA	NA

	/o/	597.2 / 77.1	1318 / 141	2
	/o/	585 / 51	1113.4 / 297	2
	/u/	482.3 / 21.2	1424.1 / 362.7	3
E3	/i/	416.7 / 92.5	2428.7 / 487.3	14
	/e/	650.6 / 227.2	2467.5 / 439.2	2
	/ɪ/	384.3 / 60	2021.9 / 333.1	4
	/ɛ/	782.3 / 128.9	1789.8 / 212.6	13
	/æ/	739.6 / 186.3	2153.3 / 253.4	2
	/ɑ/	944.8 / 23.1	1728.4 / 25	2
	[ə]	547.3 / 93.2	1614.6 / 324.7	8
	/ʌ/	711.3 / 116.3	1697.3 / 145	9
	/ɔ/	551.9 / 76.9	1600.1 / 563.5	2
	/o/	629.5 / 40.5	1559.9 / 100.3	2
	/ʊ/	635.2 / 89.7	1315.5 / 255.8	3
	/u/	422.9 / 20.9	1705.4 / 630.6	2
E4	/i/	393.4 / 84.7	2259.9 / 272	20
	/e/	558.1 / 11.2	2021 / 25.9	2
	/ɪ/	389.5 / 36.7	2156.5 / 205.8	4
	/ɛ/	646.9 / 123.1	1970.1 / 171.1	6
	/æ/	736.4 / 62.6	1778.2 / 218.9	5
	/ɑ/	657 / 75.6	1555 / 271.5	4
	[ə]	523.6 / 97.6	1725.5 / 324.8	14
	/ʌ/	662 / 106.6	1622.4 / 304.2	5
	/ɔ/	659.7 / 115.6	1339.8 / 428.8	7
	/o/	493.4 / 133.2	1242.7 / 545.7	2
	/ʊ/	577.1 / 21	1387.4 / 84.4	2
	/u/	393.2 / 39.3	1970.7 / 153.9	3
E5	/i/	329.8 / 40.5	2328.4 / 718.3	3
	/e/	454.7 / NA	1912.5 / NA	1
	/ɪ/	NA	NA	0
	/ɛ/	561.3 / 66.7	1798.6 / 334.4	6
	/æ/	514.5 / 176.6	1939.1 / 169.4	4
	/ɑ/	425.2 / 153.6	1553.1 / 85.7	2
	[ə]	496.3 / 92.2	1653.3 / 196.2	9
	/ʌ/	590.6 / 107.5	1638.4 / 81.2	8
	/ɔ/	590.2 / NA	1324.7 / NA	1
	/o/	480.7 / NA	1548.9 / NA	1
	/ʊ/	533 / 100.5	2031.2 / 429.5	2
	/u/	NA	NA	0

Table B.4. Mean frequencies (Hz) in English by individual L1 Spanish speaker

Speaker	Phoneme	(F1) Mean / SD	(F2) Mean / SD	Tokens
S1	/i/	409.2 / 34.5	2432.4 / 289.2	31
	/e/	537.7 / 48.5	1782.3 / 306.3	6
	/ɪ/	508.5 / 114.2	1997.1 / 427.5	7
	/ɛ/	613.7 / 111.4	1843.7 / 376.3	16
	/æ/	815 / 107.9	1696.6 / 166	9

	/ɑ/	731.8 / 193	1475.2 / 333.2	11
	[ə]	481.1 / 69.6	1740.3 / 290.3	25
	/ʌ/	617.7 / 107.8	1560.2 / 260	12
	/ɔ/	539.1 / 39.6	1951.9 / 269.5	6
	/o/	533.9 / 56.3	1623.9 / 196	8
	/ʊ/	NA	NA	0
	/u/	483.8 / 63.2	1519.1 / 405.1	5
S2	/i/	351.6 / 42.9	2157.9 / 312.1	22
	/e/	364.6 / 56.2	1727.2 / 261.6	10
	/ɪ/	426.2 / NA	1701 / NA	1
	/ɛ/	436.2 / 68.5	1700.1 / 120.7	12
	/æ/	459.2 / 129.1	1656.2 / 85.9	5
	/ɑ/	464.8 / 72.5	1346.8 / 207.5	7
	[ə]	405.2 / 79.9	1609.3 / 290	12
	/ʌ/	455.8 / 37.9	1526.9 / 140.8	5
	/ɔ/	438.8 / NA	1485.7 / NA	1
	/o/	387.3 / 18.7	1741.4 / 242.1	2
	/ʊ/	401.9 / 44.4	1628.2 / 566	5
	/u/	351.2 / 17.2	1896.5 / 61.7	4
S3	/i/	290.9 / 30.2	2250.1 / 120.7	18
	/e/	416.3 / 109.8	1603.4 / 228.7	8
	/ɛ/	475.7 / 112.4	1729.3 / 276	11
	/ɑ/	546.1 / 67.1	1445.9 / 461.7	6
	[ə]	364.5 / 93.4	1825.7 / 228.1	22
	/ʌ/	529.9 / 159.6	1346.6 / 471.4	9
	/ɔ/	495.8 / 163.8	1220.5 / 507.4	8
	/o/	396.3 / 92.9	1438.8 / 524.8	8
	/ʊ/	373 / 33.6	1337.3 / 349.7	4
	/u/	374 / 75.4	1846.5 / 254.6	4
S4	/i/	399.5 / 25.6	2340.7 / 462.7	11
	/e/	537.1 / 121.4	2199.7 / 506.2	3
	/ɪ/	395.1 / 18.6	2269 / 74.1	3
	/ɛ/	649.8 / 76.3	1923.4 / 165.6	3
	/æ/	858.6 / 44.9	1769.5 / 120.6	3
	/ɑ/	760.1 / 2.6	1642.1 / 12.4	2
	[ə]	477 / 72.3	1800.2 / 266.2	7
	/ʌ/	677.5 / 106.6	1678.9 / 216.6	5
	/ɔ/	558.3 / NA	1748.5 / NA	1
	/o/	544.8 / 114	1441.2 / 190	2
	/u/	334.9 / NA	1214.3 / NA	1
S5	/i/	396.1 / 48.1	2381.5 / 239	51

	/e/	488.3 / 24.6	1814.7 / 201.2	3
	/ɪ/	404.1 / 58.6	2241.2 / 200.7	6
	/ɛ/	561.6 / 56.4	1898.3 / 313.6	20
	/æ/	704.7 / 105	1732.6 / 143.4	13
	/ɑ/	673.7 / 84.8	1592.8 / 223.5	14
	[ə]	495.3 / 83.7	1801.3 / 197.8	51
	/ʌ/	627.9 / 99.9	1622.9 / 214.5	20
	/ɔ/	525.1 / 80.4	1247.6 / 456	16
	/o/	521.4 / 53.7	1218.4 / 453.3	3
	/ʊ/	470.9 / 43.9	1135.6 / 491.3	5
	/u/	392.7 / 41.7	1890.1 / 571.6	10

Table B.5. Mean frequencies (Hz) in English by individual Ukrainian HSs

Speaker	Phoneme	F1	F2	Tokens
U1	/i/	432.3 / 46.3	2435.2 / 406.9	18
	/e/	553.5 / 36.7	2083.6 / 219.9	3
	/ɪ/	423.3 / NA	2110.6 / NA	1
	/ɛ/	765.4 / 105.2	1929.3 / 95.6	7
	/æ/	825.3 / 123.1	2080.9 / 180.9	2
	/ɑ/	753.1 / 148.6	1649.2 / 176.3	7
	[ə]	511.4 / 91.9	1779.4 / 333.9	17
	/ʌ/	694 / 121.9	1608.1 / 316.4	9
	/ɔ/	653.4 / 67.2	1129.7 / 72.9	3
	/o/	656.4 / NA	1372.5 / NA	1
	/ʊ/	642.1 / 15.7	1219.6 / 51.1	3
	/u/	451.8 / NA	1063.9 / NA	1
U2	/i/	414.9 / 59.7	2081.2 / 336.9	13
	/e/	582.6 / 118.7	1681.9 / 347	5
	/ɪ/	355.1 / 11.4	2541.9 / 61	2
	/ɛ/	689.3 / 32.5	1745.1 / 213.5	4
	/æ/	783.1 / 124.4	1816.8 / 38.2	2
	/ɑ/	813.7 / 158.1	1750.3 / 35.2	5
	[ə]	448.5 / 68.6	1930.5 / 275.7	16
	/ʌ/	677.5 / 108.2	1450.6 / 206.7	10
	/ɔ/	575.9 / 108.8	1139.4 / 189.2	4
	/o/	510.8 / 105.3	1314 / 369.2	3
	/ʊ/	477.5 / NA	1600.9 / NA	1
	/u/	366.7 / NA	958.4 / NA	1
U3	/i/	372.7 / 44.2	2308.1 / 410	11
	/e/	650.3 / 109.4	1794.3 / 226.8	8
	/ɪ/	363.4 / 18.4	1981.8 / 297.8	4
	/ɛ/	714.5 / 83.6	1896.7 / 123.6	7

	/æ/	744.9 / 72.1	1773.6 / 160.4	3
	/ɑ/	718.6 / 73.6	1696.5 / 130.8	8
	[ə]	497.1 / 147.1	1772.6 / 182.3	15
	/ʌ/	708.9 / 50.5	1484.1 / 128.7	13
	/ɔ/	697.9 / 76.4	1631.3 / 272.5	2
	/o/	638.5 / 50	1413.3 / 197	3
	/ʊ/	724.3 / 62.5	930.3 / 52.1	2
	/u/	667.3 / 160.6	2099.2 / 212.6	2
U4	/i/	405 / 42.8	2303.7 / 318.8	37
	/e/	504.4 / 42	1500 / 488.7	8
	/ɪ/	495.8 / 112.1	1792.3 / 407.6	6
	/ɛ/	716.9 / 94.3	1783.2 / 76	8
	/æ/	753.4 / 234	2055.6 / 138.5	6
	/ɑ/	838.2 / 144.4	1611.2 / 99.9	7
	[ə]	537.3 / 155.1	1823.9 / 229.3	13
	/ʌ/	602.9 / 111.1	1638.4 / 197.2	13
	/ɔ/	663.9 / 110.5	1375.4 / 338	5
	/o/	586 / 82.7	1562 / 224.4	4
	/ʊ/	618.2 / 63.2	1381.2 / 63.9	4
	/u/	436.8 / 61.3	1633.8 / 507.2	6
U5	/i/	433 / 26.1	2488.8 / 275.6	11
	/e/	588.5 / 11.6	1624.6 / 306.1	4
	/ɪ/	587.5 / NA	1905.1 / NA	1
	/ɛ/	646.8 / 58.8	1834 / 118.1	6
	/æ/	809.4 / 102.5	1906.4 / 126.6	6
	/ɑ/	620.6 / NA	1770.4 / NA	1
	[ə]	497.5 / 74.4	2353.3 / 540.3	3
	/ʌ/	600.5 / 66.5	1690.6 / 93.6	3
	/ɔ/	656.6 / 103.6	1186.4 / 513.4	2
	/o/	628.3 / NA	1150.5 / NA	1
	/ʊ/	626.5 / 32.4	1229.5 / 115.2	3
	/u/	450.2 / NA	1554.9 / NA	1
U6	/i/	399.4 / 51.1	2200.5 / 202.6	23
	/e/	464.1 / 24.2	1840.3 / 272.5	2
	/ɪ/	377.6 / 6	2322.6 / 71.7	2
	/ɛ/	590.3 / 80.7	1703.7 / 218.9	11
	/æ/	658.8 / 39.2	1773.1 / 70.4	5
	/ɑ/	433.1 / 93.5	1692.4 / 2.9	2
	[ə]	416.7 / 63.8	1856.9 / 284.6	11
	/ʌ/	581.1 / 87.4	1607.4 / 231.7	14
	/ɔ/	550.4 / 143.1	1156 / 429.7	4

	/o/	559 / 53.5	1370 / 434	3
	/ɔ/	491 / 49.8	1060.4 / 320.5	3
	/u/	403.5 / 22.8	1361.1 / 679.8	3

Table B.6. Mean frequencies (Hz) in English by individual Polish HS

Speaker	Phoneme	F1	F2	Tokens
P1	/i/	407.4 / 48.9	2186.6 / 283.2	11
	/e/	494.9 / 21	1679.8 / 300.6	6
	/ɪ/	411.4 / 21.5	2135.4 / 258.4	2
	/ɛ/	666.3 / 91	1697.4 / 164.7	8
	/æ/	755.6 / 52.7	1565.9 / 199.3	4
	/ɑ/	691.7 / 103.6	1549.3 / 159.5	4
	[ə]	461 / 42.8	1741.5 / 197.1	7
	/ʌ/	584.1 / 52.7	1483.1 / 210.1	10
	/ɔ/	614.4 / 47.4	1260.8 / 273.3	4
	/o/	585.2 / 38.9	1617.8 / 164.1	2
	/ʊ/	560 / 51.2	1452.5 / 376.1	2
	/u/	NA	NA	0
P2	/i/	407.4 / 79.2	2047.4 / 335.9	21
	/e/	588.8 / 40.9	1601.5 / 568.3	4
	/ɪ/	360.1 / 28.5	2137.8 / 179.1	4
	/ɛ/	613.2 / 64.9	1683.8 / 136.2	13
	/æ/	656.8 / 99.6	1815.8 / 78.9	7
	/ɑ/	662.9 / 52.1	1560.6 / 169.6	6
	[ə]	471.2 / 78	1552.3 / 303.2	15
	/ʌ/	587.6 / 80.3	1504 / 198.9	11
	/ɔ/	678 / 39.6	1267.5 / 332.4	3
	/o/	603.4 / 39.3	1231.7 / 44.7	2
	/ʊ/	603.2 / 40.1	1197.2 / 118.8	2
	/u/	372.1 / 103.8	1695.4 / 438.2	4
P3	/i/	447 / 73.1	2320.5 / 312.3	22
	/e/	646 / 52.6	1647.6 / 514.8	10
	/ɪ/	374.5 / NA	2684.3 / NA	1
	/ɛ/	756.6 / 60.7	1744.2 / 203.5	17
	/æ/	720.7 / 76.4	1978.3 / 353.2	9
	/ɑ/	772 / 75.3	1373.5 / 157.2	6
	[ə]	530.1 / 85.3	1794.3 / 236.1	20
	/ʌ/	703.9 / 84.3	1399.4 / 205.1	16
	/ɔ/	687 / 96.8	1101.3 / 102.7	5
	/o/	590.4 / 124.1	1136.7 / 202.2	2
	/ʊ/	554.2 / 97.7	1027.2 / 217.9	7
	/u/	537.8 / NA	1101.1 / NA	1

P4	/i/	425.4 / 25	2263.9 / 230.4	11
	/e/	548.4 / 56.1	1366.9 / 212.1	4
	/ɪ/	457.3 / 36.9	1897 / 184.2	2
	/ɛ/	645.2 / 102.7	1930.6 / 253.8	3
	/æ/	670.6 / NA	1782.2 / NA	1
	/ɑ/	719.4 / 117.7	1519 / 150	3
	[ə]	535.7 / 26.9	1631.2 / 209.2	8
	/ʌ/	619.7 / 85.2	1554.3 / 125.1	8
	/ɔ/	914 / 153	1727.2 / 540.2	2
	/o/	592.9 / 60.1	1650.3 / 222.3	2
	/ʊ/	580.7 / 46.8	1154.7 / 282.1	2
	/u/	429.1 / 28.9	2045.5 / 213.7	5
P5	/i/	469.8 / 34.9	2034.4 / 600.2	8
	/e/	560.5 / 88.6	1734.1 / 348.5	6
	/ɪ/	429.5 / NA	2519.3 / NA	1
	/ɛ/	679.8 / 70.9	1686.5 / 393.5	8
	/æ/	NA	NA	0
	/ɑ/	732.6 / 72.4	1426.3 / 468.3	3
	[ə]	531.3 / 101.8	1583.5 / 451.2	8
	/ʌ/	688.7 / 42.1	1162.9 / 203	5
	/ɔ/	470.8 / NA	632.9 / NA	1
	o	689.8 / NA	1504.9 / NA	1
	/ʊ/	556.9 / 64.2	1385 / 566.6	2
	/u/	NA	NA	0
P6	/i/	379.1 / 37.2	2297.4 / 403.2	17
	/e/	468 / 77.4	1671.2 / 225	3
	/ɪ/	496.5 / 145.7	2115.7 / 268.9	5
	/ɛ/	590.3 / 136.1	1876.4 / 101.4	7
	/æ/	719 / 95.9	1918 / 320	3
	/ɑ/	757.8 / 51.5	1798.3 / 103.5	2
	[ə]	461.3 / 152.3	2016.3 / 401.9	5
	/ʌ/	580.3 / 170.5	1791.8 / 91.8	8
	/ɔ/	464.4 / 77.7	1226.8 / 448.5	2
	/o/	NA	NA	0
	/ʊ/	571.9 / 144.2	1591.6 / 346.1	5
	/u/	422 / 96.2	1924.1 / 265.4	5
P7	/i/	374.1 / 21.8	2207.3 / 244.9	6
	/e/	582.3 / 129.1	1605.7 / 305.7	5
	/ɪ/	512.7 / 220.7	1774.6 / 72.8	2
	/ɛ/	712.4 / 41.5	1635 / 86.8	4
	/æ/	638 / 61	1864.2 / 237.1	3

	/ɑ/	773.1 / 75.1	1557.2 / 33.8	2
	[ə]	527.3 / 50.1	1524.5 / 214.3	4
	/ʌ/	575.7 / 109.7	1441.9 / 248.6	6
	/ɔ/	682.9 / 30.8	1138.1 / 111.1	3
	/o/	NA	NA	0
	/ʊ/	602.6 / 32.5	1156.4 / 55	2
	u	478.9 / NA	1508.1 / NA	1
P8	/i/	420.5 / 83.5	2107.2 / 333.1	16
	/e/	524.9 / 128.7	2094.7 / 531.8	11
	/ɪ/	482.8 / 75.9	2072.4 / 375	2
	/ɛ/	772.7 / 119.3	1790.2 / 204.4	7
	/æ/	843.1 / 96.6	1880 / 90.3	5
	/ɑ/	895.9 / 34.5	1487.9 / 166	2
	[ə]	578.6 / 159.8	1697.7 / 157.2	12
	/ʌ/	737.7 / 52.5	1492.3 / 203.3	8
	/ɔ/	687.2 / 118.4	1439 / 222.9	7
	/o/	681.7 / 51.8	1419.4 / 1.8	2
	/ʊ/	496.4 / 126.9	1623.8 / 403.9	3
	/u/	684.1 / NA	1342.2 / NA	1
P9	/i/	375.7 / 37.9	2308.6 / 187.7	15
	/e/	472.2 / 44.9	1831.6 / 450.9	7
	/ɪ/	NA	NA	0
	/ɛ/	606.3 / 53.3	1665.9 / 227.8	6
	/æ/	570.2 / 42.4	1859.3 / 84.5	7
	/ɑ/	679.9 / 84	1552.9 / 182.5	5
	[ə]	451.6 / 65.7	1679.3 / 265.2	14
	/ʌ/	616 / 72.9	1269.7 / 123.8	6
	/ɔ/	539.4 / 5.9	1296.9 / 82.9	2
	/o/	514.8 / 35.1	1141.1 / 103.2	4
	/ʊ/	482.4 / NA	1344.9 / NA	1
	/u/	451.8 / 18.7	1642.3 / 343.6	4
P10	/i/	444.7 / 73.8	2315.1 / 261.2	10
	/e/	586.3 / 62.1	1861 / 433.2	12
	/ɪ/	403.1 / 37.5	2445.6 / 8.5	2
	/ɛ/	738.6 / 87.4	1708.1 / 199	10
	/æ/	689.3 / 154	2014.7 / 429.5	3
	/ɑ/	788.7 / 80.9	1491.6 / 346.1	11
	[ə]	565.7 / 83.7	1784.1 / 210.8	10
	/ʌ/	630.9 / 88.8	1403.5 / 305.5	7
	/ɔ/	655.3 / 96.1	1115.2 / 104.2	4
	/o/	589.3 / 53.1	1239.2 / 217.3	7

	/ɔ/	571.1 / 104.5	1386.4 / 382.6	4
	/u/	428.9 / NA	2350.7 / NA	1
P11	/i/	306.8 / 72.3	1966.4 / 503	8
	/e/	535.7 / 134.4	1425 / 478.3	4
	/ɪ/	386.6 / 114.8	1828.9 / 707.1	2
	/ɛ/	585.8 / 73	1528.9 / 161.7	10
	/æ/	578.2 / 123.9	1706.2 / 273.7	5
	/ɑ/	688.6 / 21.7	1376 / 213.7	5
	[ə]	428.9 / 96.3	1425.9 / 396.9	12
	/ʌ/	654 / 45.4	1187 / 168.9	8
	/ɒ/	621.7 / 61.6	1084.3 / 326.2	5
	/o/	471.2 / NA	1014.4 / NA	1
	/ɔ/	501.4 / 95.3	971.8 / 207.6	6
	/u/	364.4 / NA	933.5 / NA	1

B.1.4 Spanish vowels

Table B.7. Mean frequencies (Hz) in Spanish produced by individual L1 Spanish speaker in the narrative task

Speaker	Phoneme	F1 (Mean / SD)	F2 (Mean / SD)	Tokens
S1	/i/	403.1 / 31.6	2364.9 / 568.5	21
	/e/	507.3 / 41.8	2062.9 / 241.6	90
	/a/	695.9 / 135.4	1737.4 / 171.4	59
	/o/	533.5 / 53.6	1250.6 / 272.6	73
	/u/	436.9 / 38.4	1361.4 / 345.5	21
S2	/i/	348.9 / 35.5	2275.8 / 283.9	19
	/e/	387.9 / 34.1	1888.4 / 215.3	31
	/a/	480.6 / 208.9	1701.7 / 267.1	39
	/o/	383 / 93.2	1451.1 / 276.7	24
	/u/	323.4 / 36.1	1375.4 / 218.9	6
S3	/i/	313.6 / 33	2134.8 / 175.9	29
	/e/	369.7 / 64	1764.9 / 225.1	48
	/a/	457.9 / 116.6	1527.2 / 223.5	68
	/o/	447.1 / 130.8	1341.7 / 461.4	44
	/u/	324.8 / 102.8	1515.9 / 433.5	7
S4	/i/	395.9 / 49.3	2311.8 / 409.2	18
	/e/	531.6 / 79	2095.5 / 217.9	38
	/a/	718 / 107.7	1833.9 / 70.6	28
	/o/	583 / 122.3	1411.5 / 402.9	23
	/u/	424 / 41.9	1228 / 362.9	5
S5	/i/	394.2 / 33.8	2476.9 / 183.5	19

	/e/	485 / 47.9	1986.9 / 201.5	65
	/a/	611.6 / 85.7	1675.4 / 162.5	69
	/o/	507.3 / 44.4	1290.1 / 324.2	44
	/u/	434.2 / 43.8	1302.8 / 412.1	19

Table B.8. Mean frequencies (Hz) in Spanish produced by individual L1 Spanish speaker in the picture-naming task

Speaker	Phoneme	F1 (Mean / SD)	F2 (Mean / SD)	Tokens
S1	/i/	387.9 / 23.8	2466.2 / 518.1	14
	/e/	507.4 / 43.9	2161.2 / 298.6	23
	/a/	749.8 / 107.5	1715.2 / 157.1	37
	/o/	530.1 / 33.4	1063 / 195.9	25
	/u/	408.8 / 44.6	1147.4 / 184.7	9
S2	/i/	366.1 / 29.3	2175.2 / 307.1	13
	/e/	427.9 / 39.7	1825.4 / 144.2	23
	/a/	492.4 / 63.7	1631.5 / 172	36
	/o/	444.5 / 39.6	1236.7 / 292.8	22
	/u/	372.8 / 36.1	1738.8 / 397.7	10
S3	/i/	309.9 / 36.4	2103.7 / 98	11
	/e/	418.2 / 50.2	1802.4 / 182.2	21
	/a/	489.6 / 82.2	1378.3 / 188.7	36
	/o/	432 / 59.6	1038.1 / 304.7	21
	/u/	310.6 / 36.8	1258.9 / 352.1	10
S4	/i/	428.3 / 42.2	2591.1 / 150.8	13
	/e/	517.3 / 46	2073.5 / 206.7	20
	/a/	786.6 / 120.1	1786.2 / 88.8	34
	/o/	534.7 / 50.5	1264.7 / 278.5	19
	/u/	425.5 / 43.2	1288.4 / 249.9	10
S5	/i/	394.9 / 48.7	2501.1 / 164.9	12
	/e/	510.2 / 40.5	2044.6 / 135.4	21
	/a/	652.2 / 78.5	1677.8 / 289.3	34
	/o/	492.3 / 57.4	1072.9 / 183.9	21
	/u/	402.5 / 36.5	1240.9 / 446.1	10

Table B.9. Mean frequencies (Hz) in Spanish produced by individual L1 Spanish speaker in the sentence-reading task

Speaker	Phoneme	F1 (Mean / SD)	F2 (Mean / SD)	Tokens
S1	/i/	408.6 / 36	2604.7 / 349.3	37
	/e/	508 / 26	2067.4 / 178.6	39
	/a/	757.5 / 84.6	1663.3 / 104.6	72
	/o/	517.9 / 33.2	1151.1 / 210.6	80
	/u/	432.7 / 33.5	1110 / 256.4	37

S2	/i/	346.5 / 34.5	2269 / 237.8	39
	/e/	404.4 / 43.9	1858.5 / 137.1	38
	/a/	477 / 76.9	1634.4 / 165	73
	/o/	416.7 / 41.8	1284.7 / 330	79
	/u/	370.6 / 34.5	1411.3 / 379.9	37
S3	/i/	301.8 / 26.7	2151.4 / 283.8	39
	/e/	380.5 / 41.5	1706.8 / 132.9	39
	/a/	552.4 / 81.1	1385 / 179.7	73
	/o/	403.3 / 48.8	1004.5 / 223.6	82
	/u/	325.9 / 32.4	1019.8 / 249.9	37
S4	/i/	417.5 / 39.8	2469.3 / 470.9	39
	/e/	554.6 / 46.1	2110.9 / 194.2	38
	/a/	773 / 63.6	1788 / 91.9	74
	/o/	564.6 / 60.4	1241.5 / 311.2	82
	/u/	446.4 / 47.3	1180.5 / 379.5	37
S5	/i/	392.2 / 31.1	2391.7 / 308.1	39
	/e/	491.6 / 47.6	2056.4 / 132.6	39
	/a/	651 / 75.9	1624.7 / 228.2	73
	/o/	498.5 / 46.2	1157.5 / 300.7	82
	/u/	398.6 / 35.3	1242.4 / 359.1	37

Table B10. Mean frequencies (Hz) in Spanish produced by individual L1 Spanish speaker in the nonce words reading task

Speaker	Phoneme	F1 (Mean / SD)	F2 (Mean / SD)	Tokens
S1	/i/	367.8 / 27.4	1907.5 / 969.9	10
	/e/	511.7 / 31.9	2222.9 / 228.1	11
	/a/	782 / 105.1	1653.1 / 97.2	47
	/o/	528.1 / 35.2	1080.9 / 118.5	11
	/u/	395 / 29.8	1037.2 / 215.7	10
S2	/i/	357.4 / 19.4	2287.4 / 243.6	10
	/e/	425.9 / 42.8	1872.4 / 97.2	11
	/a/	452.1 / 83.8	1539.2 / 154.9	48
	/o/	420.4 / 36.1	1225.5 / 107.3	11
	/u/	391.7 / 35.3	1483.5 / 419.4	9
S3	/i/	291.8 / 25.2	2151.9 / 270.9	10
	/e/	385.1 / 28	1788.1 / 93.6	11
	/a/	530.5 / 75.5	1343.2 / 179.3	48
	/o/	409 / 36.2	1123.3 / 168.6	11
	/u/	343.6 / 74.4	1246.5 / 440.9	9
S4	/i/	382.1 / 58	2173.9 / 798.9	10
	/e/	522.1 / 46.3	2206.1 / 150.1	11
	/a/	798.9 / 80.7	1759.3 / 92	48

S5	/o/	561.4 / 59.6	1166.7 / 169	11
	/u/	437.2 / 19.5	988.6 / 310.1	10
	/i/	375.7 / 43.4	2426.3 / 354	10
	/e/	472.8 / 54.2	2045 / 137.7	12
	/a/	640.7 / 50.3	1576.3 / 179.2	48
	/o/	497.9 / 54	1086.9 / 199.2	10
	/u/	421.4 / 26.2	1156.1 / 507.4	10

Table B.11. Mean frequencies (Hz) in Spanish produced by individual L1 English speaker in the narrative task

Speaker	Phoneme	F1 (Mean / SD)	F2 (Mean / SD)	Tokens
E1	/i/	325.4 / 35.7	2221.8 / 279.8	29
	/e/	518.5 / 86.2	1873.5 / 166	55
	/a/	686.3 / 62.5	1545.6 / 211.2	29
	/o/	592.1 / 100.6	1364.7 / 411.2	32
	/u/	535.1 / 93.1	2090.1 / 330.6	5
E2	/i/	429.4 / 20.5	2457.9 / 587	6
	/e/	607.4 / 59.5	1531.4 / 441.5	8
	/a/	845.3 / 56.5	1392.4 / 191.8	14
	/o/	640.9 / 44.7	1286 / 116	7
	/u/	468.7 / 46.7	1121.5 / 92.8	5
E3	/i/	374.7 / 51.3	2709.4 / 400.8	7
	/e/	548.2 / 74.9	2115.6 / 229.8	20
	/a/	759.5 / 82.9	1666.6 / 83.8	24
	/o/	559.5 / 89	1288.4 / 230.1	13
	/u/	500.9 / 64.9	1691.7 / 218.8	6
E4	/i/	378.1 / 59.4	2416.8 / 292	22
	/e/	555.7 / 94.4	1931.4 / 267.9	29
	/a/	659.9 / 94.7	1588.6 / 281.8	30
	/o/	526.1 / 113	1254 / 402.9	19
	/u/	370.2 / 71.2	1735.1 / 555.8	8
E5	/i/	383.6 / 33.4	2569 / 332.5	8
	/e/	534.1 / 101.6	2232 / 424.1	12
	/a/	624.9 / 110	1680.8 / 148.4	19
	/o/	573.7 / 109.9	1247.2 / 266.9	12
	/u/	324.8 / 53.9	1096.5 / 207.5	9

Table B.12. Mean frequencies (Hz) in Spanish produced by individual L1 English speaker in the picture-naming task

Speaker	Phoneme	F1 (Mean / SD)	F2 (Mean / SD)	Tokens
E1	/i/	336.2 / 59	2104.5 / 240	11
	/e/	489.9 / 78.1	1852 / 226.3	15

	/a/	670 / 112.5	1511.3 / 141.6	29
	/o/	533.4 / 40.8	1286.2 / 275.7	15
	/u/	343.5 / 61.2	1802.4 / 197.1	9
E2	/i/	450.3 / 56.1	2304.2 / 332.5	12
	/e/	567.2 / 64.9	1842.5 / 446.8	14
	/a/	804.4 / 111.4	1578.8 / 340.6	27
	/o/	581.5 / 51.4	1203.8 / 152.8	15
	/u/	471.8 / 81.9	1675.4 / 289.4	10
E3	/i/	464.1 / 67.6	2351.3 / 381	9
	/e/	559.2 / 63.9	1981.3 / 317.2	12
	/a/	688 / 96.6	1657.1 / 124.3	20
	/o/	520.9 / 65.6	1241 / 169.6	14
	/u/	460.6 / 54.3	1569.2 / 318.6	7
E4	/i/	434.2 / 82.9	2149.6 / 254.3	11
	/e/	586.6 / 66	1952.5 / 248.3	17
	/a/	690.1 / 104.4	1628.6 / 254.6	29
	/o/	559.2 / 71.9	1272.2 / 263.1	19
	/u/	483.4 / 76.8	1875.3 / 214.2	10
E5	/i/	378.3 / 97.6	2566.7 / 326.2	10
	/e/	528.7 / 75.7	2074 / 232.3	15
	/a/	684.6 / 72	1570.7 / 157.7	28
	/o/	564.4 / 81.9	1212.9 / 216.2	16
	/u/	372.7 / 61.6	1586.4 / 431.5	8

Table B.13. Mean frequencies (Hz) in Spanish produced by individual L1 English speaker in the sentence-reading task

Speaker	Phoneme	F1 (Mean / SD)	F2 (Mean / SD)	Tokens
E1	/i/	326.3 / 36.4	2168.8 / 198.6	39
	/e/	500.7 / 56.9	1807.1 / 205.5	39
	/a/	664.2 / 69.3	1499.1 / 112.8	73
	/o/	544.7 / 47	1153.2 / 264.6	80
	/u/	349.6 / 52	1353.8 / 334	36
E2	/i/	441.2 / 38.7	2574.6 / 293.1	38
	/e/	622.6 / 94.3	2165.3 / 426.8	39
	/a/	824.6 / 73.6	1414.1 / 326.9	73
	/o/	538.1 / 46.2	985.4 / 53.6	82
	/u/	440.4 / 50.8	1267.7 / 373.1	36
E3	/i/	412.6 / 71.9	2499 / 434.5	37
	/e/	579.4 / 45.3	2077.5 / 170.3	38
	/a/	780.9 / 74.3	1612.7 / 111	74
	/o/	576.9 / 50.2	1127.4 / 156.6	82
	/u/	400.8 / 45	1241.4 / 332.9	36

E4	/i/	355.7 / 59.7	2366.3 / 173.1	39
	/e/	573 / 61.3	1987.7 / 136.9	38
	/a/	680.8 / 102.6	1666.2 / 152.7	74
	/o/	571.4 / 62.9	1191.8 / 270.1	81
	/u/	403.7 / 69.7	1464.7 / 501.5	37
E5	/i/	346.1 / 62.4	2526.8 / 221.4	38
	/e/	557.3 / 77.4	2060.7 / 188.4	39
	/a/	683.4 / 58.7	1625.7 / 143.3	73
	/o/	585.7 / 58.6	1193.4 / 198	81
	/u/	347.9 / 48.7	1332.6 / 404	37

Table B.14. Mean frequencies (Hz) in Spanish produced by individual L1 English speaker the nonce words reading task

Speaker	Phoneme	F1 (Mean / SD)	F2 (Mean / SD)	Tokens
E1	/i/	286.3 / 26.2	2190 / 145.1	9
E1	/e/	501.3 / 36.7	1901.3 / 121.1	11
E1	/a/	676.6 / 68.3	1475.1 / 89.6	51
E1	/o/	560 / 96.9	1207 / 279.5	10
E1	/u/	354.9 / 68	1262.1 / 484.1	9
E2	/i/	478.2 / 90.6	2579.1 / 455.1	10
E2	/e/	587.1 / 74.7	2238.3 / 339.4	10
E2	/a/	828 / 79.1	1424.8 / 324.1	48
E2	/o/	551.4 / 76.5	1186.1 / 326.1	11
E2	/u/	412.7 / 9.9	1047.5 / 87.6	10
E3	/i/	424 / 63.3	2493.3 / 453.6	10
E3	/e/	536.3 / 63.9	2220.5 / 324.4	11
E3	/a/	899.1 / 120.7	1610.8 / 104.8	48
E3	/o/	534.8 / 42	1135.2 / 127.6	11
E3	/u/	405.9 / 24.9	1255 / 427.6	10
E4	/i/	378.1 / 45.8	2396.9 / 227.9	10
E4	/e/	523.6 / 41.1	2067.5 / 257.9	11
E4	/a/	723.4 / 99.5	1629.9 / 199.4	48
E4	/o/	540.5 / 72.3	1189.1 / 282.8	11
E4	/u/	434.4 / 49.6	1371.4 / 503.3	10
E5	/i/	395 / 43.2	2594.2 / 222.3	10
E5	/e/	493.9 / 61.8	2206.4 / 334.9	11
E5	/a/	687.7 / 50.7	1586.1 / 80.5	49
E5	/o/	528.9 / 74.3	1211.6 / 253.4	11
E5	/u/	356.3 / 55.7	996.2 / 257.5	9

Table B.15. Mean frequencies (Hz) in Spanish produced by individual Ukrainian HS in the narrative task

Speaker	Phoneme	F1 (Mean / SD)	F2 (Mean / SD)	Tokens
U1	/i/	412.9 / 46.5	2338.7 / 495.5	11
	/e/	581.4 / 52.6	2149.4 / 228.8	23
	/i/	719.6 / 120.7	1597.7 / 259.6	26
	/o/	620.7 / 58.6	1212.6 / 160.4	20
	/u/	439.9 / 21.2	947.8 / 150.4	3
U2	/i/	385.3 / 40.4	2542.9 / 214.4	18
	/e/	504.6 / 76.5	2144 / 269.5	24
	/i/	728.5 / 91.8	1770.8 / 191.3	37
	/o/	516.1 / 64.4	1253.9 / 201.5	22
	/u/	444.5 / 41.6	1190.1 / 184.2	8
U3	/i/	415.5 / 52.5	2452.9 / 276	11
	/e/	632.3 / 84.8	2035.1 / 254.4	19
	/i/	786.9 / 143.5	1616.6 / 185.6	28
	/o/	602.3 / 67.8	1393.4 / 177.2	13
	/u/	534.3 / 127.2	1509 / 168.7	6
U4	/i/	417.4 / 31.7	2584 / 303.2	10
	/e/	558.1 / 79.6	2247.8 / 248	42
	/i/	713.5 / 114.8	1735.7 / 199	40
	/o/	581.8 / 82.2	1293.3 / 260.6	22
	/u/	494.7 / 43.6	1636.7 / 249.2	6
U5	/i/	432.1 / 25.3	2606.8 / 293.6	16
	/e/	560.7 / 40.4	2224.1 / 222.8	25
	/i/	668.4 / 69.5	1660.9 / 237.5	21
	/o/	600.7 / 25.5	1372.1 / 258.9	22
	/u/	517.5 / 72.4	1486.5 / 522.6	5
U6	/i/	391.6 / 42.6	2452.9 / 156.6	26
	/e/	470.8 / 47.3	1908.2 / 171.1	43
	/i/	565.8 / 106.2	1675.7 / 274.8	55
	/o/	529 / 41.3	1247.4 / 285.7	29
	/u/	398.2 / 66.9	1157.2 / 403.7	8

Table B.16. Mean frequencies (Hz) in Spanish produced by individual Ukrainian HS in the picture-naming task

Speaker	Phoneme	F1 (Mean / SD)	F2 (Mean / SD)	Tokens
U1	/i/	424.6 / 24.8	2520.8 / 554	10
	/e/	589.4 / 45.8	2040.4 / 129.5	11
	/i/	747.4 / 128.9	1619.2 / 243.2	17
	/o/	586 / 36.4	1073.5 / 68.1	7
	/u/	431.2 / 51.9	1154 / 151.7	4
U2	/i/	405.2 / 38.3	2565 / 124.1	11

	/e/	549.4 / 79.4	2182.7 / 227.7	18
	/i/	798.5 / 100	1643.9 / 193	34
	/o/	562.1 / 70.7	1127.2 / 197.3	19
	/u/	428.2 / 49.8	1255 / 106.6	10
U3	/i/	393.6 / 59.6	2312.7 / 436.4	10
	/e/	653.5 / 135	1969.2 / 145.6	12
	/i/	790.8 / 62.7	1693.6 / 171.4	20
	/o/	623.1 / 68.4	1056.9 / 110.1	11
	/u/	448.9 / 50.4	1309.1 / 439.9	7
U4	/i/	412.8 / 41.2	2427.7 / 232.1	10
	/e/	556 / 144	2174 / 202.7	15
	/i/	711.9 / 123.1	1717.4 / 177.9	30
	/o/	492.1 / 76.1	1274.2 / 217.1	15
	/u/	423.9 / 36.9	1478.1 / 214.3	10
U5	/i/	449.2 / 51.8	2508 / 212.1	9
	/e/	581.6 / 42.3	2115.5 / 243.4	16
	/i/	695.3 / 47.3	1750.8 / 110.3	25
	/o/	591.8 / 82.3	1268.9 / 361.5	15
	/u/	455.6 / 59.9	1919.3 / 391.4	8
U6	/i/	392.7 / 51.5	2442.8 / 242.1	9
	/e/	482.3 / 56.2	1940.1 / 149.9	18
	/i/	596.2 / 129.4	1599.2 / 207.8	31
	/o/	467 / 40	1171.2 / 271.5	19
	/u/	392.7 / 51.6	1384.8 / 313	10

Table B.17. Mean frequencies (Hz) in Spanish produced by individual Ukrainian HS in the sentence-reading task

Speaker	Phoneme	F1 (Mean / SD)	F2 (Mean / SD)	Tokens
U1	/i/	409.3 / 52.6	2658.4 / 398.6	38
	/e/	622.3 / 86.5	2049.9 / 168.6	39
	/i/	762.3 / 118.8	1509.2 / 156.5	74
	/o/	591.1 / 55.2	1147.6 / 106.4	82
	/u/	436.3 / 34.2	1055.2 / 243.3	37
U2	/i/	378.3 / 22.3	2067.9 / 322.9	39
	/e/	531.7 / 43.7	2031.4 / 157.8	38
	/i/	714.9 / 128.3	1717.4 / 100.7	74
	/o/	553.8 / 50.7	1283.9 / 227.7	82
	/u/	418.1 / 31.9	1364.6 / 297.6	37
U3	/i/	374.5 / 49.8	2424.7 / 359	36
	/e/	644.4 / 99.7	1945.7 / 117.7	38
	/i/	756.7 / 66.9	1699.1 / 154.4	73
	/o/	620.1 / 69.6	1284.7 / 356.6	81

	/u/	466.9 / 54.6	1322.6 / 428	31
U4	/i/	352.6 / 49.8	2633.4 / 228.4	39
	/e/	582.3 / 106.6	2109.6 / 334.9	39
	/i/	800.7 / 138.3	1647.2 / 163.7	74
	/o/	554.6 / 52.6	1234.8 / 145.7	82
	/u/	405.3 / 51.7	1277 / 279	36
U5	/i/	408.7 / 35.7	2613.6 / 114.9	39
	/e/	559.4 / 55.5	2188.7 / 194.5	39
	/i/	675.9 / 43.9	1724.6 / 116	74
	/o/	599.9 / 42	1276.3 / 361.5	82
	/u/	445.1 / 36.5	1276.8 / 451.3	36
U6	/i/	366.4 / 31.5	2352.4 / 258.8	39
	/e/	475.8 / 30.6	2023.7 / 126.5	39
	/i/	576.1 / 90.9	1552.3 / 143	72
	/o/	484.2 / 46.7	1136.8 / 334.9	83
	/u/	391.4 / 27.5	1452.9 / 356.6	37

Table B.18. Mean frequencies (Hz) in Spanish produced by individual Ukrainian HS in the nonce words reading task

Speaker	Phoneme	F1 (Mean / SD)	F2 (Mean / SD)	Tokens
U1	/i/	427.1 / 24.9	2691.9 / 194.5	10
	/e/	605.6 / 32.6	2089 / 185.9	11
	/i/	774.4 / 85.3	1477.9 / 116.7	48
	/o/	592.4 / 63.7	1133.9 / 80.4	11
	/u/	431.6 / 21.9	931.2 / 128	10
U2	/i/	383.7 / 19	2154.5 / 378.5	10
	/e/	526.2 / 29.6	2069 / 149.7	11
	/i/	746.3 / 147.5	1669.7 / 101.9	48
	/o/	538.1 / 50.6	1377.4 / 132	11
	/u/	393.9 / 37.6	1418.8 / 360.2	10
U3	/i/	380.7 / 42.3	2425.6 / 370.5	10
	/e/	699.9 / 57.6	1968.8 / 88.8	10
	/i/	787 / 59.3	1645.4 / 208.4	48
	/o/	652 / 42.8	1141.6 / 147.2	11
	/u/	461.3 / 30	1301 / 434	10
U4	/i/	374.2 / 59.2	2510.3 / 277.4	10
	/e/	476 / 78.7	2427.1 / 260.3	11
	/i/	748.1 / 75.2	1654.2 / 101.9	48
	/o/	576.9 / 78.6	1323.8 / 198.9	11
	/u/	417.7 / 55.4	1173.9 / 553.8	10
U5	/i/	398.3 / 42.3	2669.7 / 97.5	10
	/e/	583.4 / 53.8	2211.9 / 235.9	11

U6	/i/	690 / 50	1667.4 / 163.7	48
	/o/	598 / 38.1	1476.4 / 424	11
	/u/	424.6 / 42.3	1247.1 / 586.1	10
	/i/	351.3 / 40.3	2505.2 / 312.7	10
	/e/	485.2 / 30.4	2115.9 / 151.7	11
	/i/	715.5 / 88.1	1698.3 / 111.5	48
	/o/	496.7 / 40.1	1176.5 / 251	11
	/u/	382.8 / 37.3	1372.8 / 520.9	10

Table B.19. Mean frequencies (Hz) in Spanish by produced by individual Polish HS in the narrative task

Speaker	Phoneme	F1 (Mean / SD)	F2 (Mean / SD)	Tokens
P1	/i/	395.2 / 34	2335.8 / 362.1	20
	/e/	559 / 53.9	1968.2 / 199.3	22
	/i/	688.9 / 87.7	1528.2 / 162.7	44
	/o/	571.9 / 48.5	1206.1 / 183.6	22
	/u/	421.9 / 35.9	1159.3 / 361.3	7
P2	/i/	352.4 / 31.9	2158.7 / 242.7	5
	/e/	520.5 / 50	1994.3 / 162.4	14
	/i/	647.6 / 52.3	1557 / 142.2	9
	/o/	571.5 / 47.6	1140.6 / 403.3	10
	/u/	561.9 / NA	2100 / NA	1
P3	/i/	404.6 / 34.1	2565 / 211	13
	/e/	560.2 / 146.1	2245.1 / 236.4	3
	/i/	786.7 / 60.5	1661.9 / 204.8	7
	/o/	558.7 / 72.9	1371.9 / 345.5	7
	/u/	413.2 / NA	905.8 / NA	1
P4	/i/	414.7 / 41.2	2385.2 / 446	6
	/e/	626.1 / NA	2230.7 / NA	1
	/i/	685.9 / 97.8	1703.8 / 125.8	11
	/o/	542.4 / 57	1421.9 / 158.5	4
	/u/	NA	NA	0
P5	/i/	461.8 / 54.7	2413.5 / 88.6	19
	/e/	603.9 / 56.1	2058 / 113	13
	/a/	728.1 / 45.5	1647.8 / 197.3	32
	/o/	609.9 / 68.9	1162.9 / 388.9	14
	/u/	583.1 / 77.2	2281.6 / 108.8	4
P6	/i/	388.3 / 40.8	2715 / 237	11
	/e/	530.5 / 67	2253.4 / 253.9	16
	/a/	815.4 / 84.7	1703 / 83.5	22
	/o/	567.3 / 86.6	1379.7 / 273.2	10
	/u/	473.5 / 124.5	1500.1 / 503.5	7
P7	/i/	394.7 / 35.9	2598.7 / 263.5	11

	/e/	582.1 / 92.4	2015.1 / 248.1	21
	/a/	712.8 / 64.6	1640.5 / 138	22
	/o/	554.8 / 89.2	1228.2 / 274.2	15
	/u/	461.9 / 77.4	1029.2 / 426.4	4
P8	/i/	369.2 / 48	2000 / 373.9	24
	/e/	540.4 / 130.5	2023.2 / 364	28
	/a/	825.8 / 130.7	1640.1 / 125.1	35
	/o/	681 / 126.1	1319.3 / 204.5	29
	/u/	498.2 / 162.5	1357.8 / 395.3	13
P9	/i/	375 / 49.7	2339.6 / 147.5	9
	/e/	504.1 / 44.3	1831.8 / 261.2	21
	/a/	608.4 / 81.5	1458.9 / 289	26
	/o/	553.1 / 40.6	1030 / 89.3	16
	/u/	481.4 / 78.5	1151.4 / 439.7	8
P10	/i/	468.5 / 26.7	1997.5 / 70.7	3
	/e/	595.9 / 73.9	2063.1 / 228.1	17
	/a/	752 / 79.7	1549.8 / 248.6	11
	/o/	565.1 / 71.1	1192.5 / 108.7	5
	/u/	NA	NA	1
P11	/i/	317.5 / 55.2	2156.6 / 201.1	14
	/e/	457 / 81.9	1823 / 219.9	27
	/a/	588.3 / 80.1	1467.4 / 121.5	18
	/o/	607.4 / 104.6	1361.6 / 491.3	22
	/u/	412.6 / 60.4	956.8 / 283.7	7

Table B.20. Mean frequencies (Hz) in Spanish produced by individual Polish HS in the picture-naming task

Speaker	Phoneme	F1 (Mean / SD)	F2 (Mean / SD)	Tokens
P1	/i/	381.8 / 19.2	2365.4 / 45.2	9
	/e/	550.7 / 66.1	1907.8 / 186.2	14
	/a/	699.9 / 68.2	1415.3 / 247.5	20
	/o/	526.9 / 51.2	1119.5 / 156.8	10
	/u/	431.3 / 30.3	1254.4 / 445.8	7
P2	/i/	372.6 / 23.7	2295.7 / 261.1	11
	/e/	538.6 / 58.5	1777.2 / 350.8	12
	/a/	618 / 55.4	1533.6 / 385.8	26
	/o/	509.9 / 91.5	1149.3 / 408.4	15
	/u/	397.5 / 16.4	1251.8 / 538.2	8
P3	/i/	453.4 / 70.6	2548.9 / 174	9
	/e/	644.5 / 44.6	1884.4 / 224.8	10
	/a/	786.1 / 39.4	1477.1 / 154.3	19
	/o/	614.9 / 83.2	1289.5 / 187.6	6

	/u/	448.4 / 34.3	1549.3 / 433.4	6
P4	/i/	394.3 / 61.6	2527.5 / 198.9	9
	/e/	567.8 / 102.3	2032.7 / 250.9	12
	/a/	677 / 87.2	1711.8 / 180.4	18
	/o/	556.8 / 55.4	1330.7 / 252.9	6
	/u/	404.9 / 37.3	1274.6 / 95.5	4
P5	/i/	428.2 / 60.8	2327.9 / 186.7	12
	/e/	580.6 / 99	2004.1 / 157.3	17
	/a/	693.6 / 67.8	1647.2 / 161	29
	/o/	572.1 / 75.3	1267.9 / 465	14
	/u/	421.2 / 26.5	1512.3 / 547.5	8
P6	/i/	387.8 / 43.3	2266.4 / 401.6	11
	/e/	578.3 / 104.3	2041.3 / 191.7	15
	/a/	767.4 / 93	1728.3 / 130.1	28
	/o/	551.3 / 91.6	1444.7 / 303.8	14
	/u/	420.9 / 85.2	1641.1 / 190.4	8
P7	/i/	395 / 28.6	2439.6 / 256.6	14
	/e/	555.7 / 57.7	1970.3 / 172	17
	/a/	696.8 / 58.2	1588 / 118.8	33
	/o/	544.4 / 50.4	1163.1 / 227	16
	/u/	407.2 / 40.4	1410.3 / 247.5	10
P8	/i/	399 / 54.1	2229.1 / 281.7	12
	/e/	577.4 / 144.7	2046.9 / 205.4	14
	/a/	853.9 / 66.6	1651.5 / 136.4	23
	/o/	630.8 / 148.5	1170.1 / 232.6	12
	/u/	469.2 / 85.7	1490.4 / 243.6	7
P9	/i/	393.3 / 43.8	2237.5 / 113.9	10
	/e/	526.2 / 64.8	1791.6 / 273.5	14
	/a/	634.4 / 77.1	1413.8 / 337.9	21
	/o/	548.9 / 57.9	1099 / 242.4	16
	/u/	433.2 / 26.7	1291 / 627.8	9
P10	/i/	415.7 / 25.4	2496.8 / 130.7	7
	/e/	598.8 / 71.7	1955.1 / 110.2	9
	/a/	811.4 / 68.3	1484 / 237.1	18
	/o/	581.4 / 82.9	1064 / 228.6	14
	/u/	477.6 / 35.4	1359.8 / 280.1	6
P11	/i/	332.2 / 53.7	2284.6 / 240.5	12
	/e/	494.2 / 68.7	1803.6 / 226.2	16
	/a/	607.2 / 73.6	1409.5 / 170.8	30
	/o/	493.8 / 72.1	959.7 / 160.8	19
	/u/	386.6 / 35.3	1228.3 / 378.3	10

Table B.21. Mean frequencies (Hz) in Spanish produced by individual Polish HS in the sentence-reading task

Speaker	Phoneme	F1 (Mean / SD)	F2 (Mean / SD)	Tokens
P1	/i/	384.5 / 18.4	2415.1 / 156.6	37
	/e/	556.8 / 39.5	1851.8 / 119.6	39
	/a/	681 / 54.2	1516.2 / 110.1	72
	/o/	553.8 / 28.6	1199.9 / 113.5	80
	/u/	416 / 32.5	1133.9 / 211.4	37
P2	/i/	363 / 34.3	2238.4 / 395.4	39
	/e/	509 / 59	1836.8 / 213.5	39
	/a/	638.3 / 42.6	1422.7 / 210.1	74
	/o/	547.8 / 36.9	1023.9 / 96.3	82
	/u/	396 / 29	1094.9 / 237.1	36
P3	/i/	405.3 / 43.6	2394.7 / 468.3	38
	/e/	668.8 / 76.5	1726.1 / 402.2	38
	/a/	777.9 / 74.1	1376.1 / 306.7	74
	/o/	642.9 / 66.9	1104.1 / 205.9	80
	/u/	440.2 / 42.4	1079.5 / 270.6	37
P4	/i/	390.6 / 44.8	2749.1 / 271.9	38
	/e/	600.9 / 53.1	1899.8 / 144.5	39
	/a/	704.9 / 87.4	1651.1 / 135.6	74
	/o/	579.5 / 57.2	1213.6 / 241.8	82
	/u/	409 / 35.8	1137.3 / 351.5	37
P5	/i/	412.8 / 31.5	2460.9 / 174.6	39
	/e/	601.3 / 51.9	2003.2 / 132.4	38
	/a/	702 / 54.6	1559.9 / 258	74
	/o/	602.8 / 47.8	1053.2 / 247.7	82
	/u/	427.7 / 41.9	1126.7 / 446.6	37
P6	/i/	362.8 / 57.6	2557.1 / 270.8	39
	/e/	589.8 / 86.9	2165.3 / 188.2	39
	/a/	802.8 / 60.8	1711.8 / 180.1	74
	/o/	607 / 80	1167.4 / 313.6	82
	/u/	414 / 59	1180.5 / 378.4	37
P7	/i/	377.5 / 36.8	2577.8 / 264.3	39
	/e/	550.5 / 65.2	1920 / 133.8	39
	/a/	709.9 / 49.9	1526.6 / 100.7	74
	/o/	568.4 / 37.3	1192.7 / 120.3	82
	/u/	403.9 / 30.5	1064.2 / 205.7	37
P8	/i/	374.8 / 73.7	1950.3 / 415.2	38
	/e/	658.3 / 101	1873.5 / 208.4	38
	/a/	854.4 / 66.7	1627.1 / 145.2	74
	/o/	740.9 / 75.8	1314.8 / 274.8	82

	/u/	461.8 / 72.3	1369.2 / 335	37
P9	/i/	376.2 / 33	2287.4 / 292.4	39
	/e/	535.2 / 52.2	1699.4 / 266.5	38
	/a/	651.3 / 44.4	1377.2 / 174.2	74
	/o/	540 / 27.5	1028.1 / 91.5	83
	/u/	415.6 / 44.6	901.6 / 239.1	37
P10	/i/	407.7 / 41.7	2314.1 / 410.4	35
	/e/	606.5 / 52.6	1939.9 / 127	28
	/a/	737.5 / 43	1415.9 / 169.4	70
	/o/	562.4 / 59.6	966.7 / 153.9	78
	/u/	460.4 / 46.5	975.8 / 369.1	36
P11	/i/	311.8 / 38.2	2227.4 / 228.4	36
	/e/	487.7 / 80.3	1860.8 / 151.6	39
	/a/	650.3 / 63.6	1409.4 / 145.6	74
	/o/	536.9 / 63.4	1042.5 / 338.9	79
	/u/	362.3 / 52.9	1086.3 / 323.5	35

Table B.22. Mean frequencies (Hz) in Spanish produced by individual Polish HS in the nonce words reading task

Speaker	Phoneme	F1 (Mean / SD)	F2 (Mean / SD)	Tokens
P1	/i/	380.6 / 16.4	2412.3 / 103.1	10
	/e/	545.2 / 37.6	1941.2 / 124.3	11
	/a/	705.9 / 58	1555.4 / 112.9	48
	/o/	550.2 / 59.2	1262.8 / 165.4	11
	/u/	409.1 / 11.5	1145.4 / 428.3	10
P2	/i/	368.4 / 22.1	2185.3 / 388.2	10
	/e/	527.6 / 49.3	1915.6 / 147	11
	/a/	658.2 / 48.5	1471.1 / 230	47
	/o/	538.7 / 65.2	1118.5 / 80.3	11
	/u/	383.6 / 27	1102.6 / 233	11
P3	/i/	414.5 / 22.5	2682.9 / 184.8	10
	/e/	697.6 / 46.8	1798.6 / 316.6	10
	/a/	807.4 / 60.9	1492.6 / 225.3	48
	/o/	611.6 / 54.6	1186 / 97.8	11
	/u/	408.4 / 40.3	1038.7 / 166.3	10
P4	/i/	398.6 / 28.8	2800 / 162.8	10
	/e/	552 / 89.8	1972 / 176.1	11
	/a/	725.7 / 97.7	1636.7 / 85.1	48
	/o/	558.8 / 71.9	1279.6 / 139.2	11
	/u/	403.9 / 22	1123.3 / 384.4	10
P5	/i/	439.1 / 45.9	2424.8 / 94.4	10
	/e/	603.5 / 70.6	2119.1 / 252	10

	/a/	722.2 / 56	1416.1 / 261	47
	/o/	607.6 / 28.4	963 / 227.2	11
	/u/	448.7 / 64.6	1093.8 / 563.1	10
P6	/i/	368 / 52.7	2486.4 / 397.7	10
	/e/	607.4 / 75.3	2116.6 / 201	11
	/a/	817.8 / 57.3	1581.5 / 204.8	47
	/o/	577.1 / 52.6	1072.2 / 182.3	11
	/u/	430.2 / 97.4	1323.8 / 405.3	9
P7	/i/	392.5 / 35.4	2578.2 / 351.8	10
	/e/	559.7 / 44	1993.8 / 140.8	11
	/a/	712.7 / 43.2	1544.9 / 74	48
	/o/	557 / 43.2	1249.3 / 90.3	11
	/u/	401.7 / 34.9	1081.6 / 401.6	10
P8	/i/	307.1 / 32.5	1977.6 / 352.6	10
	/e/	651.7 / 91	1936.4 / 132.7	11
	/a/	886.4 / 69.8	1606.5 / 205.6	48
	/o/	672.2 / 100	1346.4 / 237.5	11
	/u/	424.9 / 104.5	1218.8 / 361.5	10
P9	/i/	368.5 / 34.5	2330.8 / 187.4	10
	/e/	526.6 / 84.6	1772.4 / 338.1	10
	/a/	668.7 / 49.5	1236.7 / 194	47
	/o/	539.9 / 62.9	996.6 / 92.3	12
	/u/	410.3 / 21.7	1001 / 456.6	10
P10	/i/	409.9 / 74.4	2676.9 / 190.2	9
	/e/	612.3 / 66.8	2078.2 / 82.4	9
	/a/	785.9 / 59.4	1487 / 160.2	47
	/o/	570.5 / 56.1	959.2 / 112.9	10
	/u/	424.8 / 76.4	879.6 / 419.2	8
P11	/i/	325.2 / 28	2248.8 / 167.1	10
	/e/	476.2 / 56.7	2000.1 / 216.2	11
	/a/	665.9 / 64	1394.2 / 101	48
	/o/	490.6 / 26.8	927.6 / 211	11
	/u/	361.7 / 65.1	734.3 / 150	10

B.2 Voiceless stops

The following tables summarize the mean VOT measurements, along with standard deviations, and token counts for each speaker.

B.2.1 Ukrainian voiceless stops

Table B.23. Mean VOT values (ms) in Ukrainian produced by individual Ukrainian HS

Speaker	Phoneme	Mean / SD	Tokens
U1	/p/	22.6 / 7.8	7
	/t/	17.1 / 6	24
	/k/	30.5 / 8.6	8
U2	/p/	94.7 / 19.4	2
	/t/	46.2 / 21.6	12
	/k/	47.3 / 20.3	6
U3	/p/	20 / 5.6	7
	/t/	21.5 / 4.6	7
	/k/	25.2 / 9.5	9
U4	/p/	16.8 / 7.6	11
	/t/	19.8 / 5.3	31
	/k/	30.5 / 13.7	23
U5	/p/	20.9 / 9.4	6
	/t/	23.6 / 6.4	12
	/k/	25.4 / 15	6
U6	/p/	24 / 6.5	4
	/t/	23 / 8	21
	/k/	30.3 / 5.7	3

B.2.2 Polish voiceless stops

Table B.24. Mean VOT values (ms) in Polish produced by individual Polish HS

Speaker	Phoneme	Mean / SD	Tokens
P1	/p/	35.8 / 9.2	6
	/t/	30 / 8.8	5

	/k/	42.9 / 12.2	8
P2	/p/	30 / 10.2	11
	/t/	34.1 / 10.4	11
	/k/	37.2 / 11.8	9
P3	/p/	26.1 / 16.6	14
	/t/	27.1 / 9.9	22
	/k/	49.1 / 18	11
P4	/p/	25.3 / NA	1
	/t/	40.3 / 8	10
	/k/	52.3 / 14.2	5
P5	/p/	42 / 15.2	6
	/t/	37.7 / 9.9	5
	/k/	40.3 / 17.6	10
P6	/p/	25.9 / 7.1	8
	/t/	28.7 / 12.6	15
	/k/	37.5 / 11.4	6
P7	/p/	27.1 / 14.1	3
	/t/	25.4 / 12.8	7
	/k/	31.7 / 16	6
P8	/p/	NA	NA
	/t/	23.3 / 9.4	14
	/k/	31.2 / 8.9	8
P9	/p/	17.9 / 10.2	4
	/t/	20.2 / 7.5	9
	/k/	26.4 / 7.1	7
P10	/p/	13.9 / 3.7	14

P11	/t/	19.4 / 4.8	21
	/k/	22.3 / 7.4	11
	/p/	53.4 / 17	9
	/t/	29.8 / 10.9	4
	/k/	49.8 / NA	1

B.2.3 English voiceless stops

Table B.25. Mean VOT values (ms) in English produced by individual L1 English speaker

Speaker	Phoneme	Mean / SD	Tokens
E1	/p/	39.1 / 14.6	4
	/t/	44.1 / 13.7	9
	/k/	40.1 / 8.8	8
E2	/p/	NA	NA
	/t/	91.5 / 12.1	2
	/k/	NA	NA
E3	/p/	68.7 / NA	1
	/t/	80.7 / 3.9	2
	/k/	70.5 / 21	7
E4	/p/	NA	NA
	/t/	121.3 / 23	6
	/k/	92.2 / 25.5	2
E5	/p/	96.9 / NA	1
	/t/	58.8 / NA	1
	/k/	NA	NA

Table B.26. Mean VOT values (ms) in English produced by individual L1 Spanish speaker

Speaker	Phoneme	Mean / SD	Tokens
S1	/p/	68.6 / 32.5	4
	/t/	65.6 / 21.2	13
	/k/	73.9 / 21.7	18
S2	/p/	25.2 / 10.6	4
	/t/	49.9 / 21.1	5
	/k/	47.6 / 16	7
S3	/p/	26.1 / 7.4	6
	/t/	46.3 / 25	14
	/k/	80.6 / 41	8
S4	/p/	53.5 / NA	1
	/t/	59.2 / 5.3	4
	/k/	62.3 / 12.7	4
S5	/p/	42.1 / 23.3	10
	/t/	37 / 16.4	17
	/k/	49.3 / 22.6	11

Table B.27. Mean VOT values (ms) in English produced by individual Ukrainian HS

Speaker	Phoneme	Mean / SD	Tokens
U1	/p/	81.2 / 5.8	3
	/t/	88.9 / 72.4	6
	/k/	54.6 / NA	1
U2	/p/	47.2 / 13.9	3
	/t/	81.5 / 30.4	9
	/k/	71.2 / 15.7	4
U3	/p/	33 / NA	1
	/t/	64.8 / 17.4	7

	/k/	39.8 / 5.9	7
U4	/p/	85 / NA	1
	/t/	56.1 / 17.8	10
	/k/	62.5 / 8.1	8
U5	/p/	35.3 / NA	1
	/t/	48.2 / 11.5	5
	/k/	54.2 / 8.8	3
U6	/p/	43.6 / NA	1
	/t/	40.8 / 16.5	9
	/k/	50.8 / 8.2	5

Table B.28. Mean VOT values (ms) in English produced by individual Polish HS

Speaker	Phoneme	Mean / SD	Tokens
P1	/p/	44.2 / 15.1	3
	/t/	56.5 / 23.2	5
	/k/	68.1 / 6.7	4
P2	/p/	43.2 / 30.9	2
	/t/	64.2 / 28.4	9
	/k/	63.2 / 14	7
P3	/p/	75.5 / 42.4	2
	/t/	78.9 / 33.9	6
	/k/	110.8 / 38.1	3
P4	/p/	97.4 / NA	1
	/t/	85.6 / 26.1	6
	/k/	62.2 / 47.9	4
P5	/p/	35.8 / 15	5
	/t/	97.1 / 68.7	2

	/k/	72 / 20.3	4
P6	/p/	74 / NA	1
	/t/	56.1 / NA	1
	/k/	51.1 / 2.8	3
P7	/p/	70.4 / NA	1
	/t/	52.2 / 2.9	2
	/k/	63.9 / NA	1
P8	/p/	66.3 / NA	1
	/t/	66.2 / 37.6	5
	/k/	49.1 / 16.7	5
P9	/p/	31.5 / 8.6	5
	/t/	54 / 12.7	7
	/k/	42.8 / 14	4
P10	/p/	31.6 / 1.5	3
	/t/	53.4 / 14.4	5
	/k/	38.1 / 11.3	9
P11	/p/	21.4 / 2.3	3
	/t/	82.9 / 17.5	7
	/k/	62.5 / 4.9	2

B.2.4 Spanish voiceless stops

Table B.29. Mean VOT values (ms) in Spanish produced by individual L1 Spanish speaker in the narrative task

Speaker	Phoneme	Mean / SD	Tokens
S1	/p/	13.8 / 6.2	27
	/t/	16.2 / 6.6	20
	/k/	25.4 / 8.6	50

S2	/p/	15.8 / 6	13
	/t/	24.8 / 9.8	10
	/k/	29.9 / 9.6	17
S3	/p/	19.7 / 8.9	21
	/t/	20.2 / 6.4	15
	/k/	32.7 / 13.2	34
S4	/p/	14.2 / 3.9	18
	/t/	14.8 / 2.7	7
	/k/	33.6 / 13.7	15
S5	/p/	14.7 / 4.5	21
	/t/	15.4 / 4.9	18
	/k/	22.9 / 6.1	32

Table B.30. Mean VOT values (ms) in Spanish produced by the L1 Spanish speaker in the picture-naming task

Speaker	Phoneme	Mean / SD	Tokens
S1	/p/	8.2 / 1.2	5
	/t/	12.3 / 5.9	14
	/k/	37.8 / 11.7	14
S2	/p/	15.2 / 4.8	6
	/t/	26.3 / 9	13
	/k/	26.7 / 10.8	11
S3	/p/	14.2 / 5.2	6
	/t/	14.8 / 3.9	13
	/k/	29.2 / 9.3	11
S4	/p/	11.7 / 4.5	6
	/t/	18.6 / 6.4	14
	/k/	31.7 / 7.7	11

S5	/p/	10 / 2.2	6
	/t/	17.4 / 5.1	13
	/k/	26.7 / 6.7	11

Table B.31. Mean VOT values (ms) in Spanish produced by individual L1 Spanish speaker in the sentence-reading task

Speaker	Phoneme	Mean / SD	Tokens
S1	/p/	13.6 / 14.1	36
	/t/	13.7 / 6.7	44
	/k/	31.5 / 11.3	33
S2	/p/	18.9 / 5.7	36
	/t/	26.1 / 7.2	44
	/k/	31.1 / 8.3	33
S3	/p/	13.8 / 4.8	37
	/t/	15.8 / 4.3	44
	/k/	29 / 9.4	33
S4	/p/	14 / 4	37
	/t/	16.3 / 5	43
	/k/	29.3 / 11.4	33
S5	/p/	14.1 / 6.7	37
	/t/	15.7 / 5.1	44
	/k/	30.1 / 7.8	33

Table B.32. Mean VOT values (ms) in Spanish produced by individual L1 Spanish speaker in the nonce words reading task

Speaker	Phoneme	Mean / SD	Tokens
S1	/p/	23.1 / 20.7	9
	/t/	16.8 / 10.1	17
	/k/	45.4 / 13.7	9

S2	/p/	21 / 5.1	9
	/t/	21.4 / 5.3	20
	/k/	33.7 / 7.3	9
S3	/p/	17.7 / 6.3	8
	/t/	16.1 / 4.6	18
	/k/	25.7 / 4.6	9
S4	/p/	13.1 / 6	9
	/t/	16.4 / 4.6	20
	/k/	33.2 / 17.6	8
S5	/p/	14.8 / 8.5	9
	/t/	17 / 7.4	19
	/k/	30.1 / 10.1	9

Table B.33. Mean VOT values (ms) in Spanish produced by individual L1 English speaker in the narrative task

Speaker	Phoneme	Mean / SD	Tokens
E1	/p/	42.4 / 32.5	15
	/t/	56.4 / 17.3	5
	/k/	41.3 / 8.3	13
E2	/p/	55.7 / 11.8	5
	/t/	78.2 / 39.4	2
	/k/	122.4 / NA	1
E3	/p/	30.6 / 11.9	6
	/t/	37.4 / 22	12
	/k/	58.3 / 38.8	7
E4	/p/	66.9 / 24	13
	/t/	71.1 / 34	11
	/k/	57.7 / 49.7	7

E5	/p/	65.6 / 15.2	6
	/t/	78.1 / 25.9	3
	/k/	77.6 / 40.4	8

Table B.34. Mean VOT values (ms) in Spanish produced by individual L1 English speaker in the picture-naming task

Speaker	Phoneme	Mean / SD	Tokens
E1	/p/	25.6 / 10.5	5
	/t/	37.1 / 14.4	11
	/k/	45.6 / 15.8	12
E2	/p/	80.8 / 26.9	6
	/t/	73.5 / 34.5	10
	/k/	59.2 / 22.8	10
E3	/p/	32.3 / 15.4	5
	/t/	33.8 / 14.3	9
	/k/	43 / 12	9
E4	/p/	71.9 / 13.5	6
	/t/	59.1 / 20.5	11
	/k/	55.7 / 21.9	11
E5	/p/	59.6 / 14.7	6
	/t/	74.8 / 22	10
	/k/	69.6 / 21.3	10

Table B.35. Mean VOT values (ms) in Spanish produced by individual L1 English speaker in the sentence-reading task

Speaker	Phoneme	Mean / SD	Tokens
E1	/p/	23 / 10.2	36
	/t/	37.4 / 19.8	44
	/k/	42.3 / 20.1	33

E2	/p/	59.4 / 29.8	37
	/t/	59.3 / 24.7	44
	/k/	60.7 / 31.9	32
E3	/p/	22.9 / 16.5	37
	/t/	25.6 / 17.6	44
	/k/	35.5 / 17.8	33
E4	/p/	54.1 / 26.4	36
	/t/	59.3 / 24.3	44
	/k/	61.3 / 25	33
E5	/p/	48 / 22.3	36
	/t/	53.3 / 28.6	44
	/k/	71.3 / 29	33

Table B.36. Mean VOT values (ms) in Spanish produced by individual L1 English speaker in the nonce words reading task

Speaker	Phoneme	Mean / SD	Tokens
E1	/p/	31.3 / 14.2	9
	/t/	43.9 / 21.5	20
	/k/	41.1 / 9.7	9
E2	/p/	82 / 9.7	9
	/t/	75.3 / 29.9	19
	/k/	64.9 / 25.3	9
E3	/p/	54.8 / 35.3	9
	/t/	37.6 / 30.9	19
	/k/	49.7 / 20.2	9
E4	/p/	68.8 / 24.1	9
	/t/	65.7 / 24.9	17
	/k/	64.3 / 21.3	9

E5	/p/	65.9 / 29.7	9
	/t/	59.9 / 25.8	19
	/k/	58.8 / 27	9

Table B.37. Mean VOT values (ms) in Spanish produced by individual Ukrainian HS in the narrative task

Speaker	Phoneme	Mean / SD	Tokens
U1	/p/	16.5 / 2.1	2
	/t/	12.9 / 4.9	4
	/k/	34.9 / 13.4	8
U2	/p/	20 / 6.5	11
	/t/	14.1 / 0.9	3
	/k/	29.9 / 6.3	11
U3	/p/	16.6 / 4.6	6
	/t/	35.9 / 20.8	5
	/k/	46.3 / 19	4
U4	/p/	17.1 / 9.3	11
	/t/	19.1 / 5.9	20
	/k/	32.3 / 9.7	17
U5	/p/	24.8 / 7.2	6
	/t/	31 / 14.6	6
	/k/	36.2 / 12	7
U6	/p/	16.7 / 4.3	10
	/t/	16.1 / 6.1	12
	/k/	25.2 / 5.1	18

Table B.38. Mean VOT values (ms) in Spanish produced by individual Ukrainian HS in the picture-naming task

Speaker	Phoneme	Mean / SD	Tokens
U1	/p/	9.2 / 1.2	2

	/t/	20.1 / 7.6	9
	/k/	27.2 / 5.5	8
U2	/p/	9 / 2.8	5
	/t/	14.7 / 4.6	11
	/k/	27.8 / 11	12
U3	/p/	9 / 2.6	3
	/t/	16 / 4.6	7
	/k/	31 / 4.4	10
U4	/p/	11.8 / 2.8	5
	/t/	21.7 / 7.4	10
	/k/	32.7 / 7	10
U5	/p/	39.5 / 18.2	4
	/t/	36.1 / 15.4	9
	/k/	43.4 / 16.5	9
U6	/p/	12.3 / 7.3	6
	/t/	14.2 / 8.9	12
	/k/	21.3 / 9.2	10

Table B.39. Mean VOT values (ms) in Spanish produced by individual Ukrainian HS in the sentence-reading task

Speaker	Phoneme	Mean / SD	Tokens
U1	/p/	17.7 / 8.5	35
	/t/	13.4 / 7.8	44
	/k/	27.8 / 10.7	33
U2	/p/	20.3 / 6.8	35
	/t/	20.5 / 8.8	44
	/k/	34.7 / 11.3	33
U3	/p/	16.4 / 7.6	34

	/t/	16.8 / 4.1	42
	/k/	29.4 / 8.5	31
U4	/p/	19.2 / 11.5	37
	/t/	22 / 7.7	44
	/k/	34.3 / 13.2	33
U5	/p/	32 / 10.2	37
	/t/	29.9 / 12	44
	/k/	42.1 / 15.8	33
U6	/p/	15.9 / 6.3	37
	/t/	15.3 / 5.1	44
	/k/	32.7 / 13.8	33

Table B.40. Mean VOT values (ms) in Spanish produced by individual Ukrainian HS in the nonce words reading task

Speaker	Phoneme	Mean / SD	Tokens
U1	/p/	19.2 / 10.6	9
	/t/	16.3 / 10.1	19
	/k/	24.1 / 5.4	9
U2	/p/	22.6 / 5.6	9
	/t/	19.8 / 8.6	19
	/k/	29.2 / 7.5	9
U3	/p/	14.5 / 6.6	9
	/t/	14.7 / 7.1	19
	/k/	29.1 / 5.9	9
U4	/p/	29.5 / 16	9
	/t/	25.5 / 8.1	19
	/k/	34.1 / 6	9
U5	/p/	47.9 / 13.3	9

	/t/	49.8 / 16.2	19
	/k/	47.3 / 13.2	9
U6	/p/	17.2 / 10.1	9
	/t/	15.5 / 6	19
	/k/	24.6 / 5.7	9

Table 4.41. Mean VOT values (ms) in Spanish produced by individual Polish HS in the narrative task

Speaker	Phoneme	Mean / SD	Tokens
P1	/p/	44.5 / 19.9	13
	/t/	41.8 / 21.4	9
	/k/	65.1 / 28.6	24
P2	/p/	74.8 / 25.2	2
	/t/	77.3 / 13.7	10
	/k/	82 / NA	1
P3	/p/	NA	0
	/t/	74.4 / 20.2	3
	/k/	60.5 / 27.7	5
P4	/p/	24.7 / 8.5	4
	/t/	34.3 / 5.2	5
	/k/	54.2 / 23.7	3
P5	/p/	43.4 / 11.1	3
	/t/	58.7 / 31	3
	/k/	59.6 / 39.5	11
P6	/p/	24.6 / 8.7	4
	/t/	28.8 / 12	9
	/k/	43.8 / 16.5	10
P7	/p/	20.5 / 10.8	6

	/t/	36.5 / 6.9	8
	/k/	43.9 / 14	9
P8	/p/	18.2 / 10.5	9
	/t/	39.2 / 16.5	10
	/k/	60 / 18.7	12
P9	/p/	22.6 / 9.1	13
	/t/	25.9 / 9.3	7
	/k/	32.6 / 7.5	11
P10	/p/	13.8 / 3.2	2
	/t/	19.4 / 4.4	4
	/k/	27 / NA	1
P11	/p/	21.8 / 10.8	9
	/t/	39.3 / 19.2	5
	/k/	47.4 / 19.9	7

Table B.42. Mean VOT values (ms) in Spanish produced by individual Polish HS in the picture-naming task

Speaker	Phoneme	Mean / SD	Tokens
P1	/p/	72 / 32	3
	/t/	35.1 / 10.8	11
	/k/	56.9 / 13.5	10
P2	/p/	52 / 8.5	3
	/t/	80.8 / 21.7	10
	/k/	56.4 / 14.4	11
P3	/p/	58.7 / NA	1
	/t/	55.7 / 19.6	10
	/k/	64.6 / 18	8
P4	/p/	22.3 / 2.2	3

	/t/	31.9 / 10.2	9
	/k/	41.4 / 18	8
P5	/p/	62 / 19.5	4
	/t/	59.5 / 22.6	12
	/k/	71 / 23.6	11
P6	/p/	25.7 / 6.9	4
	/t/	33.7 / 11.6	10
	/k/	30.8 / 10	11
P7	/p/	19 / 1.8	4
	/t/	21 / 6.9	13
	/k/	39.8 / 14.7	13
P8	/p/	14.7 / 5.7	4
	/t/	23.5 / 7.6	7
	/k/	29.5 / 8.9	9
P9	/p/	11.1 / 1.2	4
	/t/	16.2 / 6.4	10
	/k/	32.3 / 7.4	11
P10	/p/	12.3 / 1.7	5
	/t/	22.8 / 6.2	10
	/k/	31.7 / 6.7	8
P11	/p/	19.2 / 5.6	5
	/t/	25.5 / 9.7	10
	/k/	40.4 / 16.2	11

Table B.43. Mean VOT values (ms) in Spanish produced by individual Polish HS in the picture-naming task

Speaker	Phoneme	Mean / SD	Tokens
P1	/p/	37.9 / 14.6	37

	/t/	30.3 / 11.1	44
	/k/	54.6 / 16.3	33
P2	/p/	63.4 / 15.5	37
	/t/	60.1 / 16.7	44
	/k/	68.8 / 18.7	33
P3	/p/	34.6 / 11	37
	/t/	41.2 / 17.5	42
	/k/	59.3 / 20.5	31
P4	/p/	37.6 / 15.3	37
	/t/	35.7 / 15.1	44
	/k/	53.1 / 16.7	31
P5	/p/	44.5 / 18.8	37
	/t/	36.3 / 15.4	44
	/k/	56.1 / 22.7	33
P6	/p/	45.2 / 16.9	36
	/t/	43.4 / 13.9	44
	/k/	56.6 / 24	32
P7	/p/	19 / 7.8	36
	/t/	20.6 / 11.4	44
	/k/	35.4 / 13.1	33
P8	/p/	22.6 / 12.2	37
	/t/	22.9 / 10.8	44
	/k/	30.5 / 15.3	33
P9	/p/	15.5 / 4.4	37
	/t/	16.2 / 7.6	44
	/k/	28 / 8.2	33

P10	/p/	23.4 / 12.2	35
	/t/	27.4 / 11.8	38
	/k/	46.8 / 18	26
P11	/p/	26.3 / 18.6	35
	/t/	30.1 / 22.5	40
	/k/	55.2 / 24.1	32

Table B.44. Mean VOT values (ms) in Spanish by individual Polish HS in the nonce words reading task

Speaker	Phoneme	Mean / SD	Tokens
P1	/p/	36.8 / 17.1	9
	/t/	33.7 / 17.6	19
	/k/	32.7 / 10.6	8
P2	/p/	53.6 / 18.1	9
	/t/	42.5 / 13.2	19
	/k/	51.2 / 15.4	9
P3	/p/	44.4 / 19.9	9
	/t/	53.2 / 23.8	19
	/k/	56.2 / 16.6	9
P4	/p/	52.8 / 27.5	9
	/t/	33.1 / 15.1	19
	/k/	54 / 16.3	9
P5	/p/	57.9 / 20.5	10
	/t/	40.9 / 18.9	18
	/k/	56.8 / 23.8	9
P6	/p/	50.3 / 29.7	9
	/t/	39.8 / 13.7	19
	/k/	50 / 11.7	9

P7	/p/	26.3 / 12.8	9
	/t/	21.3 / 11.2	19
	/k/	45.1 / 11.3	9
P8	/p/	25.9 / 12.1	9
	/t/	22.6 / 15	19
	/k/	32.4 / 15.3	8
P9	/p/	16.3 / 6.8	9
	/t/	14.8 / 5	19
	/k/	27.6 / 22.6	9
P10	/p/	20.8 / 9.8	9
	/t/	18.2 / 8.3	17
	/k/	38.9 / 15.5	9
P11	/p/	48.5 / 17.4	9
	/t/	32.9 / 18.7	19
	/k/	45.3 / 23.2	9

B.3 Voiced stops

B.3.1 Ukrainian voiced stops

Table B.45. Mean RI (dB) values in Ukrainian produced by individual Ukrainian HS

Speaker	Phoneme	Mean / SD	Tokens
U1	/b/	10.8 / 6.2	11
	/d/	12.8 / 5.4	13
U2	/b/	9.2 / 3.9	12
	/d/	10.3 / 5.5	3
U3	/b/	8.1 / 4.8	4
	/d/	7.9 / 6.4	4

U4	/b/	9.6 / 4.8	7
	/d/	11.1 / 5.3	13
U5	/b/	9 / 5.1	4
	/d/	11.8 / 5.3	13
U6	/b/	12 / 6	18
	/d/	15.4 / 5.1	14

B.3.2 Polish voiced stops

Table B.46. Mean RI (dB) values in Polish produced by individual Polish HS

Speaker	Phoneme	Mean / SD	Tokens
P1	/b/	16.9 / 7.5	10
	/d/	10.5 / 6.8	5
	/g/	14.5 / 4.1	5
P2	/b/	11.5 / 4.4	14
	/d/	15.3 / 4.6	4
	/g/	12.9 / 2.9	4
P3	/b/	14.9 / 6	18
	/d/	10.3 / 6.3	4
	/g/	14 / 5.8	2
P4	/b/	12.4 / 6.3	6
	/d/	5.9 / 2.2	2
	/g/	13.3 / 5.1	2
P5	/b/	11.8 / 4.7	14
	/d/	13.8 / 4	4
	/g/	12.1 / 7.1	6
P6	/b/	6.9 / 5.1	7

	/d/	5.7 / NA	1
	/g/	11.3 / 5.2	5
P7	/b/	11.5 / 4.8	9
	/d/	NA	0
	/g/	9.9 / 3.5	2
P8	/b/	12.5 / 1.9	12
	/d/	5.9 / 1.6	3
	/g/	18.2 / NA	1
P9	/b/	10.9 / 6.2	6
	/d/	13.5 / 6.2	5
	/g/	13.2 / 10.4	2
P10	/b/	10.8 / 4.3	11
	/d/	11 / 5.1	5
	/g/	12.6 / 4.4	3
P11	/b/	11.8 / 4	4
	/d/	14.8 / 3.1	3
	/g/	NA	0

B.3.3 English voiced stops

Table B.47. Mean VOT values (ms) in English by individual L1 English speaker

Speaker	Phoneme	Mean / SD	Tokens
E1	/b/	9.9 / 7.6	10
	/d/	12.7 / NA	1
	/g/	10.9 / 5.1	7
E2	/b/	22.9 / 6.3	7
	/d/	18.9 / 8.4	2

	/g/	13.7 / 14.6	2
E3	/b/	11.7 / 3.9	15
	/d/	2.3 / NA	1
	/g/	NA	0
E4	/b/	13.9 / 3.8	9
	/d/	3.8 / 3.1	4
	/g/	13.4 / 1.9	4
E5	/b/	11.9 / 2.2	7
	/d/	4.5 / NA	1
	/g/	NA	0

Table B.48. Mean VOT values (ms) in English by individual L1 Spanish speaker

Speaker	Phoneme	Mean / SD	Tokens
S1	/b/	15.2 / 8	17
	/d/	21.4 / 9.2	5
	/g/	13.5 / 5.9	7
S2	/b/	14.5 / 4	7
	/d/	10.1 / 5.4	4
	/g/	11.6 / 5.9	2
S3	/b/	10.2 / 2.9	9
	/d/	1.2 / 1.3	2
	/g/	13.2 / 5.2	8
S4	/b/	15.1 / 5.7	8
	/d/	14.8 / 6.4	3
	/g/	20.4 / 3	4
S5	/b/	17.2 / 5.7	29
	/d/	12 / 7.6	4

	/g/	17.1 / 5	6
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Table B.49. Mean RI (dB) values in English produced by individual Ukrainian HS

Speaker	Phoneme	Mean / SD	Tokens
U1	/b/	18.8 / 6.2	9
	/d/	7.4 / 4.6	4
	/g/	17.2 / 20.6	2
U2	/b/	10.2 / 3.2	6
	/d/	5.8 / 2.5	3
	/g/	11.6 / 3	4
U3	/b/	9.3 / 2.7	11
	/d/	7.6 / 0.1	2
	/g/	16 / NA	1
U4	/b/	15.3 / 7.1	19
	/d/	19.7 / 5.7	5
	/g/	19.2 / 7.4	8
U5	/b/	8.6 / 5	7
	/d/	7.5 / NA	1
	/g/	7.7 / 4.7	2
U6	/b/	15.8 / 8.4	9
	/d/	10.2 / 2.8	7
	/g/	12.5 / 3.1	8

Table B.50. Mean RI (dB) values in English produced by individual Polish HS

Speaker	Phoneme	Mean / SD	Tokens
P1	/b/	14.2 / 6.6	9
	/d/	14.5 / 7.2	4
	/g/	18.6 / 6.7	3

P2	/b/	13.1 / 7.5	13
	/d/	8.1 / 3.5	4
	/g/	14.1 / 5.7	6
P3	/b/	20 / 7	22
	/d/	8.1 / 8.7	5
	/g/	24.9 / 5.6	5
P4	/b/	12 / 4.6	5
	/d/	9.4 / 1.9	3
	/g/	11.4 / 5.7	6
P5	/b/	10.1 / 6.2	7
	/d/	13.9 / 3.9	6
	/g/	19.4 / 3.1	3
P6	/b/	7.6 / 6.1	10
	/d/	9.6 / 4.3	8
	/g/	7.7 / NA	1
P7	/b/	18.3 / 5.3	6
	/d/	11.6 / 3.8	2
	/g/	13.4 / 2.8	4
P8	/b/	12.5 / 5.2	12
	/d/	13.1 / 2.7	3
	/g/	13.1 / 3.1	4
P9	/b/	15.3 / 6.4	8
	/d/	9.7 / 5.7	4
	/g/	19.6 / NA	1
P10	/b/	13.4 / 4.6	14
	/d/	8.1 / 1.2	4

	/g/	11.9 / 5.1	6
P11	/b/	17.3 / 5.6	10
	/d/	24.1 / NA	1
	/g/	11.9 / 5	3

B. 3.4 Spanish voiced stops

Table B.51. Mean RI (dB) values in Spanish produced by individual L1 Spanish speaker in the narrative task

Speaker	Phoneme	Mean / SD	Tokens
S1	/b/	2.1 / 2.3	8
	/d/	6.9 / 7.6	15
	/g/	1 / 1.9	4
S2	/b/	6 / NA	1
	/d/	2.2 / 1.8	3
	/g/	2.1 / 2.6	5
S3	/b/	2.4 / 1.8	4
	/d/	4.2 / 4.6	19
	/g/	1.9 / 1.6	3
S4	/b/	8.7 / 6.1	6
	/d/	3.7 / 3.9	8
	/g/	3.3 / NA	1
S5	/b/	7.2 / 3.8	10
	/d/	5.5 / 6.5	17
	/g/	8.9 / 8.4	3

Table B.52. Mean RI (dB) values in Spanish produced by individual L1 Spanish speaker in the picture-naming task

Speaker	Phoneme	Mean / SD	Tokens
S1	/b/	15.9 / 6.6	10
	/d/	13.4 / 5.1	8
	/g/	13.9 / 3.7	6
S2	/b/	2.8 / 2.3	10
	/d/	2.9 / 2.9	10
	/g/	4.5 / 4.9	6
S3	/b/	5.2 / 2.5	10
	/d/	3.9 / 3.7	9
	/g/	4.4 / 2.1	6
S4	/b/	9.4 / 5.9	12
	/d/	7.9 / 5.3	8
	/g/	10.9 / 3.5	5
S5	/b/	12.9 / 5.3	10
	/d/	6 / 4.7	9
	/g/	9.8 / 3.2	6

Table B.53. Mean RI (dB) values in Spanish produced by individual L1 Spanish speaker in the sentence-reading task

Speaker	Phoneme	Mean / SD	Tokens
S1	/b/	12 / 4.4	43
	/d/	12 / 7.2	32
	/g/	16.4 / 6.9	17
S2	/b/	2.7 / 3.1	46
	/d/	2.2 / 2.8	32
	/g/	2.2 / 3	17
S3	/b/	4.6 / 2.7	46

	/d/	4.3 / 3	32
	/g/	7 / 3.7	17
S4	/b/	7 / 3.8	46
	/d/	5 / 2.8	32
	/g/	10.3 / 4	17
S5	/b/	9.5 / 4.6	46
	/d/	5.6 / 4.1	32
	/g/	11.2 / 5.7	16

Table B.54. Mean RI (dB) values in Spanish produced by individual L1 Spanish speaker in the nonce words reading task

Speaker	Phoneme	Mean / SD	Tokens
S1	/b/	15.8 / 4.7	14
	/d/	17.3 / 4.8	6
	/g/	14.2 / 7.4	9
S2	/b/	4.4 / 3.9	14
	/d/	4.8 / 4.1	6
	/g/	3 / 3.7	9
S3	/b/	4.6 / 3.2	14
	/d/	6 / 4.4	6
	/g/	5.8 / 3.5	9
S4	/b/	9.3 / 3.8	14
	/d/	11.9 / 4.6	6
	/g/	13.2 / 3.1	9
S5	/b/	13.8 / 6.5	14
	/d/	17.7 / 9.1	6
	/g/	14.8 / 6.9	9

Table B.55. Mean RI (dB) values in Spanish produced by individual L1 English speaker in the narrative task

Speaker	Phoneme	Mean / SD	Tokens
E1	/b/	5.3 / NA	1
	/d/	7.3 / 4.3	8
	/g/	7.5 / 4.7	4
E2	/b/	21.7 / 1.1	2
	/d/	34.3 / NA	1
	/g/	14.4 / 5.4	4
E3	/b/	9 / 5.4	6
	/d/	7.2 / 9	7
	/g/	18.7 / NA	1
E4	/b/	8.4 / 6.6	2
	/d/	9.7 / 4	5
	/g/	13.4 / NA	1
E5	/b/	12.8 / 2.6	2
	/d/	14.9 / 5.6	9
	/g/	20.6 / NA	1

Table B.56. Mean RI (dB) values in Spanish produced by individual L1 English speaker in the picture-naming task

Speaker	Phoneme	Mean / SD	Tokens
E1	/b/	10.4 / 4.3	5
	/d/	7.8 / 3.2	7
	/g/	9.8 / 3.1	4
E2	/b/	16.2 / 5.8	6
	/d/	13.8 / 5.7	7
	/g/	25.9 / 19.4	4
E3	/b/	13.1 / 0.3	3

	/d/	7.7 / 5.1	6
	/g/	8.5 / 3.5	3
E4	/b/	9.7 / 2.3	7
	/d/	9.3 / 3.2	7
	/g/	7.8 / 4.2	5
E5	/b/	10.2 / 2.7	5
	/d/	7.3 / 3.5	7
	/g/	11.4 / 3	4

Table B.57. Mean RI (dB) values in Spanish produced by individual L1 English speaker in the sentence-reading task naming task

Speaker	Phoneme	Mean / SD	Tokens
E1	/b/	13.1 / 4.5	23
	/d/	10.8 / 4.6	32
	/g/	15.8 / 6.2	17
E2	/b/	22.9 / 7.4	23
	/d/	16.3 / 9.2	23
	/g/	23.5 / 7.4	17
E3	/b/	13 / 6.3	23
	/d/	10.7 / 7.8	30
	/g/	16.4 / 5.7	16
E4	/b/	10.5 / 6.1	23
	/d/	9 / 5.4	19
	/g/	13.9 / 6.8	17
E5	/b/	9.3 / 3.5	23
	/d/	10 / 4.3	31
	/g/	13.6 / 2.6	17

Table B.58. Mean RI (dB) values in Spanish produced by individual L1 English speaker in the nonce words reading task naming task

Speaker	Phoneme	Mean / SD	Tokens
E1	/b/	14 / 5.6	12
	/d/	18 / 4.5	6
	/g/	14.8 / 6.1	8
E2	/b/	23.2 / 7.1	14
	/d/	25.4 / 2	5
	/g/	22.1 / 6.7	9
E3	/b/	15.8 / 5.8	14
	/d/	18.4 / 6.8	6
	/g/	16.1 / 4	9
E4	/b/	16.8 / 8.3	12
	/d/	20.6 / 1.5	4
	/g/	15.6 / 7.2	9
E5	/b/	12 / 5.5	14
	/d/	12 / 3.2	6
	/g/	10.8 / 6.4	9

Table B.59. Mean RI (dB) values in Spanish produced by individual Ukrainian HS in the narrative task

Speaker	Phoneme	Mean / SD	Tokens
U1	/b/	9.5 / 7.2	3
	/d/	5.6 / 3.7	2
	/g/	8.8 / 5	4
U2	/b/	8.6 / 5.1	11
	/d/	7.7 / 3.8	8
	/g/	12.2 / 4.3	5
U3	/b/	7.4 / 2.9	5

	/d/	8.4 / 6.2	7
	/g/	13.8 / 4.4	4
U4	/b/	11.8 / 6.6	4
	/d/	6.9 / 2.8	5
	/g/	15.5 / NA	1
U5	/b/	7 / 0.5	3
	/d/	8.7 / NA	1
	/g/	5.2 / 4.8	4
U6	/b/	5.9 / 4.8	8
	/d/	9.2 / 5.4	8
	/g/	8.3 / 6.7	9

Table B.60. Mean RI (dB) values in Spanish produced by individual Ukrainian HS in the picture-naming task

Speaker	Phoneme	Mean / SD	Tokens
U1	/b/	4.9 / NA	1
	/d/	11.8 / 3.5	4
	/g/	16.9 / 0.8	2
U2	/b/	10.3 / 3.4	8
	/d/	9.4 / 4.5	9
	/g/	12.1 / 4.1	5
U3	/b/	9.5 / 4.4	4
	/d/	10.1 / 2.7	6
	/g/	6.9 / NA	1
U4	/b/	10.5 / 6.8	5
	/d/	5.8 / 3.9	7
	/g/	7.4 / 5	5
U5	/b/	7.7 / 3.2	6

	/d/	7.4 / 3.4	5
	/g/	7.4 / 3.1	5
U6	/b/	9.1 / 5.4	8
	/d/	7.5 / 5	7
	/g/	2.4 / 1.3	5

Table B.61. Mean RI (dB) values in Spanish produced by individual Ukrainian HS in the sentence-reading task

Speaker	Phoneme	Mean / SD	Tokens
U1	/b/	14.8 / 6	23
	/d/	13.5 / 4.6	31
	/g/	16.5 / 4.9	17
U2	/b/	9.7 / 4.8	23
	/d/	7.5 / 4	31
	/g/	10.6 / 3.8	17
U3	/b/	12.2 / 3.6	22
	/d/	12.6 / 4.3	30
	/g/	15.3 / 3.7	13
U4	/b/	10.5 / 3.9	22
	/d/	9 / 3.4	31
	/g/	13.1 / 5.8	16
U5	/b/	10 / 6.7	22
	/d/	6.8 / 3.4	31
	/g/	9.9 / 4.6	12
U6	/b/	9.2 / 4.8	22
	/d/	10.5 / 5.6	30
	/g/	9.4 / 7.6	15

Table B.62. Mean RI (dB) values in Spanish produced by individual Ukrainian HS in the nonce words reading task

Speaker	Phoneme	Mean / SD	Tokens
U1	/b/	17.1 / 5	14
	/d/	15.4 / 2.9	6
	/g/	15.7 / 7	9
U2	/b/	8.5 / 6.9	14
	/d/	9.6 / 5.4	6
	/g/	8.8 / 4	9
U3	/b/	16.5 / 5.2	14
	/d/	14.9 / 3.5	6
	/g/	19.1 / 4.5	7
U4	/b/	12.7 / 6.8	14
	/d/	11.8 / 8.7	6
	/g/	13.8 / 6	8
U5	/b/	11.2 / 6.3	14
	/d/	10.8 / 6.4	6
	/g/	11.8 / 9.3	9
U6	/b/	10.4 / 6.7	14
	/d/	13.8 / 9.8	6
	/g/	7.4 / 5.6	9

Table B.63. Mean RI (dB) values in Spanish produced by individual Polish HS in the narrative task

Speaker	Phoneme	Mean / SD	Tokens
P1	/b/	6.4 / 3.3	3
	/d/	8.1 / 5.8	3
	/g/	14.8 / 5.1	8
P2	/b/	10.2 / 4.8	3

	/d/	9 / 7.3	3
	/g/	8.7 / NA	1
P3	/b/	19.9 / 10.9	2
	/d/	13.6 / NA	1
	/g/	17.4 / 0.5	2
P4	/b/	18.2 / 8.2	2
	/d/	NA	0
	/g/	NA	0
P5	/b/	6.3 / 5.4	4
	/d/	9.1 / 4.2	7
	/g/	8.9 / NA	1
P6	/b/	3.6 / 3	4
	/d/	7 / 4.2	6
	/g/	8 / NA	1
P7	/b/	6.8 / 5.5	3
	/d/	6.3 / NA	1
	/g/	15.1 / 2.4	3
P8	/b/	11.4 / 3.7	8
	/d/	7.7 / 3.4	6
	/g/	15.8 / 2.1	6
P9	/b/	8.3 / 1.1	3
	/d/	16.2 / 6.4	3
	/g/	NA	0
P10	/b/	8.2 / NA	1
	/d/	15.8 / NA	1
	/g/	NA	0

P11	/b/	11.9 / 5.8	5
	/d/	10.4 / 3.7	5
	/g/	NA	0

Table B.64. Mean RI (dB) values in Spanish produced by individual Polish HS in the picture-naming task

Speaker	Phoneme	Mean / SD	Tokens
P1	/b/	13.4 / 3	4
	/d/	13.7 / 1.6	6
	/g/	16.2 / 2.4	3
P2	/b/	11.4 / 3.8	4
	/d/	9.3 / 1.6	5
	/g/	10.4 / 3.5	4
P3	/b/	17.6 / 4.2	3
	/d/	16.7 / 2.9	4
	/g/	12.9 / 5.4	2
P4	/b/	15.1 / 4.4	3
	/d/	14.8 / 2.1	3
	/g/	NA	0
P5	/b/	11.2 / 4.3	5
	/d/	12.1 / 3.8	7
	/g/	12.2 / 2.7	5
P6	/b/	6.5 / 1.9	5
	/d/	6.2 / 4.5	5
	/g/	6.9 / 1	5
P7	/b/	12.2 / 2.6	7
	/d/	10.2 / 3.8	7
	/g/	12.6 / 2.7	5

P8	/b/	11.4 / 7.1	4
	/d/	8.1 / 4.7	5
	/g/	12.1 / 3.2	3
P9	/b/	17.5 / 8	5
	/d/	14.7 / 4.2	4
	/g/	12.8 / 3.8	4
P10	/b/	13.6 / 7.2	5
	/d/	15.1 / 2	4
	/g/	13.9 / 2.3	2
P11	/b/	12.7 / 9.6	7
	/d/	7.2 / 4.9	8
	/g/	7.9 / 3.3	5

Table B.65. Mean RI (dB) values in Spanish produced by individual Polish HS in the sentence-reading task

Speaker	Phoneme	Mean / SD	Tokens
P1	/b/	16.3 / 4.9	22
	/d/	16 / 6.2	30
	/g/	15.5 / 5.6	14
P2	/b/	11.7 / 4.1	23
	/d/	12.2 / 3.8	31
	/g/	16 / 4.6	16
P3	/b/	18.6 / 4.3	22
	/d/	17.2 / 4.8	29
	/g/	21.5 / 7.2	16
P4	/b/	13.3 / 5.4	23
	/d/	11 / 5	30
	/g/	13.9 / 4.9	16

P5	/b/	13.7 / 4.9	22
	/d/	14.4 / 4.9	31
	/g/	18.9 / 5.1	17
P6	/b/	10.8 / 5.4	23
	/d/	7.8 / 5	31
	/g/	9.9 / 4.6	16
P7	/b/	13 / 3.9	23
	/d/	12.4 / 2.4	31
	/g/	17 / 5.1	16
P8	/b/	14.3 / 3.8	22
	/d/	11 / 4.4	31
	/g/	18.7 / 3.4	16
P9	/b/	14.1 / 5.6	22
	/d/	12.1 / 5.4	31
	/g/	14.2 / 5.7	16
P10	/b/	17.7 / 5.8	22
	/d/	17.9 / 4.4	29
	/g/	21.2 / 5.8	16
P11	/b/	15.1 / 10.6	23
	/d/	8.6 / 6.7	29
	/g/	15.2 / 9	17

Table B.66. Mean RI (dB) values in in Spanish produced by individual Polish HS in the nonce words reading task

Speaker	Phoneme	Mean / SD	Tokens
P1	/b/	16.3 / 4.9	14
	/d/	20.1 / 8.2	6
	/g/	18.5 / 5.2	9

P2	/b/	10.5 / 3.3	14
	/d/	14 / 4.1	6
	/g/	10.8 / 6.5	9
P3	/b/	19.7 / 7	14
	/d/	20.5 / 7	6
	/g/	20.3 / 5.1	9
P4	/b/	11.2 / 7.8	14
	/d/	12 / 6.3	6
	/g/	10.3 / 2.6	9
P5	/b/	14.6 / 3.8	14
	/d/	18.9 / 5.8	6
	/g/	17.6 / 4.7	8
P6	/b/	10.9 / 3.7	13
	/d/	11.5 / 5.1	6
	/g/	7.9 / 3.3	7
P7	/b/	16.4 / 3.6	14
	/d/	16.6 / 5.6	6
	/g/	13 / 3.4	9
P8	/b/	15.1 / 5.7	14
	/d/	12.1 / 5.7	6
	/g/	16.3 / 2.9	9
P9	/b/	14.4 / 4.5	14
	/d/	13.3 / 8.3	6
	/g/	17.5 / 5.9	8
P10	/b/	23.5 / 10.4	14
	/d/	19.5 / 1.6	5

	/g/	17.6 / 3.1	9
P11	/b/	22.4 / 9.6	14
	/d/	23.4 / 11.7	6
	/g/	23.4 / 8.4	9

Appendix C

Outliers

Outliers are an important part of a data set. In addition to helping determine whether there were any errors in the way the data was logged and processed, they also allow for an assessment of speaker variation. Knowing where outliers occurred and which speaker produced them helps inform conclusions regarding the final results and determine whether the task design caused a deviated result or if it was the speaker profile that played a role in the outlier production. Since this study incorporates four different tasks and investigates participants with different linguistic backgrounds, the following section is dedicated to an overview of outliers. In this study, an outlier was defined as a data point that is three standard deviations away from the mean.

C.1 Vowels

C.1.1 Ukrainian vowels

Several outliers (i.e., values that were produced three standard deviations away from the group mean) were discovered in the Ukrainian narrative task. Table C.1 summarizes the F1 outliers and Table C.2 presents the F2 outliers. Speaker U4 produced three F1 outliers, all of the phoneme /ε/ (two stressed, one unstressed) that were pronounced as either high segments or experienced lowering. Participants U1 and U6 produced F1 outliers in the pronunciation of unstressed /i/, with the former raising the segment and the latter lowering it. Speaker U1 displayed an F2 outlier in the production of unstressed /i/ pronouncing it as a back segment. Participants U1 and U4 both produced F2 outliers in the pronunciation of unstressed /ɑ/, with the former realizing it as back segment and latter as a front vowel. Finally, participant U6 displayed two F2 outliers in the production of unstressed /ɪ/, producing it as a far back segment.

Table C.1. F1 outliers produced by the Ukrainian HSs

Speaker	Word	Phoneme	F1	F2
U3	зачіпається	/i/	267.7651	2006.737

	/za.tʃi.'pa.jɛ.tsʲa/ 'bothers'			
U4	немає 'nɛ.'ma.jɛ/ 'there is no'	/ɛ/	379.3555	1544.021
U4	речі 'rɛ.tʃi/ 'things'	/ɛ/	955.5264	1868.475
U4	дає 'da.'jɛ/ 'gives'	/ɛ/	984.0885	1974.327
U5	неї 'nɛ.ji/ 'her'	/i/	578.8698	2625.997

Table C.2. F2 outliers produced by the Ukrainian HSs

Speaker	Word	Phoneme	F1	F2
U1	сміялася 'smi.'ja.la.sʲa/ '(she) was laughing'	/i/	457.3583	989.6338
U1	якийсь 'ja.'kij'sʲ/ 'some' (masc. sing)	/a/	371.6079	2577.209
U4	якісь 'ja.'kisʲ/ 'some' (pl.)	/a/	458.9482	2691.172
U6	трохи 'tro.xi/ 'a little bit'	/i/	510.7122	746.102
U6	бачила 'ba.tʃi.la/ '(she) saw'	/i/	607.5671	886.9787

C.1.2 Polish vowels

Several F1 and F2 outliers were discovered in the Polish narrative task. Table C.3 displays the F1 outliers and Table C.4 summarizes the F2 outliers. Speaker P6 produced two of the F1 outliers, pronouncing the stressed /ɔ/ as a low segment and unstressed /i/ as a very high vowel. Participant P11 also produced an F1 outlier of unstressed /i/, pronouncing it as a very high segment. Finally, speaker P8 displayed an F1 outlier in the production of stressed /ɛ/, pronouncing it as a low segment. Participant P5 produced the greatest number of F2 outliers (two in the production of stressed /i/ and one each in the realization of unstressed /i/ and /a/), all of

which were backed. Speakers P1, P6, and P10 each produced an F2 outlier in the pronunciation of unstressed /i/, producing it as a back segment. Finally, speaker P10 displayed an F2 outlier in the production of stressed /a/, which underwent fronting.

Table C.3. F1 outliers produced by the Polish HSs

Speaker	Word	Phoneme	F1	F2
P6	ona 'she'	/ɔ/	930.8775	1667.029
P6	czytała '(she) was reading'	/i/	178.5292	1856.411
P8	przyjechał 'arrived'	/ɛ/	838.7024	1986.955
P11	duży 'big'	/i/	216.2082	2276.698

Table C.4. F2 outliers produced by the Polish HSs

Speaker	Word	Phoneme	F1	F2
P1	kolegami 'friends'	/i/	432.3618	1082.3273
P5	oni 'they'	/i/	395.5976	1325.6751
P5	przyszła '(she) came'	/a/	694.2543	803.4344
P5	było '(it) was'	/i/	550.7772	798.8244
P5	była '(she) was'	/i/	551.4712	779.2011
P6	Pani 'miss'	/i/	480.3405	1233.4925
P10	Odmianek 'change'	/a/	629.9851	2330.7302
P10	Pani	/i/	498.8045	1155.6847

C.1.3 English vowels

Only one outlier was found in the L1 English L2 Spanish control group's data set. Speaker E1 produced an F2 outlier in the pronunciation of /ʌ/ in the word 'just', where the segment was fronted.

Table C.5. F2 outlier produced by the L1 English control group

Speaker	Word	Phoneme	F1	F2
E1	just	/ʌ/	321.5	2593.8

Three outliers were discovered in L1 Spanish L2 English speakers' English narrative task. Speaker S1 produced an F1 outlier in the word 'because,' where the unstressed /ɪ/ (F1: 726, F2: 1431) was lowered. The Table C.6 summarizes the two F2 outliers. One outlier was produced by the participant S2 in the pronunciation of unstressed /i/, which was realized as a central vowel, and another was produced by speaker S5, where stressed /æ/ was fronted.

Table C.6. F2 outliers produced by the L1 Spanish control group

Speaker	Word	Phoneme	F1	F2
S2	she	/i/	356.4	1467.6
S5	carrying	/æ/	545.7	2139.6

Two outliers were found in the Ukrainian HSs' data set. The F1 outlier was produced by speaker U4, who pronounced [ə] in the word 'the' as a low segment. The F2 outlier was produced by participant U6 in the word 'went,' where /ɛ/ was pronounced as a back vowel.

Table C.7. F1 outlier produced by a Ukrainian HS

Speaker	Word	Phoneme	F1	F2
S2	the	[ə]	837.5	1848.5

Table C.8. F2 outlier produced by a Ukrainian HS

Speaker	Word	Phoneme	F1	F2
S2	went	/ɛ/	545.8	1112.3

Finally, several outliers were discovered in the Polish HSs' English narrative task. Table C.10 summarizes the F1 outliers and Table C.11 presents the F2 outliers. Speakers P3, P4, P8 each produced one F1 outlier in the pronunciation of stressed /i/, stressed /ɔ/ and [ə], respectively, where the three segments were lowered. Participant P6 produced the other two F1 outliers in the pronunciation of stressed /ɛ/ and /ʌ/, which were produced as high vowels. Participant P5 produced two F2 outliers in the pronunciation of unstressed /i/ and stressed /ɛ/, which were realized as back segments. Finally, speakers P6 and P11 each produced one outlier in

the pronunciation of [ə] and unstressed /i/, respectively, where the former was fronted and the latter was produced as a back segment.

Table C.9. F1 outliers produced by the Polish HSs

Speaker	Word	Phoneme	F1	F2
P3	really	stressed /i/	653.3	1822.5
P4	long	/ɔ/	1022.2	1793.7
P6	every	/ɛ/	301.6	1687
P6	but	/ʌ/	325.6	1905
P8	the	[ə]	977.9	1793.7

Table C.10. F2 outliers produced by the Polish HSs

Speaker	Word	Phoneme	F1	F2
P5	every	/i/	445.6	709.3
P5	went	/ɛ/	544.5	769.2
P6	the	[ə]	386.5	2725.1
P11	anymore	/i/	225.5	852.5

C.1.4 Spanish vowels

C.1.4.1 L1 Spanish control group

Several outliers were discovered in Spanish narrative task completed by the L1 Spanish control group. The F1 outliers are summarized in Table C.11 and the F2 outliers are presented in Table C.12. Speaker S3 produced the greatest number of F1 outliers in the pronunciation of unstressed /e/ and /o/ vowels. The front vowel was raised, while the back vowel was produced lower than expected. Participant S4 produced F1 outliers of unstressed and stressed /e/ segments, which were lowered. Finally, S2 produced an F1 outlier of unstressed /a/, which was fronted. Participants S1 produced two F2 outliers in the pronunciation of unstressed /i/, which were produced as backed segments. Speakers S2 and S3 show outliers in the pronunciation of unstressed /a/, with S2 producing it as fronted segment, and S3 as a backed one. Finally, speaker S3 produced outliers in the pronunciation of unstressed /e/ and /o/, with the front vowel exhibiting a back-like production and the back vowel a fronted production.

Table C.11. F1 outliers produced by the L1 Spanish control group in the narrative task

Speaker	Word	Phoneme	F1	F2
S2	clima ‘climate’	/a/	1554.5	2977.2
S3	que ‘that’	/e/	181.9	2098.8
S3	se (passive construction)	/e/	210.2	1707.2
S3	conocer ‘to know’	/o/	855.2	2689.6
S3	se	/e/	204.5	1558.1
S3	video	/o/	854	1688.3
S4	parece ‘seems’	/e/	789.8	1971.6
S4	ella ‘she’	/e/	831.4	1853.6

Table C.12. F2 outliers produced by the L1 Spanish control group in the narrative task

Speaker	Word	Phoneme	F1	F2
S1	y ‘and’	/i/	408	897.5
S1	y	/i/	368.6	992
S2	clima	/a/	1554.5	2977.2
S3	de ‘of’	/e/	463.2	1083.1
S3	conocer	/o/	855.2	2689.6
S3	una ‘a’	/a/	434.2	884.5

There are several outliers in the picture-naming task completed by the L1 Spanish control group. Table C.13 summarizes the F1 outliers and Table C.14 presents the F2 outliers. Both of the F1 outliers were produced by speaker S4, who displays a very low production of stressed and unstressed /a/ segments. Participant S1 produced two of the F2 outliers; stressed /i/ displays a great degree of backness and unstressed /a/ was pronounced as fronted. The last two F2 outliers were produced by speakers S3 and S5, who displayed very posterior productions of unstressed /a/.

Table C.13. F1 outliers produced by the L1 Spanish control group in the picture-naming task

Speaker	Word	Phoneme	F1	F2
S4	boda ‘wedding’	/a/	1107.2	1800.5
S4	lago ‘lake’	/a/	1109.5	1835.3

Table C.14. F2 outliers produced by the L1 Spanish control group in the picture-naming task

Speaker	Word	Phoneme	F1	F2
S1	comida ‘food’	/i/	367.9	1139.7
S1	cebolla ‘onion’	/a/	474.7	2430.7
S3	abogada ‘lawyer’	first /a/	416.6	865.6
S5	tortuga ‘turtle’	/a/	617.8	903.8

Twelve outliers were discovered in the sentence-reading task. The F1 outliers are presented in the Table 4.39 and the F2 outliers are summarized in Table 4.40. Speaker S4 produced all three of the F1 outliers in the pronunciation of unstressed /o/ and /u/ segments, which were lowered. Participants S3 and S2 produced five F2 outliers in the pronunciation of unstressed /a/, which was produced as a back vowel. Speaker S1 pronounced stressed /i/ as a back vowel and participant S2 produced a very fronted realization of unstressed /o/.

Table C.15. F1 outliers produced by the L1 Spanish control group in the sentence-reading task

Speaker	Word	Phoneme	F1	F2
S4	abogado 'lawyer'	word-final /o/	734.2	1585.4
S4	bovino 'bovine'	word-final /o/	736.6	1911.1
S4	vacuna 'vaccine'	/u/	636.4	761.9

Table C.16. F2 outliers produced by the L1 Spanish control group in the sentence-reading task

Speaker	Word	Phoneme	F1	F2
S1	risa 'smile'	/i/	425	1205
S2	godo 'Gothic'	word-final /o/	418.6	2112
S3	Cuba	/a/	490.4	985.9
S3	roba 'steal (imp.)'	/a/	387.3	739.6
S3	copa 'glass'	/a/	493	959.5
S4	Misuri	first /i/	336.4	886.8
S4	botado 'generous'	word-final /o/	549.9	2127
S5	roba	/a/	521	797.8
S5	vacuna	first /a/	632.5	905.5

The nonce words reading task yielded two F1 and five F2 outliers. Table C.17 presents the F1 outliers and Table C.18 summarizes the F2 outliers. The F1 outlier was produced by participant S4, who pronounced /o/ as a low vowel. All three F2 outliers are the productions of unstressed /a/, which was realized as very posterior in the pronunciation of speakers S3 and S5.

Table C.17. F1 outliers produced by the L1 Spanish control group in the nonce words reading task

Speaker	Word	Phoneme	F1	F2
S4	noca	/o/	719.1	1322.2

Table C.18. F2 outliers produced by the L1 Spanish control group in the nonce words reading task

Speaker	Word	Phoneme	F1	F2
S3	piluca	/a/	478.7	855.9
S3	mateba	word-final /a/	550.6	900.4
S5	galefa	word-final /a/	623.6	973.1

C.1.4.2 L1 English control group

Three outliers were discovered in the narrative task completed by the L1 English control group: one F1 outlier and two F2 outliers. The F1 outlier (Table C.19) was produced by speaker E4 in the word *tenían* (*they had*) where unstressed /e/ was pronounced with a much lower F1 frequency than the overall mean. The F2 outliers are summarized in Table 4.49. Participant E1 produced stressed /o/ with a very fronted realization and speaker E2 produced unstressed /a/ as a back segment.

Table C.19. F1 outliers produced by the L1 English control group in the narrative task

Speaker	Word	Phoneme	F1	F2
E4	tenían ‘they had’	/e/	272.1	1521.8

Table C.20. F2 outliers produced by the L1 English control group in the narrative task

Speaker	Word	Phoneme	F1	F2
E1	socioeconómicos ‘socioeconomic (adj.)’	/o/	706.1	2484.9
E2	la ‘the’	/a/	725.3	919.8

Two outliers were discovered in the picture-naming task. The F1 outlier (Table C.21) was produced by speaker E4 where the unstressed /o/ was raised. The F2 outlier (Table C.22) was produced by the same participant where the unstressed /o/ was pronounced as a front vowel.

Table C.21. F1 outliers produced by the L1 English control group in the picture-naming task

Speaker	Word	Phoneme	F1	F2
E4	cocina ‘kitchen’	/o/	333.9	1620.7

Table C.22. F2 outliers produced by the L1 English control group in the picture-naming task

Speaker	Word	Phoneme	F1	F2
E4	autobús ‘bus’	/o/	458.8	2025.6

Twenty three outliers were discovered in the sentence-reading task. Table C.23 summarizes the F1 outliers and Table C.24 presents the F2 outliers. Speaker E2 produced two of the F1 outliers, pronouncing stressed /e/ and unstressed /u/ segments as low vowels. Participant E4 produced the other five F1 outliers, demonstrating raising in the pronunciation of unstressed

/a/, lowering of unstressed /u/, and both lowering and raising of unstressed /o/. Speaker E1 produced six F2 outliers, fronting the stressed and unstressed /o/ and producing unstressed /e/ and /i/ segments with a back-like pronunciation. Speaker E2 produced five F2 outliers, pronouncing unstressed /a/, and stressed and unstressed /e/ as back segments. Speaker E3 produced one instance of stressed /i/ as a back segment. Finally, speaker E4 produced four F2 outliers by pronouncing word-final-unstressed /o/ with a fronted realization.

Table C.23. F1 outliers produced by the L1 English control group in the sentence-reading task

Speaker	Word	Phoneme	F1	F2
E2	hoteles 'hotels'	stressed /e/	810.5	1845.1
E2	turismo 'tourism'	/u/	634.9	1566.6
E4	cacao 'cacao'	unstressed /a/	426	1837.4
E4	potente 'powerful'	/o/	388.2	1837.4
E4	bovino 'bovine'	word-final /o/	759.3	1792.4
E4	vacuna 'vaccine'	/u/	638.9	2007
E4	vacuna	word-final /a/	343.7	1751.7

Table C.24. F2 outliers produced by the L1 English control group in the sentence-reading task

Speaker	Word	Phoneme	F1	F2
E1	abogado 'lawyer'	first /o/	450.7	1805.5
E1	mínimo 'minimum'	/o/	620.7	1901.9
E1	gogó 'go-go'	unstressed /o/	522.9	2320.9
E1	gogó 'go-go'	stressed /o/	653.9	2109.5
E1	dude 'doubts'	/e/	507.9	1137.9
E1	viruta 'shaving'	/i/	426.6	1469.8
E2	Perú 'Peru'	/e/	618	929
E2	abogado	unstressed /a/	830.4	899.8
E2	película 'movie'	/a/	836.7	870.9
E2	género 'genre'	stressed /e/	448	826.7
E2	gota 'grop'	/a/	499.2	826.7
E3	rímel 'mascara'	/i/	436.3	873.4
E4	pepino 'cucumber'	/o/	501.1	1806.9
E4	bovino	word-final /o/	759.3	1792.4
E4	dopado 'drug'	word-final /o/	546.4	1822.1
E4	mínimo	word-final /o/	725.9	2022.9

The nonce words reading task yielded seven outliers. The F1 outliers are summarized in Table C.25 and the F2 outliers are outlined in Table C.26. Speakers E1, E2, and E3 each produced one F1 outlier: E1 produced stressed /o/ as a low vowel, E2 produced unstressed /i/ as

lowered, and E4 produced unstressed /a/ with a very low F1 value. Participants E2 and E3 produced three F2 outliers, pronouncing stressed and unstressed /a/ as back vowels. Finally, E3 pronounced unstressed /a/ with a very fronted production.

Table C.25. F1 outliers produced by the L1 English control group in the nonce words reading task

Speaker	Word	Phoneme	F1	F2
E1	jansoda	/o/	825.7	1282.4
E2	piraga	/i/	664.5	1870.1
E3	mateba	/a/	1150.7	1652.7

Table C.26. F2 outliers produced by the L1 English control group in the nonce words reading task

Speaker	Word	Phoneme	F1	F2
E2	bochaca	/a/	870	915.4
E2	mítabusa	/a/	670.9	880.1
E3	tandagal	/a/	670.8	2171.6
E4	tibana	/a/	655.5	909.3

C.1.4.3 Ukrainian HSs

The Ukrainian HSs produced five F2 outliers in narrative task and no F1 outliers. The F2 outliers are summarized in Table C.27. Speaker U1 produced stressed /i/ with a very posterior position. Participant U4 pronounced unstressed /o/ as a front vowel. Finally, speakers U5 and U6 both produced unstressed /a/ as a back vowel.

Table C.27. F2 outliers produced by the Ukrainian HSs in the narrative task

Speaker	Word	Phoneme	F1	F2
U1	termina ‘ends’	/i/	440.5	1364.2
U4	joyería ‘jewelry’	/o/	496.8	2016.1
U5	estaba ‘was’	word-final /a/	569.4	926.3
U6	estaba ‘was’	word-final /a/	479.2	858.6
U6	paró ‘stopped’	/a/	655.6	946.7

Four F2 outliers (summarized in Table C.28) were discovered in the picture-naming task. Speaker U1 pronounced unstressed /i/ as a back segment, participant U5 produced unstressed /u/ as a front segment, and speaker U6 produced unstressed /a/ with a very low F2 value and unstressed /o/ with a high F2.

Table C.28. F2 outliers produced by the Ukrainian HSs in the picture-naming task

Speaker	Word	Phoneme	F1	F2
U1	camiseta ‘T-shirt’	/i/	443.1	1005.9
U5	museo ‘museum’	/u/	558.2	2632.4
U6	abogada ‘lawyer’	/a/	556.5	991.1
U6	cuchillo ‘knife’	/o/	412.1	1945

The sentence-reading task yielded the highest number of outliers out of the four tasks.

Table C.29 summarizes the F1 outliers and Table C.30 outlines the F2 outliers. Speakers U2 and U4 pronounced /a/ as a very low segment, speaker U3 produced unstressed /o/ and /u/ as low segments, and participant U4 produced the stressed /u/ as a very high vowel. Participants U1, U4, and U6 together produced three F2 outliers, pronouncing unstressed /a/ as a back segment. Participants U3 and U4 produced five instances of word-final unstressed /o/ as a front segment. Participant U4 produced word-final unstressed /e/ with a very low F2 value, and finally, participant U5 produced stressed /u/ as a front segment.

Table C.29. F1 outliers produced by the Ukrainian HSs in the sentence-reading task

Speaker	Word	Phoneme	F1	F2
U2	papá ‘father’	/a/	1099.5	1760.7
U3	turismo ‘tourism’	/o/	802.8	2304.4
U3	vacuna ‘vaccine’	/u/	643.2	1866.4
U3	godo ‘Gothic’	/o/	782.8	865
U4	vacuna	/a/	1128.7	1781.5
U4	bubute ‘beetle’	/u/	224.3	484.9

Table C.30. F2 outliers produced by the Ukrainian HSs in the sentence-reading task

Speaker	Word	Phoneme	F1	F2
U1	acabado ‘finished’	/a/	655.3	1134.5
U3	turismo	/o/	802.8	2304.4
U3	bovino	/o/	677.9	2205.1
U4	copa ‘glass’	/a/	546.6	1086.6
U4	bubute	/e/	347.1	518
U5	vivo ‘living’	/o/	626.1	2232.5
U5	mínimo ‘minimal’	/o/	638.4	2204.5
U5	gapo ‘spit’	/o/	616.8	2092.3
U5	pitufu ‘career politician’	/u/	403.1	2512.5
U6	gota ‘drop’	/a/	484.9	1137.5

Two outliers were discovered in the nonce words reading task: one F1 outlier and one F2 outlier. The F1 outlier (Table C.31) was produced by speaker U2 where stressed /a/ was pronounced as a very low segment. The F2 outlier was produced by participant U3 in the word ‘fadola’ where the unstressed /a/ was realized as severely posterior.

Table C.31. F1 outliers produced by the Ukrainian HSs in the nonce words reading task

Speaker	Word	Phoneme	F1	F2
U2	musá ‘father’	/a/	1267	1715

Table C.32. F2 outliers produced by the Ukrainian HSs in the sentence-reading task

Speaker	Word	Phoneme	F1	F2
U3	fadola	/a/	732.3	1150.1

C.1.4.4 Polish HSs

Several outliers were discovered in the narrative task completed by the Polish HSs. The F1 outliers can be found in Table C.33 and the F2 outliers can be viewed in Table C.34. Speaker P5 produced one F1 outlier, where unstressed /i/ was pronounced like a middle vowel. Participant P8 produced two F1 outliers, where stressed and unstressed /o/ were pronounced as high vowels. Speakers P1, P8 and P9 produced three of the F2 outliers pronouncing the front unstressed segments /i/ and /e/ as back vowels. Finally, the fourth F2 outlier was produced by participant P11, who pronounced unstressed /o/ as a front vowel.

Table C.33. F1 outliers produced by the Polish HSs in the narrative task

Speaker	Word	Phoneme	F1	F2
P5	y ‘and’	/i/	570.4	2371.9
P8	cómo ‘how’	/o/	262.2	1106.4
P8	cómo ‘how’	/o/	303.3	1446.7

Table C.34. F2 outliers produced by the Polish HSs in the narrative task

Speaker	Word	Phoneme	F1	F2
P1	allí ‘there’	/i/	366.5	941.8
P8	que ‘that’	/e/	607.2	1020.6
P9	tiene ‘has’	/e/	533.2	1040.1
P11	tiempo	/o/	640.6	2214.6

The picture-naming task yielded thirteen outliers. The F1 outliers are summarized in Table C.35 and the F2 outliers are outlined in Table C.36. Participants P3 and P8 produced two of the F1 outliers, pronouncing unstressed /e/ as a low vowel. The other three F1 outliers were produced by speakers P2, P3, and P8, where the segments /i/ and /u/ were pronounced as low segments and /o/ experienced raising. Four /a/ segments were produced as F2 outliers. Speakers P2 and P4 pronounced unstressed /a/ as a front vowel, while P2 and P9 produced stressed and unstressed /a/, respectively, as back vowels. The unstressed /e/ segment was produced in a back-like fashion in the speech of participants P2 and P9. Unstressed /o/ was produced as a front segment by informant P5 and the unstressed /i/ was pronounced as a back vowel by participant P6.

Table C.35. F1 outliers produced by the Polish HSs in the picture-naming task

Speaker	Word	Phoneme	F1	F2
P2	cocina ‘kitchen’	/o/	277.3	1542.1
P3	comida ‘food’	/i/	613.6	2769.6
P6	teatro ‘theater’	/e/	866.1	1879.4
P8	película ‘movie’	/u/	589.1	1469.7
P8	teatro	/e/	847.6	1852.2

Table C.36. F2 outliers produced by the Polish HSs in the picture-naming task

Speaker	Word	Phoneme	F1	F2
P2	televisión ‘television’	/e/	594.8	779.9
P2	basura ‘trash’	/a/	658.3	2331.7
P2	regalo ‘present’	/a/	488.3	607.1
P4	cebolla ‘onion’	/a/	549.2	2286.1
P5	perro ‘dog’	/o/	628.7	2309.5
P6	máquina ‘machine’	/i/	333.1	1227.1
P9	navidad ‘Christmas’	/a/	715.8	830.2
P9	cebolla ‘onion’	/e/	483	1027.9

As in the previous speaker groups, the sentence-reading task yielded the highest number of outliers in the data of the Polish HSs. Table C.37 summarizes the F1 outliers and Table C.38 presents the F2 outliers. Participant P8 produced the highest number of F1 outliers; the segments /i a o u/ were produced considerably lower than the average height displayed by the group. In

speaker P11's production, the segments /i e a/ are raising. Informants P3 and P4 produced unstressed /o/ as low vowels. Finally, stressed /a/ and unstressed /u/ segments are raised in the production of speakers P3 and P9, respectively. Participant P3's data yielded the highest number of F2 outliers, where the segments /i e a/ were all produced as back vowels. Speakers P6, P8 and P11 produced eight instances of stressed and unstressed /o/ with a fronted realization. Participants P2 and P9 produced the unstressed vowels /i/ and /e/ as back segments and speaker P5 demonstrates fronting of unstressed /a/.

Table C.37. F1 outliers produced by the Polish HSs in the sentence-reading task

Speaker	Word	Phoneme	F1	F2
P3	tacón 'heel'	/a/	396.4845	840.3995
P3	turismo 'tourism'	/o/	841.4829	939.2385
P4	vacuna 'vaccine'	/a/	431.1948	1489.915
P8	gabarro 'tumor'	/o/	837.6684	1003.099
P8	ropa 'clothing'	/o/	858.3508	1629.731
P8	pavo 'turkey'	/a/	1019.508	1697.521
P8	turismo	/o/	844.9669	882.2284
P8	pipirigallo 'sainfoin'	/i/	551.9047	1120.298
P8	vacuna	/u/	742.4693	1647.788
P8	rato 'a little while'	/o/	862.4595	890.0388
P8	pupila 'pupil'	/i/	650.1924	1527.338
P8	vocal 'vowel'	/o/	854.603	1999.451
P8	pitufu 'career politician'	/o/	854.0784	1203.91
P9	tutela 'protection'	/u/	260.2871	1981.198
P10	bocado 'bite'	/o/	828.256	1225.536
P11	cada 'every'	/a/	445.9934	1692.448
P11	pepino 'cucumber'	/e/	280.5454	2092.542
P11	pipirigallo	/i/	221.174	2409.581

Table C.38. F2 outliers produced by the Polish HSs in the sentence-reading task

Speaker	Word	Phoneme	F1	F2
P2	pitufu	/i/	407.0649	1203.938
P3	cabeza 'head'	/e/	689.9683	1158.252
P3	billete 'ticket'	/e/	487.7786	667.9052
P3	debe 'should'	/e/	637.2271	951.3596
P3	tacón	/a/	396.4845	840.3995
P3	tulipán 'tulip'	/i/	321.7897	1117.311

P3	pega ‘hits’	/e/	378.3728	961.2091
P3	culillo ‘fear’	/i/	384.3073	1153.068
P3	vadera ‘wide ford’	/e/	685.3541	866.3465
P5	cabeza	/a/	784.491	2223.659
P6	tímido ‘shy’	/o/	658.7406	1938.149
P6	abogado ‘lawyer’	/o/	706.5129	1899.768
P6	pepino	/o/	813.7131	1973.024
P6	total ‘complete’	/o/	569.7496	1875.704
P8	hoteles ‘hotels’	/e/	729.8682	1131.5
P8	pipirigallo	/i/	325.5132	1139.453
P8	pipirigallo	/i/	551.9047	1120.298
P8	vocal	/o/	854.603	1999.451
P9	tuve ‘(I) had’	/e/	516.1648	1162.362
P11	codo ‘elbow’	/o/	590.3944	2080.517
P11	bovino ‘bovine’	/o/	654.7029	1850.55
P11	rato	/o/	619.7518	2074.276
P11	tope ‘limit’	/o/	607.4923	2127.051

Finally, several outliers were discovered in the sentence-reading task. Table C.39 outlines the F1 outliers and Table C.40 presents the F2 outliers. Speakers P5, P6 and P8 produced four F1 outliers in the pronunciation of stressed and unstressed /u/, which was realized as a low vowel. Participants P8 and P10 also produced stressed /a/ and /o/ with F1 values that are much lower than the group’s average. Speakers P1, P2, P5, P6, P8 and P9 produced six /u/ and /a/ F2 outliers, where the segments were realized as front vowels. Finally, participants P3, P5, and P6 produced the vowels /e a o/ as back segments.

Table C.39. F1 outliers produced by the Polish HSs in the nonce words reading task

Speaker	Word	Phoneme	F1	F2
P5	musá	/u/	625.0	2266.8
P6	musá	/u/	652.3	1801.8
P8	noca	/o/	829.5	1838
P8	piluca	/u/	608.8	1253.5
P8	mítabusa	/u/	591	2012.9
P10	bochaca	/a/	1038.1	1683.8

Table C.40. F2 outliers produced by the Polish HSs in the nonce words reading task

Speaker	Word	Phoneme	F1	F2
P1	musá	/u/	426.5	2245.7

P2	mateba	/a/	676.4	2389.4
P3	beta	/e/	764.1	1019.4
P3	jansoda	/a/	705.6	806.4
P5	fadola	/o/	598.4	841.9
P5	musá	/u/	625	2266.8
P6	desa	/a/	625	2266.8
P8	noca	/a/	829.5	1837.9
P9	lula	/a/	639.8	735.4
P9	fadola	/a/	492.9	843.4
P9	súbal	/u/	405.7	2274.9

C.2 Voiceless stops

C.2.1 Ukrainian voiceless stops

In the Ukrainian narrative task, all six outliers were produced by speaker U2, who pronounced /p t k/ as long-lag. Table C.41 summarizes these outliers.

Table C.41. VOT outliers produced by the Ukrainian HSs

Speaker	Word	Phoneme	VOT
U2	пані /ˈpa.ni/ ‘lady’	/p/	108.4
U2	пори /ˈpo.ri/ ‘seasons’	/p/	81
U2	там /ˈtam/ ‘there’	/t/	74.6
U2	там /ˈtam/ ‘there’	/t/	69.3
U2	тим /ˈtim/ ‘that one’	/t/	80.9
U2	кожного /ˈkɔʒ.no. ɦɔ/ ‘every’	/k/	81.4

C.2.2 English voiceless stops

C.2.2.1 L1 Spanish control group

Only one outlier was discovered in the English narrative task completed by the L1 Spanish speakers. It was produced by speaker S3, who pronounced the velar /k/ with a very long VOT. Table C.42 presents this outlier.

Table C.42. VOT outliers produced by the L1 Spanish control group

Speaker	Word	Phoneme	VOT
S3	kind	/k/	157.6

C.2.2.2 Ukrainian HSs

Similar to the L1 Spanish control group, the Ukrainian HSs produced only one outlier in the English narrative task, summarized in Table C.43. Participant U1 pronounced the alveolar /t/ with a very long VOT value.

Table C.43. VOT outliers produced by the Ukrainian HSs

Speaker	Word	Phoneme	VOT
S3	to	/t/	215.9

C.2.3 Spanish voiceless stops

C.2.3.1 L1 Spanish control group

Five outliers were discovered in the Spanish narrative task completed by the L1 Spanish control group. Four of the outliers were produced by speaker S3 who pronounced two instances of /k/ and once instance of /p/ and /t/ as long-lag. The other outlier was produced by participant S4 whose /k/ displays a long-lag VOT. Table C.44 outlines these outliers.

Table C.44. VOT outliers produced by the L1 Spanish control group in the narrative task

Speaker	Word	Phoneme	VOT
S3	chico ‘boy’	/k/	77.7
S3	que ‘that’	/k/	64
S3	tiempo ‘time’	/t/	36.1
S3	punto ‘point’	/p/	38.7

S4	que	/k/	67.4
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Two outliers (summarized in Table C.45) were discovered in the picture-naming task. One outlier was produced by speaker S1 and another by participant S2 who pronounced segments /k/ and /t/ as long-lag.

Table C.45. VOT outliers produced by the L1 Spanish control group in the picture-naming task

Speaker	Word	Phoneme	VOT
S1	comida ‘food’	/k/	62.3
S2	turista ‘tourist’	/t/	52.8

Six outliers were found in the sentence-reading task. Four of the outliers were discovered in participant S1’s data and two in S2’s production, who pronounced segments /p t k/ as long-lag.

Table C.46. VOT outliers produced by the L1 Spanish control group in the sentence-reading task

Speaker	Word	Phoneme	VOT
S1	pavo ‘turkey’	/p/	72
S1	vacuna ‘vaccine’	/k/	65.3
S1	pulido ‘polished’	/p/	58.9
S1	tulipán ‘tulip’	/t/	42.6
S2	total ‘complete’	/t/	43.2
S2	tutela ‘protection’	/t/	40.8

Speaker S1 produced three out of the four outliers in the nonce words reading task. Participant S2 also produced one outlier. Table C.47 summarizes these productions.

Table C.47. VOT outliers produced by the L1 Spanish control group in the nonce words reading task

Speaker	Word	Phoneme	VOT
S1	tiroga	/t/	46.4
S1	quetá	/t/	72.3
S1	curpulin	/p/	71
S5	tibana	/t/	39.7

C.2.3.2 L1 English control group

No outliers were found in the picture-naming and the nonce words reading tasks completed by the L1 English control group. One outlier was discovered in the narrative task, produced by speaker E1, and two outliers were found in the sentence-reading task, where speakers E2 and E4 produced /p/ as long-lag.

Table C.48. VOT outlier produced by the L1 English speaker in the narrative task

Speaker	Word	Phoneme	VOT
E1	pero ‘dog’	/p/	146

Table C.49. VOT outliers produced by the L1 English control group in the sentence-reading task

Speaker	Word	Phoneme	VOT
E2	puro ‘pure’	/p/	142.1
E4	pupila	/p/	129.1

C.2.3.3 Ukrainian HSs

Two outliers were found in the Spanish narrative task, both produced by speaker U3, who pronounced /p/ and /t/ as long-lag.

Table C.50. VOT outliers produced by a Ukrainian HS in the narrative task

Speaker	Word	Phoneme	VOT
U3	película ‘movie’	/p/	71.8
U3	sintió (‘he/she felt’)	/t/	69.8

Similar to the narrative task, the picture-naming elicitation yielded two outliers, both produced by speaker U5, who pronounced /p/ and /t/ as long-lag.

Table C.51. VOT outliers produced by a Ukrainian HS in the picture-naming task

Speaker	Word	Phoneme	VOT
U5	pavo ‘turkey’	/p/	66.5
U5	turista ‘tourist’	/t/	68.2

The sentence-reading task yielded the greatest number of outliers. One outlier was found in the data set of participant U1. Two other outliers were produced by speaker U4. Participant U5 produced six outliers and finally, speaker U6 produced one outlier.

Table C.52. VOT outliers produced by the Ukrainian HSs in the sentence-reading task

Speaker	Word	Phoneme	VOT
U1	tulipán ‘tulip’	/t/	56.4
U4	cobarde ‘cowardly’	/k/	76.3
U4	pipirigallo ‘sainfoin’	/p/	67.8
U5	tagalo ‘Tagalog’	/t/	65.6
U5	tulipán	/t/	58
U5	pulido ‘polished’	/p/	61.8
U5	culín ‘drop’	/k/	76.8
U5	culillo ‘fear’	/k/	80.6
U5	tutiplén ‘freely’	/t/	49
U6	culillo	/k/	84.6

Finally, five outliers were found in the nonce words reading task and all were produced by speaker U5.

Table C.53. VOT outliers produced by the Ukrainian HSs in the nonce words reading task

Speaker	Word	Phoneme	VOT
U5	tiroga	/t/	78.6
U5	tibana	/t/	71.8
U5	pítabel	/p/	79.9
U5	pítabel	/t/	75.2
U5	quetá	/k/	68.9

C.2.3.4 Polish HSs

Three outliers were discovered in the narrative task completed by Polish HSs. Participants P1 produced two of the outliers and speaker P2 produced the third outlier.

Table C.54. VOT outliers produced by the Polish HSs in the narrative task

Speaker	Word	Phoneme	VOT
P1	pelo ‘hair’	/p/	106
P1	que ‘that’	/k/	139.8
P2	por ‘for’	/p/	92.6

The picture-naming task also yielded three outliers. Participants P1, P2, and P5 each produced one outlier.

Table C.55. VOT outliers produced by the Polish HSs in the picture-naming task

Speaker	Word	Phoneme	VOT
P1	perro ‘dog’	/p/	107.3
P2	tortuga ‘turtle’	/t/	123.6
P5	calculadora	/k/	111.6

The sentence-reading task yielded the highest number of outliers in the Polish HSs’ data.

Table C.56 summarizes these outliers.

Table C.56. VOT outliers produced by the Polish HSs in the sentence-reading task

Speaker	Word	Phoneme	VOT (ms)
P2	tímido	/t/	96.2
P2	tuvo ‘had’	/t/	93.7
P2	pipirigallo	initial /p/	107.2
P2	tabú ‘taboo’	/t/	100
P2	pupila	internal /p/	93.5
P5	pipirigallo	initial /p/	100
P6	pavo	/p/	110
P6	cadera ‘hip’	/k/	129
P6	culillo	/k/	116
P11	pipirigallo	initial /p/	101.9
P11	vacuna	/k/	149.4
P11	virtud ‘virtue’	/t/	102.9

Finally, only one outlier was found in the nonce words reading task and it was produced by speaker P3.

Table C.57. VOT outliers produced by the Polish HSs in the picture-naming task

Speaker	Word	Phoneme	VOT
P3	tibana	/t/	99.6

C.3 Voiced stops

C.3.1 English voiced stops

C.3.1.1 L1 English control group

One data point of the L1 English control group data set is classified as an outlier and was produced by speaker E2 in the word *but*, where /b/ shows an RI of 33.5 dB.

C.3.1.2 Polish HSs

There is one outlier in the Polish HSs data; participant P3 produced the phoneme /b/ in the word *book* with a RI of 40.2 dB.

C.3.2 Spanish voiced stops

C.3.2.1 L1 Spanish Control group

Two outliers were found in the L1 Spanish speakers' narrative task. One outlier was produced by speaker S4 in the word *bueno* ('well'), where /b/ reaches a RI value of 20.8 dB, and another was produced by participant S5 in the word *jugando* ('playing'), where /g/ shows a RI value of 17.8 dB.

Three outliers were found in this sentence-reading task completed by the L1 Spanish control group. All outliers were produced by speaker S1, who pronounced the segment /d/ in the word *debe* ('should') with a RI of 27.4 dB, the stressed /d/ in the word *dude* ('doubts') with a RI of 27.1 dB, and the stressed /d/ in the word *dedo* ('finger') with a RI of 23.3 dB. All three outliers were produced with a high degree of constriction.

C.3.2.2 L1 English Control group

One outlier was discovered in the picture-naming task completed by the L1 English control group. It was produced by speaker E2, whose pronunciation of /g/ in the word *tortuga* ('turtle') registered a RI of 53.7 dB.

The two outliers in the sentence-reading task were both produced by speaker E2 who pronounced /d/ in the word *dopado* ('drug') with a RI of 35.9 dB, and /g/ in the word *pipirigallo* ('sainfoin') with a RI of 37.2 dB.

C.3.2.3 Ukrainian HSs

There are three outliers in the sentence-reading task completed by the Ukrainian HSs. Two of the outliers were produced by informant U1, who displayed a RI of 28.7 dB in the word *acabado* ('finished') for the segment /b/ and a RI of 32.7 dB for /b/ in the word *bota* ('boot'). The third outlier was produced by speaker U5 in the word *botado* ('generous'), where /b/ has a RI of 28.3 dB.

C.3.2.4 Polish HSs

There were seven outliers in this sentence-reading task completed by the Polish HSs. Two of the outliers were produced by participant P1, who pronounced /d/ in the word *dopado* with an RI of 32.6 dB, and /d/ in the word *botado* with an RI of 35.8 dB. Speaker P11 produced the other five outliers. In the word *gabarro* ('tumor'), the segment /g/ was produced with an RI of 37.5 dB. The rest of the outliers are the productions of the bilabial segments: initial /b/ in *bovino* ('bovine') – 37.4 dB, /b/ in *bata* ('robe') – 32.6 dB, /b/ in *tubérculos* ('tubercles') – 32.9 dB, and /b/ in *bubute* ('beetle') – 32.8 dB.

One outlier was found in the nonce words reading task and it was produced by speaker P10 in the word *mítabusa*, where /b/ displays an RI of 52.7 dB.