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The Effects of multilingualism and Music Experience on Tone and Vowel Discrimination Ability

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Abstract

This study investigates the effects of language background (monolingual/bilingual and early/late bilingual exposure), knowledge of a tonal language and music experience on auditory discrimination by employing tone and vowel discrimination tasks. A total number of 8,769 observations were analyzed using logistic regression to answer the following questions: (1) Do vowel and tone discrimination abilities correlate with language background in diverse groups of speakers such as monolinguals and bilinguals of different types (with early or late L2 exposure)? (2) Does musical training affect tone and vowel discrimination? (3) Does knowledge of a tonal language affect tone discrimination? The findings suggest that with regard to vowel discrimination, the only effective variable is early bilingual exposure. In the case of tone discrimination, early bilingual exposure, knowledge of a tonal language and music experience all have positive effects, while bilingualism (independent of early or late bilingual exposure) is associated with less accurate performance in auditory perception. The results suggest the positive impact of early bilingual exposure, knowledge of a tonal language and music experience on enhancing auditory discrimination. Through its focus on the effects of language and music experience on auditory discrimination, this study contributes to the fields of linguistics and psycholinguistics.

Keywords

Bilingualism, Early bilingual exposure, Tonal language, Music experience, Auditory sensory memory, Vowel discrimination, Tone discrimination.

Summary for Lay Audience

In this MA thesis, I study bilinguals and people with music experience in order to see how linguistic and musical experience affects one's ability in discriminating the vowels and tones in a pair. Since nowadays and especially in modern and multicultural societies the number of bilinguals and musicians is increasing, more research has been conducted in this field. Previous literature reviews indicated the enhancement of bilinguals and musicians in auditory perception, working memory, control attention and inhibition. The primary focus of this study is auditory discrimination, in particular vowel and tone discrimination, nevertheless, I have also associated the findings with the sensorimotor system, in particular, auditory sensory memory. The findings shed light on auditory discrimination in people with diverse linguistic and musical backgrounds. Auditory discrimination refers to the ability and capacity to distinguish sounds and phones in speech, even when the phonetic characteristics of the sounds are very similar (Wepman, 1960; Weiner, 1967; Kuczynski & Kolakowsky, 2011). Moreover, this study briefly addresses the literature gap between the connection between auditory sensory memory and phonetic and phonological learning. The findings of this study help us to gain a better understanding of speech perception and auditory discrimination in various circumstances, and this knowledge could be used to inform pedagogical strategies.

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Chapter 1

1 Introduction

Recent years have seen an increased interest in the areas of music training and bilingualism, as they both may play an important role in the enhancement of executive functions and prevention of age-related cognitive decline (Bidelman & Alain, 2015; Vega-Mendoza et al., 2015). In this study, I investigate the relationship between language background (being monolingual or bilingual), music experience and auditory discrimination by comparing tone and vowel discrimination in monolingual and bilingual speakers of different languages and music backgrounds. Furthermore, I examine the effect of tonal language knowledge on discriminating unfamiliar tones. The contradictory results of previous studies regarding the possible effects of bilingualism on speech perception (Antón et al., 2016; Higby et al., 2013; Morales et al., 2013; Ratiu & Azuma, 2015) and lack of literature on its effect on sensorimotor system, in particular auditory sensory memory have motivated me to conduct this research. In the modern multicultural and multilingual societies, bilingualism could become a central issue in pedagogy and more understanding of its effects and characteristics, in particular those relevant to executive functions will help us plan and provide efficient and practical pedagogical strategies that would meet bilingual's needs.

1.1 Executive functions

Executive functions, which are also referred to as executive control or cognitive control, are typically thought to include four cognitive processes: inhibitory control, interference control, working memory[1] and cognitive flexibility (Diamond, 2016). Cognitive processes are part of daily life and are crucial to decision making, concentration, and attention capabilities. These functions are trainable at any age through different approaches (Diamond, 2016). The preventative effect of bilingualism and music training on age-related cognitive decline has been examined in Bialystok and DePape (2009),

[1] Working Memory is not considered an executive function in all cognitive process's models.

Vega-Mendoza (2015) and Bidelman et al. (2015), among others. The reason bilingualism enhances executive function is thought to be the frequent language switching that employs domain-general cognitive mechanisms (Green & Abutalebi, 2013). As there is a belief that shared regions in the brain govern linguistic and musical processing (Koelsch & Siebel, 2005), this study is focused on the correlation between language background and music experience. To clarify this specific brain function, I can refer to Moreno et al.'s (2014) study on neural plasticity difference in monolinguals, bilinguals, musicians, and non-musicians. As Moreno et al. (2014) claimed, bilinguals and musicians have increased and enhanced neural plasticity, compared to non-musicians and monolinguals. Music training modifies the P2, a waveform feature of the event-related potential, and N2 waves, a component of event-related potential (ERP). Bilingualism modifies the N2 and P3, a wave of the event-related potential (ERP) component (Moreno et al., 2014). According to previous literature, musicianship is associated with enhanced language-related processing such as voice-pitch discrimination (Bidelman & Krishnan, 2010).

1.2 Auditory discrimination

Turning now to auditory discrimination that has been studied in this thesis, it is the ability and capacity to distinguish sounds and phones in speech, even when the phonetic characteristics of the sounds are very similar (Forgeard et al., 2008; Kuczynski & Kolakowsky-Hayner, 2011; Weiner, 1967; Wepman, 1960). Since speech perception is my focus in this study, first, I take a short look at the literature identifying the effects of language background and music experience on speech perception. Many of the previous investigations on the effect of bilingualism indicate that bilinguals display enhanced cognitive performance, ability to perceive foreign speech sound and acquisition of a second language (Bialystok et al., 2017; Ressel et al., 2012). This advantage is thought to result from the larger volume of Heschl's Gyrus in bilinguals' primary auditory cortex (Ressel et al., 2012). As Ressel et al. (2012) conclude, learning a second language would lead to an increase in the size of the auditory cortex. Moreover, Calabrese (2012) proposes that auditory sensory memory plays a crucial part in novel sound acquisition. Regarding working memory, even though some of the previous studies confirm a bilingual advantage in working memory (Alain et al., 2018; Blom et al., 2014), some studies have challenged this finding, stating that there is no bilingual advantage in working memory (Ratiu & Azuma, 2015). Perhaps the contradictory results of these studies are due to the difficulty of defining 'bilingualism' and testing populations with differing characteristics. For instance, the age of statistical population is important in a sense that bilingual advantages are mostly muted in adulthood (Spinu et al., 2018). It is also said that methodological and conceptual differences in previous studies cause the conflicting results related to bilingual advantages. These differences include talent, language-pair factors, experimental task complexity across studies (Spinu et al., 2020).

1.3 Musicians versus non-musicians

Turning to the differences between musicians and non-musicians, the majority of the studies reveal that when it comes to speech perception and auditory recognition memory for both musical and non-musical sounds, musicians have better performance (Cohen et al., 2011; Gottfried et al., 2004). In a study conducted by Gottfried (2007), musicians' ability to perceive and produce unfamiliar music tones was assessed. Given this thesis' focus, in what follows I only report the results of the perception task for which participants were asked to determine the pitch of a sine-wave tone and identify the four different tones of Mandarin. All the participants were native speakers of English and divided into two groups: musicians and non-musicians. The findings were that musicians' performance was significantly better than that of non-musicians. Moreover, a positive correlation between music training and L2 acquisition has also been found in studies by Zeromskaite (2014) and Levitin & Menon (2003). Compared to non-musicians, musicians are better at the acquisition of auditory-related features of an L2 such as discrimination and identification of phones and tones (Delogu et al., 2010; Marie et al., 2011).

1.4 Music experience and language learning

A considerable amount of literature published on music training and language reports a positive correlation between music training, phonological abilities and, L2 pronunciation (Milovanov et al., 2009; Milovanov et al., 2010; Slevc & Miyake, 2006). Musical training develops auditory perception; hence, it simplifies the process of learning L2 acoustic features including pitch and duration (Chobert & Besson, 2013; Kraus & Chandrasekaran, 2010; Strait et al., 2010). In addition, musical expertise positively affects the perception of new phonological contrasts (Bettoni-Techio et al., 2007).

Regarding the other advantages of music training, I can refer to its effects on working memory that is effectively enhanced by music training (Posedel et al., 2012). An investigation by D’Souza et al. (2018) on executive function in bilinguals and monolinguals with or without musical training, showed that the only group with enhanced working memory was musicians. By applying fMRI imaging and n-back task, Alain et al. (2018) assessed the effects of musical training and bilingualism on executive functioning and working memory. Their results indicated that compared to monolinguals and non-musicians, bilinguals and musicians expended less cognitive effort for equally successful performance on WM tasks. As the researchers reported, this advantage is caused by more efficient use of neural resources in musicians and bilinguals.

1.5 Vowel and tone discrimination

The next section of this chapter will define some of the terms and tasks applied throughout this study and the effect of language background and music experience on vowel and tone discrimination based on previous literature. According to Ladefoged and Maddieson (1996), the term 'vowel' refers to a syllabic speech sound pronounced without causing any strictures in the vocal tract and is part of prosodic variations such as tone. An earlier study on vowel discrimination conducted by Levey and Cruz (2004), postulates that discrimination is the basis of phonological awareness. To further the understanding of vowel discrimination, Levey and Cruz (2004) examined English vowel discrimination in monolinguals and bilinguals (Spanish and English speakers). Surprisingly, bilinguals had more difficulties discriminating certain vowels whereas monolinguals displayed enhanced performance. According to the authors, three variables affected bilinguals’ performance. One of these variables is the age of L2 acquisition. Bilinguals who had learned English earlier in life demonstrated better performance compared to late bilinguals. Since this factor influences bilinguals' auditory discrimination ability, I have considered it in the current study and have divided the participants into two groups of early or late bilinguals. For the current study, the age of 5 has been considered as the line between the early and late exposure to bilingualism, to make sure the second language would be a home language and not one taught in school. In addition, individuals who have the L2 exposure between the ages 0 to 5, have better pronunciation performance in comparison to those who learn an L2 after the age of 5 (Yeni-Komshian et al., 2000).

Regarding the influence of musical training or abilities in discriminating vowels, Gottfried and Xu (2008) compared musicians and non-musicians on discrimination and production of unfamiliar Mandarin tone and vowel contrasts and reported a positive relationship between musicianship and Mandarin vowel perception, as demonstrated by musicians' better performance compared to non-musicians.

Concerning tone, generated pure tones are applied in the present study. According to Roederer's (2008) definition, "When a sound causes a simple harmonic motion of the eardrum with constant characteristics (frequency, amplitude, phase), we hear what is called a pure tone" (p. 28). The relevant literature has uncovered a positive correlation between bilingualism and tone discrimination (Tong et al., 2015; Wang & Saffran, 2014). In a study by Tong et al. (2015) Cantonese-English (a tonal and stress language, respectively) bilinguals outperformed monolinguals in both tone and stress perception tasks. Tong et al. (2015) claimed that bilinguals might benefit from suprasegmental representation that shares acoustic cues relevant to tone and stress and separates both tone and stress-specific cues. Hutka et al. (2015) report that although musicians and native speakers of tonal languages both display enhanced aspects of auditory acuity, musicianship enhances the auditory process in a broader manner, leading to increased development of tuning pitch and timbre-related brain processes. Previous findings on musical ability and tone perception, however, have been inconsistent and contradictory. While the majority of studies support the correlation between musical experience and tone perception (Gottfried, 2007; Lee & Hung, 2008; Wong et al., 2007), a number of other investigations have found no link between musical abilities and tone perception (Li & DeKeyser, 2017; Zhao & Kuhl, 2015).

1.6 Tonal languages

Specific language background (speaking a tonal or non-tonal language) and typology seems to affect tone discrimination in individuals (Francis et al., 2008; Qin & Mok, 2014). Numerous studies have described the role of tonal languages on tone discrimination. Data from these sources have mostly identified knowledge of tonal language as a positive factor in tone discrimination (Burnham et al., 1996; Qin & Mok, 2014; Wayland & Guion, 2004). The advantage for speakers of tonal languages in identifying tones could be expanded to the tones of an unfamiliar tonal language, as well (Wayland & Guion, 2004). Wayland & Guion (2004) state that knowledge of a tonal language might enhance tone perception in another language. Departing from this statement, several investigations reported results based on which knowing a tonal language does not lead to enhanced auditory discrimination ability for tones (Francis et al., 2008; Wang, 2013). A good example of this is Wang's paper (2013) on the influence of a native tonal language on tone perception in an unfamiliar tonal language and the effectiveness of training on perceptual learning of L2 tone. The results showed that knowing a tonal language does not lead to an advantage in discriminating individual pitches. Therefore, it is not yet clear whether the presence of a tonal language enhances auditory ability in tone discrimination.

1.7 Auditory sensory memory and phonetic and phonological learning

Relatively few studies have addressed the connection between auditory sensory memory (ASM) and phonetic and phonological learning (PPL), hence this area is understudied. My interest in this area stems from this critical gap in the literature. ASM is engaged when a sound is heard (Nees, 2016). In addition, Calabrese (2012), indicates that ASM (which he refers to as "echoic memory") plays a fundamental part in PPL. Recent studies have shown the enhancement of auditory skills in bilinguals (Krizman et al., 2012) and speculated that ASM and PPL might be related (Spinu et al., 2020; Spinu et al., 2018). Krizman et al. (2012) investigated whether there is a connection between bilingualism and enhanced experience-dependent plasticity in subcortical auditory processing. Results indicated that bilinguals had enhanced subcortical representation of the fundamental frequency of speech sounds alongside improved sustained selective attention. In a study conducted by Cohen et al. (2011), auditory and visual memory (parts of sensory memory) in musicians and non-musicians was investigated. The authors found that musicians display superior auditory recognition memory for musical and non-musical auditory information.

1.8 Present study

Turning now to the topic of executive function, even though, it has been widely investigated in bilinguals, sensorimotor mechanisms have often been overlooked (Kühne & Gianelli, 2019; Simmonds et al., 2011). A first step in understanding these mechanisms better would be to examine auditory sensory memory. The main aim of this MA thesis is to determine whether there is a correlation between language background and auditory discrimination. The secondary aim is to investigate the relationship between music training and tone and vowel discrimination. Finally, this study investigates the effect of tonal language knowledge on auditory discrimination ability for tones. This work will contribute to research on the effects of language background and music training on auditory discrimination by examining auditory working memory using a vowel and tone discrimination task in four groups: bilinguals (with different ages of L2 exposure), monolinguals, musicians and non-musicians. The current study will contribute to both linguistics and psycholinguistics by studying the auditory sensory memory and vowel and tone discrimination of musicians, non-musicians, bilinguals, and monolinguals. Its findings have the potential to inform practical pedagogical strategies for PPL of a second language to musicians, non-musicians and monolinguals. PPL helps us to learn how to properly recognize and articulate the sounds of a language.

91 participants with different language backgrounds and music experience were recruited for this study. The main experimental tasks, designed to assess auditory discrimination ability, are vowel and tone discrimination. An auditory discrimination task required listeners to determine whether two members of a pair of vowels, consonants, or tones, are the same or different. To examine the vowel discrimination, for the vowel matching task, Crowder's (1982) methodology was followed. For the tone matching task, a tone-

discrimination task, such as that used in Winkler and Cowan (2005) and Rabinowicz et al. (2000), was chosen to assess ASM.

In order to conduct this research, three research questions were established as follows:

1. Do vowel and tone discrimination abilities correlate with language background in diverse groups of speakers such as monolinguals and bilinguals of different types (early/late bilinguals)?
2. Does musical training affect tone and vowel discrimination?
3. Does knowledge of tonal language affect tone discrimination?

The remainder of this thesis is structured as follows: in the second chapter, I present a summary and relevant results from existing literature. First, I address the effect of bilingualism and music experience on speech perception. Then, I cover the literature regarding the differences between monolinguals and bilinguals and musicians and non-musicians. Furthermore, I delve deeper into the relationship between language background and musical training, and I focus on vowel and tone discrimination and how it could be affected by bilingualism and music experience. This chapter briefly reports the influence of tonal languages on vowel and tone discrimination. Finally, a comprehensive review of auditory sensory memory and its function is provided. The literature review is followed by the third chapter that describes and provides a detailed review of the methodology applied in the present study. In the methodology section, I provide information regarding the participants, the instruments used to collect the data, tasks, stimuli, procedure employed and the data analysis process. Chapter 4 analyses the data obtained from four groups of participants: monolinguals with no music experience, monolinguals with music experience, bilinguals with no music experience and bilinguals with music experience. The Results chapter presents the exclusion criteria employed and the significant and non-significant results of the vowel and tone discrimination tasks. The chapter is closed by the summary of results. The last chapter discusses the findings in the context of the proposed research questions for this thesis. In addition, it clarifies and situates the results in the larger context of the literature review and previous studies.

Overall, the discussion chapter includes the discussion, conclusion, proposed directions for future work, and an overview of the study's limitations.

Chapter 2

2 Literature review

The following literature review is divided into five subsections, starting with the definition of the term bilingualism, which in its broadest form refers to the ability to speak two languages (Bhatia & Ritchie, 2014), and its advantages and disadvantages in regard to phonological and phonetic learning (PPL), as well as the effects of language background on speech perception. PPL refers to learning how to properly recognize and articulate the sounds of a language. This subsection is followed by a discussion of the perceptual advantage for musicians compared to non-musician counterparts and the impact of musical ability on speech perception. In the third subsection, I take a comprehensive look at the correlation between bilingualism and musical experience and the potential factors behind this interaction. This leads to the subsection on vowel and tone discrimination and the effect of bilingualism and musical experience on individual performance on vowel and tone discrimination tasks. As already mentioned, auditory discrimination is the ability and capacity to distinguish sounds and phones in speech, even when the phonetic characteristics of the sounds are very similar (Weiner, 1967; Wepman, 1960). The last section focuses on the role of auditory sensory memory (ASM) on auditory perception and the results of previous investigations of ASM in bilingualism and music experience.

2.1 The effects of bilingualism on speech perception

Since this MA thesis is mainly focused on bilingualism and musical experience, I must be explicit in defining the term bilingualism. Although differences of opinion still exist, there appears to be some agreement that a bilingual is an individual who is able to speak two languages (Bhatia & Ritchie, 2014). There are two main types of bilinguals in terms of age of acquisition, specifically early and late bilinguals. Early bilingual refers to individuals acquiring and being exposed to two languages up to the age of 4 before the critical period around age 6-7, while late bilinguals acquire their L2 after the age of 4 (Meisel, 2009; Tsimpli, 2014).

Previous research shows bilinguals have enhanced cognitive abilities compared to monolinguals (Adesope et al., 2010; Bialystok, 2017; Bialystok et al., 2012). The positive effects of bilingualism in regard with inhibition (Bialystok et al., 2005) control attention (Abutalebi & Green, 2007) working memory and executive functions (Bialystok et al., 2014; Higby et al., 2013; Morales et al., 2013; Morrison et al., 2019; Pelham & Abrams, 2014) have been studied. As it can be seen, the advantages of bilingualism have been mainly found in executive function. Despite the number of previous studies confirming a bilingual advantage in executive functions and working memory, some investigations have challenged these findings (Antón et al., 2016; Ratiu & Azuma, 2015). To determine the effects of bilingualism on executive functions, I refer to a research conducted by Bialystok et al. (2014). Bialystok *et al*. (2014) compared the performance of monolinguals and bilinguals by employing a Stroop[2], letter, and figure task. Less interference was observed in bilinguals regarding the Stroop and figure task. The authors associate the bilingual's enhanced performance with their enhanced executive abilities, in particular working memory. Furthermore, Pelham and Abrams (2014), also investigated cognitive advantages in three groups of monolinguals, early and late bilinguals and their performance in a picture naming and an attentional network task. For the attentional network task that was designed to assess participant's executive functions and is relevant to the present study, participants were asked to look at the stimuli presented on a computer and press keyboard buttons on each side of the computer corresponding to the direction of stimuli. As predicted by the authors, both early and late bilinguals had an enhanced performance compared to monolinguals. Pelham and Abrams (2014), suggest that this executive function advantage is due to speaking two languages and is not limited to the age of acquisition.

As it has been mentioned, previously published studies on the effect of bilingualism are not consistent. Ratiu and Azuma, (2014) studied the performance of English-Spanish bilinguals and English monolinguals for both verbal and non-verbal working memory

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[2] Stroop task is considered as one of the standard tests of assessing executive functions Bialystok *et al*. (2014)

tasks. Three tasks were employed in this study: a backward digit-span task, an operation span task, and a symmetry span task. Although there was no significant difference between the performance of bilinguals and monolinguals for the non-verbal and symmetry span tasks, bilinguals performed significantly with less accuracy on the operation task. The contradictory results of these investigations are perhaps due to the difficulties of defining ‘bilingualism’, testing populations with differing characteristics and other factors including age, task and participants’ talent (Higby et al., 2013). In regard to sensorimotor system and functions, as previously mentioned, despite their importance, there remains a paucity of evidence of bilingualism effect. Few studies have investigated this topic and they have mostly focused on the bilingual's brain systems and L2 production and proficiency (Kühne & Gianelli, 2019; Simmonds et al., 2011). In this thesis, I address how bilingualism affects the sensorimotor system in perception. So far based on what is known about the effect of bilingualism, I can refer to its positive effects on the complexity of sensorimotor processing that would help with better interaction with the environment. This effect has been observed in bilingual and multilingual children (Berken et al., 2017). In a study conducted by Simmonds et al. (2011) on the possible changes occurring in motor-sensory control due to native and non-native speech production, the authors observed a great activity in sensory regions of bilinguals, including auditory and somatosensory areas. These results help them to conclude that learning an L2 is followed by functional consequences on bilingual's cortex. In accordance with Simmonds et al's. (2011) result, McDonald's (2006) findings also demonstrated that speaking an L2 leads to a greater level of activation in bilingual's brain. The author explains this higher level of activation could be due to the need to make more effort to retrieve and articulate an L2.

Regarding bilingualism and phonetic learning, Antoniou et al. (2015) recruited English-Mandarin and English-Korean bilinguals and English monolinguals for two experiments on phonetic learning. The monolingual and English-Mandarin bilingual participants were asked to learn vocabulary items that required the use of foreign phonetic contrasts to signal word meaning. Artificial languages were used for this study. First, each word was presented accompanied by its picture. Then in the second part, a test phase took place during which words were auditorily presented beside the pictures and participants had to choose which picture belonged with each word. The results of the first experiment demonstrated that bilinguals learn phonetic distinctions better than monolinguals even when there is no phonetic similarity between the target language and the native language. The results of the second experiment, for which English-Korean bilinguals were also included and participants were asked to produce vocabulary in a new Korean-like artificial language, showed that even though bilinguals outperformed monolinguals, only Korean-English bilinguals demonstrated a learning advantage for Korean-like lenition which was difficult to produce. Therefore, Antoniou et al. (2015) claim that specific language background affects the learning of different foreign phonetic contrasts. Overall, the authors conclude that bilinguals have an advantage in phonetic learning and argue that this advantage may be due to bilinguals' enhanced working memory and executive functioning. In the same vein, Tremblay and Sabourin (2012) evaluated the effects of language background on the development of speech perception abilities and noted that compared with monolinguals, multilinguals and bilinguals benefit from a robust speech perception ability.

While previous findings (Spinu et al., 2020; Spinu et al., 2018) indicate a connection between bilingualism and novel accent learning, the results of studies examining bilingualism and vowel discrimination indicate that bilinguals do not demonstrate enhanced performance with vowel discrimination (Rinker et al., 2010). Rinker et al. (2010) carried out an investigation on the discrimination of native and non-native vowels in bilingual and monolingual children aged 3 to 5 years. The participants were placed in an electrically shielded and sound-attenuated booth and given a headphone through which the words containing the target vowels were played. The participants were then asked to choose a silent cartoon and to focus their attention on it. A significant reduced MMN (Mismatch negativity) was reported in bilinguals for non-native vowel contrasts while monolinguals displayed better discrimination for the same vowel contrasts (in their native language). Regarding the contrasts for vowels present in both native and non-native languages, no difference was shown between bilingual and monolingual groups. Hence, despite the fact that these bilinguals were exposed to the L2 all their life, the monolinguals demonstrated a more robust discrimination ability. The authors believed that the degree to which the children were exposed to the L2 caused the reduced MMN.

In order to have native-like performance in their L2, the children must be immersed in the L2 environment. Hojen and Flege (2006) conducted an experiment to examine vowel discrimination of English as an L2 by English and Spanish monolinguals and early native Spanish learners of English. As they expected, early bilinguals received a high score and had a nativelike performance in discriminating the vowels, leading authors to assume that it is arising from their considerable perceptual learning. Taken together, the findings suggest that there is a negative correlation between the age of acquisition of L2 and native-like discrimination.

2.2 The effects of musical experience on speech perception

Studies have found that compared with non-musicians, musicians are better at processing auditory information in attentive conditions, in other words when participants are paying full attention to the stimulus, (Peretz & Zatorre, 2005; Tervaniemi et al., 2005). Nevertheless, previous research findings into musicians' superiority in processing auditory information in the pre-attentive condition have been inconsistent and contradictory (Koelsch et al., 1999; Tervaniemi et al., 2005). In the pre-attentive condition, the stimulus is first presented in a previous task and then is presented again under a condition during which participants are not paying attention. Koelsch et al. (1999) examined the effect of long-term training on pre-attentive acoustic processing in professional musicians and non-musicians. They argued that musicians extract more information out of musically relevant stimuli in pre-attentive conditions. By contrast, an investigation conducted by Tervaniemi et al. (2005) examined the pitch discrimination of musicians and non-musicians to determine whether those with different degrees of expertise in music could detect the changes in pitch at both automatic and attentive levels. The results demonstrated that musicians were faster than non-musicians in detecting pitch changes. However, this advantage for musicians was only observed in attentive conditions and not during non-attentive ones. Therefore, their results showed that musicians are not always better during pre-attentive levels. Nevertheless, in the present study, tones are presented to all participants in an attentive condition.

Regarding the relationship between music training and second language acquisition, most of the literature is focused on the effect of music training on the acquisition of phonological aspects of an L2 (Besson et al., 2011; Delogu et al., 2010). These studies concluded that there is a positive correlation between music training and acquisition of auditory-related features of an L2 such as pronunciation, discrimination, and identification of phonemes and tones. One such study is that of Sadakata et al. (2011), who found that music training enhances the ability to perceive timing information in speech signals and discriminate between the members of an L2 vowel contrast. These findings were further corroborated by Martínez-Montes et al. (2013) who also demonstrated that musicians benefit from a larger mismatch negativity (MMNs) to pitch contour deviations in both harmonic sounds and L2 syllables compared to non-musicians. In order to assess the effects of musical aptitude and training on L2 learning, Talamini et al. (2018) conducted a study involving a dictation and grammar task. The purpose of including a grammar task was to examine the effect of music training on an L2 grammatical feature that has not been specifically examined in previous investigations. The musicians outperformed non-musicians in both tasks; nonetheless, while the difference was significant for the dictation task, it was not significant for the grammar task. This led the authors to suggest that musicians benefit from enhanced ability to pay attention to L2 phonology. Regarding the effect of musical experience and tone discrimination, Gottfried (2007) examined the extent to which professional musicians are able to perceive and produce unfamiliar linguistic tones. Mandarin was the language chosen for his study. All the participants were native speakers of American English and did not speak Mandarin. Since in this MA thesis, the focus is speech perception, I only address the perception task and its results. Gottfried’s investigation consisted of two experiments requiring participants to determine the pitch of a sine-wave tone and identify the four different tones of Mandarin, respectively. Musicians performed significantly better on determining sine-wave tone pitches compared to non-musicians. Overall, the results of his experiment suggest that musicians have an advantage in both tone perception and production.

It is well-established that musicians benefit from superior auditory recognition memory for musical and non-musical sounds, as well as demonstrate enhanced cognitive function, such as speech perception, when compared to non-musicians (Cohen et al., 2011; Gottfried et al., 2004). Strait et al. (2010) examined musicians and non-musicians' cognitive and perceptual behavior by conducting various experimental tasks. Musicians displayed better performance for frequency discrimination and auditory attention tasks. According to the authors, the reason behind musicians' enhanced performance lies in their strengthened cognitive modulation of auditory processing, originating in the relationship between auditory-specific cognitive functions and sensory perception. Furthermore, musicians' brains undergo structural transformations, including functional differences in sensorimotor skills (Gaser & Schlaug, 2003). Gaser and Schlaug (2003) studied highresolution anatomical images of the whole brain of 20 professional musicians, 20 amateur musicians, and 40 non-musicians with the use of a voxel-by-voxel morphometric technique. Using this technique, they found a positive association between the degree of musical experience and an increase in Grey Matter (GM) volume, found in motor, auditory, and visual regions of the brain. In other words, the more experienced the musician, the greater the concentration of GM amounts in the aforementioned regions. Koelsch, Schroger, and Tervaniemi (1999) investigated the influences of long-term experience on auditory memory in musicians and non-musicians, using major chords and single tones. A distinct MMN was elicited only in professional musicians when the slightly impure chords were played. Their results suggest that regarding the relevant music stimuli, musicians have a more accurate performance in pre-attentive conditions compared with non-musicians.

2.3 The relationship between language background and music training

It is well known that shared regions in the brain govern musical and linguistic processing, (Koelsch & Siebel, 2005) and that there are neural network differences in musicians and bilinguals, with increased neural plasticity, compared to non-musicians and monolinguals. As it has been previously mentioned in Introduction chapter, both musical training and bilingualism modify N2 which is a component of event related potential (Moreno et al., 2014). According to previous studies, musical training appears to have a positive correlation with language learning (Levitin & Menon, 2003; Tillmann et al., 2003). Further exploring this relationship, Zeromskaite (2014) reported that musical training and aptitude enhanced different aspects of L2 learning, such as reading acquisition, phonological awareness, and pitch perception of L2 speech sounds. The summary of his review article reveals that musical experience leads to enhanced processing of phoneme duration and language segmentation of L2, better L2 phonological production abilities, and enhanced L2 comprehension. Musical training, expertise, and general musical abilities are predictive of phonological abilities and, therefore, lead to better L2 pronunciation (Milovanov et al., 2009; Milovanov et al., 2010; Slevc & Miyake, 2006). In order to examine L2 production and discrimination skills and their relationship to musical aptitude, Milovanov et al. (2009) examined the performance of L1 Danish L2 English learners on a pronunciation task, a phonemic discrimination task, and a Seashore test[3]. For this study, all its subtests including pitch, loudness, rhythm, time, timbre, and tonal memory were employed. The results of Milovanov et al. (2009) demonstrate that participants with more musical aptitude and skills have significantly better L2 pronunciation compared to participants with less musical aptitude and skills. In another study by Slevc and Miyake (2006), the question whether musical ability affects L2 acquisition in general was examined. For this study, 50 native speakers of Japanese were recruited. The participants' musical ability was measured and assessed using two different methods: completion of three subtests of the Wing Measures (Wing, 1948) and a tonal-memory production task for which they were asked to sing three to seven tunes from immediate memory. The tasks were designed to assess participants in the areas of receptive phonology, productive phonology, syntax, and lexical knowledge. The results show that participants with musical abilities demonstrate better performance for receptive and productive phonology tasks compared with the other participants with lower music ability.

Since musical training enhances auditory perception and processing, it is probable that musical training facilitates the process of learning L2 acoustic features such as pitch and duration (Besson et al., 2011; Chobert & Besson, 2013; Kraus & Chandrasekaran, 2010; Strait et al., 2010). Furthermore, Posedel et al. (2012) propose that since musical training and language experience both enhance working memory, working memory could act as a mediator between musical training and language production. In their attempt to explore the relationship between working memory, musical training, and L2 acquisition, Posedel et al. (2012) analyzed the performance of 45 participants on operation span and pitch perception tests. The results indicated that pitch perception and working memory are positively altered by musical training and result in better L2 pronunciation. In a more recent study, D’Souza et al. (2018) investigated musical training, bilingualism, and

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[3] Seashore is a test applied to measure musical aptitude. Based on this test, it is possible to divide musicality into discrete talents (i.e., pitch, tonal memory efficacy and etc) (Milovanov et al., 2009).

executive function and found no advantages for bilingualism in working memory and inhibitory control. However, musicianship demonstrated an advantage in working memory.

Studies over the past decade have provided important information regarding the effects of musical training and bilingualism on cognitive control and executive function. Behavioral studies, such as the work of Schroeder et al. (2016), examined both the separate and combined effects of bilingualism and musical knowledge. They studied four groups of participants: monolingual musicians, non-musician bilinguals, musician bilinguals, and a control group consisting of non-musician monolinguals. This investigation revealed similar benefits of musical training and bilingualism on cognitive control and executive function. One of the benefits found in Schroeder's study (2016) was a reduction in the interference effect for musicians, bilinguals, and musician bilinguals. This finding indicates that these groups benefit from enhanced interference suppression compared to the control group of non-musician monolinguals. The authors conclude this result is attributable to the added music and language experience that leads to plasticity in cognitive functions. Moreover, bilingual musicians were also found to experience a lower interference effect and a smaller Simon effect[4] compared with bilingual non-musicians, monolingual musicians, and monolingual non-musicians.

Bialystok and DePape (2009) investigated whether intensive musical experience leads to enhancements in executive processing, as shown for bilingualism. Their findings were that musical expertise, but not bilingualism, enhanced control in a version of the Stroop task, which includes an auditory and linguistic conflict between a word and its pitch. Alain et al. (2018) examined the effects of musical training and bilingualism on executive functioning and working memory (WM), using fMRI imaging and the n-back task to assess WM. For the first n-back task, the participants had to identify whether the incoming stimulus was in the same semantic category as in one or two trials ago. For

[4] The Simon effect is a term in psychology that assesses the effect of stimulus location in reaction time. Reaction time is faster when the stimulus and response correspond with the location (Simon & Rudell, 1967).

their second n-back task, the participants had to remember the position of one or two trials ago and decide whether the incoming stimulus was presented in the same position. Compared to monolinguals and non-musicians, bilinguals and musicians expended less cognitive effort for equally successful performance on WM tasks. Musicians exhibited greater activation in auditory areas, while bilinguals showed different patterns of activity in language areas. Alain et al. (2018) concluded that even though a WM advantage is observed in both bilinguals and musicians resulting from more efficient use of neural resources, this advantage is mediated by different neural networks specific to the individual life experiences of musicians and bilinguals.

2.4 Vowel and tone discrimination

According to Ladefoged and Maddieson (1996), some of the main features of vowels include that they are syllabic and do not cause major strictures in the vocal tract while being produced. In some languages, vowels can form words without consonants and be pronounced alone. In general, vowels function as components of the prosodic variation, such as tone, and can be distinguished based on quality, loudness, and duration (Ladefoged & Maddieson, 1998). This study focuses on vowel discrimination in monolingual and bilingual speakers from different languages and musical backgrounds. According to Pisoni (1973), the procedure of vowel discrimination involves both phonetic and auditory memory. Based on Cowan and Morse's (1986) description, in case of vowel discrimination, auditory memory decays very quickly and is used to discriminate differences within and between phonetic categories while, phonetic memory lasts longer and is only helpful for in between-category comparisons. Furthermore, Pisoni (1973) reports that while phonetic memory is reliable for both vowels and consonants, auditory memory is more reliable for vowels. In the process of vowel discrimination, phonetic memory is used while comparing the vowels that belong to different phonetic categories and auditory memory is applied when the differences are discriminated between and within phonetic categories. A study conducted by Levey and Cruz (2004) examined the effects of monolingualism and bilingualism on vowel discrimination. According to the authors, discrimination is considered the basis of phonological awareness. For their investigation, they studied the discrimination of English vowels by

English monolinguals and bilinguals who spoke English and Spanish. The bilingual participants included both early and late bilinguals. The results demonstrated that bilinguals (Spanish/English) had difficulties with certain vowel contrasts in English while monolingual speakers of English did not face significant difficulty in vowel discrimination. Three main variables were found to affect bilinguals' performance: the absent vowels in Spanish, the presence of novel words, and the age of acquisition of the second language (L2). Since the early bilinguals displayed better performance compared with the late bilinguals, the findings suggested that the early acquisition of an L2 is an advantage for the bilinguals' performance. As mentioned before, there are two main types of bilinguals in terms of age of acquisition, including early and late bilinguals. Early bilinguals acquiring and being exposed to two languages up to the age of 4 before the critical period around age 6-7, while late bilinguals acquire their L2 after the age of 4 (Meisel, 2009; Tsimpli, 2014). The result of an investigation by Luk et al. (2011) on early and late bilinguals using a flanker task also demonstrated the same results. Early bilinguals outperformed both monolinguals and late bilinguals on the flanker task. Furthermore, they showed a similar level of English proficiency to that of monolinguals. The age of onset of the L2 for their study was 10 years old.

Regarding the influence of musical training or abilities in discriminating vowels, Gottfried and Xu (2008) compared musicians and non-musicians on discrimination and production of unfamiliar Mandarin tones and vowel contrasts. 25 native speakers of English who did not speak Mandarin were recruited for this research. The control group included five native speakers of Mandarin. Musicians were categorized based on their self-rating of musicianship on an 8-point scale. Both vowel and tone discrimination tasks were applied in this study. For the tone discrimination task, musicians performed better compared to non-musicians and native listeners. With respect to the vowel discrimination task, even though musicians performed significantly better than non-musicians, native listeners performed better overall compared to the two other groups. The results show a positive relationship between musicianship and Mandarin vowel and tone perception, as demonstrated by musicians' better performance compared to non-musicians.

Much of the current literature on musical training and expertise focuses on the topic of pitch discrimination. As is comprehensively noted in the Encyclopedia Britannica (2019, June 11), pitch in music refers to "the position of a single sound in the complete range of sound". The frequency of vibration of the sounds that produce the pitch determines whether that pitch is high or low. Regarding pitch in the context of speech, the aforementioned encyclopedia states that "pitch is the relative highness or lowness of a tone as perceived by the ear, and it is the main acoustic correlate of tone and intonation" (Britannica, T. Editors of Encyclopaedia,1998, July 20). Several studies have reported that musicians can detect pitch changes in music and language stimuli faster and more accurately compared with non-musicians (Tervaniemi et al., 2005; Wong et al., 2007). In Hutka et al. (2015), the authors studied the bidirectionality of this music-language association by employing three groups of participants including native English-speaking musicians, native tonal language (Cantonese) non-musicians, and native English-speaking non-musician controls. Their results indicated that although musicians and native speakers of tonal languages both display enhanced aspects of auditory acuity, musicianship enhances the auditory process in a broader manner, leading to increased development of tuning pitch and timbre-related brain processes.

However, previous findings on musical ability and tone perception have been inconsistent and contradictory. While the majority of studies support the correlation between musical experience and tone perception (Alexander et al., 2005; Gottfried, 2007; Lee & Hung, 2008; Li & DeKeyser, 2017), a number of other investigations have found no link between musical abilities and tone perception (Zhao & Kuhl, 2015). For instance, Alexander et al. (2005) assessed brainstem encoding of the linguistic pitch in musicians and non-musicians and found that musicians performed better in both tone identification and discrimination. Based on their results, the researchers concluded that musical ability enhances the aptitude to produce and perceive sound structures, and therefore claimed that a positive correlation exists between musical experience and tone perception. Nevertheless, the results of an investigation conducted by Zhao and Kuhl (2015), lead to a different interpretation. This study consisted of two experiments involving musicians with no prior experience of tonal languages and non-musicians. Participants were asked to take part in a pitch and memory task, followed by discrimination and identification tasks, in order to examine their perception of the lexical tone continuum. The results showed a similar perception of tone continuum in both the musician and non-musician participants. Nevertheless, musicians displayed greater sensitivity to acoustic differences between the stimuli. In the second experiment, the influence of musical training on perceptual learning of lexical tone categories was examined. Half of the participants from each group (musicians and non-musicians) were randomly selected for the experiment. For the training, for two weeks, the participants became familiarized with Tone 2 and Tone 3 (used in the stimuli) and then asked to complete two tasks of 180 trials of two-alternative forced-choice. Then, they were assessed by an identification and discrimination task. Taken together, the results of both experiments show that musicians have higher sensitivity to lexical tonal changes, although they perceive the lexical tone continuum similarly to non-musicians. Furthermore, performance in the training phase that was given to both groups of participants did not result in significant differences between musicians and non-musicians.

Tone holds different but slightly similar definitions in the fields of both music and linguistics. In the field of linguistics, as Yip (2002) notes, tone is a linguistic term that consists of different pitches on syllables. Contrastive tones help us differentiate the meanings of words. These changes of meaning are not only a matter of nuance but can also affect the core meaning. In terms of music, tone refers to a steady and periodic sound that has its specific characteristics such as duration, timbre, pitch, and intensity (Roederer, 2008, p. 2-8). In this study I am working with artificially generated pure tones, hence tones correspond to the second definition. As mentioned before, based on Roederer’s (2008, p.28) explanation, a pure tone is a simple harmonic motion of the eardrum with constant characteristics caused by a sound.

Based on previous research (Tong et al., 2015; Wang & Saffran, 2014), bilinguals also demonstrate greater performance in tone discrimination compared with monolinguals. According to one study conducted by Tong et al. (2015), bilingual speakers of tonal and stress languages, Cantonese and English respectively, outperformed monolinguals on both tone and stress perception. In this study, the authors aimed to address the perception of Cantonese tones in English monolinguals and bilingual children and adults in

Cantonese and English. The authors suggest that bilinguals might benefit from suprasegmental representation that shares acoustic cues relevant to tone and stress and separates both tone and stress-specific cues. In support of this result, using an artificial tonal language, Wang and Saffran (2014) investigated the process of word segmentation in a tonal context. The study consisted of two experiments for which English monolinguals, Mandarin monolinguals, and English and Mandarin bilinguals were recruited. Participants were asked to listen to an artificial language, and after listening for 9 minutes, a forced-choice task was conducted during which participants had to listen to two trisyllabic strings and decide which of the two strings sounded more familiar to them. Based on the results, Wang and Saffran (2014) reported that bilingual individuals' experience enhanced the learning outcomes of novel words, and the authors attributed this finding to bilinguals' potentially enhanced ability to pay attention to both tonal and syllabic cues, alongside enhanced inhibitory control.

2.5 The influence of tonal language knowledge on tone discrimination

Only a handful of studies have investigated the effects of tonal languages on tone discrimination and the majority of them claim that there is a positive correlation between speaking a tonal and perceptual discrimination of tones (Qin & Mok, 2014). In this section, I discuss the ones with relevant results towards this study. The research by Cooper and Wang (2012) offers an empirical analysis of the relative and combined influence of linguistic and musical experience on Cantonese word learning and tone perception in groups of native speakers of a tonal language, Thai, and natives of a non-tonal language, English. These groups were then subdivided based on their music experience into groups of musicians and non-musicians. The target language was Cantonese. The tasks administered in their study were tone identification, musical aptitude, and tone word identification. Even though for tone identification no effects of having a native tonal language were observed on auditory ability to identify tones, being a native speaker of a tonal language positively influences the acquisition of new words. In addition, the authors found that musical experience significantly enhances tone identification.

Wayland and Guion (2004) investigated the effect of having a native tonal language, Chinese, and a native non-tonal language, English, in discriminating between mid and low tones in an unfamiliar tonal language, Thai. Their variables were first language background, tonal or non-tonal native language and the interstimulus interval (ISI) of the presentation (500 ms vs. 1500 ms). The primary purpose was to examine the difference in the ability to perceive tones among the above-mentioned groups. For this purpose, the ability to discriminate tones was examined before and after auditory training. Their results showed an advantage of being a native speaker of a tonal language in the ability to discriminate two tones in an unfamiliar language. As Wayland and Guion (2004) point out: “These results suggest that prior experience with the tone system in one tonal language may be transferable to the perception of tone in another language” (p. 681). The study by Burnham et al. (1996) offers one of the most comprehensive empirical analyses of tone discrimination in speakers of tonal and non-tonal languages. In order to assess the tone discrimination ability, they presented Thai tones for perceptual discrimination in three different linguistic contexts including normal speech, low pass filtered speech, and musical sounds. The participants were placed in two groups of tonal speakers and non-tonal speakers. Tonal speakers were subdivided into groups of Thai native speakers and Cantonese native speakers. The results demonstrated that English speakers had significantly better performance discriminating the tones in a musical context than in filtered speech and full speech. With regard to speakers of tonal languages, Thai and Cantonese, they discriminated tones very well in all three linguistic contexts. Therefore, it can be concluded that there is a positive correlation between tone discrimination and speaking a tonal language. Moreover, Pfordresher and Brown (2009) examined whether the presence of tone in one’s native language could lead to different results in one's ability to imitate pitch through singing and their perceptual ability for pitch differences. For their study, they conducted a pitch production and perception task. In addition, they compared participants' accuracy in processing single pitches, and also relationships between pitches. Their participants included 12 undergraduate students who spoke an Asian tonal language as their native language and were fluent in English as their second language. The participants had little or no music training. Regarding the production and perception of musical intervals, results showed that native speakers of tonal languages perform better than speakers of non-tonal languages. Nevertheless, no advantage was observed for either group in the production and discrimination of pitches. To address the lack of a control group in this study, Pfordresher and Brown (2009) replicated their experiment by recruiting a new sample of 22 participants. The results of the second study were very similar to those of the first study. The researchers believe that their results suggest that "the use of pitch to convey lexical information in one’s native language facilitates the use of pitch in nonlinguistic contexts " (p. 1395).

In contrast to the aforementioned studies, a handful of other investigations show different results. For example, a study conducted by Wang in 2013 examined the influence of having a native tonal language on tone perception in an unfamiliar tonal language and the effectiveness of training on perceptual learning of L2 tone. In tonal languages, the use of tone would change the meaning of the words and help us to differentiate them. Three groups with different L1 backgrounds were chosen for this study: Hmong, Japanese, and English, a tonal language, a pitch and accent language and a non-tonal language, respectively. Their tasks included a perceptual and a computer-based training task. Since this MA thesis focuses on tone perception, I only refer to their perception task and its results. For the pitch perception task, participants took a tone perception test on Mandarin. The results revealed no advantage on discriminating individual pitches for native speakers of a tonal language. To be more precise, the perceptual accuracy scores of Mandarin tones obtained by the native speakers of Hmong (a tonal language) were reported to be significantly lower than those of the native speakers of the other two languages that are considered non-tonal languages (English and Japanese). To justify this result, the authors claimed that Hmong speakers' perception of Mandarin tones was at the phonemic level while that of English and Japanese speakers was at the phonetic level. Therefore, they believed that this difference in mode of perception might have caused the poor performance of the Hmong speakers.

In a similar study by Francis et al. (2008), Cantonese tone perception by native speakers of a tonal language, Mandarin Chinese, and native speakers of a non-tonal language, English, was investigated. Participants' perception of Cantonese tone was investigated before and after perceptual training. Both groups of participants showed very similar performances before and after perceptual training, therefore no significant difference was observed. This result led the authors to conclude that knowing a tonal language itself is not enough for performing non-native tone perception successfully.

2.6 Auditory Sensory Memory

Auditory sensory memory (ASM) is considered the first stage in auditory perception, which captures audio information. It involves cortical and subcortical components and is more automatic compared to working memory (WM) and lasts for a very few seconds (Alain et al., 1998). Nevertheless, in a more recent study, Schröger (2007) reports that auditory information in ASM can last up to 20 s, or even longer. One of the most prominent differences between the WM and ASM are that active manipulation and rehearsal are accomplished by WM but do not involve ASM (Nees, 2016). Traditionally explored via digit span tasks with and without suffix, it has been shown that ASM can also be tested through various types of discrimination tasks, eliminating potential interference or processing issues brought about by number cognition. Nowadays ASM is measured via electroencephalography (EEG). Critical structures regulating tone-matching ability reside within both ASM and the prefrontal cortical regions (Rabinowicz et al., 2000). To date, the connection between ASM and phonetic and phonological learning (PPL) is understudied (Mahajan et al., 2017). As mentioned in the introduction to this section, PPL refers to learning how to properly recognize and articulate the sounds of a language. In the present study, speech perception is the focus of my research. Previous findings show that ASM is engaged when a sound is heard (Nees, 2016). As noted by Calabrese (2012), ASM, also referred to as echoic memory, plays a fundamental part in PPL. Calabrese (2012) reports that in the case of a foreign language, when learners are exposed to a foreign language, they hear the sounds that exist in that language, therefore even though learners are not yet able to articulate them, the sounds are always presented to the learners. Nevertheless, in the beginning, language learners may face difficulties recognizing or articulating these sounds. Over time, however, learners overcome these difficulties by developing the ability to recognize and articulate the sounds through the construction of representations of the utterances, via two models of phonetic and phonemic perception.

Recent studies, such as that of Krizman et al. (2012), have shed light on the enhancement of auditory skills in bilinguals. They investigated whether bilingualism could lead to enhanced experience-dependent plasticity in subcortical auditory processing. For this purpose, both English monolingual and English-Spanish bilingual adults were asked to take part in a task of integrated visual and auditory sustained selective attention. In this research, the role of attention was studied by presenting the stimuli in both quiet and multi-talker babble conditions. Interestingly, bilinguals' performance demonstrated robust F0 encoding in the noise condition but not during the non-noise condition. The monolingual group performed more poorly during the noise condition. Results indicated that bilinguals had enhanced subcortical representation of the fundamental frequency of speech sound alongside improved sustained selective attention. Therefore, I can conclude that bilingualism promotes auditory skills. Studies have also speculated that ASM and PPL might be related (Repp et al., 1979; Spinu et al., 2020; Spinu et al., 2018). Similarly, Cohen et al. (2011) examined auditory and visual memory in musicians and non-musicians. For this purpose, familiar music, spoken English and visual objects were used. The authors found that musicians display superior auditory recognition memory for both musical and non-musical auditory information. In Spinu et al. (2018) for instance, the authors studied the properties of phonetic and phonological learning during the initial exposure to a new English accent. In this study, the production of English monolinguals, French-English bilinguals, English and other language bilinguals, and non-English monolinguals were examined. The experiment included a baseline, training, and a test. The results demonstrated that bilinguals were able to make more progress in learning the novel English accent compared to monolinguals. The researchers claimed that the results could be explained by bilingual cognitive advantages related to auditory sensory memory. In summary, previous research has demonstrated that both musicians and bilinguals benefit from enhanced cognitive and auditory abilities (Cohen et al., 2011; Krizman et al., 2012). Musicians exhibit better performance regarding vowel and tone discrimination compared with non-musicians (Alexander et al., 2005; Gottfried & Xu, 2008; Hutka et al., 2015). In the case of bilingualism, even though bilinguals do not hold any advantage against monolinguals for vowel discrimination, early bilinguals have better performance compared to late bilinguals (Levey & Cruz, 2004). Furthermore, bilinguals demonstrate better perception of L2 speech sounds and an advantage in phonetic learning (Antoniou et al., 2015; Ressel et al., 2012). Finally, regarding the relationship between musical experience and bilingualism, studies have concluded that there is a positive correlation between music training and acquisition of auditory-related features of an L2 such as pronunciation, discrimination, and identification of phonemes and tones (Delogu et al., 2010; Marie et al., 2011).

Over the years, executive function has been widely investigated in bilinguals, but sensorimotor mechanisms have often been overlooked. A first step in understanding more about these mechanisms would be to examine auditory sensory memory in this group, which constitutes the overarching goal of the current thesis. This study will contribute to research on the effect of language background and music training on auditory discrimination by examining auditory working memory using vowel and tone discrimination tasks with four groups: bilinguals (with both early and late L2 exposure), monolinguals, musicians and non-musicians. Previous issues identified in the literature are also addressed by employing a continuum-based approach, as opposed to an exclusively binary one (mono- versus bilingual), using information regarding proficiency, age of acquisition, and length of use of the languages spoken by the participants. The findings have the potential to inform practical pedagogical strategies for PPL of second languages for musicians, non-musicians, monolinguals and bilinguals alike. Through its focus on different types of language background and their effects on speech processing and cognition, the current MA thesis will contribute to both the fields of linguistics and psycholinguistics. In the present chapter, the previous literature regarding bilingualism, music experience, vowel and tone discrimination, and auditory sensory memory was addressed. In the next chapter, the methodology applied in this MA thesis is explained.

Chapter 3

3 Methodology

The preceding chapter focused on the results of previous studies on the relationship between language background and music experience and the effect of bilingualism and musical experience on individuals' performance on vowel and tone discrimination. In this chapter, I focus on describing the methodology employed in the current study. In order to assess auditory sensory memory in participants with different language backgrounds and music experience, three tasks were administered, comprising a vowel identification task, a vowel discrimination task, and a tone discrimination task. Prior to testing, participants were asked to complete a background questionnaire. All tasks were administered individually in a single session and took approximately 40- 45 minutes to complete. The testing took place in a quiet room at the main library of the University of Toronto. The data was then analyzed using Stata/MP (2019), version 16.

In this chapter, Subsection 3.1 provides information regarding the background questionnaire. Subsection 3.2 describes the participants and provides a brief overview of their language and music background. Subsection 3.3 focuses on the two main experimental tasks employed in this study. For the vowel discrimination task, Crowder's (1982) methodology was followed. For the tone discrimination task, a task, such as that used in Winkler and Cowan (2005) and Rabinowicz et al. (2000), was chosen to assess ASM for this study. In the following, subsection 3.4 presents the stimuli employed for the tasks. Subsection 3.5 describes the procedure that was followed in order to collect the data, including information about the consent forms used and the corresponding ethics protocol. Finally, section 3.6 provides more information regarding the data analysis. The statistical analysis software employed for this thesis is Stata/MP. The tokens were analyzed quantitatively.

3.1 Background questionnaire

Prior to data collection, participants completed a questionnaire that consisted of two parts. In the first part, they provided information regarding their language background, and in the second part, music experience. Based on self-reported assessments, participants answered questions about the number of languages they spoke at a native or near-native level, the total number of languages they spoke (at any level), the age of first exposure to their L2, and their self-perception as monolingual, bilingual, or trilingual. In the second part, participants provided information regarding the number of musical instruments on which they had received training (including voice training), the highest music level of expertise they had attained (evaluated on a 5-point Likert scale ranging from beginner to expert), and the highest number of years of training attained with a single instrument. The sum of all years of training for all instruments played was later computed separately. The questionnaire can be found in Appendix B.

3.2 Participants

There were 91 participants recruited for this study from the undergraduate student population at the University of Toronto. Their age ranged between 19-40, the mean age of participants was 21.84. Out of the 91 participants, 13 identified as male and 78 identified as female. The only inclusion criterion required participants to be at least 18 years of age. All participants were students in a large *Language Acquisition* class. Once the data were collected, based on the information provided by the participants in their questionnaires, post-hoc category assignment was decided. The participants self-reported as monolingual, bilingual, and trilingual. Even though some of the participants self-reported as trilingual, for the purpose of this study, only the languages they spoke at a native or near-native level were considered and therefore participants were ultimately divided into two groups: monolinguals or bilinguals. The cut-off age between early and late bilinguals was established at 5 years of age. As it has been discussed in the Introduction chapter, to make sure an L2 would be a home language and due to enhanced performance of bilinguals who have learnt their L2 before the age of 5, in a previous research (Yeni-Komshian et al., 2000), this age was chosen.

The participants were of different language backgrounds. Participants spoke one of the following languages: English, Spanish, Persian, French, Akan, Ga, Mandarin, Cantonese, Ukrainian, Vietnamese, Armenian, Korean, Japanese, Harari, Tagalog, Hebrew, Russian, Urdu, Hindi, Punjabi, Portuguese, Arabic, Serbian, and Lisan-ud-dawat, Ukrainian. The tonal languages included in this study are as follows: Akan, Ga, Mandarin, Cantonese, Vietnamese, Hebrew, Punjabi.

Regarding music experience, participants played different instruments including baritone, saxophone, guitar, double ban, clarinet, Chinese zither, daf, drum, keyboard, recorder, trombone, erhu, ukulele, santoor, bass, clarinet, viola, percussion, alto saxophone, classical guitar, bass clarinet, and double bass. In addition, participants who had received professional voice training were also included in the music training group. By voice training, I am referring to the participants who did not play an instrument but were trained vocalists and had received lessons. This involved learning how to read musical scores.

3.3 Tasks

After completing the questionnaires, tasks were employed. The tasks were all administered via a laptop computer and headset using the software PsychoPy (Peirce et al., 2019). For all three tasks, participants were individually placed in a quiet room at the main library of the University of Toronto. Before the testing took place, participants were given instructions for each task. The three experimental tasks took approximately 5 minutes each to complete. In total, all the tasks including the background questionnaire took less than 45 minutes for each participant.

3.3.1 Vowel identification task

For the vowel identification task, 24 words were played. Participants were asked to listen to each word and select between the two choices provided for them. The aim of this task was assessing participants' ability to identify vowels. In this study, I do not focus on the vowel identification task.

3.3.2 Vowel discrimination task

For the vowel discrimination task, 51 pairs of stimuli were played. For each pair, the participants were asked to indicate whether two stimuli within each pair were the same or different.

3.3.3 Tone discrimination Task

60 pairs of stimuli were played for the tone discrimination task. The participants were asked to listen to the stimuli and decide whether the pairs were the same or different. The stimuli were presented in random order and the order was individually generated for each participant.

In the following subsections, 3.4.1-3.4.2, the stimuli employed for the tasks are described.

3.4 Stimuli

In the following subsections, 3.4.1-3.4.2, the stimuli employed for the tasks are described.

3.4.1 Vowel identification and discrimination tasks

First, in order to verify that participants could distinguish prototypical tokens, the vowel identification task was administered. This task consisted of 12 recorded stimuli and 24 trials. For each target, two trials were provided. These were artificial tokens constructed as follows: a 12-step continuum from *heat* to *hit*. For this task, the participants heard a word and had to select between two choices provided to them.

Second, to assess auditory discrimination, a vowel discrimination task (Crowder, 1982; Repp et al., 1979) was used. The same artificial 12-step continuum from <heat> [hit] to <hit> [hɪt] used in the identification task was employed for the vowel discrimination task as well. A 4000-ms inter-stimulus interval (ISI) was used in between the two members of each pair. A total of 51 pairs of stimuli were constructed for vowel discrimination tasks. These pairs were selected and played randomly for each participant. Before the experimental vowel discrimination task, a practice session with 12 stimuli was conducted. For the training, 12 pairs of vowels were played once, out of which 4 pairs were the same and 8 pairs were different.

3.4.2 Tone discrimination task

Following Rabinowicz et al. (2000), a reference tone of 500 Hz was used. Additional tones were created using Praat (Boersma & Weenink, 2020) to reflect a percentage change in frequency of 1%, 2%, 2.5%, 3%, 5%, 7.5%, 10%, 15%, 20%, 30%, 40%, 50%, 75%, and 100%. The stimuli consisted of 15 pairs of identical tones, starting with 500Hz. Also, 28 tone pairs were used: 14 in which the 500 Hz tone precedes the higher tones for which the first tone is presented lower (505 Hz, 510 Hz, 510 Hz, 512 Hz, 515 Hz, 525 Hz, 537 Hz, 550 Hz, 575 Hz, 600 Hz, 650 Hz, 700 Hz, 750 Hz, 875 Hz, 1000 Hz,) and 14 in which the 500 Hz tone comes second, and the first presented tone is higher. The goal behind the change in the frequency (as in the original study) was to present participants with pairs that are more or less similar (e.g., a difference of 10 Hz versus a difference of 100 Hz) and identify the threshold of discriminability for the different groups. Each tone was 1,000 msec in duration. All the tones were presented at a nominal intensity level of 70 dB and 4 tone pairs were presented for each level of frequency. As in the original study (Rabinowicz et al., 2000), pairs of tones (same and different) were constructed with a 3000-ms ISI between the reference and test tone, which was either filled with silence (no distractor) or with a 1-second composite distractor stimulus. This composite distractor sound consisted of a rapid series of 5 tones, 3 low and 2 high-pitched tones (with low and high alternating) with a nominal intensity level of 70 dB. The distractor tone frequencies were outside the range used for the test tones. For experimental condition 60 pairs of tones were randomly played for each participant. Similarly, to the vowel discrimination task, the tone discrimination task started with a short practice session. For the training, 20 pairs of tones were played, out of which 9 pairs contained the same tones and 11 consisted of different tones.

3.5 Ethics protocol

The ethics protocol for this study was approved on April 4, 2017, by the University of Toronto. The NMREB certificate can be found in Appendix C. In the document presenting information about the study and the informed consent, the topic of the study is identified as echoic memory in bilinguals and monolinguals. The letter also informs that the tasks would take no more than 45 minutes to complete and that there would be no foreseeable harm from participating in this research. Participants were informed that they will receive compensation in the form of extra credit towards their final grade in the JLP315 course. The participants were asked to read this document, then given the opportunity to ask clarification questions regarding the research. Lastly, they were asked to sign the consent form.

3.6 Analysis

The data extracted from the mentioned tasks were quantitatively analyzed using Stata/MP (2019), version 16, and applying logistic regression. Stata is a statistical software similar to SAS and SPSS that allows researchers to conduct statistical analysis, report results in a standardized fashion and create graphs. Logistic regression is a statistical model used to study the effect of independent variables on a binary outcome. In my context, the score accuracy is a binary outcome (fail or succeed), such that logistic regression allows us to learn about the effect of language and music variables on the probability of success. In this chapter, I looked at the methodology, statistical population and the tasks employed in this study. In continuation, the analysis and the results are explicitly discussed and presented in Chapter 4.

Chapter 4

4 Data analysis and results

In the previous chapter, I focused on the methodology and tasks employed in this study. In this chapter, I am presenting the empirical data and the results of the two main experimental tasks applied in this study. The main aim of this MA thesis is to determine whether there is a correlation between language background and auditory discrimination by examining tone and vowel discrimination in monolinguals, bilinguals (with early or late bilingual exposure) and speakers of tonal languages. The secondary aim is to investigate the relationship between music training and tone and vowel discrimination. Further, the effect of tonal language knowledge on tone discrimination is assessed. The data provided by 79 participants were analyzed in this study in a series of logistic regressions using the statistical software program Stata/MP (2019), version 16.

This chapter begins with subsection 4.1 where the data analysis is explicitly explained, following that in subsection 4.2 demographic breakdown of the participants is presented. Tables 1 to 6 illustrate this demographic breakdown. Subsection 4.3 presents the results of the vowel discrimination and tone discrimination tasks. Finally, in the last subsection (4.4), the summary of the results is presented. The research questions addressed are:

1. Do vowel and tone discrimination ability correlate with language experience in diverse groups of speakers such as monolinguals and bilinguals of different types (with early-late bilingual exposure)?
2. Does musical training affect tone and vowel discrimination?
3. Does knowledge of a tonal language affect tone discrimination?

For the purpose of this MA thesis, the vowels and tones were analyzed according to the acoustic distance between the two stimuli presented in each pair. In the case of the vowel discrimination task, vowels were synthesized and the transition from one vowel to the other was made in a 12-step continuum during which the F1 and F2 incrementally moved in one direction. Regarding the tone discrimination task, a percentage change in the frequency of tones reflects the distance. In the following sections (4.1-4.3), the results are explained in detail.

4.1 Data analysis

In order to analyze the data, first, the information from the background questionnaire was coded in excel. Apart from the linguistic and music information, the lateral information such as age, gender, and place of birth of participants was also added to the excel file. Regarding the language background, participants were placed into groups of monolinguals or bilinguals and also, early (bilingual exposure before the age of 5) or late bilinguals. In addition, participants were grouped based on speaking tonal languages. For this purpose, they were placed into groups of speakers of tonal languages and speakers of non-tonal languages. For the music experience, the number of years with music experience was declared for each participant. Those with 0 years of participants were claimed as participants without music experience. Participants' music level and the number of instruments they played were also included.

Second, two separate Excel sheets were administrated for the data obtained from the vowel and tone discrimination tasks. Participants' accurate and inaccurate answers were coded as 1 and 0, respectively. With the intention of studying the interaction between the various independent variables, linguistic and music variables, and their correlation with the dependent variable, accuracy, categorical variables were also numerically coded. The data was analyzed by applying Logistic regression, a statistical model used to study the effect of independent variables on a binary outcome. In context of this MA thesis, accuracy is a binary outcome (fail or succeed), such that logistic regression allows to learn about the effect of language and music variables on the probability of success.

4.2 Demographic breakdown of participants

A total of 91 participants were recruited from the undergraduate population of the University of Toronto. The results of 12 participants were excluded due either to medical reasons (reported hearing disorders/surgery) or to having provided insufficient information in terms of linguistic background (such that their degree of proficiency and age/type of exposure to the languages they reported speaking could not be established). In this chapter, I am focusing on the results of 79 participants, out of which 10 identified as male and 69 as female. The mean age of participants was 22.67 years (SD=3.40 yrs.). For the statistical analysis, the 79 participants were further subdivided demographically based on language background and music experience.

4.2.1 Language background

For the language background, three variables including the age of first exposure, degree of nativeness, the total number of the languages spoken by participants and knowledge of a tonal language were studied. Regarding proficiency, based on self-reported data, the participants were divided into three groups post data-collection: monolingual (n= 37), bilingual (n= 34), and trilingual (n= 8). The number of participants and their percentages are presented in Table 1. This data was not used for statistical analysis. For the purpose of the present statistical analysis, participants were classified under the two groups of monolinguals and bilinguals. Since there were only 8 trilingual participants in this study, there was not enough statistical power to include a trilingual group, separately. Moreover, as Higby et al. (2013) explain, it has not yet been determined in what aspects bilinguals and multilinguals are different. Also, the participants who identified as trilingual did not have native or near-native proficiency in their third language. In this study, participants were placed in groups based on their native or near-native proficiency level in the languages they spoke. Therefore, for statistical analysis, 37 participants were considered monolinguals and 42 bilinguals. In this MA thesis, participants who had native or near-native proficiency in two languages and have been exposed to their L2 before or after the age of 5 were considered as bilinguals. In the continuation of the analysis, bilinguals were placed into two groups of early and late bilinguals based on their bilingual exposure age.

Table 1: Participants by Language Background

	Number	Percent
Monolingual	37	46.84
Bilingual	34	43.04
Trilingual	8	10.13
Total	79	100.00

Regarding the age of bilingual exposure, bilingual participants were divided based on whether their exposure to the second language occurred before or after the age of 5. According to the information provided in a study conducted by Schulz and Grimm (2019), by the age of 5, individuals are able to make complex sentences in their first language. In addition, in an investigation realized by Yeni-Komshian et al. (2000), the results show that bilingual participants (Korean–English) who were exposed to the L2 from the ages of 1 to 5 had better L2 pronunciation than bilingual participants who had the L2 exposure between the ages of 6 and 23. Based on the results of the mentioned studies, the age of 5 has been considered as the line between the early and late exposure to bilingualism. Hence, participants with bilingual exposure before the age of 5 were labeled as early bilinguals. Participants who were exposed to their second language after the age of 5 were placed in the late bilingual group.

With regard to the presence of tonal languages, 59 participants were speakers of tonal languages. Meanwhile, 20 participants spoke non-tonal languages. The tonal languages included in the present dataset were Akan, Ga, Mandarin, Cantonese, Vietnamese, and Hebrew. Table 2 presents the number and percentage of speakers of tonal and non-tonal languages.

Table 2: Speakers of Tonal Languages

	Number	Percent
Not a tonal language	59	74.68
Tonal language	20	25.32
Total	79	100.00

4.2.2 Music experience

The numbers pertaining to music experience were also self-reported. The variables studied in the music experience includes the total number of instruments played per person, music level, the highest year of playing a musical instrument and the sum of years of musical training for each instrument.

Participants self-reported their highest music level attained along a 5-point Likert scale, ranging from expert to beginner: 1- expert, 2- advanced, 3- intermediate, 4- low intermediate, and 5- beginner. The participants without musical experience chose the option “no experience”. Table 3 summarizes the self-reported music level attained by the participants. Participants with no music experience (22.8%) and those with an intermediate level (21.5%) comprised the largest proportion of the sample while expert musicians (12.7%) and those with beginner-level experience (10.1%) made up the smallest proportion of the sample.

Table 3: Highest Music Level

Music Level	Number	Percent
0	18	22.78
1	10	12.66
2	13	16.46
3	17	21.52
4	13	16.46
5	8	10.13
Total	79	100.00

4.2.3 The correlation between language background and music experience

In the crosstabulation for participants based on their language background and music experience, 18 participants had no musical experience, 9 of whom were monolinguals and 9 bilinguals. 61 participants with musical experience were divided into groups of monolinguals and bilinguals with 28 monolinguals and 33 bilinguals, respectively. Table 4 illustrates the number of participants in each group.

Table 4: Number of Participants based on Language Background and Music Experience

Musical Experience/Language Background	no music exp	music exp	Total
Monolingual	9	28	37
Bilinguals	9	33	42
Total	18	61	79

4.3 Analysis

Regarding the vowel and tone discrimination tasks, participant data were analyzed by employing logistic regression in Stata. Logistic regression is a statistical model used to study the effect of independent variables on a binary outcome. In context of this MA thesis, accuracy is a binary outcome (fail or succeed), such that logistic regression allows to learn about the effect of language and music variables on the probability of success. The results of vowel and tone discrimination tasks are presented in the following subsections (4.3.1.1 – 4.3.2.7).

4.3.1 Vowel discrimination

The vowel discrimination task was conducted to examine participants' auditory discrimination ability of vowels. The participants were asked to indicate whether two stimuli within each pair were the same or different. A total of 51 pairs of stimuli were constructed and administrated for this task. In the following analysis, our dependent variable is accuracy, and the independent variables are linguistic background, musical background, and the distance between the stimuli in each pair. Linguistic background variable indicates whether participants are monolingual or bilingual with early or late L2 exposure and whether they speak a tonal language or not.

4.3.1.1 The relation between vowel discrimination and vowel distance

The first set of analyses examined the participants' auditory perception of vowels across different distances, regardless of their language background and music experience. As we see in the data from Figure 1, when the same pair of vowels were played, participants performed very well with the average accuracy of almost 0.9. This performance was then followed by a dramatic decrease when different vowels were played in the same pair. A clear trend can be observed whereby, as the acoustic distance between the two members of a pair increases, the accuracy also gradually increases. Hence, a correlation is observed between vowel acoustic distance and vowel discrimination accuracy. The average accuracy reaches its highest level (almost 1) when the distance between the two pairs of vowels is at 9. By the distance between the vowels, I am referring to the fact that the vowels were synthesized and the transition from one vowel to the other was made through 9 different steps during which the F1 and F2 incrementally moved in one direction. After reaching the peak, the average accuracy falls, reaching less than 0.7 when the acoustic distance is 11. The results obtained are summarized in Figure 1. To create the following graph, a logistic regression was applied using Stata.

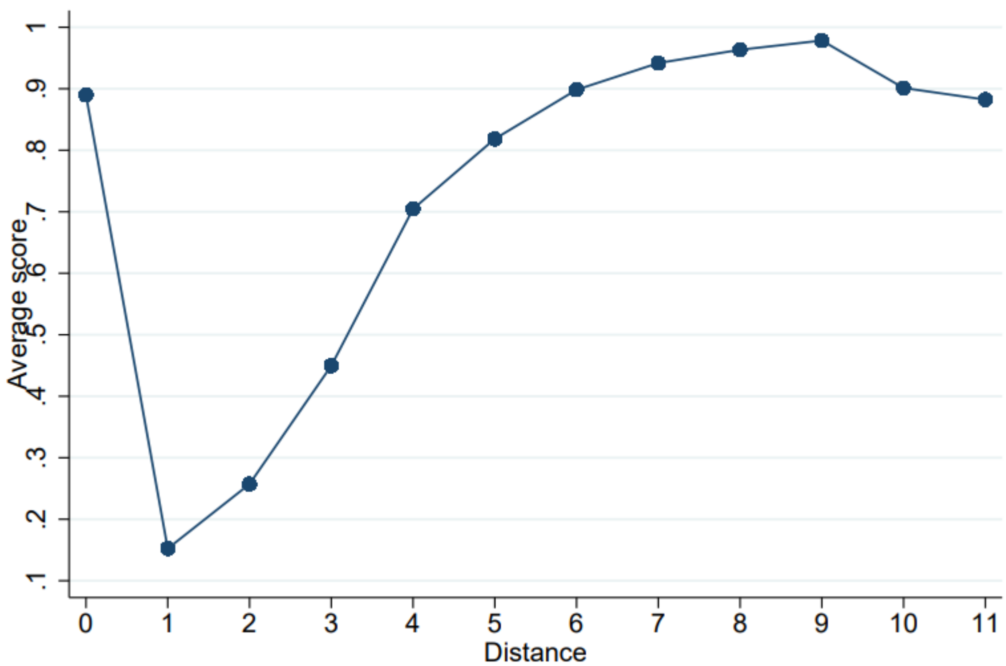

Figure 1: Vowels Score Average Across the Distance – Unconditional

4.3.1.2 The relation between the probability of success for vowel discrimination across distance based on language background and musical experience

In order to assess the probability of success in participants' auditory perception for vowel discrimination based on language background and musical experience, participants were placed in four groups as follows: monolinguals without musical experience, monolinguals with musical experience, bilinguals without musical experience and bilinguals with musical experience. Only distances greater than 0 are examined in this section. As Figure 2 demonstrates, while there is a positive trend between the increase in distance and the rise in the probability of success, there is no significant difference between the performance of the four different groups. For all the groups, the peak is reached at distance 11, where the probability of success is almost 1. A closer inspection of Figure 2 shows that monolinguals with musical experience had a slightly better judgement compared with their counterparts. This group is followed by monolinguals without musical experience, bilinguals with music experience and bilinguals without music experience, respectively. Even though I cannot solidly interpret the negative effect of bilingualism on vowel discrimination based on Figure 2, I can see that bilingual groups fell behind the monolingual groups.

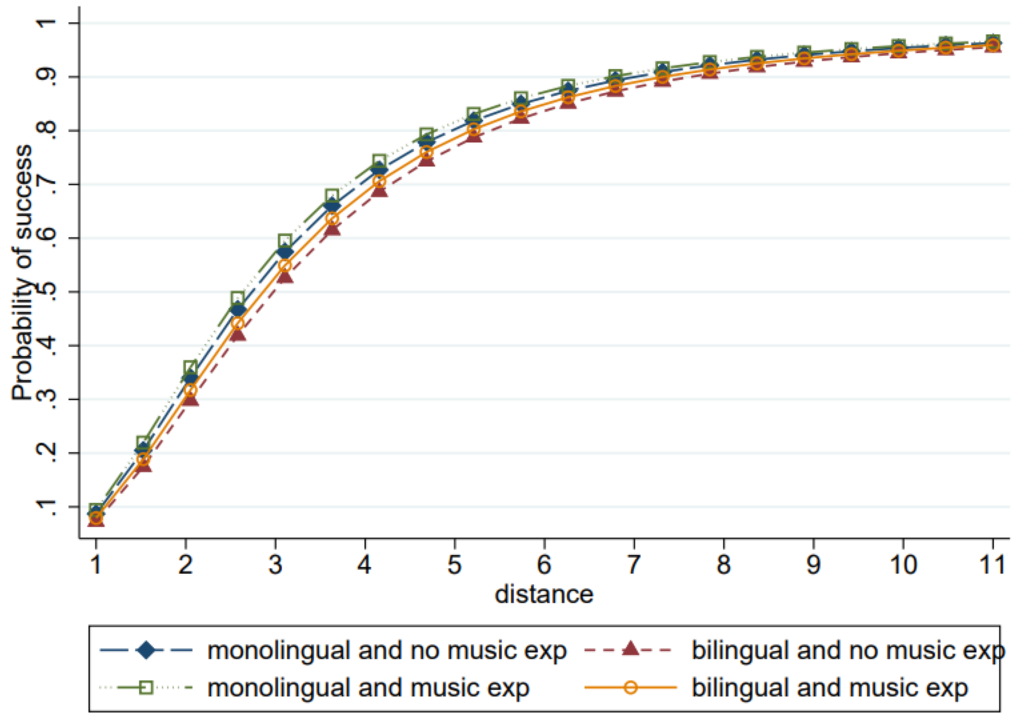

Figure 2: Probability of Vowel Success Across Distance

4.3.1.3 The effects of bilingual exposure before the age of 5 on vowel discrimination

With respect to early bilingual exposure, the results of this study show that overall early bilinguals exposed to their second language before the age of 5 demonstrated higher accuracy rates in comparison to participants with late bilingual exposure regardless of whether the participants had been placed in the monolingual or bilingual group. As it can be seen, some of the early bilinguals before the age of 5 are placed in the monolingual group. This is due to the fact that some of the participants reported less than native or near-native proficiency in the second language. This could be due to forgetting their L2 or not being in contact with speakers of their L2 and not being exposed to the L2. Hence, they were exposed to an L2 but as adults, the mentioned group of participants were not able to speak or understand the L2 they were once exposed to.

To be more precise, for the monolinguals exposed to early bilingualism, the probability of success was slightly higher than that of bilinguals. As shown in Figure 3, the probability of success is almost 0.68 for monolinguals without early bilingual exposure and 0.65 for bilinguals without early bilingual exposure. For those participants with early bilingual exposure before age 5, the probability of accuracy is 0.74 for monolinguals and 0.72 for bilinguals, respectively. To examine the influence of early bilingual exposure, a logistic regression was applied, I plotted the 95% confidence intervals. According to the Figure 3, I can conclude that the effect is statistically different when there is a bilingual exposure before age 5.

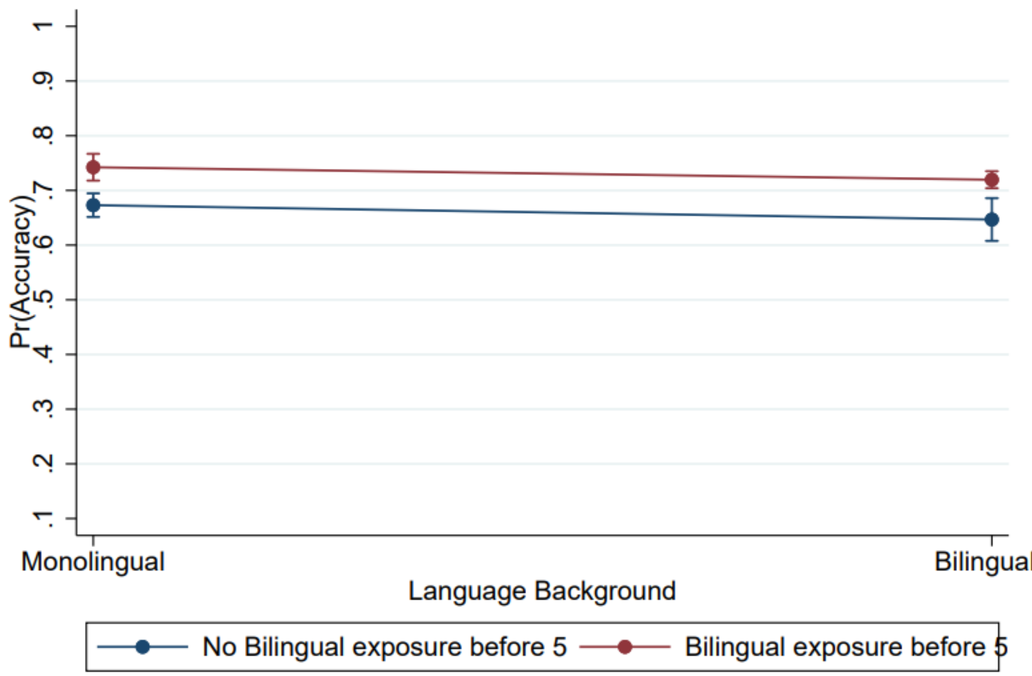

Figure 3: The Effect of Early Bilingual Exposure on Vowel Discrimination

Further analysis of the influence of early bilingual exposure across the different vowel distances demonstrates that the increase in distance leads to a higher probability of success for both groups (with and without early bilingual exposure). Nevertheless, the upward trendline observed in Figure 4 for participants with early bilingual exposure demonstrates a steeper slope in comparison to that of participants without early bilingual exposure. The difference between the probability of success for these groups is more pronounced between the distances 2 to 7, where there is no overlap between their respective confidence intervals. The probability of success reaches its highest point at distance 11 for both groups. At distance 11, the probability of success is 0.93 and 0.95 for participants with and without early bilingual exposure, respectively. To summarize, Figure 4 shows that, overall, early bilingual exposure has a positive influence on auditory discrimination ability of vowels. As the distance between the two stimuli in the same pair increases, vowel discrimination becomes more accurate.

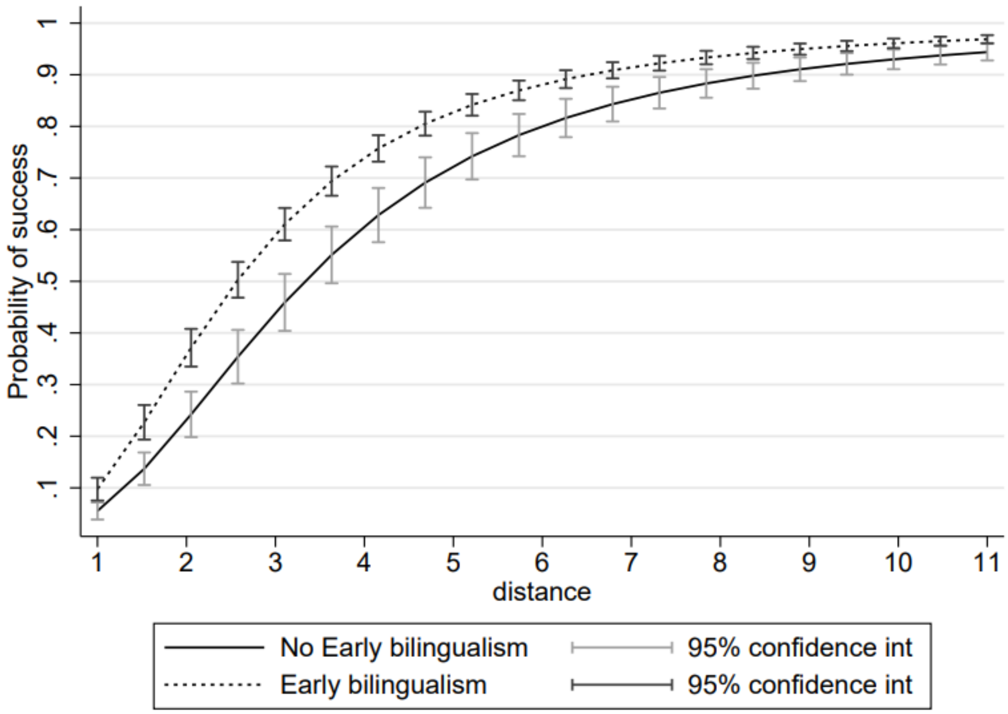

Figure 4: The Effect of Early Bilingual Exposure on Vowel Discrimination Accuracy Across the Distance

4.3.1.4 The additive effects of language background and music experience on vowel discrimination

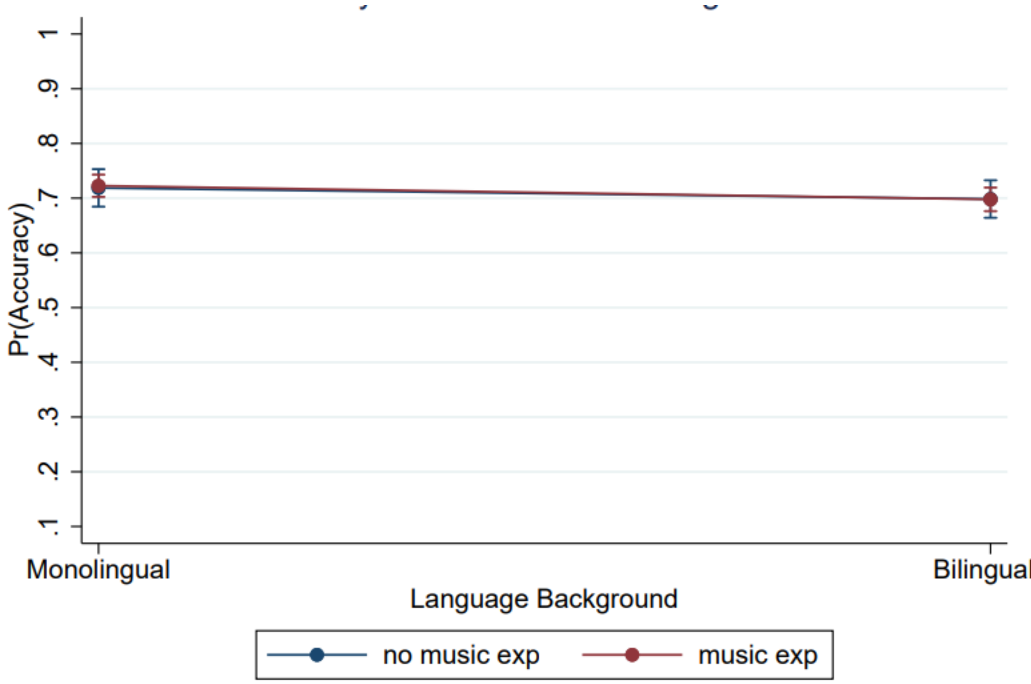

Figure 5: The Effect of Language Background and Music Experience on Vowel Discrimination

Figure 5 displays the effect of music experience and language background on vowel discrimination. The interaction between these two variables shows that there are no additive effects of music experience and language background. Monolinguals with or without music experience have the same expected probability of success (0.72). A similar trend is observed for bilinguals as well, suggesting that the presence of music experience does not affect bilingualism effectively. Both bilinguals with and without music experience reached 0.7 probability of success. In addition, in general, very similar performance and rates of accuracy were obtained by both monolinguals and bilinguals.

4.3.1.5 The effects of tonal language experience on vowel discrimination

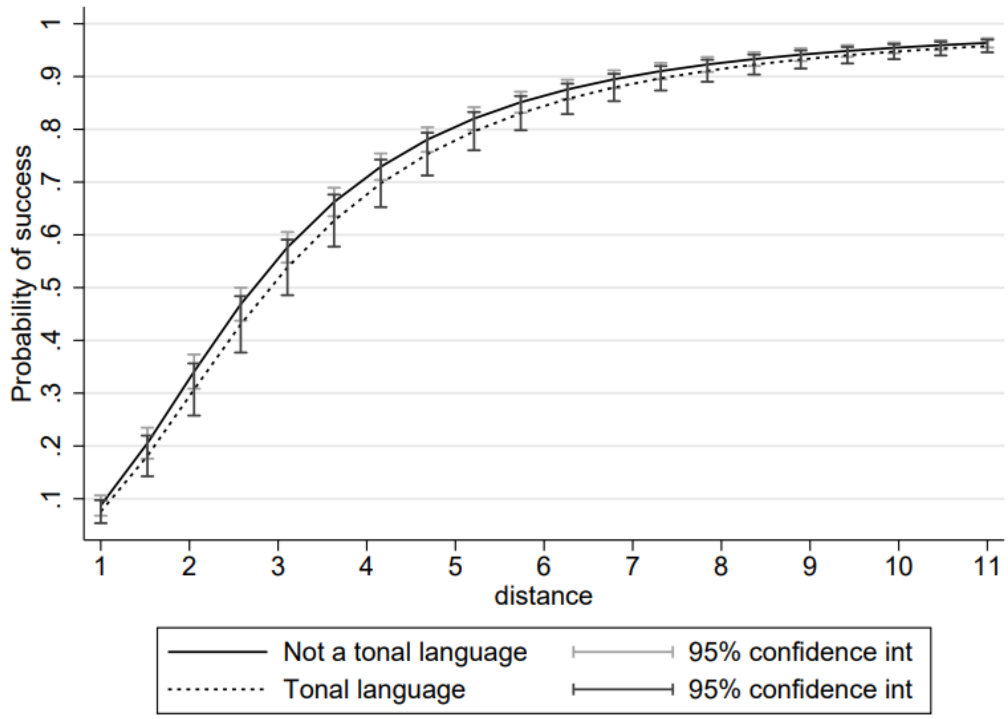

Figure 6: The Effect of the Presence of Tonal Languages on Vowel Discrimination Across the Distance

Even though my focus was not to assess the effect of knowing a tonal language on vowel discrimination, I included this in my statistical examination to find out whether there is an effect. Regarding the influence of the presence of tonal languages across the distance, a very similar trend is seen for both participants of tonal languages and non-tonal languages with speakers of tonal languages registering a better performance, however, the difference between the two is not considerable. Figure 6 provides an overview of results for speakers of tonal languages and non-tonal languages in this study by employing logistic regression in Stata.

4.3.1.6 The effects of linguistic and music variables on vowel discrimination

In this subsection, the effect of linguistic and music variables is examined regardless of the distance by normalizing this factor. Tables 5 and 6 illustrate the results provided using logistic regression in Stata.

Table 5: The Effects of Music Variable on the Probability of Success Across Language Backgrounds in Vowel Discrimination

	Individual effect	P-value
1.music experience		
Monolingual	0.00394	(0.831)
Bilinguals	-0.000576	(0.977)
1.bil_before5_num		
Monolingual	0.0693***	(0.000)
Bilinguals	0.0728***	(0.000)
1.tonal_language		
Monolingual	-0.00546	(0.697)
Bilinguals	-0.00573	(0.696)
Observations	4029	

p-values in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 5 shows that early bilingualism before the age of 5 has a significant effect on monolinguals and bilinguals (p < 0.001). Hence, exposure to a second language before the age of 5 is followed by an enhanced ability to discriminate vowels. The other two variables, having music experience and presence of tonal languages, do not have any significant effects on either group.

Table 6: The Effects of Linguistic and Music Variables on the Probability of Success in Vowel Discrimination

	Individual Effect	P-value
Bilinguals	-0.0238	(0.129)
music exp	0.00165	(0.905)
Bilingual exposure before 5	0.0712^{***}	(0.000)
Tonal language	-0.00560	(0.696)
Observations	4029	

p-values in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

With regard to the independent effects of linguistic and music variables studied in this MA thesis, regardless of the acoustic distance, we can see that similarly to Table 5, the only significant factor in Table 6 is early bilingual exposure before the age of 5. In other words, early exposure to a second language (before the age of 5) contributes to the development of a robust auditory ability to discriminate pairs of vowels. The other three factors, language background, music experience and knowledge of tonal language do not have a significant effect on the probability of success.

4.3.1.7 The effects of linguistic and music variables on vowel discrimination across acoustic distances

Table 7: The Effects of Music Variable on the Probability of Success Across Language Background in Vowel Discrimination

	Distance > 0	P-value	Distance = 0	P-value
Main				
Monolingual	0.341***	(0.000)	0	(.)
Bilinguals	0.352***	(0.000)	0	(.)
1.music_experience				
Monolingual	0.0126	(0.620)	-0.00402	(0.871)
Bilinguals	0.0141	(0.602)	-0.0298	(0.287)
1.bil_before5_num				
Monolingual	0.0909***	(0.000)	0.0333	(0.146)
Bilinguals	0.0936***	(0.000)	0.0383	(0.214)
1.tonal_language				
Monolingual	-0.0227	(0.234)	0.0209	(0.234)
Bilinguals	-0.0234	(0.229)	0.0242	(0.265)
Observations	2586		1443	

p-values in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Logistic regression was applied to analyze the effects of music variables across language background and distances. The results of the analysis are set out in Table 7. From the data (2,586 observations) in the Table above, it is apparent that for distances over zero, the only significant variables affecting auditory perception in the vowel discrimination task are distance and bilingual exposure before the age of 5. Strong evidence of distance is found for both monolinguals and bilinguals (p < 0.001). Also, bilingual exposure before age 5 has a significant positive effect on monolinguals and bilinguals (p < 0.001). Regarding distance 0, 1,443 observations were analyzed, and no significant effect was found. Hence, from crosstabulation 7, I can conclude that the acoustic distance and bilingual exposure before the age of 5 have a positive effect on the vowel discrimination task. Therefore, an increase in the acoustic distance between two pairs of vowels and exposure to a second language before the age of 5 enhance vowel discrimination.

Table 8: The Effect of Linguistic and Music Variables and Distance on the Probability of Success in Vowel Discrimination

	Distance > 0	P-value	Distance = 0	P-value
logDistance	0.347^{***}	(0.00570)	0	(.)
Bilinguals	-0.0284	(0.0209)	-0.0179	(0.0233)
music exp	0.0134	(0.0189)	-0.0166	(0.0188)
Bilingual exposure before 5	0.0923^{***}	(0.0222)	0.0360	(0.0270)
Tonal language	-0.0231	(0.0193)	0.0226	(0.0196)
Observations	2586		1443	

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The logistic regression employed for further analysis provides more information regarding the independent effects of linguistic and music variables and distance on the probability of success. Table 8 presents an overview of the results. The growth in acoustic distance has a positive effect on the probability of success ($p < 0.001$). Looking at the other factors, it is clear that the only other variable with a significant effect is bilingual exposure before the age of 5 ($p < 0.001$). The presence of these factors assists individuals in discriminating vowels. For distance 0, none of the linguistic and music variables were found significant.

4.3.2 Tone discrimination

For the tone discrimination task, 60 pairs of stimuli were played. For this part of the experiment, the participants listened to pairs of tones, consisting of artificial sounds, that were either identical, very similar, or very different (along a continuum). Participants had to indicate whether the two sounds were the same or different. Similarly to the vowel discrimination task, the two stimuli within a pair were either identical or different. The pairs that were different varied in the amount of acoustic distance, with the percent change in frequency between the two items ranging incrementally from 1% to 100% (e.g., for a reference tone of 500 Hz, the frequency of the other member of the pair could range from 505 Hz to 1,000 Hz). The purpose of this task was to examine the effects of language and music experience on participants' tone discrimination ability. In the following analysis, the dependent variable was accuracy, and the independent variables were linguistic (monolingual or bilingual, early or late bilingual and knowledge of a tonal language) and musical background (with or without music experience).

4.3.2.1 The relation between tone discrimination and tone distance

For the analysis of the tone discrimination task, the same strategies were employed as those of the vowel discrimination task. First, a set of analyses was conducted to examine the participants' auditory discrimination ability for tones regardless of language background and music experience. From these data, plotted in Figure 7, we can see that the results are very similar to those of the vowel discrimination task where at distance 0 (i.e., when the two members of a pair were identical), the average score of participants was high, reaching the rate of 0.9. At distance 1% (i.e., a 1% difference in frequency value between the two tones), with an average score of less than 0.2. As we might expect, as the frequency values between the tones increases, it is easier for the participants to discriminate between the two tones stimuli in the same pair and receive a better average score. Thereupon, there is a positive correlation between tone distance and discrimination accuracy.

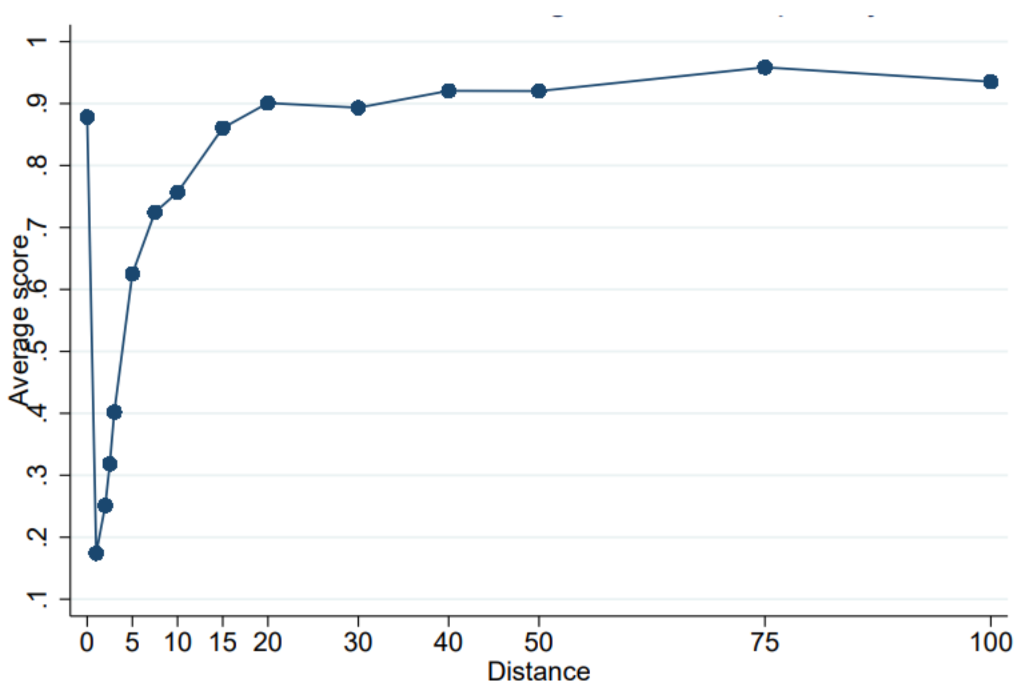

Figure 7: Tones Score Average Across the Distance – Unconditional

4.3.2.2 The relation between the probability of success for tone discrimination across distance based on language background and musical experience

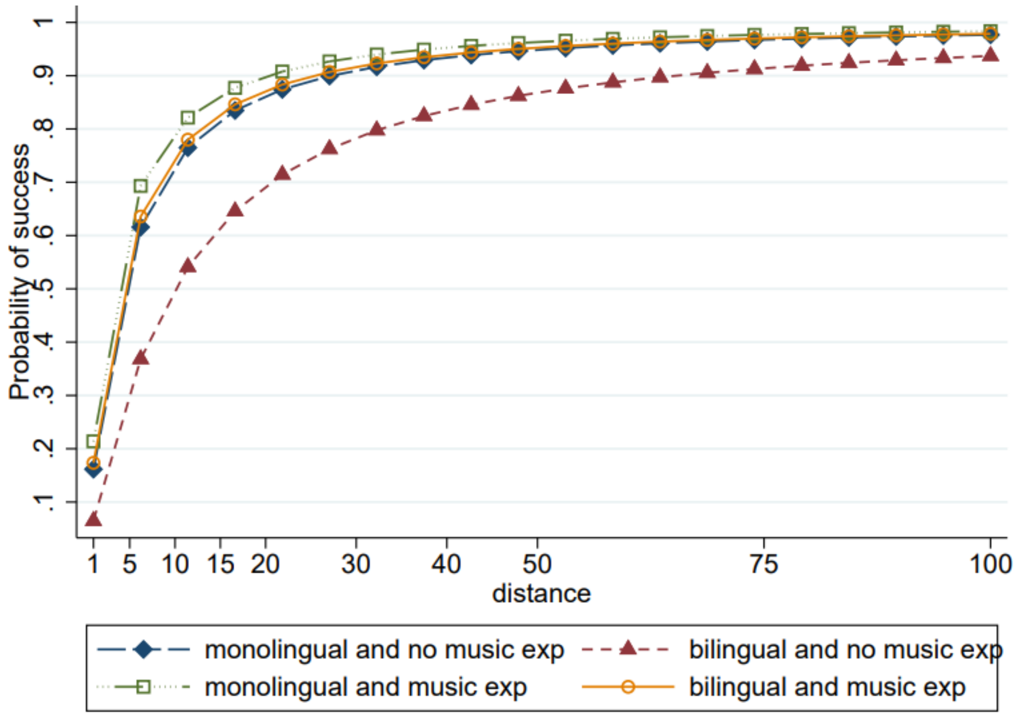

Figure 8: Tones Probability of Success Across Distance

Regarding the probability of success, it can be seen that for distances greater than 1, all the groups experienced an upward trend. At distance 1%, the probability of success for the monolinguals with music experience was at the highest point in comparison to other groups, 0.2, while bilinguals with no music experience had the lowest probability of success, with less than 0.1. From the data in Figure 8 it is apparent that monolinguals with music experience displayed better performance compared to the other groups across the board. The probability of success in all the groups, experiences a sharp growth from distances 1% to 40%. At distance 100%, the probability of success is almost 1 for monolinguals, with or without music experience, and bilinguals with music experience. Overall, no considerable difference is seen between the performance of different groups at distance 100%. Graph 8 shows that monolingualism and music experience positively affect auditory discriminative ability for tones.

4.3.2.3 The effects of bilingual exposure before the age of 5 on tone discrimination

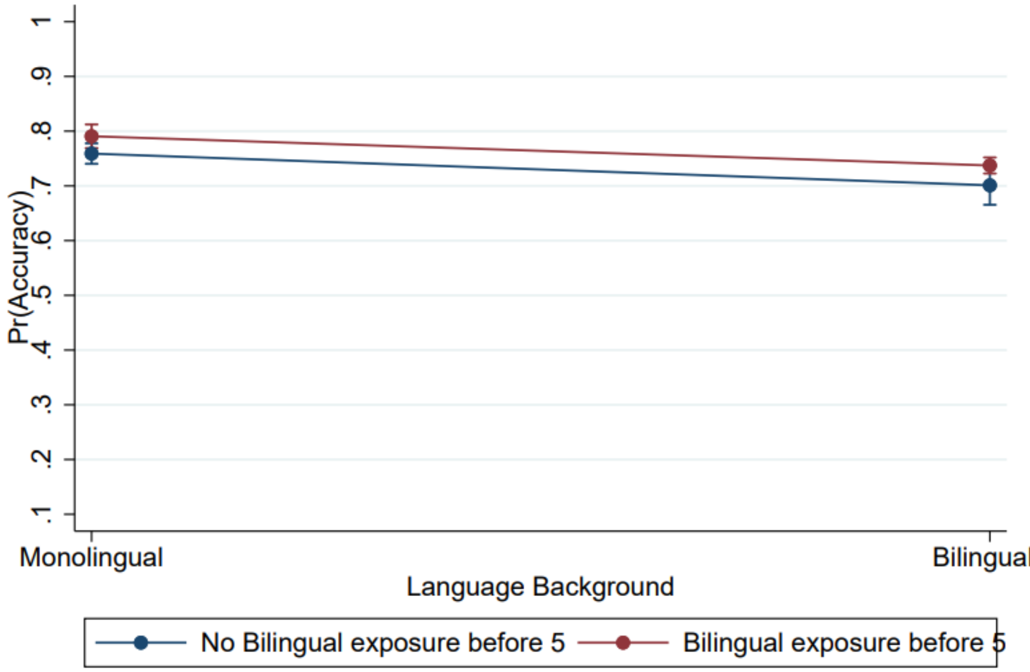

Figure 9: The Interaction between Language Background and Music Experience on Tone Discrimination

Figure 9 illustrates the rate of accuracy obtained by monolingual and bilingual participants with or without music experience. The difference between the accuracy rates for monolinguals with or without music experience is not significant (with accuracy rate of 0.77 for monolinguals without early bilingual exposure and 0.79 for monolinguals with early bilingual exposure). Overall, no significant difference is noted between the accuracy rates of bilinguals with or without early bilingual exposure before the age of 5 (0.78 and 0.72, respectively). Overall, bilingual exposure before the age of 5 improves tone discrimination accuracy.

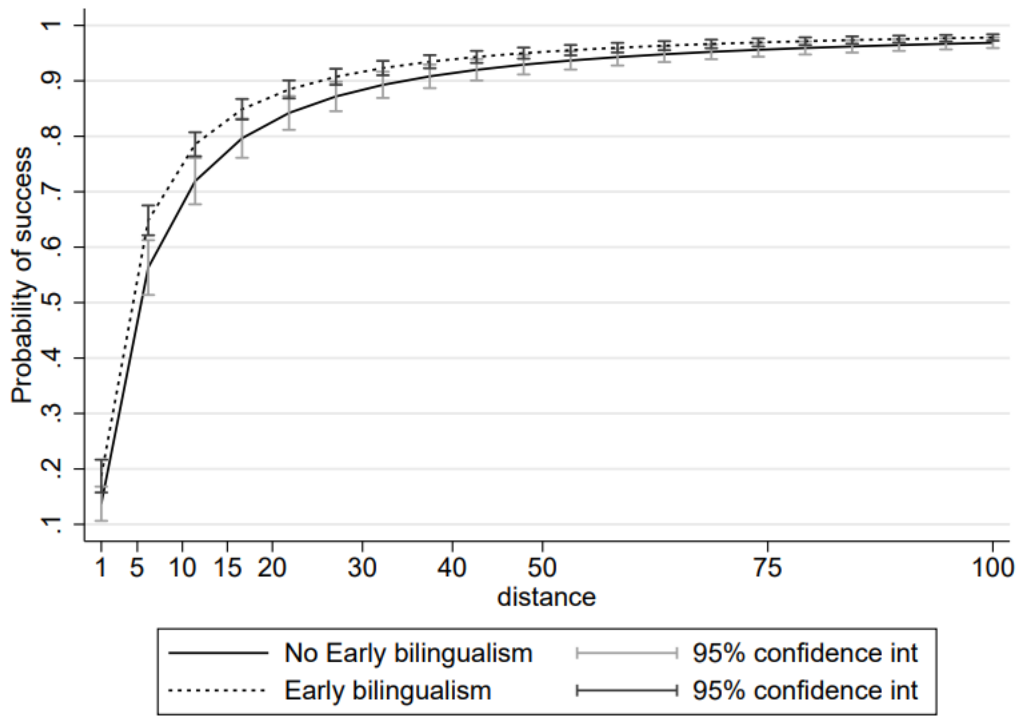

Figure 10: The Effect of Early Bilingualism on Tone Discrimination Across the Distance

Further examination of the influence of early bilingual exposure on tone discrimination across different acoustic distances indicates that across distances (1-100%) for the tone discrimination task, participants with early bilingual exposure had a higher probability of success compared to participants with late bilingual exposure (Figure 10). The difference between the performance of the two groups is more apparent between the distances 10% to 50%. Figure 10 shows the probability of success across acoustic distance between the tones forming a pair. The greater the distance, the higher the probability of success becomes for both groups. Early and late bilinguals display their most accurate responses at distance 100%, reaching 0.98 and 0.97 probability of success, respectively.

4.3.2.4 The additive effect of language background and music experience on tone discrimination

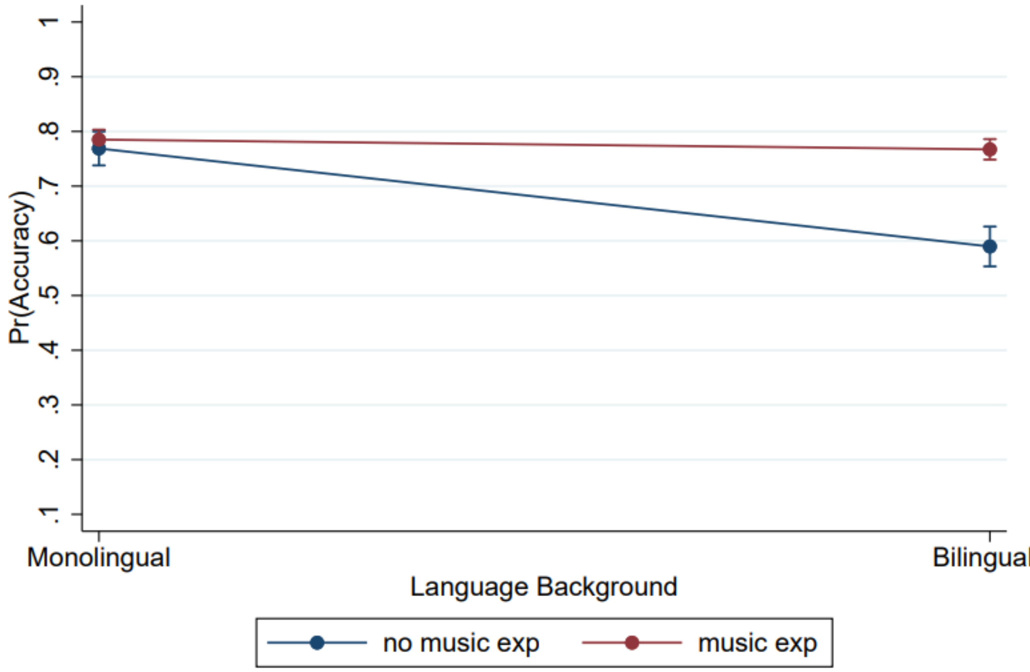

Figure 11: The Effect of Language Background and Music Experience on Tone Discrimination

The effect of music experience across language background on tone discrimination is observed in Figure 11. Interestingly, monolinguals with and without music experience showed very similar probability of success (0.78, 0.79 respectively), however, the difference between the accuracy rate obtained by bilinguals with (0.78) and without music experience (0.59) is remarkable. It could be concluded that music experience has a strong positive effect on bilinguals regarding tone discrimination.

4.3.2.5 The effects of tonal language experience on tone discrimination

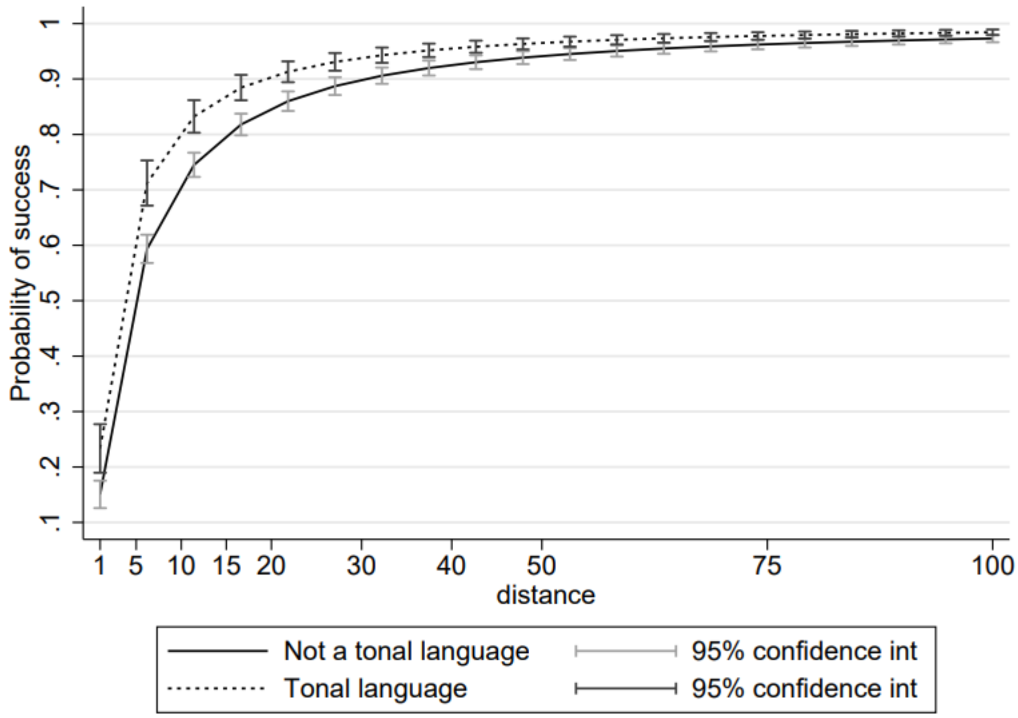

Figure 12: The Effect of the Presence of Tonal Languages on Tone Discrimination

Regression analysis was employed to predict the probability of success for speakers of tonal languages and non-tonal languages in this study. The results obtained from this analysis, across the distances 1% to 100%, are presented in Figure 12. As Figure 12 shows the accuracy across the distances is the lowest at distance 1%. When the acoustic distances between the pairs increases the probability of success rises as well. At distance 100%, the probability of success reaches 0.99 for speakers of tonal languages, and 0.98 for speakers of non-tonal languages. Thereupon, apart from the positive influence of the increase in acoustic distance that leads to a higher probability of success for all participants regardless of whether they speak a tonal language or not, we observe that knowing a tonal language is associated with better auditory discrimination ability for tones.

4.3.2.6 The effects of linguistic and music variables on tone discrimination

Similar to subsection 4.3.1.6, in order to exclude the effect of distance, I normalized the distance, removed this variable, and examined the effect of linguistic and music variables using logistic regression. Tables 9 and 10 present the statistical results.

Based on Table 9, the most striking observation to emerge from the data comparison was the fact that regardless of acoustic distance, music experience seems to positively influence bilinguals but not monolinguals ($p < 0.001$). More specifically, bilinguals with music experience performed better than bilinguals without music experience. In addition, speakers of tonal languages from both groups of monolinguals and bilinguals had better performance in comparison with the participants who did not speak a tonal language ($p < 0.001$). Thus, there is a positive interaction between early bilingual exposure, knowledge of a tonal language, music experience and tone discrimination. The results are presented in Table 9.

Table 9: The Effect of Music Variable on the Probability of Success Across Language Backgrounds in Tone Discrimination – Regardless of the Distance

	Individual Effect	P-value
1.music_experience		
Monolingual	0.0162	(0.335)
Bilinguals	0.178^{***}	(0.000)
1.bil_before5_num		
Monolingual	0.0316^{*}	(0.022)
Bilinguals	0.0363^{*}	(0.030)
1.tonal_language		
Monolingual	0.0419^{***}	(0.000)
Bilinguals	0.0483^{***}	(0.000)
Observations	4740	

p-values in parentheses
$^{*}\ p < 0.05$, $^{**}\ p < 0.01$, $^{***}\ p < 0.001$

As we can see in Table 10, bilingualism is associated with a significant decrease in accuracy ($p < 0.001$). The other three factors were found to have a positive effect on the probability of success: music experience and tonal languages ($p < 0.001$), early bilingual exposure before the age of 5 ($p < 0.05$). Table 10 illustrates the results.

Table 10: The Effect of Linguistic and Music Variables on the Probability of Success in Tone Discrimination- Regardless of the Distance

	Individual Effect	P-value
Bilinguals	-0.0550***	(0.000)
music exp	0.0992***	(0.000)
Bilingual exposure before 5	0.0341*	(0.026)
Tonal language	0.0453***	(0.000)
Observations	4740	

p-values in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

4.3.2.7 The effects of linguistic and music variables on tone discrimination across the distances

Table 11: The Effect of Music Variable on the Probability of Success Across Language Backgrounds in Tone Discrimination

	Distance > 0	P-value	Distance = 0	P-value
Main				
Monolingual	0.160***	(0.000)	0	(.)
Bilinguals	0.170***	(0.000)	0	(.)
1.music_experience				
Monolingual	0.0482*	(0.034)	-0.0431	(0.056)
Bilinguals	0.169***	(0.000)	0.189***	(0.000)
1.bil_before5_num				
Monolingual	0.0516**	(0.006)	0.00443	(0.825)
Bilinguals	0.0546**	(0.008)	0.00578	(0.828)
1.tonal_language				
Monolingual	0.0722***	(0.000)	-0.00912	(0.613)
Bilinguals	0.0774***	(0.000)	-0.0119	(0.603)
Observations	3121		1619	

p-values in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

A logistic regression analysis examined the effect of music variables on the probability of success in tone discrimination across language backgrounds. The findings are compared and summarized in Table 11. This table is informative in several ways: first, the distance itself was significant ($p < 0.001$) for monolinguals and bilinguals, respectively. Second, there is a significant positive correlation between music experience and auditory perception for tones for bilinguals ($p < 0.001$) and monolinguals ($p < 0.05$). Bilinguals with music experience demonstrated better auditory discriminative ability compared with bilinguals without music experience. The statistical tests applied at this stage also reveal a significant effect of early bilingual exposure before the age of 5 that resulted in more accurate responses ($p < 0.01$). Finally, the presence of tonal languages significantly increased the probability of success ($p < 0.001$) and enhances listeners' discriminative ability for tones. At distance zero, the only significant variable is music experience for bilinguals ($p < 0.001$). Hence, bilinguals with music experience show more enhanced auditory ability for tones in comparison with bilinguals without music experience. In summary, the increase in acoustic distance, music experience, early bilingual exposure and knowledge of a tonal language have a significant effect on tone discrimination.

Table 12: The Effect of Linguistic and Music Variables and Distance on the Probability of Success in Tone Discrimination

	Distance > 0	P-value	Distance = 0	P-value
logDistance	0.166^{***}	(0.000)		
Bilinguals	-0.0629^{***}	(0.001)	-0.0442^{*}	(0.045)
music exp	0.112^{***}	(0.000)	0.0793^{***}	(0.000)
Bilingual exposure before 5	0.0534^{**}	(0.007)	0.00510	(0.827)
Tonal language	0.0753^{***}	(0.000)	-0.0105	(0.607)
Observations	3121		1619	

p-values in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The table above (12) focuses on the independent effect of linguistic and music variables on tone discrimination. These factors were examined across the different distances using logistic regression. At distances over 0 (number of observations = 3,121), the following factors have a positive significant effect on tone discrimination: the increase in acoustic distance ($p < 0.001$), early bilingual exposure ($p < 0.01$), music experience ($p < 0.001$) and speaking a tonal language ($p < 0.001$). Bilingualism is associated with reduced auditory ability to discriminate tones ($p < 0.001$). At distance 0, participants with music experience showed enhanced auditory discrimination for tones ($p < 0.001$). While music experience had a positive effect on tone discrimination, bilingualism affected the participants' auditory ability negatively, decreasing the probability of success ($p < 0.05$).

4.4 Summary of the results

For the vowel discrimination task, no variable was found to be significant with respect to the effect of music variables on the probability of success across language backgrounds in vowel discrimination at distance 0 (i.e., identical vowels presented in a pair). For distances greater than 0, two variables were statistically significant for both groups of monolinguals and bilinguals: (1) acoustic distance between the two members of a pair and (2) bilingual exposure before the age of 5. Both variables have a statistically significant effect on the probability of success and appear associated with enhanced auditory discrimination ability for vowels. As the distance between the members of a vowel pair increases, early bilingual exposure (before the age of 5) leads to the enhanced auditory ability for vowel discrimination. Regardless of the distance, early bilingual exposure was found to have a significant effect on the accuracy rate of monolinguals and bilinguals. There was no significant effect of linguistic and music variables and distance on the probability of success in vowel discrimination at distance 0. At distances greater than 0, a significant effect of bilingualism and bilingual exposure before the age of 5 was found. Not taking acoustic distance into account, only early bilingual exposure has a significant effect on accuracy rate.

With respect to the tone discrimination task, at distance 0, music experience has a significantly positive influence on bilinguals but not monolinguals. Regarding the distances greater than 0, the following variables have a positive effect on both monolingual and bilingual participants: (1) acoustic distance between the two members of a pair, (2) music experience, (3) early bilingual exposure before the age of 5, and (4) speaking a tonal language. After further analysis of the individual effects of variables across acoustic distance, results demonstrate that at distances greater than 0, the rise in acoustic distance, music experience, early bilingual exposure before the age of 5, and the presence of a tonal language in the individual's linguistic repertoire all have a significant positive influence on accuracy rate. On the other hand, results also demonstrate that bilingualism has a significant negative effect on the auditory discrimination ability for tones. In other words, bilingual participants had more difficulty discriminating the tones. At distance 0, a negative effect of bilingualism and a positive effect of music experience were detected. When acoustic distance was not considered, the data show that while music experience has a significant positive effect for bilinguals, early bilingual exposure before the age of 5 and knowing a tonal language have a significant positive influence on accuracy rate for both the monolingual and the bilingual group. As stated before, in Chapter 4, the data analysis and results were presented in great detail. In the next Chapter (5), the mentioned results and their explanations are discussed.

Chapter 5

5 Discussion and conclusion

In the previous chapters (Chapters 3 and 4), I investigate whether there is an effect of linguistic background and music experience on speech perception and auditory discrimination. In this chapter, I discuss the results presented in Chapter 4, situating these findings in the larger context formed by existing literature on the topic. Sections 5.1.1 – 5.1.5 will focus on the findings from the vowel and tone discriminations tasks. Sections 5.2 – 5.3 are dedicated to concluding remarks and a discussion of the contribution and limitations of the present study as well as directions for future work.

5.1 Discussion of results

5.1.1 The effect of bilingualism

My first set of questions aimed to verify whether bilingualism has an effect on vowel and tone discrimination. I start this subsection with the results of vowel discrimination task. In general, it was easier for all the participants to discriminate the vowels when there was no acoustic distance between them (same vowels were played in a pair) and when the acoustic distance was greater than 4. With respect to vowel discrimination, no significant effect of bilingualism was observed. However, compared to monolinguals, bilinguals performed less accurately, while this difference was not significant. In the case of tone discrimination, surprisingly, a negative correlation was observed between the individual effect of bilingualism on tone discrimination accuracy at acoustic distance zero ($p < 0.05$), distances greater than zero ($p < 0.001$), and also overall ($p < 0.001$). In other words, bilingual participants had more difficulties perceiving the difference between pairs of tones and made more errors compared to monolinguals. Thus, the results cautiously suggest that bilingualism is associated with diminished ability to discriminate tones. As it has been mentioned in the Result chapter, tonal language knowledge has a positive effect on tone discrimination. Hereupon, more research is needed regarding this issue to investigate the effect of bilingualism on tone discrimination. The potential explanation for the discrepancy between my results and those of previous studies (Tong et al., 2015; Wang & Saffran, 2014) is that different methodologies were used. The population employed in these studies included bilingual speakers of a tonal language, hence, it could be argued that bilingual's enhanced ability to discriminate tones could be mainly due to knowledge of a tonal language and cannot be attributed solely to the positive effect of bilingualism. In the current study, not all but some of the participants in both groups of monolinguals and bilinguals were speakers of tonal languages. A considerable amount of literature on the effect of bilingualism on tone discrimination focuses on bilinguals who speak a tonal language. To be able to present a general hypothesis regarding the effect of bilingualism on tone discrimination, however, the bilingual population examined must include speakers of both tonal and non-tonal languages. In the current study, not all the bilinguals were speakers of a tonal language.

5.1.1.1 Dual linguistic system in the bilingual brain

The existing literature on the effects of language background (monolingualism versus bilingualism) on vowel discrimination suggests that monolinguals outperform bilinguals in discriminating vowels (Hisagi et al., 2015; Levey & Cruz, 2004). Nevertheless, the vowels examined in this previous literature are those of monolinguals' L1. In light of this methodological details, the possibility arises that monolinguals' better familiarity with their L1 explains their better performance while bilinguals spoke the examined language as their L2. With respect to the effect of language background on tone discrimination, previous literature (Tong et al., 2015; Wang & Saffran, 2014), found a significant positive effect of bilingualism on tone discrimination. To explain bilinguals' poorer performance compared to that of monolinguals in the current study, I can refer to how speech processing takes place in the bilingual brain. The fact that bilinguals have a more extensive repertoire of phonological categories compared to monolinguals (Tamminen et al., 2013) implies that when comparing two stimuli in a pair of tones, bilinguals necessarily have a wider range of sounds from which to choose, thereby delaying phonetic retrieval and subsequently reducing their accuracy rate with speech identification and discrimination. It is encouraging to compare my results with those obtained by Tamminen and colleagues (2013); their study presents a similar disadvantage in bilinguals for mismatch negativity (MMN). According to their findings, bilinguals had a significantly longer MMN latency compared to monolinguals. The authors believed this longer MMN is caused by two existing phonological systems in the brain that are intertwined and decrease access to exemplars. This result is consistent with ours. Since both phonological systems are posited to be simultaneously active in bilinguals, the process of retrieval takes place slower than in monolinguals (Tamminen et al., 2013). Therefore, I propose that this process places greater load on working memory, causing weaker retrieval of the first stimulus in a pair of tones, and ultimately decreasing bilinguals' ability to discriminate the pair. Previous literature also reports greater activation in the bilingual brains compared to the monolingual brain during language processing (Parker Jones et al., 2012).

5.1.1.2 The greater activity in the bilingual brain compared to the monolingual brain

Other investigations on the effect of bilingualism on the sensorimotor system acknowledge greater activity compared to monolinguals in auditory and somatosensory regions of the bilingual brain (Rüschemeyer et al., 2006; Simmonds et al., 2011), in particular in the case of a non-native language (McDonald, 2006). Since these studies focused on production, this activation was associated with retrieval and articulation of an L2. Hence, I can cautiously interpret that the auditory sensory memory might not be strongly enhanced in bilinguals in case of discriminating unfamiliar tones or vowels. However, this result might be due to the interstimulus interval (4000-ms in vowel discrimination task and 3000-ms in tone discrimination task) that might have been long, or the unrelated tone sequence played between the two tones presented in a pair. It must be noted that the obtained results were investigated in respect to young bilingual adults who speak both their languages at (near)native level. In the case of other types of bilingualism, different effects of auditory sensory memory might be observed. In addition, bilingual advantages are often muted in adulthood (Bialystok et al., 2012), therefore bilinguals in their childhood or older age might display better performance (Bialystok et al., 2005). In general, to have a better understanding of ASM in bilinguals, more investigations are highly recommended.

5.1.2 The effect of early bilingual exposure

The results of the current study showed that participants with early bilingual exposure (before the age of 5) in comparison with late bilinguals demonstrated better auditory discrimination ability for both vowel and tone discrimination. With regard to vowel discrimination, a significant effect of early bilingual exposure is seen for both bilinguals and monolinguals. Surprisingly, early bilingual exposure before the age of 5 is the only significant factor that has an individual positive effect ($p < 0.001$), both considering acoustic distance between the two members of a pair ($p < 0.001$) and overall ($p < 0.001$). For the tone discrimination task, the effect of early bilingual exposure is seen for distances greater than zero ($p < 0.01$) and also regardless of acoustic distance ($p<0.05$).

5.1.2.1 Grey matter in the brain of early bilinguals

Grey matter (GM) density in the brain of early bilinguals could be the reason behind this significant effect, having a positive influence on early bilinguals' auditory perception. GM processes information relevant to sensory perception, memory, self-control and, speech in one's brain (Miller et al., 1980). Richardson et el. (2011), specifically studied the relation between GM density and auditory short term memory capacity, confirming that there is a high correlation between the two. GM density correlates with auditory short term memory capacity. It has been demonstrated that the density of GM is greater in the bilingual brain than in the typical monolingual and late bilingual brain, particularly in the left inferior parietal lobule (Mechelli et al., 2004). Interestingly, GM density was reported to be highest in individuals with the earliest age of acquisition. The findings of Mechelli et al. (2004) are supported by the enhanced performance of participants exposed to an L2 before the age of 5 observed with vowel and tone discrimination tasks in the current study.

5.1.2.2 The middle temporal gyrus in the brain of early bilinguals

Claussenius-Kalman et al.'s (2020) research supports bilingual, and more importantly early bilingual, advantages in the brain. Claussenius-Kalman et al. (2020) investigated GM density, volume, and thickness in the brain by applying whole-brain linear models, comparing bilinguals and monolinguals. The findings suggest that early bilinguals have greater volume in their left middle temporal gyrus in comparison with late bilinguals. The middle temporal gyrus is known to be responsible for language, semantic memory and processing (Onitsuka et al., 2004). This benefit leads to enhanced cognitive abilities and could be another reason behind the comparatively more accurate performance of early bilinguals and the significant effect of early bilingual exposure on auditory perception.

5.1.2.3 The effect of early bilingual exposure on the sensorimotor system

The findings of Jasinka and Petitto (2013), also show that bilingualism causes fundamental changes to classic language areas in the brain related to higher cognitive executive functions and enhances these areas. Their findings demonstrated that bilinguals benefit from the fullest biological extent of the neural tissue underlying language, while this ability might be lost in monolinguals. Baigorri et al., (2019) examined discrimination and production ability in early and late Spanish-English bilinguals and found that early bilinguals had greater ability to perceive phonetic differences compared with late bilinguals. Similarly, Hojen and Flege (2006) uncovered a negative correlation between the age of acquisition of L2 and native-like discrimination. The reason behind the differences in the early bilingual advantage in comparison to the late bilingual advantage is the fact that the capacity of neural circuitry is mostly affected by early sensory experience (Berken et al., 2017). Berken et al., (2017) state that exposure to more than one language since birth would lead to increased complexity of sensorimotor processing. Since, in the human brain, the motor and sensory areas are the ones that mature first while other areas still develop into adulthood (Gogtay et al., 2004), it is expected to see enhanced discrimination by early bilinguals who have been exposed to the L2 during childhood and their sensorimotor system has been more affected by the executive advantages of bilingualism as a result. The changes that take place in a child’s brain after early L2 exposure are also a reason for the positive effect of early bilingual exposure on participants who now consider themselves as monolinguals but had experienced early L2 exposure.

Overall, the current study thus corroborates previously mentioned findings regarding the positive effects of early bilingual exposure on vowel and tone discrimination (Højen &

Flege, 2006; Levey & Cruz, 2004; Ortiz-Mantilla et al., 2010). I believe that GM density in early bilingualism, its corresponding volume in the middle temporal gyrus and its positive effect on memory and the effect of early bilingual exposure on human's sensorimotor system are tenable explanations (Ortiz-Mantilla et al., 2010) for the positive influence of early bilingualism on auditory perception, leading to its relatively strong correlation with auditory perception. The difference between the performance of early and late bilinguals in this study leads us to confirm that some of the advantages in regard to executive controls and function (attentional control and auditory sensory memory), would only occur before the critical period (Luk et al., 2011).

5.1.3 The effect of music experience

Although a considerable amount of work has emerged examining the effects of linguistic knowledge of a tonal language and musical experience on lexical tone perception, as well as the interaction of these two factors (Cooper & Wang, 2012), the effect of linguistic background (monolingual versus bilingual) and musical experience on artificial tones, and the combined effect of these factors remains understudied. One of the aims of this master's thesis is to fill this gap. In the present study I found music experience to be one of the factors that had a significant effect on participants' performance on the tone discrimination task. A positive effect of music experience was observed in both monolinguals and bilinguals. Nevertheless, this effect was stronger in bilinguals. At acoustic distance zero, that is when there is no acoustic distance between the two stimuli in a pair (the same vowels are compared), the positive effect of music experience is only observed in bilinguals ($p < 0.001$), whereas no effect is observed in the case of monolinguals. At distances greater than zero, the significant effect of music experience – while present for both groups - is stronger for bilinguals than monolinguals. When collapsing all acoustic distances together, a significant effect of music experience is observed only in bilinguals ($p < 0.001$).

5.1.3.1 The overlap between brain areas involved in processing music and language

Cooper and Wang (2012) found long-term experience with musical pitch perception in musicians is subject to change and this change could be generalized and transferred to the linguistic domain, as music and language domains are associated in the brain (Cooper & Wang, 2012; Peretz & Coltheart, 2003). In addition, Delogu et al. (2010) found that musical ability and experience positively influence linguistic intonation and tone perception and argued that one of the fundamental factors shared between music and language is the application of sounds, speech production. Furthermore, the academic literature on music and language processing in the brain has revealed that music and language share the same cortical and subcortical areas of the brain (Delogu et al., 2010; Koelsch & Siebel, 2005). The findings of Delogu et al. (2010) on the effect of musicality and music experience on phonological and lexical tone processing in the case of Mandarin Chinese confirms that musicians are more accurate at lexical tone discrimination tasks. Surprisingly, musicians performed equivalently to those participants with knowledge of Mandarin. Delogu et al's. (2010) evidence is consistent with my findings leading us to conclude de novo that musical experience has a significant effect on tone discrimination. It is worth mentioning that Delogu et al. (2010) found no effect of musicality in the case of phonological processing. Since no effect of music experience was reported in the vowel discrimination task in the current study, the findings of Delogu et al. (2010) are consistent with our findings. They explain that developed tonal performance is caused by the absence of linguistic categories; since their musician participants had no previous knowledge of Mandarin, they were not able to label tones based on linguistic categories. Hence, they processed them like musical tones. In other words, they used their musical competence to resolve the linguistic perceptual issue. According to the mentioned study and my findings, it is possible, therefore, to infer that music experience has a positive effect on tone discrimination. This inference may be explained by the fact that there are overlaps in areas of the brain involved in language and music processing (Alexander et al., 2005). Musicians have developed to a greater extent the areas of the brain exposed to musical training and, therefore, the overlap between these areas with areas involved in language processing affords them a perceptual advantage with tone discrimination. Extending beyond previous research on lexical tones, my findings suggest that musicians also benefit from enhanced auditory perception for artificial tones.

5.1.3.2 Grey matter in the brain of musicians

Apart from the accurate auditory perception for tones, the positive effect of music training in discriminating tones may also be due to enhanced executive functions, retrieval, and auditory sensory memory in musicians. The previous findings support this view by demonstrating that musicians benefit from enhanced cognitive function, and superior auditory recognition memory for musical and non-musical sounds (Cohen et al., 2011; Gottfried et al., 2004). In addition, musical training and expertise result in a musician's brain structural transformation that leads to functional differences in sensorimotor skills and hence better performance. This enhancement could be due to a positive correlation between the amount of GM in a musician's motor, auditory and visual regions of the brain and the level of music experience (Gaser & Schlaug, 2003). As has already been mentioned in the previous subsection (5.1.2), there is a high correlation between auditory memory and GM density in the brain (Richardson et al., 2011). Finally, the fact that music and language share some of the same areas in the brain (Cooper & Wang, 2012) and bilinguals have higher GM density compared to monolinguals (Claussenius-Kalman et al., 2020), could both be the reason for the existence of stronger effects of music experience on bilinguals in comparison with monolinguals in current study.

5.1.3.3 Tone identification in musicians

As mentioned in the literature review, prior studies (Cooper & Wang, 2012; Delogu et al., 2010; Gottfried, 2007) have also noted the positive effect of music experience on tone discrimination. Gottfried's (2007) investigation, examining the extent to which professional musicians perceive and produce unfamiliar linguistic tones, found that musicians have an advantage in tone perception. To provide a tentative explanation for the positive effect of music experience on tone identification detected in my study, I refer to Cooper and Wang's (2012) research assessing the effect of linguistic and musical experience on Cantonese word learning and tone perception in groups of native speakers of a tonal language and a non-tonal language. The participants were divided into two groups: musicians and non-musicians. Results indicated that musical experience significantly enhances tone identification. Although a positive effect of previous knowledge of a tonal language was detected, musicianship demonstrated a stronger effect on tone identification, a finding that is consistent with previous investigations (Alexander et al., 2005; Gottfried, 2007). The finding of Cooper and Wang (2012), combined with those of previous investigations (Delogu et al., 2010; Wong et al., 2007) demonstrate that in the case of lexical tones, musicians benefit from enhanced perception, likely thanks to their long-term pitch exposure that eventually alters and improves their supra fundamental sensory circuitry (Cooper & Wang, 2012). Since musicians are better at identifying tones, this enhanced ability in identification could also lead to better tone discrimination.

5.1.4 The effect of tonal language knowledge

Another factor examined in this MA thesis is the effect of knowledge of a tonal language on tone perception by assessing participants' tone discrimination ability. Most previous research on this topic examines native (L1) knowledge of a tonal language (Francis et al., 2008; Wang, 2013; Wayland & Guion, 2004). The present study adopts a broader perspective as I include in my analysis tonal languages learned both natively (L1) and non-natively (L2). In addition, most previous studies examining the effect of tonal languages have exclusively focused on Mandarin and Cantonese. In the present study, a variety of tonal languages are considered, including Akan, Ga, Mandarin, Cantonese, Vietnamese, Hebrew, Punjabi. This broader approach allows us to examine if the observed tonal language advantage uncovered in previous studies could be generalizable to all tonal languages. Apart from the use of a variety of tonal languages, the involvement of distinct non-tonal languages and the comparison of the performance between native tonal language monolingual and bilingual speakers and non-native tonal language speakers allows for a more comprehensive analysis of the tonal language effect. Although one aim of this study is to investigate the effect of tonal language knowledge on tone discrimination, the effect of tonal language on vowel discrimination was also examined but no significant effect was detected. Overall, the knowledge of a tonal language as an individual factor or in interaction with other factors such as language background (monolingual vs bilingual) was found to have a significant effect only on tone discrimination. Results showed that regardless of participants' language background (i.e., monolingual vs. bilingual) and independently of acoustic distance, knowing a tonal language leads to more accurate discrimination of the two stimuli in a pair of tones ($p < 0.001$).

In order to provide a more comprehensive explanation of these results, I will also consider the findings of Lee et al. (1996) who examined the effects of linguistic experience on tone perception by employing both lexical and non-lexical Chinese and Cantonese tones. In line with the present results, Lee et al. (1996) found that native speakers of tonal languages discriminate tones more accurately compared to native speakers of a non-tonal language. This finding broadly supports my work by indicating that listeners' native linguistic experience affects the accuracy of tone perception. Hence, I can conclude that the experience of tone perception in native speakers of tonal languages leads them to acquire more general abilities of tone discrimination. Similarly to Lee et al. (1996), Qin and Mok (2014) also showed that native speakers of tonal languages made fewer errors on a tone discrimination task. Therefore, L1 experience once again impacted tone discrimination ability. Furthermore, Wayland and Guion (2004) reported similar findings on the effect of tonal language competence on discriminating tones in an unfamiliar tonal language (Thai) in which native speakers of Mandarin (tonal language) exhibited an enhanced performance in comparison to native speakers of English (a non-tonal language). Wayland and Guion (2004) claim that since native speakers of a tonal language exhibited superior performance even in discriminating an unfamiliar tonal language, experience affords a transferable advantage. Burnham et al. (1996) employed Thai tones in three linguistic contexts including normal speech, low pass filtered speech and music sounds. Participants with a non-tonal language as their L1 exhibited their best performance when tones were presented in a musical context. However, native speakers of tonal languages demonstrated an ability to generalize L1 tone discrimination to other tones in different linguistic contexts. Thus, they performed accurately in all contexts. Pfordresher and Brown (2009) provide an innovative perspective exploring the influence of knowing a tonal language on non-linguistic domains by using music pitches and engaging their participants in two tasks of note and interval discrimination tasks. The stimuli generated were sine tones that were generated by MATLAB. Their results obtained from the interval discrimination task demonstrated that tonal language speakers were more accurate compared to non-tonal language speakers (English). Interestingly, the authors claim that their interval discrimination task was more complex and difficult compared to the note discrimination task. Pfordresher and Brown (2009) propose that “the use of pitch to convey lexical information in one’s native language facilitates the use of pitch in nonlinguistic contexts” (p. 1395). In the present study, the non-linguistic aspect of tone was examined as well and the same result was found, supporting Pfordresher and Brown's (2009) findings. My findings demonstrate that, as well as lexical tone discrimination, speakers of tonal languages also hold an advantage for non-lexical tone discrimination.

5.1.5 The effect of acoustic distance

The vowel discrimination task consisted of synthesized vowels that transitioned from one vowel to the another through a 12-step continuum. Participants were asked to listen to the two stimuli presented in a pair and decide whether they were the same or different. Statistical tests show that the increase in acoustic distance for vowels is associated with a higher rate of accuracy for both monolinguals and bilinguals ($p < 0.001$). This effect of acoustic distance corroborates the findings of Levey (2004) who investigated English vowel discrimination in monolinguals and bilinguals. Both monolingual and bilingual participants in Levey’s study (2004) demonstrated reduced accuracy in discriminating between vowels separated by smaller acoustic distances. The current findings align with those of other studies (Flege et al., 1994; Levey, 2004).

Turning now to the tone discrimination task, the pairs that were different varied in the amount of acoustic distance, with the percent change in frequency between the two items ranging incrementally from 1% to 100%. Similar results to those obtained in the vowel discrimination task demonstrate that there is also a significant effect of increasing acoustic distance on tone discrimination accuracy ($p < 0.001$). Qin & Mok's (2014) study in which participants were asked to discriminate two stimuli in a pair of tones yielded similar results. Consistent with the results of my study, the more acoustically similar the tones, the more errors were made by participants. Meanwhile, as the acoustic distance between the tones in the same pair grew, more accurate discriminations were made. According to Qin and Mok (2014), smaller acoustic distances between the tones confused all the participants including the speakers of a tonal language. Qin and Mok (2014) argue that “the psychoacoustic similarity or dissimilarity of the two tones in each pair is one of the determining factors of perceptual difficulty in the discrimination task” (p. 19). Thus, I may conclude that acoustic dissimilarity leads to more accurate discrimination of tones. Taken together, these results suggest that there is a positive correlation between the increase in acoustic distance (acoustic dissimilarity) and accuracy rate in speech perception. This positive interaction is regardless of one’s language background (monolingual versus bilingual) and music experience.

5.2 Conclusion

This present study was designed to determine the effect of language background (monolingual versus bilingual, early versus late L2 exposure) and music experience on one’s auditory discrimination. Furthermore, the effect of tonal language knowledge on tone discrimination was studied. The most important finding to emerge from this study is the positive correlation between early bilingual exposure and auditory discrimination (potentially supported by auditory sensory memory and other mechanisms as described above). It was shown that music experience leads to enhanced tone discrimination, as well. This enhanced performance was ascribed to structural transformations that take place in the brains of musicians and individuals with early L2 exposure, specifically increased GM density in the sensory and auditory areas of their brain. Furthermore, acoustic distance emerged as a reliable predictor of auditory discrimination independent of one’s language background and music experience. Regarding the effect of speaking a tonal language, we observed the existence of positive effects of this factor in tone discrimination. Bilingualism was associated with a disadvantage in tone discrimination. Although no significant effect of bilingualism was observed for vowel discrimination, the bilingual participants performed less accurately in comparison to monolinguals. In general, the bilingualism disadvantage could be explained by the high number of native speakers of tonal languages in the monolingual group of the statistical population of this study (that cause an enhanced ability in discriminating tones) and the competition between two language systems that coexist in the bilingual’s brain. Finally, music experience was found to have an individual significant effect on tone discrimination. Music experience had a greater effect on bilinguals than monolinguals This higher positive effect could be due to the stronger amount of GM in the bilingual’s brain and the involvement of the same areas of the brain for language and music.

5.3 Contribution, limitations, and future work

The findings of this study contribute to our understanding of how bilingualism and music experience affect auditory perception, hence they add to the body of work on the topics in the fields of linguistics and psycholinguistics. Furthermore, this investigation partly targeted the literature gap for the effects of bilingualism on the sensorimotor system. Besides providing a broader understanding of these topics, these findings could lead to the development of more effective pedagogical methods for PPL of a second language for bilinguals and musicians based on their advantages and disadvantages with respect to auditory ability and sensory auditory memory.

The generalizability of our results is subject to certain limitations. For instance, sociolinguistic factors such as age and gender were not controlled in this investigation. On one hand, the previous sociolinguistic study shows the intersection between language and gender and also language use (Fuchs, 2017), on the other hand, there are mixed opinions regarding the effect of different sex on brain organization for language(Shaywitz et al., 1995; Weiss et al., 2003). Therefore, I believe it would be interesting to see how auditory discrimination takes place in different sex. When it comes to bilingualism the age is another important factor that could be considered, as it has been mentioned the advantages of bilingualism are mostly muted during adulthood (Bialystok et al., 2012), therefore it would be helpful to have participants of same age to have more precise result.

The effect of these factors could lead to distinct results. The study is also limited by the participants' heterogeneity in terms of linguistic and musical background. Many of the participants did not share their first or tonal language and the instrument they played. As we know some of the monolinguals and bilinguals in this study were native speakers of tonal languages. Speakers of tonal languages have more advantage in discriminating tone (Qin & Mok, 2014), hence, to obtain more specific results it would be recommended to work with participants of the same L1, either a tonal or non-tonal language. In addition, since the neuronal activity is affected in musicians based on the instrument they play (Coro et al., 2019), by studying the musicians who play one specific musical instrument, the results would be more reliable. Finally, participants' level of proficiency in the languages they spoke, and music experience was self-reported. For future studies, the help of linguistic and musical tests is recommended.

Notwithstanding these limitations, the findings of the present study suggest that general outcomes and statements regarding the effects of bilingualism and music experience on auditory discrimination that would have not been achieved if it was limited to a certain L1, tonal language or musical instrument. I believe in order to have a study that further examines these factors, first we need to have a broader perspective of how they would generally affect auditory discrimination and it has been presented in this MA thesis.

Future research could explore how gender and age could affect the findings. Especially since the bilingual advantage is presumed to be muted in adulthood (Bialystok et al. 2012), it would be helpful to apply the same methodology longitudinally to groups of bilinguals in their childhood, adulthood, and older age. Controlling for the L1, tonal language knowledge and musical instrument training is also recommended.

Finally, for future studies the use of MRI is suggested to obtain a clearer vision of GM density and sensorimotor functions in the bilingual brain and musician's brains. In the present study I have relied on the previous literature review regarding the GM density in bilingual’s and musician’s brain. Also, the use of MRI while participants are performing the tasks would illustrate the similarities and differences between other brain areas in monolinguals, bilinguals, musicians, and non-musicians.

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Appendices

Appendix A: Letter of Information

CONSENT TO PARTICIPATE IN AN EXPERIMENTAL LINGUISTICS STUDY:

Exploring the bilingual advantage in phonetic learning: Echoic memory in bilinguals and monolinguals I understand that I have been asked to participate in a research project conducted by Dr. Laura Spinu, from the Department of Linguistics at the University of Toronto.

A. PURPOSE I have been informed that the purpose of the research is to investigate the mechanisms underlying speakers' cognitive abilities.

B. PROCEDURES I have been informed that the experiment in which I will be participating will take no more than 45 minutes. I will be required to listen to pairs of audio stimuli. My task will be to determine whether of these stimuli are the same or different. Additionally, I will listen to spoken digits and recall the order in which they were presented. I have been informed that the only information I will need to provide is my name, gender, age, location(s) where I grew up and where I lived for extended periods of time (>1 year), my linguistic background as well as that of my parents, the amount of musical training I have received and whether I have ever been diagnosed with speech/hearing disorders. I will then be assigned a subject number which will be used for the purposes of the experiment. All the collected data will be used confidentially and stored in a password-protected secure environment.

C. RISKS AND BENEFITS I have been informed that there is no foreseeable harm that can come to a person from participating in this research, and the risk will not be beyond that of everyday life. Since the goals of the project are research-oriented rather than applied, there is no direct benefit to the subjects, except for the extra credit earned towards the final grade in the JLP315 course.

D. CONDITIONS OF PARTICIPATION

• I understand that I am free to withdraw my consent and discontinue my participation at any time without negative consequences.

• I understand that my participation in this study is CONFIDENTIAL.

• I understand that the data from this study may be published.

I HAVE CAREFULLY STUDIED THE ABOVE AND UNDERSTAND THIS AGREEMENT. I FREELY CONSENT AND VOLUNTARILY AGREE TO PARTICIPATE IN THIS STUDY.

NAME (please print) ____

SIGNATURE ____

If at any time you have questions about the proposed research, please contact Dr. Laura Spinu. If at any time you have questions about your rights as a research participant, please contact the Office of Research Ethics at the University of Toronto.

Appendix B: Background questionnaire

PARTICIPANT NO (please leave blank) _______ Gender: Age (in years): Place of birth: What places have you lived in for longer than 1 year continuously? (if you lived in more places, please list them below, specifying between what ages you lived in each of them) Do you consider yourself bilingual/trilingual? Explain. List all languages you speak, your level, the age when you started learning them, the amount of time you use this language and the context in which it is used. Do not forget to include English!

LANGUAGE	**LEVEL** 1= NATIVE; 2=IN BETWEEN; 3=CONVERSATIONAL; 4=IN BETWEEN; 5=BEGINNER	**AGE OF EARLIEST EXPOSURE**	**AMOUNT OF USE** (HOURS PER DAY, AND DAYS PER MONTH, ON AVERAGE) hours/day days/month	**CONTEXT** (WHERE SPOKEN MOST, E.G. HOME, SCHOOL, CHURCH, WITH FRIENDS, WITH EXTENDED FAMILY, AT WORK, ETC.)

What is your parents' native language (or languages)?

Mother:

Father:

Do you have any musical training/expertise?

INSTRUMENT/ **TYPE OF MUSIC**	**LEVEL** 1= NATIVE; 2=IN BETWEEN; 3=CONVERSATIONAL; 4=IN BETWEEN; 5=BEGINNER	**YEARS OF MUSICAL TRAINING**	**AMOUNT OF PRACTICE** (HOURS PER DAY, AND DAYS PER MONTH, ON AVERAGE) hours/day days/month	**AGE OF EARLIEST EXPOSURE** (how old were you when you started music lessons?)

Have you ever been diagnosed for, or have you ever had hearing/speech problems? If your answer is yes, please elaborate.

Have you participated in similar experiments in the past?

Appendix C: Ethics Protocol Certification

Western Research

Date: 21 July 2021

To: Dr. Yassaman Rafat

Project ID: 119433

Study Title: The effect of bilingualism/multilingualism and music experience on tone and vowel discrimination

Short Title: The effect of bilingual experience on tone and vowel discrimination

Application Type: NMREB Initial Application

Review Type: Delegated

Full Board Reporting Date: 06/Aug/2021

Date Approval Issued: 21/Jul/2021 15:59

REB Approval Expiry Date: 21/Jul/2022

Dear Dr. Yassaman Rafat

The Western University Non-Medical Research Ethics Board (NMREB) has reviewed and approved the WREM application form for the above mentioned study, as of the date noted above. NMREB approval for this study remains valid until the expiry date noted above, conditional to timely submission and acceptance of NMREB Continuing Ethics Review.

This research study is to be conducted by the investigator noted above. **All other required institutional approvals and mandated training must also be obtained prior to the conduct of the study.**

Documents Approved:

Document Name	Document Type	Document Date	Document Version
Language and music background_Questionnaire	Paper Survey	10/Jun/2021	1
Stimuli	Other Data Collection Instruments	21/Jun/2021	1

No deviations from, or changes to the protocol should be initiated without prior written approval from the NMREB, except when necessary to eliminate immediate hazard(s) to study participants or when the change(s) involves only administrative or logistical aspects of the trial.

The Western University NMREB operates in compliance with the Tri-Council Policy Statement Ethical Conduct for Research Involving Humans (TCPS2), the Ontario Personal Health Information Protection Act (PHIPA, 2004), and the applicable laws and regulations of Ontario. Members of the NMREB who are named as Investigators in research studies do not participate in discussions related to, nor vote on such studies when they are presented to the REB. The NMREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000941.

Please do not hesitate to contact us if you have any questions.

Sincerely,

Ms. Katelyn Harris , Research Ethics Officer on behalf of Dr. Randal Graham, NMREB Chair

Note: This correspondence includes an electronic signature (validation and approval via an online system that is compliant with all regulations).

Curriculum Vitae

Name:	Niloufar Ansari Dezfuly
Post-secondary Education and Degrees:	University of Tehran Tehran, Tehran, Iran 2014-2018 B.A. Spanish language and literature
	The University of Western Ontario London, Ontario, Canada 2019-2021 M.A. (Hispanic Studies – Linguistics (Specialization in Migration and Ethnic Relations)
	The University of Western Ontario London, Ontario, Canada 2021- present Ph.D. Speech and Language Science
Honours and Awards:	Dean's Entrance Scholarship (Western University) 2019
Teaching Experience:	Teaching Assistant The University of Western Ontario 2019-2021
	Research Assistant The University of Western Ontario – The brain and mind institute 2019-2020
	Spanish Instructor University of Tehran - Center of Foreign Languages 2017-2019
Related Work Experience:	Associate Editor The University of Western Ontario – Entrehojas, Journal of Hispanic Studies 2020
Presentations:	Western Interdisciplinary Student Symposium on Language Research, 2020, Canada
	Quebec-Ontario Dialogues on Acquisition and Spanish 2020, Canada