Tonal Adaptation in Mandarin-English Code-Switching

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Abstract

In this thesis, I investigated the existence of tonal adaptation, a phenomenon that the pitches of non-tonal words are impacted by its surrounding tonal words in an utterance, in the code-switched speech by Mandarin-English bilinguals. I recruited 14 college students who currently study in the United States and identify themselves as Mandarin-English bilinguals and collected linguistic data from them. The data analysis was performed using Praat and a Praat script. English vowels with specific pitch contours were identified, annotated, and eventually extracted to a pitch contour plot, along with the Mandarin tone contours. The majority of the participants showed resemblance in pitch contour between English pitches and the Mandarin 3rd and 4th tones, which suggests that they applied tonal knowledge in Mandarin to English while code-switching between the two languages and hence exhibited tonal adaptation. The degree of the resemblance is also potentially relevant to participants' linguistic background and language behaviors. The results of this thesis are consistent with previous studies that explored the interactions between the phonetics and phonology of tonal and non-tonal languages.

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1. Introduction

In the current era, people with knowledge of more than one language are ubiquitous. It is generally believed that people who know multiple languages outnumber those who only speak one language (Valdés 2012). For people who know or learnt to speak multiple languages, the languages are not isolated in their brains, and they sometimes alternate between the languages in a discourse, a phenomenon known as code-switching.

This senior thesis investigates tonal adaptation in Mandarin-English code-switching. In this study, tonal adaptation is defined by the author as the phenomenon that the pitches of non-tonal words are impacted by and potentially assimilated to their surrounding tonal words in a single utterance. According to Ethnologue (2021), among the world languages, English and Mandarin Chinese rank as the top two languages with the most speakers. Although with a relatively smaller number of native speakers, English is commonly spoken around the world, which makes it the most widely-spoken language in the world (counting both native and non-native speakers). Mandarin Chinese, on the other hand, has the largest number of native speakers in the world with a growing number of non-native speakers. As a native speaker of Mandarin Chinese and a second language speaker of English, I have frequently encountered and experienced code-switching between Mandarin and English in my daily life, in an interesting and coordinated way. A prominent linguistic difference between Mandarin and English is that the former is a tonal language, whereas the latter is not. However, these two features may interact with each other when the code-switching between the two languages takes place, producing a tonal adaptation that is unique to Mandarin-English code-switching.

Following past literature that found evidence on speakers with tonal knowledge applying such concepts to speaking or learning other language(s), I investigated whether tonal adaptation

exists among Mandarin-English bilingual speakers when they code-switch between the two languages. This study employed phonetic analysis on speech data collected from 14 bilingual college students who study in the United States as well as using supplementary information on participants' linguistic backgrounds and behaviors as references in result interpretation.

The structure of this thesis is as follows: Section 2 provides a review of concepts and past literature that are relevant to the topic; Section 3 states the research questions and hypotheses; Section 4 introduces the research design and methodology being used in conducting the experiment and analyzing the results; Section 5 presents the findings from the collected data; Section 6 discusses the results and concludes the thesis.

2. Literature Review

2.1 Code-Switching

The concept of code-switching refers to the phenomenon of alternating between two languages or language varieties either within a sentence or between sentences (Li 2000). Bhatia & Ritchie (2012) also describes code-switching as a case when a bilingual talks to another bilingual with the same linguistic background and changes from one language to another in the course of conversation. Generally speaking, the term *code-switching* does not have a prescriptive definition, and different linguists may refer to slightly different phenomena when talking about code-switching, as quoted from Milroy and Muysken (1995):

> "The field of CS research is replete with a confusing range of terms descriptive of various aspects of the phenomenon. Sometimes the referential scope of a set of these terms overlaps and sometimes particular terms are used in different ways by different writers." (Milroy and Muysken, 1995, p. 12)

There are also other terms that add complexity to the terminology, such as *code-mixing*, *borrowing*, and *translanguaging*. These terms also describe the use of elements from another language in the current interacting language (Liu 2017). Some scholars use *code-mixing* and *code-switching* interchangeably as both terms describe the use of two or more languages alternatively in a speech, while others argue that there is a slight difference between the two. Li (2018) distinguishes between code-switching and translanguaging that the two terms have different analytical focuses: *code-switching* refers to the alternation between languages in a specific communicative episode, while *translanguaging* focuses on how the language user draws upon different linguistic, cognitive, and semiotic resources to make meaning and make sense. I use the term *code-switching* in this thesis since the word "switching" not only captures the form of a mixture of languages but also emphasizes the speaker's movement from the system of one language to that of another.

There are several types of code-switching, the most common among which are intersentential switching and intra-sentential switching (Woolford 1983): the former occurs outside the sentence or the clause level (i.e. at sentence or clause boundaries) and the latter occurs within a sentence or a clause (Li 2000). The examples below illustrate the two types of code-switching respectively[1].

(1) Intersentential switching
DON'T FEEL BAD, 我们也只是运气好而已。
DON'T FEEL BAD, *wǒmen yě zhǐshì yùnqì hǎo éryǐ*.
'Don't feel bad, we also just got lucky.'

(2) Intrasentential switching
我明天有个 QUIZ 要考。
wǒ míngtīan yǒugè QUIZ *yào kǎo*.
'I have a quiz tomorrow.'

[1] In this thesis, Mandarin words in code-switched examples are both written in Chinese characters and transcribed using the Pinyin system. Transcriptions are in *italics*, and English words are in CAPITAL LETTERS.

2.2 Tones

Zsiga (2013) defines tones as the use of pitch to create lexical contrast, just like vowels and consonants do. Tones are a prominent feature of seventy percent of the languages in the world, and are especially common in many languages in East and Southeast Asia, the Pacific, Africa, and the Americas (Yip 2002). Not all tonal languages employ the same tonal system. The simplest tone system only involves a relatively high pitch and a relatively low pitch, as in many Bantu languages. Languages such as Yoruba and Punjabi distinguish among three pitches - low, mid, and high - and some other languages contrast among four or even five different pitch levels. The languages described above only contrast pitch levels and ignore the distinctive shape of the pitch, so they are referred to as the register tone languages, as opposed to the contour tone languages (Yip 2002). As described in Zsiga (2013), the contour tone languages also take the internal patterns in which the pitch moves up or down (or both) over the course of the syllable. Typical contour tone languages include Mandarin Chinese and Thai. Most tonal languages combine both register and contour tones, such as Cantonese, which produces three varieties of contour tones at three different pitch levels, and the Omotic language Bench, which employs five level tones and one or two rising tones across levels (Yip 2002).

A common confusion often brought up by people who are not familiar with tones is the distinction between *tones* in tonal languages and *stress* in non-tonal languages. Bloomfield (1933) introduces stress as "consisting in speaking one of these syllables louder than the other or others." In non-tonal languages like English, stress refers to "a relation between syllables and successive variations in this relation constitute the rhythmic pattern of an utterance just as successive variations in tone-relations make up the intonation pattern" (Fry 1958). Tones in tonal languages, on the other hand, specifically refer to the lexical tones, meaning that they are

assigned through different vocal pitches (or pitch contours) to distinguish lexical items at the syllable level, and a tone is assigned to every syllable (Chao, 1968).

2.3 Tones in Chinese Languages

Chinese languages are known to be tonal, most of which use contour tones (Norman 1988, Yip 2002). A few dialects of northern China only have three tones, while some dialects in southern China may have up to 6 or 8 tones (Norman 1988). The Standard Chinese (also known as Mandarin or Mandarin Chinese) typically has four main tones: the first tone has a high-level pitch, the second tone is high-rising, the third one is low-falling-rising (usually just low-falling in natural speech), and the fourth tone is high-falling (Norman 1988). Figure 1 below illustrates the tone contours in Mandarin Chinese.

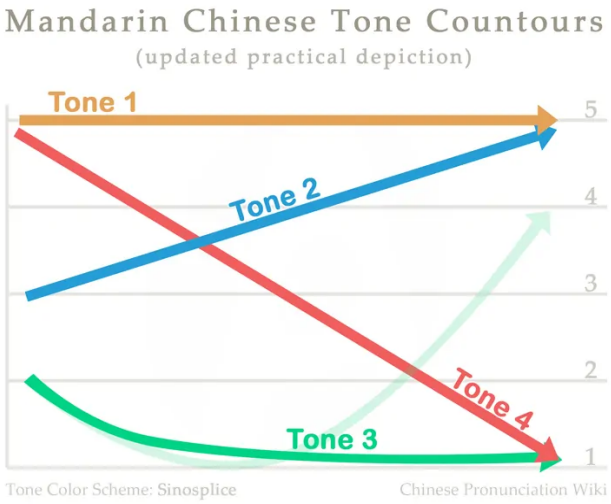


Figure 1: Mandarin Chinese Tone Contours
(Source: Chinese Pronunciation Wiki)

In the official romanization system for Mandarin Chinese named Pinyin, the four contour tones are denoted with diacritics. For example, the vowel *a* /a/ with the four contour tones are denoted as *ā*, *á*, *ǎ*, and *à*, respectively. There is also a neutral tone *a* in Mandarin Chinese, which

is said to be unstressed and shorter than the other four tones. The neutral tone is commonly used on sentence-final particles such as *ma*, *ba*, *le*, or on the second syllable of a two-syllable word.

2.4 Tonal Coarticulation

Hardcastle & Hewlett (2006) broadly defines coarticulation as "the fact that a phonological segment is not realized identically in all environments, but often apparently varies to become more like an adjacent or nearby segment." An example of coarticulation is the English phoneme /k/ in the words *key* and *caw*. When the phoneme /k/ occurs before a front vowel like the /iː/ in *key* [k̟iː], it is articulated with the tongue in an advanced position; when /k/ occurs before a back vowel like the /ɔː/ in *caw* [k̠ɔː], it is articulated with the tongue further in the back. The same manner also applies to tones since adjacent tones inevitably interact with each other while being articulated (Hardcastle & Hewlett 2006). Coarticulation not only affects the onset and offset of the tone value, but also affects the overall tone heights (Shen 1990).

Coarticulation is bidirectional, meaning that a segment can influence its neighboring segments in either direction (Daniloff & Hammarberg 1973). Tonal coarticulation is also bidirectional, but the effects are symmetric: anticipatory and carryover are similar (Shen 1990). Anticipatory coarticulation and carryover coarticulation are the two types of coarticulation, and Daniloff & Hammarberg (1973) define them in the following manner:

> "Given a sequence of segments ABC, if B exerts an influence on C we talk about *left-to-right* or carryover coarticulation. If B exerts an influence on A we talk about *right-to-left* or anticipatory coarticulation." (Daniloff and Hammarberg 1973)

The presence of tonal coarticulation has been observed in Mandarin by many scholars. The contours of the tones sound stable and invariant while being pronounced in isolation, but

when they are pronounced within contexts, the tonal contours may vary depending on the adjacent tones (Chao 1968). Wu (1988) indicates that in a sequence of two high falling tones (Tone 4), the second tone has a lower pitch than the first one, and the first does not drop as far in pitch as those spoken in isolation. Shen (1990) observes changes in tonal height and slope as a function of adjacent tones. Xu (1997) finds a difference between anticipatory and carryover coarticulation in Mandarin, in terms of both magnitude and nature. Specifically, anticipatory effects in Mandarin are mostly dissimilatory - a low onset value of a tone raises the maximum F_0 value of a preceding tone and vice versa - except for Tone 3, where the pitch lowers before the fall-raising tone.

2.5 Tone Sandhi in Mandarin Chinese

Tone sandhi refers to a type of phonological change in tonal languages like Mandarin Chinese, where tones assigned to individual words or morphemes change based on the pronunciation of adjacent words or morphemes (Yip 2002). Factors that may trigger tone sandhi in Mandarin Chinese include phonetic interaction between neighboring syllables, tones on special syllables, and polyphones. One of the most encountered types of tone sandhi in Mandarin Chinese occurs when there are consecutive third tone syllables. In the case of a series of two third tones, the tone of the first syllable becomes a second tone while the tone of the second syllable stays on the third tone. For example, the common greeting 你好 *nǐhǎo* 'hello' has the third tone assigned to both syllables, but when the two syllables are pronounced together, the tone of the first syllable changes to a second tone, hence resulting in *níhǎo*. When there are three or more consecutive third tones, the rules become more complicated, and factors such as word

boundaries, stress, and dialectal variations need to be taken into account while deriving the rules (Duanmu 2000).

Zhang & Liu (2011) distinguishes tonal coarticulation from tone sandhi by pointing out that the former is a gradient phonetic effect and is highly variable across speech rates and styles, while the latter is categorical, often neutralizing, and stable across speech rates and styles.

2.6 Phonetics and Phonology of Code-Switching

Code-switching has been extensively studied by scholars from the perspectives of syntax and sociolinguistics, while relatively less attention is put on phonetic and phonological aspects. Most studies on the phonetic and phonological aspects focus on the voice-onset-time (VOT) of code-switched vowels. Balukas and Koops (2014) examines the VOT values of New Mexican Spanish and New Mexican English-language words and argues that there is no evidence of a causal connection between code-switching and long-term phonological convergence - a process where the pronunciation of directly interacting segments becomes more similar to each other (Lewandowski & Jilka 2019). Muldner et al (2017) investigates the effects of code-switching on vowel quality, pitch, and duration among English–French bilinguals, which reconfirms previous findings that code-switching does not influence phonology (Olson, 2013; Piccini & Arvaniti, 2015), but on the other hand finds that the pitch of a code-switched word approached the pitch of a non-switched word of the other language. In this study, participants are asked to read sentences that are completely in French, completely in English, French-carried sentences with embedded English words, or English-carried sentences with embedded French words. Researchers then estimate the fundamental frequency (F_0) of the words in these sentences and find that English words have higher pitches in a code-switched context with French, while French words have

lower pitches while code-switched with English. Muldner et al (2017) argues that this could be interpreted as a sign of hyper-articulation since the pitches of the embedded words would approach the pitches of the non-switched words in the matrix language[2].

Some other researchers also investigate the tonal aspects of code-switching, mostly involving at least one tonal language and sometimes involving neither. Zheng (1997) examines the tonal aspects of Chinese-Australian English code-switching and observes that switches to English are usually following the Chinese fourth, half third, and neutral falling tones or weak stress of word, which may also facilitate transitions between Chinese and English. Olson (2016) shows that code-switched words between English and Spanish are produced with an overall higher pitch and duration relative to non-switched words. The researcher in this study compares the normalized pitch ranges of tokens in different contexts[3] and finds significant differences between the pitch ranges of code-switched and non-switched tokens. The analysis result from Shen (2019), which focuses on tonal interactions that happened in Mandarin-English code-switching, exhibits that Mandarin words become less tonal while English words become more pitchy when code-switched.

2.7 Applying Tonal Knowledge to a New Language

The results from Shen (2019) potentially indicate that having a perception of tones as a speaker affects the way that the speaker uses another language. There is a number of literature that provide support for this association. Choi et al (2017) investigates how Cantonese lexical tone sensitivity contributed to English lexical stress sensitivity within second-to-third grade

[2] The language of the carrier phrase (Muldner et al 2017).
[3] Monolingual context – non-switched targets, monolingual context – switched targets, bilingual context – switched targets, and response language (L1 and L2). (Olson 2016)

Cantonese ESL[4] children. The results indicate that there are both direct and indirect pathways that connect the two. Ortega-Llebaria & Wu (2021) examines pitch perception in Mandarin and English words and nonwords by Mandarin-English speakers and a group of native English controls and finds that English words, like Mandarin words, were stored with a pitch shape in the bilingual lexicon of Mandarin-English speakers. Another study, Schaefer & Darcy (2020), investigates whether L2 Mandarin learners can generalize experience with Mandarin tones to unfamiliar tones (i.e., Thai). They find that L2 Mandarin learners and L1 Mandarin speakers perceived Thai tones more accurately than L1 English non-learners. This study shows that speakers with knowledge or experience in the tonal language(s) may be more sensitive to tones or pitches. In this case, Mandarin speakers were able to apply their tonal knowledge in Mandarin to another tonal language like Thai.

Following the results of Ortega-Llebaria & Wu (2021) and Schaefer & Darcy (2020), I wish to investigate this tonal knowledge application in the opposite direction, i.e., whether speakers of a tonal language carry their tonal perceptions to their usage of a non-tonal language such as English, especially when they code-switch between these two languages.

3. Research Questions and Hypotheses

To build on the past research, my thesis seeks to explore the potential resemblance in the pitch shapes of English words to Mandarin tones in a code-switched utterance between Mandarin and English. Although the results of Shen (2019) already show evidence of pitch changing in a code-switched utterance between the two languages, I check this phenomenon again with more considerations on the selection of participants. In this thesis, I use the term *tonal adaptation* for

[4] ESL stands for "English as Second Language."

the phenomenon described in the previous sentence to distinguish it from *coarticulation*, since in this case the phonology of one language is imposed on the phonology of another language.

This study asks two research questions:

(1) When Mandarin-English speakers code-switch between Mandarin and English, do English words in the utterances become pitchy under the effect of the neighboring Mandarin words? If so, do their pitch contours resemble Mandarin tones?

(2) If (1) is substantiated, does this phenomenon exist among Mandarin-English bilinguals with all levels of proficiency in the two languages?

Based on the previous research reported in the literature, I hypothesize the following:

(1) English words will become pitchy in a code-switched utterance between Mandarin and English, and there will be a resemblance between the pitch contours of English vowels and Mandarin tones. The mapping of Mandarin tones to English pitches is systematic but potentially speaker-dependent.

(2) Mandarin-English bilinguals with higher proficiency in Mandarin are more likely to exhibit the pattern than those with lower proficiency.

4. Research Design and Methods

4.1 Participants

I recruited 14 college students who have knowledge in both Mandarin Chinese and English and have code-switched between the two languages in their daily life. Due to the relatively small number of participants in need, they were identified and recruited through personal connections. Half of the participants are native Mandarin speakers who have learned English as their second language and the other half are speakers whose first language is English

but also use Mandarin in their daily life. The rationale behind this is that I expect the linguistic backgrounds of the participants may have a certain effect on the way they code-switch between languages. However, even for speakers who share the same first language, there may be discrepancies among their knowledge of the two languages, and these discrepancies may be seen more conspicuously in the group of English-L1 participants. This group of English-L1 participants were restricted to Chinese Americans who have either immigrated to the United States at a young age or were born and raised in the United States but learned to speak Mandarin under families' influences. Depending on factors such as the number of years they have known Mandarin, the way that they acquired Mandarin, and the frequency of them using Mandarin, their code-switching behaviors may differ. The same factors for English also apply to the Mandarin-L1 English-L2 speakers, and I also expect the differences to be partially reflected in their code-switching patterns.

The data collection process entailed in this study was divided into two parts that each served different purposes and collected different types of information, and all participants finished both parts of the data collection. More details on the data collection process are elaborated in the next two sections.

4.2 Interview

The first part of the data collection process collected code-switching speech data by recording the speech of the participants. I have constructed a list of 48 sentences (see Appendix A) that are code-switched[5] between Mandarin and English (28), fully Mandarin (10), or fully English (10). Each participant was asked to read these sentences to a recorder, and the recordings

[5] The code-switched sentences were constructed based on linguistic intuition of the author as a bilingual speaker of Mandarin and English.

were analyzed using a speech analysis software. Due to the scope of this thesis, all code-switched utterances only involve intrasentential code-switching, i.e., the alternation of the languages only occurs in the middle of the sentence. Each code-switched sentence thus contains one English word/phrase that was targeted for analysis. An example of such sentences is presented below:

(3) 我准备坐火车去PHILLY.
wǒ zhǔnbèi zuò huǒchē qù PHILLY.
'I planned to take the train to Philly.'

To control for the potential effect that the tone on the preceding Mandarin character may pose on the pitch contours of the inserted English words, the 28 code-switched sentences were divided into 5 groups based on the tones on the word preceding the English word in the sentence, with 6 sentences for each contour tone and 4 sentences for the neutral tone. Sentences that are completely in English and Mandarin were also included in the list, but they served different purposes. Since the fully Mandarin sentences do not contain any English words, they were used to obtain the "baseline" of each participant's tonal contours for the Mandarin tones. Although, as shown in the literature review, all speakers of Mandarin generally have the same pitch contours for the Mandarin tones, there are intra- and/or inter-speaker variations that may ultimately lead to discrepancies in pitch contours for different Mandarin speakers. This fact is especially important for this study because the participants have dissimilar linguistic backgrounds that pose an effect on the way they speak. Hence, I did not use a universal tonal contour as the baseline for all participants but chose to find a baseline for each of them for intra-speaker comparisons. On the other hand, the fully English sentences are filler items that were not analyzed but were included in the list to obscure the purpose of the data collection. All sentences were shuffled in order before being presented to the participants. Each participant was asked to read the constructed

sentences one by one, at a moderate pace (but not robotically), and calmly so that the analyzing software could detect the pitch contours as clearly as possible. The recorder only recorded the participant's voice once the data collection starts, and I directed them using hand gestures in case any sentences needed to be read again due to the pace, background noise, participant laughing, or other reasons.

Of the English-L1 Mandarin-L2 speakers, two of them were interviewed with a different methodology. The interview procedure described above required the participants to be able to recognize Mandarin characters, but these two participants do not read Mandarin. Hence, I engaged in natural occurring conversations with them and recorded the conversations. The two participants were not explicitly informed that the research was about code-switching, but they code-switched frequently between Mandarin and English during the data collection. Each conversation was recorded for around 10 minutes to make sure that there was enough code-switched data for analysis. The audio files of these two participants were analyzed in the same way as the rest of the participants, but they were put into a different pool for the interpretation of the results.

During the recruiting process, all participants were informed that the research was generally about Mandarin-English bilingualism, and the true purpose of analyzing the pitch contours was debriefed at the end of the data collection process. Once the participants finished reading all sentences, I revealed the purpose of the study to them. All participants also received an email that contained the consent form for using the collected data, a written debrief, and a link to a questionnaire, which collected information on participants' demographics, linguistic background, and code-switching behaviors. More details on the questionnaire are discussed in the next section.

4.3 Questionnaire

As the second component of the data collection, the Mandarin-English Code-Switching (MECS) questionnaire (see Appendix B) was designed to collect demographic information as well as linguistic behaviors from the participants. The questionnaire entailed five sections: Demographic Information, Linguistic Background, Proficiency in Second Language, Questions for English-L2 Speakers, and Questions on Mandarin-English Code-Switching. All participants were required to fill out four of the five sections, and the fourth section was required only for participants who identified themselves as English-L2 speakers. As mentioned earlier in this thesis, there are a lot of factors that could impact one's code-switching patterns, hence the aim of this questionnaire was to create a coding scheme that categorizes the participants based on their linguistic backgrounds and characteristics. Specific identifying information such as names was not collected through the questionnaire.

The first section, Demographic Information, asked for participants' age, class year, pronoun(s), places where they grew up and now live, and the approximate number of years they have spent living in the current location. The second section asked the participants to identify their first and second languages, as well as other languages, if any, that they also speak. This section also asked for the time point when the participants started to acquire their second language and the interlocutors with whom they use their second language.

The third section contained questions that help assess participants' proficiency in their second language. Questions in this section were a partial adaptation of the Linguistic Profile and Proficiency Assessment questionnaire designed by Nicté Fuller Medina, which was adapted from the Language Acquisition Research Lab (LAR-LAB) at University of Ottawa. A number of

activities were divided into four categories based on the language skill required for performing that activity - Oral Comprehension, Oral Production, Written Comprehension, and Writing (or in more general terms, listening, speaking, reading, and writing). Each category contains 5 or 6 activities, and the speakers should select the activities that they believe they can carry out in their second language. Each speaker was assigned an L2 proficiency score based on their answers to these questions, which is a number calculated from dividing the number of checked boxes by the total number of boxes. Being able to perform over 80% of the activities in each category indicates that the speaker is relatively proficient in the language. Below I present some examples of the activities that appear on the questionnaire.

Oral Production	Order food in a restaurant.
	Do a twenty-minute presentation in front of twenty people.
Oral Comprehension	Understand a short, conversational text message.
	Understand the content of an introductory text of a university level subject.
Written Comprehension	Be able to follow a conversation between two people at the bus stop or store without any problem.
	Understand a movie without subtitles.
Writing	Write an email to a professor.
	Write a letter to an editor where you express your opinion about a current event.

Table 1: Sample proficiency indices
(Source: Linguistic Profile and Proficiency Assessment questionnaire)

Section 4 of the questionnaire was designed only for participants who identified their second language as English. Due to the nature of the two groups of participants I recruited, while English-L1 Mandarin-L2 speakers may acquire Mandarin through taking lessons or simply just early family influences, the Mandarin-L1 English-L2 speakers universally acquired English from school, i.e. they learned English as a foreign language. Acquiring a language through being

immersed in a language environment is essentially different from acquiring a language through taking language classes since the knowledge that the speaker gets from the two environments is not identical. Most English teachers in China are not native speakers of English, so students did not start learning the language through talking to a native speaker; on the other hand, most Chinese Americans acquired Mandarin because they have family members who are native speakers of Mandarin, thus enabling them to be exposed to the language environment naturally and at an early age, and may result in two distinct kinds of bilingualism - simultaneous and sequential bilingualism[6]. All these differences may lead to discrepancies in speakers' proficiency in their second language (Freed 1998). For example, an English-L1 Mandarin-L2 speaker who learned Mandarin through communicating with family members may speak Mandarin without any foreign accent, but they may not be able to under any Mandarin characters; a Mandarin-L1 English-L2 speaker who acquired English at school could write an academic paper in English, but they may have trouble understanding wordplays or jokes in English. Hence, to potentially identify the effect of learning process on code-switching behaviors, I included three questions that asked for the age at which the participants started to learn English, the time frame during which the participants started to frequently speak English with a native speaker of English, and the time frame during which the participants can fluently communicate with people in English.

Lastly, the fifth section asked questions about code-switching between Mandarin and English. The participants were asked to rate their frequency of code-switching between the two languages on the scale from 1 to 5 (with 1 being "very rare" and 5 being "all the time"), identify the interlocutors with whom they code-switch, and share their reason(s) for code-switching.

[6] Simultaneous bilingualism occurs when children are exposed to two languages from a very early age and concurrently; while sequential bilingualism occurs when a child begins learning a second language after the first language is at least partially established. For more information on simultaneous and sequential bilingualism, see Tabors (1997) for reference.

4.4 Instrument

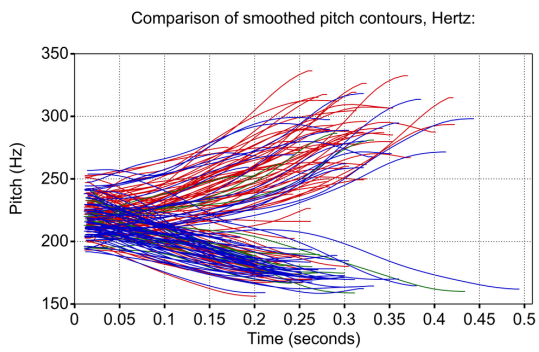
All speech analysis in this study was performed using Praat, a software package developed and maintained by Paul Boersma and David Weenink of the University of Amsterdam (Styler 2021). To satisfy the need to extract and compare pitch contours in both Mandarin and English, the analysis could be performed either using the in-built functions of Praat, which allow for immediate visualization of formants and pitch heights, or using a separate Praat script created specifically for this purpose. I chose to combine the two ways - use a Praat script that extracts and visualizes pitch contours with the help of Praat's in-built 'show pitch' function[7].

The Praat script, created by Hiram Ring, is a complementary tool that automates F_0 extraction, normalization, and visualization using Praat in combination with annotated TextGrid/ audio file pairs (Ring 2017). After a recording is imported into Praat, the user needs to first manually annotate the tones with unified labels on Praat. According to Ring (2017), tonal realizations often differ greatly both between speakers and within a single speaker's speech, which is mostly due to speakers' different apparatuses and the articulatory context in which speakers produce each tone, but Praat cannot perceive this variation. Hence, before running each sound file, the system asks for the pitch parameters (the lower and upper bounds of F_0) according to the range[8] of fundamental frequency of each individual speaker. When the script is run on Praat, the pitch contours of all annotated audio segments are visualized on a plot; all tones annotated with the same label are drawn in one color. Apart from plotting every single tone, the

[7] This function allows for pitch tracking for the voice segment. When the function is enabled, a blue line will be placed on top of the spectrogram to represent the pitch, where Praat can find it. Once the pitch track is placed, the user can use the cursor to check the pitch at any given point in the word. (Styler 2021)
[8] The ranges were retrieved by using the "get maximum pitch" and "get minimum pitch" functions in Praat.

script also normalizes pitch contours for all tones with the same label. The normalization helps average out the differences that occur due to the reasons stated above.

For each recording, the Mandarin tones and English pitches were annotated on the same tier so they could be plotted on one plot for direct comparisons. The script is essentially used for tone visualization of tonal languages, so theoretically it does not work for a non-tonal language like English. However, since the purpose of this study is to investigate the resemblance between pitch contours on English words in code-switched utterances and Mandarin tones, it was possible to annotate these English words just like Mandarin tones based on how the pitch contours are conceived by a native speaker of Mandarin[9]. For example, if the pitch contour on an English syllable sounds like the fourth tone in Mandarin, that audio segment was labeled as E4 (which stands for "English fourth tone"). The four tones in Mandarin that are extracted from the speech of fully Mandarin sentences, on the other hand, were annotated using numbers 1 through 4. When the annotation was finished, I ran the script for each file and generated two plots - before and after normalization[10] (the difference is shown below) - and the Mandarin tones and "English tones" were compared based on the shape of the pitch contours.



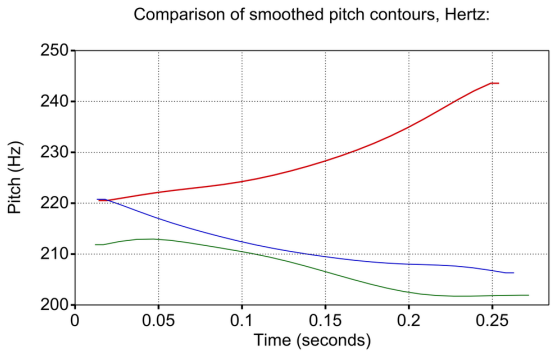


Figure 2: plot of pitch contours before normalization Figure 3: plot of pitch contours after normalization (Source: Ring (2017))

[9] The author of this thesis was the annotator. All tones and pitches were labeled by ear.

[10] Normalization refers to a process that makes something more normal or regular. In this case, the process of normalization maps the numerous pitch contours to a single line that represents the general shape of that pitch contour.

5. Results

5.1 Participant Profile

With the information collected through the MECS questionnaire, all participants were divided into two groups based on their self-assessed language dominance between Mandarin and English - the Mandarin-Dominant Group (MDG) and the English-Dominant Group (EDG). Here I use the word *dominant* instead of L1 and L2 because some bilingual speakers often find it difficult to determine their first language: some may choose the language that they started to speak first as their first language (time-based), while others may choose the one that they are more proficient in as the first language (proficiency-based). The question included in the questionnaire still asked the participants to identify their first and second languages, but the intention was to obtain their assessment for their proficiencies in the two languages.

I grouped 6 of the 14 participants to MDG and the remaining 8 to EDG. There was one participant who identified Mandarin as her first language but was grouped into EDG instead. This change in grouping was made based on my impressionistic assessment to the participant's language proficiency. It was difficult to determine this participant's dominant language since she was born in China and lived there till 10 years old. The participant started to learn English at 8 but has been speaking English on a daily basis since she immigrated to the United States at 10 years old. During the data collection, this participant exhibited similar proficiencies in understanding the two languages, but when it came to reading the Mandarin sentences, it took her a slightly longer amount of time to recognize the characters and read them out loud than the length of time a native speaker of Mandarin would take. This situation was not present while she was reading the English sentences, however. For this reason, I asked this participant to fill out Section 3 of the questionnaire (Proficiency in Second Language) again, but based on her

proficiency in Mandarin. Her self-assessment showed a proficiency score of 0.83, a lower score than her English proficiency score of 1, which indicates that she is more proficient in English, and may consequently, be an English-dominant speaker. Hence, I decided to assign this participant into EDG instead of MDG.

Although participants were not evenly divided into two groups according to their language dominance, they were divided into three groups for results interpretation. As mentioned in Section 4, EDG two participants were in a different pool, so their results were interpreted separately. Consequently, the rest of the participants were evenly divided into two groups of 6, thus enabling a direct comparison between the two groups.

All participants are aged between 18 and 22, and 78.6% of them use she/her pronouns to address themselves. 8 of the 14 participants indicated that they are now living in a different country from where they were born. Apart from being bilingual speakers of Mandarin Chinese and English, 8 participants also reported to speak at least one other language, and French is the most popular third language being spoken among the participants.

Participants from the two groups have very different linguistic backgrounds. All MDG participants indicated that they started to learn/speak English from a young age, ranging from 0 to 9 years old, and most of them were able to fluently communicate with people in English sometime after high school. The average L2 proficiency score of MDG is 0.97, which shows that participants in this group generally perceived themselves as being proficient in English. This is a large number considering that most MDG participants have only spent fewer than 4 years living in an English-speaking country. Results of EDG suggest that this group is remarkably different from the other group. Most EDG participants were born and raised in the United States, and most of them started to speak Mandarin from a very young age (between 0 and 4 years old). However,

their average L2 proficiency score is 0.62, which is significantly lower than that of MDG and is below the proficiency line. All EDG participants reported possessing high ability in speaking and listening comprehension, but their scores for reading and writing are much lower since these two types of activities have to be carried out with knowledge of Mandarin characters.

The two groups use their L2 in very distinct contexts. All EDG participants reported that they speak their second language to their parents, and some of them also speak Mandarin with their friends. On the other hand, none of the MDG participants would speak English with their parents, but most of them reported that they would speak English with friends both at and outside school as well as in a working environment. If we think about the participants' proficiency scores together with their frequent L2 interlocutors, we may be able to draw a connection since different types of conversational topics are involved with different interlocutors. Compared to a setting where one speaks with their family members, a school or workplace setting may require speakers to possess more professional vocabularies as well as better expression ability, which may explain the discrepancy between two group's mean proficiency scores.

All participants reported to code-switch frequently in their lives because all of them gave themselves a rating of 3 or higher on a Likert scale of 1 to 5, with 1 being "rarely code-switch" and 5 being "always code-switch." Friends and family members are the most common interlocutors with whom the participants code-switch, and 4 participants reported that they would also code-switch with strangers. This implies that most participants generally consider code-switching as a casual way of speaking since they feel comfortable doing so with people who have relatively closer relationships with. While responding to the question "please share your reason(s) for code-switching," participants mainly provided three types of answers. First, the meanings of some words are better expressed in one language than in the other; second, there

are vocabularies in more complex domains (such as academic and technical) that the participants are only familiar with in one language; third, EDG participants tend to switch to Mandarin when the topic of conversation is about Chinese culture. Other participants also mentioned reasons like "not wanting other people to understand me when I'm sharing personal matters in a public setting" and "to fit the context more."

5.2 Resemblance between Pitch Contours

The resulting pitch contour plots show resemblance between Mandarin tones and their English counterparts mainly in two pairs: the 3rd tones and the 4th tones. The two criteria I used to determine resemblance are pitch shape and pitch height. Pitch shape is the primary determinant because it shows the contour, which is the most prominent feature of Mandarin tones; pitch height serves as the secondary determinant since it helps distinguish the tone in addition to the pitch shape. The pitch contour of the Mandarin 2nd tone is not present on the English vowels for any participant, and it is too ambiguous to check resemblance for the Mandarin 1st tone on the English vowels since its shape is merely a flat line with a high-level pitch, which could exist even in a non-tonal language while not being code-switched. On the contrary, the pitch contours for the Mandarin 3rd and 4th tones are unique to Mandarin Chinese, so the appearance of these pitch contours on English words is considered as more convincing evidence for the interaction between tonal and non-tonal words. During the annotation process, I started with annotating all of the identifiable pitch contours on the vowels. However, doing so rendered the pitch contour plots difficult to interpret. Because of this and the reasons stated above, I later decided to only annotate the 3rd and the 4th tones for all of the participants.

Albeit to different extents, all MDG participants exhibit this resemblance and are similar in three ways. First, the pitch contours of the Mandarin tones correspond to the standard model of the pitch contours very well. Pitch contours of all 3rd tones and 4th tones are downward sloping, and the overall pitch heights of the 4th tones are always higher than the pitch heights of the 3rd tones. Second, the pitch contours of the Mandarin tones resemble those of their English counterparts, e.g. the pitch contour of the English 3rd tone has a similar shape to that of the Mandarin 3rd tone. Finally, the pitch height difference within each Mandarin-English tone pair is relatively small, indicating a strong similarity between not only the shapes but also the pitch height ranges of the Mandarin tones and English "tones." These results show that for MDG speakers, tonal adaptation does exist when they code-switch between Mandarin Chinese and English, and it is a salient phenomenon.

To illustrate the points raised above, Figures 4 and 5 are the pitch contour plots of two MDG participants. MDG participant 1 in Figure 4 shows the strongest resemblance within each tone pair in the group, and MDG participant 2 in Figure 5 shows the weakest resemblance. For both participants, the pitch contours of the Mandarin 3rd and 4th tones correspond to their falling feature (4th tone is high-falling, and 3rd tone is low-falling), and the 4th tones are higher in terms of pitch height than the 3rd tones. This holds true even for the English tones since the English 4th tones for both participants have higher pitch heights than both Mandarin and English 3rd tones, which indicates that despite the two tones being similar in pitch shapes, they are essentially different as can be distinguished by the pitch heights.

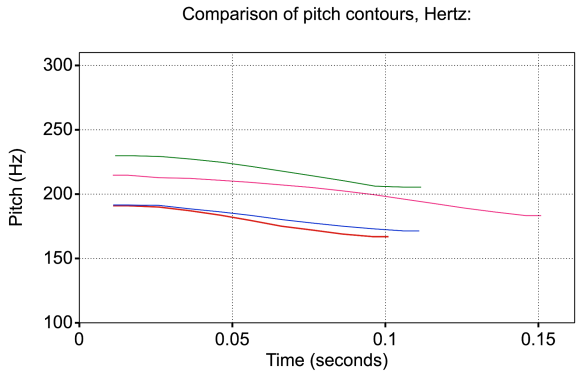


Figure 4: plot of pitch contours of MDG participant 1[11]

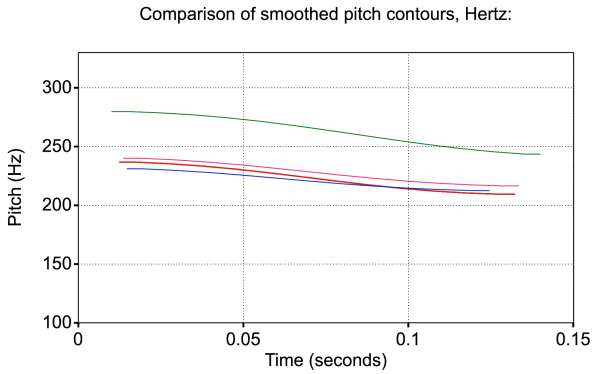


Figure 5: plot of pitch contours of MDG participant 2[12]

There is variation in the extent of how the Mandarin tones resemble their English counterparts between the two participants. Figure 4 shows an MDG participant with very similar tone pairs. The pitch contours of the Mandarin and English 3rd tones are almost overlapping, and the pitch contours of the Mandarin and English 4th tones are also identical in shapes and about 25 Hz apart from each other. The result suggests that tonal adaptation is expressed very saliently in this participant. In practical terms, this participant applies the tonal conception in Mandarin to the English words to a great extent in a code-switched speech. For the participant in Figure 5, on the other hand, there is a larger gap between the pitch height of their Mandarin 4th tone and English 4th tone than the participant in Figure 4, and the English 4th tone has a similar pitch height range as the 3rd tones. Although the result of this participant generally satisfies the patterns summarized above, the extent of resemblance is much weaker than the other participant. There is information collected through the questionnaire that may be accountable for this discrepancy. Although the two participants both rated themselves as being highly proficient in English and they both started to fluently communicate with native speakers of English since high school, the participant in Figure 5 spent 4 more years staying in the United States than the other

[11] Green represents Mandarin tone 4; pink represents English tone 4; blue represents Mandarin tone 3; red represents English tone 3.
[12] Green represents Mandarin tone 4; pink represents English tone 4; red represents Mandarin tone 3; blue represents English tone 3.

participant and also reported to code-switch less frequently than the other participant. This suggests that the time length of staying in the language environment and the frequency of code-switching are relevant to how strong the tonal adaptation can be. Regardless, as the participant in Figure 5 being the one with the "messiest" results in the MDG group, the results show that overall, the Mandarin-dominant speakers exhibit tonal adaptation in Mandarin-English code-switching.

The EDG participants vary significantly in terms of linguistic background and proficiency in Mandarin, making it difficult to generalize their tonal patterns in code-switching as with the MDG results As a result, it is difficult to generalize their tonal patterns in code-switching as with the MDG results. Of the 6 EDG participants who read the sentences during the interviews, only one exhibited clear tonal adaptation. The pitch contour plot of this participant is shown in Figure 6.

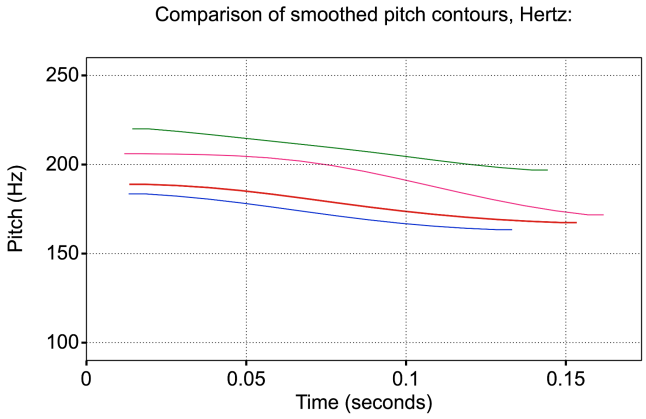


Figure 6: plot of pitch contours of EDG participant 1[13]

This participant has a pitch contour graph similar to that of an MDG participant: the pitch shapes are parallel, and there are only slight differences in pitch heights within each tone pair. The 4th tones have higher pitch ranges than the 3rd tones do, and within each pair the English

[13] Green represents Mandarin tone 4; pink represents English tone 4; red represents Mandarin tone 3; blue represents English tone 3.

pitch contour resembles the Mandarin tone contour. This participant stands out in the pool in that she is the only participant in the EDG pool who started to speak Mandarin since she was born. This participant also reported to have a relatively high Mandarin proficiency score compared to others in the same pool and a high frequency of code-switching.

For the remaining 5 EDG participants, the resemblance is either weak or nonexistent. Based on their pitch contour plots, these participants generally still have downward sloping pitch contours for the Mandarin 3rd and 4th tones, but oftentimes they are not as steep as those of the MDG speakers, suggesting that tonal perception is not as ingrained in their brain as for MDG speakers. A comparison of the slopes of the Mandarin tone contours between MDG and EDG speakers is shown in Figures 7 and 8. If only focusing on the 4th tone (green) and 3rd tone (red), it is clear that the MDG participant's pitch contours are steeper than that of the EDG participants.

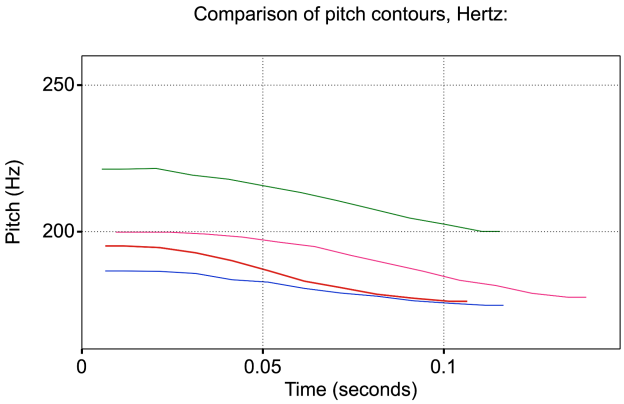


Figure 7: plot of pitch contours of MDG participant 3[14]

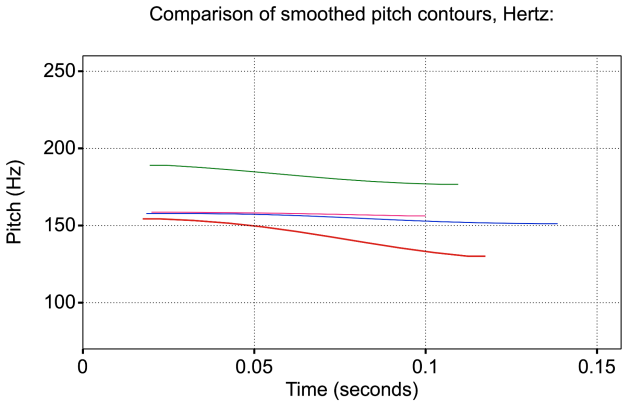


Figure 8: plot of pitch contours of EDG participant 2[15]

EDG participant 2 in Figure 8 is an example of the case where there is no tonal adaptation exhibiting while code-switching. The English tone 3 and tone 4 are almost overlapping with each other but are independent of the Mandarin tones since they do not show

[14] Green represents Mandarin tone 4; pink represents English tone 4; red represents Mandarin tone 3; blue represents English tone 3.
[15] Green represents Mandarin tone 4; pink represents English tone 4; red represents Mandarin tone 3; blue represents English tone 3.

any falling feature but remain flat in shape. There is also little resemblance in pitch ranges between the Mandarin and English tones. Taken together, it can be seen that for EDG participant 2, the pitches on English vowels in a code-switched utterance are not impacted by its surrounding Mandarin tones. This finding is also consistent with the participant's linguistic background. Despite being a Chinese American, she did not start speaking Mandarin until she was 16, and her self-assessed proficiency score is the lowest among the 6 EDG participants in the pool. This participant also chose "3" on the 1-5 scale for the question that asks for the frequency of code-switching, indicating that she does not code-switch very often in daily speech.

Another finding from two other EDG participants is that their English tones appear to have more salient contour features than their Mandarin counterparts do. Figures 9 and 10 present the two participants who show this pattern.

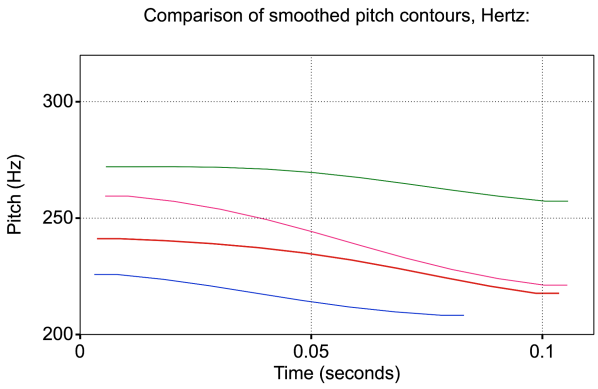


Figure 9: plot of pitch contours of EDG participant 3[16]

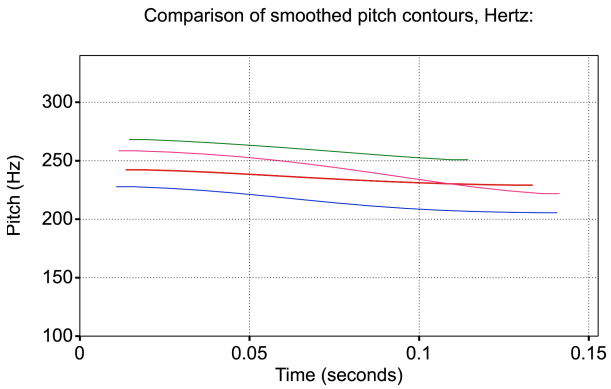


Figure 10: plot of pitch contours of EDG participant 4[17]

For both EDG participants 3 and 4, the pink lines (English tone 4) and blue lines (English tone 3) are prominently steeper than the green lines (Mandarin tone 4) and red lines (Mandarin tone 3), which indicates that they actually exhibit more tonal features on the English vowels than

[16] Green represents Mandarin tone 4; pink represents English tone 4; red represents Mandarin tone 3; blue represents English tone 3.
[17] Green represents Mandarin tone 4; pink represents English tone 4; red represents Mandarin tone 3; blue represents English tone 3.

on Mandarin vowels while code-switching between English and Mandarin. This is an interesting phenomenon, and the factors that lead to this are unclear. The information collected through the questionnaire is not particularly helpful since these two participants are not significantly different from the rest. However, it is possible that these two participants are accustomed to the tonal aspect of Mandarin, but when it comes to mixing a non-tonal language with it in an utterance, they subconsciously feel the need to incorporate the non-tonal language into the tonal language by means of deliberately adding tonal features to the non-tonal words.

The two EDG participants that were assigned into a separate pool also showed distinct patterns. The result of the first participant is largely consistent with most EDG participants that she exhibited a moderate degree of tonal adaptation. This participant started to speak Mandarin at the age of 2, and despite not being able to read or write in Mandarin, she reported a relatively high proficiency in listening and speaking, which may be related to the pattern she exhibited. The other participant in this pool barely showed any tonal adaptation, which can be seen as consistent with her linguistic background. Just as the EDG participant 2, she started to speak Mandarin at an older age (7 years old), and her proficiency score is at the lower bound of all EDG participants. The results of the EDG participants implied an implicit relationship between age and language behaviors, which may be associated with the critical period hypothesis[18].

To sum up, tonal adaptation in Mandarin-English code-switching commonly exists in MDG participants but is not prevalent among EDG speakers. For those who exhibit this phenomenon, the mapping of Mandarin tones to English pitches is systematic since it only appears saliently in the 3rd tone and the 4th tone. Within the EDG speakers, the ones who do not exhibit tonal adaptation happen to also be the participants with lower proficiency in Mandarin and lower frequency of code-switching; for EDG speakers who do exhibit tonal adaptation, there

[18] For more information on the critical period hypothesis, please see Penfield & Roberts (1959).

is a lot of variation in the similarity between the pitch contours of Mandarin tones and their English counterparts. Factors that can account for these discrepancies are not clearly defined since these participants appear to not be significantly different from each other based on the questionnaire results. This suggests that there might be other factors that are not captured by the questions in the questionnaire but are accountable for the variation.

5.3 Massive Inter-speaker Variation

After presenting the results on the resemblance between pitch contours, I believe it is worth mentioning that there exists a great deal of inter-speaker variation in their pitch contours. Since different speakers have different vocal apparatuses and different ways of speaking, even though they pronounce the same four tones in Mandarin, there will be differences in features such as pitch durations, ranges, and heights. This explains why different participants have different pitch ranges and pitch durations in their pitch contour plots. Figure 11 below shows the pitch contour plot of an MDG participant who has a monotonic speech regardless of the language being spoken. His pitch contours also generally satisfy the three characteristics shared by the MDG participants, but all of his pitch contours are very flat compared to those of the remaining MDG participants. Although certain EDG speakers also have flat pitch contours for the Mandarin tones, their English pitch contours are discernibly different in slopes from the Mandarin pitch contours. In the case of this participant, however, there is no significant difference in the flatness of the 4 pitch contours. I still evaluated him as exhibiting tonal adaptation because there are resemblances within each tone pair, but it is also an ambiguous judgment considering how monotonic his speech is - the resemblance may be due to the unchanging intonation instead of actual tonal adaptation.

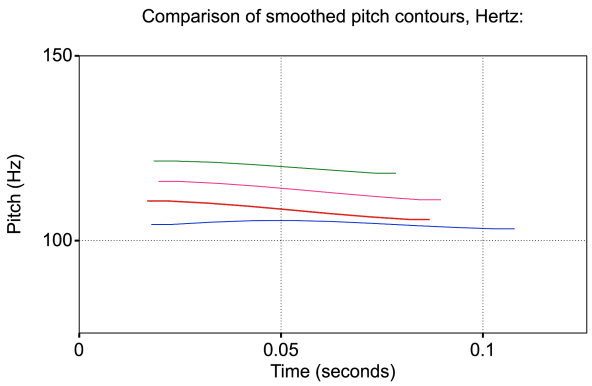


Figure 11: plot of pitch contours of MDG participant 4[19]

The inter-speaker variation needs to be acknowledged while interpreting the results because the pitch contours of different participants cannot be compared directly. Hence, except for the comparison drawn between the MDG and the EDG participant (Figures 7 and 8), all interpretations and comparisons provided in the previous section focus on the patterns that exist within the participant.

6. Conclusion and Discussion

In this senior thesis, I investigated the phonetic and phonological interaction between tonal words and non-tonal words in a code-switched context. Specifically, I looked at whether the pitches on English words are affected by the neighboring Mandarin words in a code-switched sentence in Mandarin Chinese and English, a phenomenon defined as tonal adaptation. After this inquiry received a positive answer, I used speech analysis to explore the extent to which English words become pitchy in this context by comparing their pitch contours to Mandarin tones. The speech data were collected through collecting interviews with 14 current college students who are Mandarin-English bilinguals. The participants were coded into two different groups according to their language dominance. The results found evidence of tonal adaptation in

[19] Green represents Mandarin tone 4; pink represents English tone 4; red represents Mandarin tone 3; blue represents English tone 3.

Mandarin-English code-switching, i.e. the pitch contours on certain English vowels do resemble the Mandarin tones, in the 3rd tones and the 4th tones. The resemblance within each tone pair is prevalent and salient in Mandarin-dominant participants, and it is also subtly exhibited in some of the English-dominant participants. English-dominant participants who started to speak Mandarin at a younger age tend to self-assess themselves as more proficient Mandarin speakers and are more likely to show tonal adaptation than those who started to learn the language later in their lives.

Various factors may be accountable for the results presented above. There is evidence that high proficiency in Mandarin Chinese may be directly related to the exhibition of tonal adaptation. The biggest difference between the two groups of participants is their proficiency in Mandarin, and the results do show that MDG participants, who are more proficient in Mandarin than EDG participants are, are more likely to exhibit tonal adaptation. The questionnaire that all participants filled out also collected information on participants' linguistic background and language behaviors, which may also explain certain phenomena observed in the results. Of all factors mentioned in the questionnaire, the age when the participants started to speak L2, proficiency of L2, and frequency of code-switching seem to be the most relevant factors to tonal adaptation. The length of time that participants have spent in a language environment, which is impacted aggregately by factors like the frequency of speaking the language, the context of using the language, and the interlocutors, may also affect a speaker's proficiency in the language as well as their code-switching behaviors.

The methodology employed in this study is a combination of speech and informational data collection from human subjects and data analysis using speech analysis software. However, the whole study is relatively small in scale due to limited time and small sample size.

Participants are restricted to college students in the United States, which was a decision made on purpose since they are a population with dynamic linguistic resources but remain understudied in research on code-switching. In keeping education and age as the invariants, I could focus on the influence on their language usage brought by their upbringing, learning experience, language competency and so on. Granted that the participants originally came from different geographical areas, as they were recruited through personal connections of the author, I expect there to be underlying similarities among them that were not controlled in the experiment. For example, the geographical distribution of the EDG participants is quite spread-out, but most MDG participants come from big cities in China such as Beijing and Shanghai, which are cities with more educational resources and potentially better language-learning environments. This homogeneity among the MDG participants may also partially explain the unified pattern observed in the MDG results.

The majority of the speech data in this study were collected through recording participants read pre-constructed sentences instead of recording naturally occurring data. Despite the common concern that the process of producing this kind of phonetic data makes the interviewees self-conscious about the way they speak (Podesva & Sharma 2013), I believe that it can still produce data that mimic the naturally occurring speech to some extent. Even though participants were notified of the general topic of the research, it was hard for them to connect it to the investigation of pitch contours. An alternative way to collect code-switched data is through recording the participants code-switch naturally. However, this method has several limitations. First, doing so requires an interview setting in which a conversation goes on between the interviewer and the interviewee. Since the recording is made in an environment where the participant may not feel comfortable with talking about random topics, even though the

conversation naturally occurs, the utterances may not be as natural as how the participants normally speak. Second, the participants do not know that the study is about code-switching, so they may deliberately speak more "standardly" - fully in Mandarin or English - rather than code switching between the two languages. The test run[20] I did for this method also proved that even if the interviewer deliberately code-switches with the interviewee to elicit code-switched utterances, the chance is still very low. Third, unlike in the current setting where participants are asked to speak at a moderate pace, participants have a lower control over the speed of speech and the clarity of the utterance when they are having natural conversations, which may lead to difficulties in the analysis process. Finally, collecting and analyzing naturally occurring code-switching data is both complicated and time-consuming. Each interview would last at least for ten minutes, and the useful speech segments need to be separated from the sound file manually, which requires a large amount of time. For the reasons stated above, I decided to use the method introduced in the Methodology section as the way to collect code-switched data.

An innovation of this study is the use of Praat script to look for specific patterns in resemblance between pitch contour instead of only focusing on the big picture. According to Ring (2017), the script used for analysis was originally designed for phonetic data documentation with two particular features: (1) to quickly visualize the tonal properties of a large number of tokens, and (2) to output a permanent image with the option to easily re-adjust the visualization parameters. Although I adapted the script with a different purpose, it enabled me to visualize tonal contours in a straightforward way while preserving variation among different speakers. As mentioned in Section 4, all annotations were made based on my own tonal knowledge of

[20] Before the data collection process, I performed two test runs with two bilingual speakers of Mandarin Chinese and English. During the test run, the interview was divided into two parts. In the first part, the participants were expected to engage in natural occurring conversation with the interviewer while code-switching. In the second part, the participants were asked to read the constructed sentences. After the test runs, the first part of the interview was deleted from the interview process. The data collected during the test run were not used for analysis.

Mandarin Chinese, but there was a limitation posed by Praat in pitch identification. Due to the way that the script was written, it would not run properly if the annotated pitch is identified as too low in pitch height or too short in length by Praat, even though it sounds normal to human ears. Hence, during the data analysis, lots of segments that were identified by the annotator as having pitch contours were left unannotated and hence not plotted. Another possible cause of bias is related to the nature of the speech data. During annotation, I noticed that the duration of the pitch varies depending on where the word is in the sentence. This is inevitable since all participants spoke the language in a natural way rather than robotically, hence cannot guarantee that all vowels could be pronounced in the same manner. However, there is a chance that it affects the accuracy of the pitch contour measurements. Sometimes the script would also set a minimum pitch height before running, which may exclude certain annotated segments with pitch heights lower than the set amount from getting plotted. Granted, the methodology used in this study is not optimal, but I consider it as a good first attempt at investigating specific patterns in tonal adaptation.

The results of this study open a discussion on why this phenomenon arises among Mandarin-English bilingual speakers. The phonology of English involves stress on syllables, which could be perceived as involving pitch height changes and eventually pitch contours (Fry 1958). The stressed syllable is pronounced with a higher pitch while the unstressed syllable is pronounced with a lower pitch to form a contrast with the stressed syllable. With tonal knowledge of Mandarin, the Mandarin-English bilingual speakers may draw connections between the emphasis on English pitch height and the intrinsic features of Mandarin 3rd and 4th tones, which are both falling tones that go from a higher pitch height to a lower one. While annotating the data, I observed that the “English 4th tones” usually appeared on the stressed

syllable while the “English 3rd tones” were often present on the unstressed syllable at the end of a word. However, this is only a general observation that needs to be attested in a systematic way for its validity. It was also interesting that the common intonation pattern in English disappeared in the data of participants who exhibited tonal adaptation, even when the degree of adaptation was relatively weak. This phenomenon is consistent with previous literature that possessing tonal knowledge does greatly affect multilinguals’ speech while code-switching between tonal and non-tonal languages.

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Appendix A: Constructed Sentences

Code-switched Sentences (with Chinese translations)

- 1st tone
    - 这其中有很多variation
        - There are a lot of variation in it.
    - 我刚刚literally第一次和他说话
        - I just literally talked to him for the first time.
    - 我可以提供moral support
        - I can offer moral support.
    - 所以他就直接assume你一个人去的吗？
        - So did he just assume that you went by yourself?
    - 我刚刚跟Kate说我去不了了
        - I just told Kate that I couldn’t make it.
    - 我喜欢casual一点的relationship
        - I prefer casual relationships.
- 2nd tone
    - 这种行为特别annoying
        - This kind of behavior is very annoying.
    - 我宁愿学econ也不想学bio
        - I’d rather study econ than study bio.
    - 你现在来library吗？
        - Are you coming to the library now?
    - 我们家离Washington很远
        - My home is very far from Washington.
    - 我和professor约了周五meet
        - I had plans to meet with the professor on Friday.
    - 我的摄影课学film
        - My photography class studies film.
- 3rd tone
    - 我这个学期没有finals
        - I don’t have any finals this semester.
    - 他说话好mean啊
        - He is so mean when he talks.
    - 我决定走traditional的路线
        - I decided to go the traditional way.
    - 他老deliberately找我聊天
        - He always came to talk to me deliberately.
    - 你得告诉我number
        - You have to tell me the number.
    - 但是我就有点concerned
        - But I’m just a bit concerned.
- 4th tone
    - 我明天有个quiz

        - I have a quiz tomorrow.
    - 新冠的英文是covid
        - The English for “covid” is “covid.”
    - 我刚去gym回来
        - I just came back from the gym.
    - 我准备坐火车去Philly
        - I planned to take the train to Philly.
    - 我明天有好几个meeting
        - I have several meetings tomorrow.
- neutral tone
    - 我和几个人一起去买了Starbucks
        - I went to buy Starbucks with a few people.
    - 我不知道读什么program
        - I don’t know which program to apply for.
    - 你有好的suggestions吗
        - Do you have any good suggestions?
    - 他重重地punch了我一下
        - He heavily punched me.

Fully English Sentences

- Sept 13 is the last day for add/drop.
- What a mean thing to say!
- Have you got the covid vaccine?
- Languages are systematic but there is also variation within one single language.
- Is the econ final on Dec 14th?
- At Swarthmore, students listen deeply and share experiences with those who have different viewpoints, identities, and histories.
- Chinese people wear red during traditional holidays such as New Year.
- As generally understood today, the term bel canto refers to the Italian-originated vocal style that prevailed throughout most of Europe during the 18th and early 19th centuries.
- It’s super annoying when someone talks loudly in the library.
- I’m just here for moral support.

Fully Mandarin Sentences

- 你吃完晚饭准备干什么？
- 语言学是以人类语言为研究对象的学科。
- 你喜欢打游戏吗?
- 过几天我要去纽约看演唱会。
- 我小时候学过打乒乓球。
- 我今天吃了麻婆豆腐。
- 我家有一架钢琴。
- 今天晚上我们打算点外卖。
- 我做了桃子冰茶喝。
- 我真想念下雪的日子。

Appendix B: Mandarin-English Code-Switching (MECS) Questionnaire

Part I: Demographic Information

1. How old are you?
2. What is your class year?
    1. Freshman
    2. Sophomore
    3. Junior
    4. Senior
3. What pronoun(s) do you use to address yourself?
    1. She/her
    2. He/him
    3. They/them
    4. Other
4. Place where you grew up?
5. Place where you now live?
6. How long have you been living in the location you provided in the previous question?

Part II: Linguistic Background

1. Please identify your first language (the language that you speak the best)
    1. Mandarin Chinese
    2. English
2. Please identify your second language
    1. Mandarin Chinese
    2. English
3. If you also speak other languages, please indicate here
4. At what age did you start to learn/speak your second language?
5. When would you use your second language?
    1. When you speak with your parent(s)
    2. When you talk to your friends at school
    3. When you talk to your friends outside school
    4. When you are at work
    5. Other

Part III: Proficiency of Second Language

1. Please consider the activities below. Check the box if you can carry out the activity in your second language.
    1. Introduce yourself to someone
    2. Order food in a restaurant
    3. Complete a job interview
    4. Actively participate in a conversation while eating at a cafeteria, fast food place, etc
    5. Do a twenty-minute presentation in front of twenty people
    6. Give your opinion about current events

2. Please consider the activities below. Check the box if you can carry out the activity in your second language.
    1. Understand a short, conversational text message
    2. Understand a restaurant menu
    3. Understand a post from the social media
    4. Understand the front page news of the newspaper
    5. Understand the content of an introductory text of a university level subject
    6. Understand the content of a novel
3. Please consider the activities below. Check the box if you can carry out the activity in your second language.
    1. Send a text message to a friend
    2. Write a postcard to a friend
    3. Write a short social media post
    4. Write an email to a professor
    5. Write a letter to an editor where you express your opinion about a current event
    6. Write an academic paper
4. Please consider the activities below. Check the box if you can carry out the activity in your second language.
    1. Tell the difference between a request (can you close the door) and a question (is the door closed)
    2. Be able to identify the topic of conversation between two people at the bus stop or store
    3. Be able to follow a conversation between two people at the bus stop without any problem
    4. Understand and follow directions (e.g. how to get to the bus stop)
    5. Understand a movie without subtitles
    6. Understand jokes and wordplay

Part IV: Questions for English-L2 Speakers

1. At what age did you start to learn English?
2. Since when did you start to frequently speak English with a native speaker of English?
    1. Sometime during preschool
    2. Sometime during elementary school
    3. Sometime during middle school
    4. Sometime during high school
    5. Sometime during college
2. Since when can you fluently communicate with people in English?
    1. Sometime during preschool
    2. Sometime during elementary school
    3. Sometime during middle school
    4. Sometime during high school
    5. Sometime during college

Part V: Questions about Mandarin-English Code-Switching

1. Please rate your frequency of code-switching based on the scale from 1 to 5

This question is presented using the Likert scale, with 1 being "I rarely code-switch between Mandarin and English" and 5 being "I code-switch between Mandarin and English all the time."

2. Who would you code-switch with?
    1. Family members
    2. Friends at school
    3. Friends outside school
    4. Colleagues
    5. Strangers
3. Please share your reason(s) for code-switching