Native Language Tone Attrition in Mandarin Among Late Bilinguals

By

Xiangjie Cao

Newcastle University

School of English Literature, Language and Linguistics

A thesis submitted to the Faculty of Humanities and Social Sciences at the University of Newcastle upon Tyne in partial fulfilment of the requirements for the degree of Doctor of Philosophy (Integrated)

In

Linguistics

February 2019

Abstract

The present study addresses whether Mandarin tones undergo attrition for late Mandarin-English bilingual speakers who live in an English–speaking environment. Mandarin in this research refers to Standard Chinese, namely *Putonghua*, which is the official language spoken in mainland China and is based on the Beijing dialect. Four tones in Mandarin are used to differentiate lexical items or to express morphological functions. This is one of the identifying features of Mandarin.

The majority of the research on L1 attrition has been on the lexicon, morphology, and syntax (Schmid, 2002), but in recent years, attention has moved to phonetic and phonology. In Mandarin, phoneme attrition has been found among second generation Mandarin Chinese speakers in California due to L2 influence (Young *et al.*, 2007), and among L1 Hakka Chinese speakers living in a Mandarin-speaking area for five years, tone has been found to undergo attrition (Yeh, 2011). Less is known about what happens when tone language speakers move to a non-tone language environment.

Hence, to examine native language tone attrition in Mandarin, 50 participants are recruited, including 10 monolingual Mandarin speakers living in China and 40 late bilingual Mandarin-English speakers in the UK, with different lengths of residence. Perception and production at the word and sentence level are tested using listening comprehension tasks, an interview task, and a story-retelling task to elicit both formal and casual speech. The data is analysed acoustically using Praat (Boersma and Weenink, 2016), and statistical analysis is performed in SPSS.

The results reveal that late bilinguals who have lived in an L2 environment for over three years showed signs of tone 3 attrition. Bilinguals with over five years of residence show stronger tone 3 attrition, which indicates that tone attrition is proportional to the length of residence. Furthermore, to study other potential language factors related to native language tone attrition, language use and language proficiency in both Mandarin and English are investigated for each participant. The results show that language exposure and actual language use are also important factors in tone attrition.

Acknowledgements

I would like to take this opportunity to present my deep and sincere gratitude to those who helped me to the completion of my Ph.D. study and this research.

I would like to forward many thanks to two finest academics, my supervisors Professor Martha Young-Scholten and Dr. S. J. Hannahs. With their supervision and unconditional support, I finished my work and enjoyed my study very much. It is my lucky to have them as my supervisors. Their guidance and encouragement make me confidence in my research and promote me to move forward. Special thanks to Martha, for your emotional support in the past few years. The talk we had in the train station released my fear for being a female PhD student.

I am grateful I met many superior academics and colleagues in this journey. They inspired my life. Thank you, Dr. Rebecca Musa, Enas Filimban, Dr. Danielle Turton, and Yiling Chen. I was fortunate to work with all of you. I am also grateful to Vicci Harwood, Dr. Daniel Bell and Jack Deverson to proofread my work carefully.

Particular thanks must be mentioned to my friends Maoge Hou, Jiarui Liu, Yameng Ji, Meng Xia, Vicci Harwood, Salorm Kwawukume, and Boxia Wang. Thanks for all your belief in me that I could finish.

A very special gratitude goes out to my parents. Thank you for your love throughout my life. Without your foreseeing and support, I cannot be free to live the life I want. I am very proud of you and I know you are proud of me too.

Last but not least, my wholehearted love to my husband Feng Jiao and our little Edward.

Contents

List of Tables

List of Figures

Chapter 1. Introduction

To lose your own language was like forgetting your mother, and as sad, in a way…because [it] would be like losing part of one's soul.

-------*The Full Cupboard of Life (Smith, 2003: 163)*

It has been 30 years since English language learning became a compulsory module in China, from elementary school to university, in the 1980s. As the only foreign language studied domestically on a large scale, the upsurge of learning English has not subsided since. English second language (L2) acquisition has been the focus of much attention in linguistic research across different approaches and subfields.

Along with economic prosperity and a change in mindset, the number of Chinese students studying abroad has drastically increased in the last 10 years. In 2015, 523,700 Chinese students went overseas to study, which represented an increase of 13.9% from 2014. Four countries out of the top five destinations (US, Australia, Canada, Japan, and UK) are English-speaking (Wang and Miao, 2016). The number of Chinese immigrants in the above countries greatly increased at the same time. For instance, 46,000 Chinese people migrated to the UK permanently in 2013, of which 7,289 Chinese people naturalised to the British nationality (2013). In other words, more and more Chinese-English bilinguals are exposed to an L2 environment.

However, the majority of research on L2 acquisition is still focused on the impact of L1 on L2 acquisition and loss, regardless of the language environment. Though the dynamic theory (Heridina and Jessner, 2002; de Bot *et al.*, 2007; Larsen-Freeman and Cameron, 2008) has been widely accepted, the reverse impact of L2 on L1 remains seriously understudied. This is because, for a long time, L1 was assumed to be stable and unchanging (Köpke, 2007b; Schmid, 2013). In fact, native languages also may undergo attrition under certain conditions. In practice, many immigrants have found themselves having difficulties in using appropriate words or phrases at the right time in conversation in their native languages after spending time speaking a second language. Their native L1 became rusty. This rustiness was usually first found in their syntax or semantics (Schmid, 2002). This is a sign of L1 attrition.

The original motivation to start the present research came from my personal experience. After three years of studying in the UK, during which time I talked with my family and friends in China, I realised that I was using advanced Chinese idioms less and less, although I used to use them frequency. The most serious case occurred when I could not find a proper description in Mandarin for my feelings, although I knew I could have done so before. Thus, the initial purpose of this research was to explore this strange phenomenon that occurred in my native language.

In light of recent theoretical studies on cross-linguistic influence and language competence among bilinguals (Cook, 2003), dynamic interactions between L1s and L2s (Heridina and Jessner, 2002; de Bot *et al.*, 2007; Larsen-Freeman and Cameron, 2008), and language regression order (Green, 1986; Paradis, 1993), several questions became apparent in terms of the relationships between L2 acquisition and L1 attrition.

1. What are the signs of L1 tone attrition?
2. What kinds of bilinguals are vulnerable to undergoing attrition?
3. Will bilinguals with higher L2 proficiency demonstrate stronger attrition than those with lower L2 proficiency?
4. What factors in the process of L2 acquisition impact L1 attrition?

Thus, this research sets out to explore whether Mandarin-English bilinguals may undergo attrition in L1 Mandarin tone once their language dominance changes, and to establish links between levels of L2 proficiency and L1 attrition. The research aims to capture tones in naturally occurring speech instead of asking subjects to produce a single tone on purpose. Hence, a series of tasks, such as listening comprehension and video retelling, were designed to elicit natural speech and to minimise deliberate control of speech (Labov and Waletzky, 1967).

Forty Mandarin-English late bilinguals who have lived in the UK for some time were examined on their native tone perception and production. Ten Mandarin monolinguals living in China were recruited as the control group to provide baseline data for Mandarin speech. The stimuli not only collected data on L1 Mandarin, but also on L2 English exposure. The investigation covered main aspects of language use, for instance, the length of residence in the L2 environment and the amount of language daily use.

In line with the models mentioned above, this research will discuss the signs of L1 attrition in Mandarin tones. The potential variables, such as language proficiency, language contact, and language dominance, will be analysed in terms of their influences on L1 attrition.

The literature and previous findings on L1 attrition will be reviewed and discussed in Chapter 2. On the basis of the literature review, the methodology will be set out in Chapter 3. Chapter 4 will analyse the data and present the results regarding L1 Mandarin perception and production and L2 English exposure levels. In Chapter 5, the findings will be presented, which will lead to a subsequent discussion. The thesis will end with a final conclusion to the research exploring its contribution and limitations in Chapter 6. An overview for future investigation will also be provided.

Chapter 2. Literature Review

Attrition, noun, /əˈtrɪʃ(ə)n /

> *the process of reducing something's strength or effectiveness through sustained attack or pressure (Oxford Dictionary of English, 2010)*

The definition of the word "attrition" in the Oxford Dictionary of English (2010:103) is provided above. Given the definition, it is possible to deduce that language attrition refers to a reduction or decrease in language capacity. For linguistic outsiders, language attrition can simply be explained as the reverse procedure of language acquisition. In reality, this is close to the academic definition. However, for linguists, due to different research objectives and foci, the definition of language attrition is far more complicated.

Reviewing the literature of language attrition, there are many books, journals, and dissertations that explore the expansion of interest and the development of this linguistic subfield. Since the early 1980s, issues surrounding language attrition have been raised as a new research approach in Second Language Acquisition (SLA)in *Applied Psycholinguistics* (1986), *Language Attrition in Process* (1986), and *ITL-Review of Applied Linguistics* (1989) (van Els, 1986; Weltens *et al.*, 1986). Research on language attrition has been conducted to recent in books such as Language Attrition (2014) (Schmid *et al.*, 2004) and First Language Attrition (Schmid and Köpke, 2013). Nearly all of the existing literature on the topic emphasises the importance and implications of language attrition: on the one hand, research into language attrition provides an innovative way to "understand human memory and language change individually and in groups, and the relations and correspondences between processes of acquisition and loss" (de Bot and Weltens, 1991). On the other hand, it provides empirical foundations for language planning and language teaching, especially in second language acquisition.

This chapter provides a brief review of the types of language attrition. It introduces first language attrition in five sections: 1) excluded types of language attrition, 2) relationships between attrition and bilingualism, 3) interrelated issues with cross-linguistic influence and language competence, 4) concerns with previous models, and 5) potential variables in first language attrition. It ends with several updated case studies in first language attrition on phonology and the Chinese language.

2.1. Origins of language attrition research

In the late 1980s, language attrition, which at the time was studied widely in individual non-pathological language loss, was formally proposed as a research topic in a conference held at the University of Pennsylvania in the United States (Lambert and Freed, 1982; van Els, 1986; van Els, 1989). Almost immediately, research related to language attrition began to be carried out throughout Europe and elsewhere. A series of workshops, projects, and pieces of research related to language attrition were first introduced and launched in Germany, Israel, and the Netherlands. This relatively narrow-ranging topic not only attracted attention from academics, but also from governments. The US government launched a programme to study language loss of selected languages among immigrants. In a very short time, language attrition gained notable attention.

Prior to this conference, language attrition was combined with other language phenomena such as language loss and language shift, and there was overlap with several fields having different concerns and methodologies. Language loss is a general term applied to any instance of the decline of linguistic skills, whether of individuals or speech communities. Language shift refers to the gradual change of language use in generations of a community (Fishman, 1972). More and more studies have focused on intra-generational language loss subject to individual longitudinal reductions in language use and proficiency. New terminology was required to clearly describe the phenomenon of non-pathological language reductions and to distinguish this type of attrition from complete language loss and language shift. The word “attrition” (de Bot and Weltens, 1995) began to be used and was applied to “the decline of any language (L1 or L2) skills or portion thereof in a healthy speaker” (Ecke 2004: 322). Language attrition refers to the gradual forgetting of a language by individuals.

There has been confusion regarding the topic of language attrition in to how to classify it as a linguistic research field. De Bot (1999) classified language attrition as a subfield of second language acquisition (SLA) because of the existence of significant parallels between language attrition and SLA. Not only are the majority of research variables in SLA, such as cross-linguistic influences, age, individual differences, language environment, attitude, and motivation, also seen in language attrition research, but there is also the involvement of psycholinguistics due to the close link between long-term memory and language reduction (de Bot, 1999).

Across over thirty years of development, a theoretical foundation and systematic structure of language attrition research has formed, with several different research focuses: L1 attrition, L2 attrition, adult language attrition, child language attrition, language attrition, and pathological language attrition. All these focuses form independent research areas that involve close collaboration with various fields. For instance, L1 attrition occurring because of pathological reasons more of a focus of neurologists than sociolinguists.

2.2. Language attrition

Two current definitions of language attrition are as follows:

1. A permanent or temporary regression from a participant's previous linguistic performance or competence at any linguistic level (phonology, morphology, syntax, and pragmatics) in exerting any linguistic skill (speaking, listening, reading, writing, and metalinguistic judgment) (Yukawa, 1997).
2. The non-pathological decrease in a language that had previously been acquired by an individual (Köpke and Schimid, 2004).

There are four types of language loss (van Els, 1986; de Bot and Weltens, 1995):

Attriting Languages	Language Environment	
	L1	L2
L1	1. Pathological / Normal aging	2. Language Shift / Attrition
L2	3. L2 Loss in SLA	4. Ageing immigrants

The first type of language loss is the loss of an L1 in an L1 environment, for instance, people losing their first language through ageing. A classic review of this instance can be found in Goral (2004). The second type is the loss of an L1 in an L2 environment, including both language shift and language attrition. Individual language loss that refers to attrition of a first language will be discussed in depth below. An excellent research timeline can be found in Welten, de Bot, and van Els (1986), Seliger and Vago (1991), Köpke (2007), Cazzoli-Goeta and Young-Scholten (2011), and Schmid and Köpke (2013). Also, a comprehensive overview is given by Schmid (2013).

The third type of language loss is the loss of an L2 in an L1 environment. Research on this type of language loss usually focuses on foreign languages learned at school. There are various classic works in this field, ranging from Kloss (1966), Clyne (1967), and Haugen (1969) to the more recent Schmid (2006). The fourth type of language loss is the loss of an L2 in an L2 environment, which often is seen in ageing immigrants. It will not be discussed here as there is too little research and evidence available.

The term “L1 attrition” can refer “a permanent or temporary regression from a participant’s first / native language…” or “the non-pathological decrease in the first / native language” based on the definitions of language attrition given by Yukawa (1999:2) and Köpke and Schmid (2004:8) in Section 2.1.

The Term L1 attrition can refer “a permanent or temporary regression from a participant’s first / native language…” or “the non-pathological decrease in the first / native language”, based on the definitions of language attrition given by Yukawa (1999:2), and Köpke and Schmid (2004:8) in Section 2.1.

2.2.1. L1 Attrition in Phonetics and Phonology

The majority of L1 attrition studies focus on structural consequences for morphology and syntax, which are usually the first aspects of language affected. Research provides more solid evidence regarding morphology and syntax than phonetics and phonology (Köpke *et al.*, 2007). Research concerning L1 attrition in phonetics and phonology is still plentiful, but compared to research concerning syntax and morphology, it lacks both structural detail and the analysis of quantitative data. Early studies in this domain saw divergent findings for L1 attrition. Some research indicated that phonetic properties in L1 and L2 merged due to a bi-directional effect (Mennen, 2004). L1 attrition was also found to correlate to L2 proficiency (Köpke *et al.*, 2007). However, these findings cannot be generalised due to high levels of inter- and intrapersonal variations (Flege, 1987; Major, 1992; de Leeuw *et al.*, 2011).

Phonology has also been studied, and the findings are consistent with Flege’s conclusions (Flege, 1987). Bilinguals demonstrate signs of merging prosodic elements in L1 and L2. For instance, Dutch-Greek late bilinguals were unable to produce the intonational alignment of the prenuclear rise in their L2 Greek correctly, and their L1 Dutch intonational alignment also deviated (Mennen, 2004). Later research found similar evidence among native German speakers in Canada who changed their pre-nuclear intonational alignments in German (de Leeuw *et al.*, 2011).

It is of note that most of the prominent research on L1 attrition has focused on non-tone languages. Research on tone language attrition is still relatively young and large numbers of bilinguals have not been observed. Most available studies have focused on either phonetic change in tone or tonal change in the immigrant generation (Young *et al.*, 2007; Zhou and Broersma, 2014b; Shittu and Tessier, 2015).

One important reason for the paucity of studies on L1 tone attrition is the methodological difficulty in testing the degree of remaining L1 capacity. The most suitable data for analysis of L1 attrition are collected from simultaneous spoken data, which allow each speaker to demonstrate their language knowledge without the restriction of monitoring their speech (Schmid, 2002; Köpke *et al.*, 2007). Such free spoken data are mainly collected through interviews, which need to be transcribed and the elements under scrutiny identified and coded for quantitative analysis of L1 attrition (Samata, 2014).

However, language in use is a complex process in which multiple variables change over time. It is impossible to model language processing in full detail because collecting enough free-spoken data for quantitative analysis is a great challenge. Hence, various theories have been applied in L1 attrition to exclude potential factors.

L1 attrition as studied in this thesis excludes two types of attrition. The first one is very obvious and has already been given in the definition: pathological language attrition. Pathological language attrition is attrition caused by diseases or external forces that damage the language function area of the brain (Hyltenstam and Obler, 1989; Paradis, 1993). Examples are dementia or aphasia. However, pathological factors are not linguistic variables.

Another excluded factor in L1 attrition is ageing – natural ageing. Certain language skills can be changed or reduced by the process of growing older (Linville and Rens, 2001; Goral, 2004). This type of language loss, occurring in natural and healthy ageing, is also known as language attrition. Age-related language loss is not relevant to L1 attrition in the present thesis.

2.2.2. Bilingualism

In the majority of cases of language attrition, identifying and recruiting speakers is always the most complicated part, especially in L1 attrition. There are several reasons for this. First, the targeted L1 attriters are bilinguals, somehow, different from others who can only speak their native languages. Second, most predicted attriters are usually active L2 speakers who have been living long-term in an L2 environment. This implies that the subjects have potentially been influenced, not only in terms of language contact, but also in terms of education, attitudes, and social contact. Due to this, it is difficult to create a homogeneous map. Third, L1 attrition occurring in adults seems entirely different from that in children due to the fact that adults acquire an L1 completely, compared with incomplete L1 acquisition by children.

Based on the above, the best term that can be used when describing the population under investigation is “bilingual”, although “defining exactly who is or is not bilingual is essentially elusive and ultimately impossible” (Baker, 2001) as the levels of bilingualism are so variable. One possible definition is the most restricted one, which only considers people as bilinguals if they have native-like proficiency in both languages (balanced bilingualism) (Bloomfield, 1933). An alternative to this most restricted definition considers people to be bilingual when they have incipient knowledge of another language (Mackey, 1962). This second definition may be too loose for the present study.

Both balanced bilingualism and dominant bilingualism need to be understood. The former defines bilinguals as those who have equal levels of proficiency in their two languages. However, these levels can be either advanced, medium, or low, which differs from the most restricted definition (Baker, 2001). The latter involves a dominant/first language, either L1 or L2. As Fishman (1972) stated, people with highly developed skills in both languages nonetheless have different domains in terms of language use.

The acquisition age of L2 is another relevant concern. Based on the age of onset of acquisition, one can distinguish early bilinguals and late bilinguals (Baker, 2001). Early bilinguals acquire their L2 in childhood. Late bilinguals, also known as adult bilinguals or adult language learners, start learning another language after puberty, often in a school context. Early bilinguals, known as simultaneous bilinguals, have learnt two languages since they were born. In contrast to simultaneous bilinguals, late bilinguals are, in some circumstances, only bilingual when they move to an L2 environment (also recognised as circumstantial bilingual). Circumstantial bilinguals usually have stable proficiency in the L2, but the level can vary (Valdés and Figueroa, 1994).

2.2.3. Cross-linguistic Influence and Language Competence

So far, the discussion has concentrated on definitions of attrition and bilingualism that identify the present study as one of non-pathological L1 attrition among late bilinguals in an L2 environment. Now, it will focus back on L1 attrition. Why does L1 attrition occur? What are the triggers? Is the rate of L1 attrition for bilinguals or multilinguals higher than that for monolinguals?

The following statement may offer a hint:

> …it is usually assumed that mature native languages are typically stable as opposed to interlanguages or developing L1 systems, which are characterized as typically unstable…it would appear from this assumption that once attained, the mature L1 is "fixed" and needs no further input either to disconfirm faulty learner hypotheses or to maintain its final state. The L1 data that served once as input is therefore no longer input except to the receptive system as a whole. Why then should attrition occur? (Smith and van Buren, 1991:22).

Before answering the questions above, one important issue that must be raised here is the question of how two languages interact in the same mind for bilinguals. Goods are organised and stored in a supermarket in perfect order so as to make it easier for people to find them. Languages are like goods, and are organised and stored in an orderly fashion by the brain, allowing people to find the right words and use them appropriately in a very short timeframe (Smith and van Buren, 1991). However, storage space is limited in that people only have one mind for languages. For monolinguals, there is no problem with the storage of one language in one space. However, for bilinguals or multilinguals who have knowledge of two or more languages, the organisation and storage of languages can be complicated (Wray and Trott, 1998; Piercea *et al.*, 2014a; Zhou and Broersma, 2014a).

The answer to the questions above could lie in the fact that expertise in more than one language is a reason for bilinguals to deviate from the norms of either language in speech (Weinreich, 1953; Yilmaz and Schmid, 2018). In terms of influencing the process of L1 attrition, an additional language is assumed to be a replacement of L1 (Köpke and Schimid, 2004). This may explain to some degree the fact that, compared with native speakers, bilinguals or multilinguals are more vulnerable to undergoing attrition in their first language (Yilmaz and Schmid, 2018).

Cook (1991) proposed an integration continuum that tried to explain how people manage the organisation and storage of two languages. It discussed three models: the separation model, the integration model, and the interconnection model. The first two – the separation and integration models – are extreme situations, and have been discarded. “Total separation is impossible since both languages are in the same mind; total integration is impossible since L2 users can keep the languages apart” (Cook 2003: 7). Hence, the interconnection model is the only possibility for explaining the organisation of two languages. The suggestion is that bilinguals form a super-system containing multiple languages rather than completely single and separated systems (Cook, 2003).

The interconnection model assumes that there are connections between L1 and L2 of various types and degrees. For instance, L1 and L2 can be linked without overlap or integrated with partial overlap. Importantly, it assumes that two languages influence each other internally. Other studies support the model but refer to this influence using different terms, such as cross-linguistic influence, interference, transfer, or inter-linguistic effect. Cross-linguistic influence is used widely, as it covers a wide range of phenomena (Smith, 1983; Seliger and Vago, 1991; Smith and van Buren, 1991).

Cross-linguistic influence is bi-directional for each language for bilinguals, which is to say not only does the already existing L1 impact the L2, but reverse is true as well: the L2 can also impact the L1 (Köpke, 2007b). Moreover, the influence can be both positive and negative, since in language processing, both L1 and L2 compete for finite processing and memory space in the same mind (Seliger and Vago, 1991; MacWhinney and Pléh, 1997; Costa *et al.*, 2000; Marian and Spivey, 2003).

Positively, the acquisition of an L2 benefits from the L1: bilinguals perform better than monolinguals in both metalinguistic awareness and sociocultural skills (Bialystok, 2001). The pre-existing L1 provides experience when acquiring an L2. Negatively, the solid foundation of the L1 impacts the improvement of L2 acquisition, and L2 acquisition may harm the mature L1, which directly relates to the core of this study: L1 attrition, where one may to some degree lose the ability to use a first language while acquiring and using a second language (Cook 2003: 12).

However, negative interaction, especially where the L2 impacts the L1, points to a direct relationship between the proficiency levels of L1 and L2. In other words, L1 attrition can be linked to advanced levels of bilingualism or the acquisition of an L2 (Seliger and Vago, 1991; Schmid, 2013). Imagine L1 and L2 as two sponges in one box. If they each take up half of the volume, they will share the box equally, but if one has a larger volume, the other must be squeezed into a corner. This refers to language competition. Thus, as L2 improves and occupies more and more space for memorising and processing, the previously acquired language could become weaker. In other words, L1 attrition occurs. The higher the proficiency of the L2, the more potential there is for L1 attrition.

2.3. Previous Models

This section will review previous models concerning the relationships between different language systems, and discuss the implications for L1 attrition studies.

2.3.1. The Activation Threshold Model

The first model that we will examine here is the activation threshold model, which was initially proposed almost 20 years ago and discussed mainly in the neurolinguistic field (Paradis, 1993; Paradis, 2004). Simply, it discussed the use frequency, including activation and availability, of a linguistic item by and to the language user (Gürel, 2004).

The mechanism of the activation threshold model assumes that each linguistic item has a different activation threshold level. If this threshold is reached by a certain quantity of positive impulses, the item will be activated. The activation of an item means this item has been selected for production. With the increasing of activation frequency, that is, a higher use frequency in production, the activation threshold will decrease, and fewer positive impulses will be needed to react or reproduce the item. On the contrary, the decrease of activation or the lower use frequency will increase the activation threshold. Hence, for a linguistic item, more positive impulses will be required in order to reactivate it (Paradis, 1993). For instance, if A has a lower activation threshold than B, A will be selected for production, as fewer impulses are needed. Moreover, A will probably be selected for production the next time as well, since the activation threshold will be even lower than B with the increasing use frequency. B, which already has a higher activation threshold, will be increasingly rarely selected, as its activation threshold will be raised higher and higher due to its inactivation or disuse. However, activation thresholds depend less on comprehension than on reconstruction (production), which is to say that a linguistic item with a higher activation threshold may still be available for comprehension, but the activation threshold to produce it may be too high. This can be summarised in three points: 1) language disuse will cause language loss gradually, 2) lesser-used L1 elements will be replaced by their most frequently used L2 counterparts, and 3) compared with comprehension, production will be attrited sooner, since self-activation requires a lower threshold (Paradis, 2007).

This model can be applied to L1 or L2. In the context of bilingualism, it is assumed that when one language is activated, the other one is simultaneously deactivated or inhibited. Therefore, the activation threshold of the other language is heightened, which can directly apply to L1 attrition. Based on the activation threshold model, we could say that L1 attrition occurs as the result of a long-term lack of stimulation or as the natural consequence of lack of use (Paradis, 2004). In other words, L1 may undergo attrition simply because of long-term disuse, which to some degree does not require interference from L2. However, this is not the case for bilinguals in the short- or long-term.

First, in the short-term dimension, to protect selection and avoid interference in language processing for bilinguals, a linguistic item must have a low enough activation threshold in the first place – lower than most others – to ensure selection. As Paradis (1993) stated, when a bilingual speaker selects one language to speak, the activation threshold of the non-selected language is raised sufficiently to prevent interference during production. However, it is not sufficient to stop borrowing and mixing, or comprehension in the other language (Paradis, 1993). Therefore, this causes competition between languages in which one has to have a low enough activation threshold to prevent interference from another language. In terms of L1 attrition, if the overall activation threshold of L2 is low enough due to its use frequency, it will lead to interference in L1 production.

Second, once the item has been selected, it will spread activation to other items that are connected to it. This function is called activation spreading (Paradis, 1993). Applying the function to one language, if an item has been activated in the language, a large number of related items will be activated too, not only the selected one. In other words, if one L2 item has been selected with a low enough activation threshold in L1 production, this means that a potentially large number of L2 items will have low activation thresholds as well, which may cause interference in the long term.

Third, a language is not entirely switched off due to inhibition or a high activation threshold. Also, bilinguals will never find themselves in pure monolingual situations, since a language will always remain active to some degree (Green, 1986). When looking up an item in one language, both languages will be searched. However, if a word from L2 is more available than one from L1, the speaker will use the more available word instead and stop continuously searching within the L1. Both situations are signs of L1 attrition.

Furthermore, in the long-term, the change of the activation threshold of the L1 alongside the use of the L2 is permanent. The more frequent the use of the L2, the higher the activation threshold of the L1. Therefore, the L1 activation threshold will gradually be raised. It may eventually become higher than that of the L2, which would lead to reduction in its accessibility.

Hence, the acquisition of L2 is directly connected to L1 attrition. Specifically, if the L2 has a higher use frequency than the L1, which often occurs among bilinguals living in an L2 environment, this will interfere with the production of L1 and attrition will occur. If this competition between two languages persists for a certain time, the L1 will have a higher threshold, which will make the L1 less likely to be selected in language processing and production. To conclude, the activation threshold model points out that on one hand, L1 attrition is related to L2 acquisition and use frequency. On the other hand, the degree of L1 attrition may depend on the level of L2 acquisition, which relates to both proficiency and use.

2.3.2. The Dynamic Model of Multilingualism

The dynamic model of multilingualism (DMM) analyses multi-competence based on dynamic systems theory (Jessner, 2003). Multi-competence was first introduced to describe a mind with more than one grammar, in contrast to a mind with only one (Cook, 1991; Cook, 1992; Cook, 1995). A series of studies has looked at multi-competence in different contexts. For example, with L2 competence, it is as if the L2 is housed in a different mind than a mind with only a single, first language (Cook, 1995; Cook, 2003).

Dynamic systems theory is a complex systems theory that has been studied in other scientific fields for several decades. It is characterised by complete connectedness and mutual interaction between systems. Mutual interaction causes reversible effects of one system on another over time. Hence, the system can change between stable and unstable states, which leads to qualitative changes through feedback. The core of dynamic systems is that each system is always part of another system. In the DMM, the dynamic system has been defined as a system of interacting variables that is constantly changing due to both interactions with its environment and self-reorganisation (Briggs and Peat, 1989; Ecke, 2004; de Bot and Makoni, 2005).

The DMM was initially proposed by Heridina and Jessner (2002) based on the assumption that every multilingual system has cognitive and psychological limits. Specifically, for multilinguals, languages in the same mind cannot stay stable when different languages are competing for finite resources. In terms of language attrition, DMM implies a new and unique approach whereby language attrition is a normal part of language development rather than an isolated phenomenon (de Bot, 2004).

Language attrition, in the DMM, is interpreted as a process of developmental change in language proficiency among bilinguals or multilinguals rather than a set of invariant single-state grammars. Hence, in the context of bilingualism, L1 attrition can be interpreted as the erosion resulting from the acquisition and gradually increasing proficiency of an L2. In the DMM, the balance between the bilingual system and the individual psycholinguistic system is essential. Also, the development of the bilingual system depends on a dynamic balance between the psycholinguistic system and its environment. That is to say, the developing bilingual system is in a continuous process of adaption to constantly changing requirements of its environment. It can be seen as the dynamic and complex process of competition between existing and developing psycholinguistic systems for limited resources in terms of "language effort" over time. Hence, this development will lead to displacement in the system due to the change in dominance (Valdman, 1982; Heridina and Jessner, 2002). In other words, dominant change, including environmental and social change, is a factor in the process of L1 attrition due to the differing language effort required (Ecke, 2004).

The DMM normalized language effort to language acquisition effort and language maintenance effort in units (Hansen, 2001). Bilinguals with different L2 proficiencies and in different language environment required different language maintenance and language acquisition efforts, as shown in Figure 2.1 below. The changes in language maintenance effort and language acquisition effort are nonlinear. For instance, if a bilingual needs two units to maintain a high proficiency in L1 and three units to maintain a high proficiency in L2 in the L1 environment, he/she would increase one unit for L1 maintenance effort, from two to three, to maintain high L1 proficiency in the L2 environment. In an L2 environment, L2 acquisition effort is automatically added on to L2 general language effort in order to compete with L1 language general effort. If L1 maintenance effort does not increase, L1 general effort will probably reduce, which means that the proficiency for L1 will decrease.

For language maintenance effort, language use and language input are vital (Hansen, 2001). Once a language is acquired, it requires some effort for maintenance to ensure that the language is kept at a certain level. This maintenance effort increases nonlinearly with the strength of language proficiency, which is to say, the effort to maintain two language systems with a similar proficiency level in bilinguals is not equal to double the maintenance of one language for monolinguals. It requires much more than twice the maintenance effort (Heridina and Jessner, 2002).

For monolinguals, maintaining their native language in the L1 environment is not a problem at all. While being exposed to an L1 environment, the L1 is used at anytime and anywhere with naturally presented input. The majority of monolinguals are often not aware at all that the function of language maintenance is operating, even though the proficiency of L1 (native level) requires the maximum power of maintenance. But bilinguals, for whom language maintenance is more complicated, are always involved in the process of matching and differentiating between two or more language systems. Language maintenance effort includes metalinguistic and monitoring processes to reduce interference and to ensure a certain speed of information recall (Jessner, 2003).

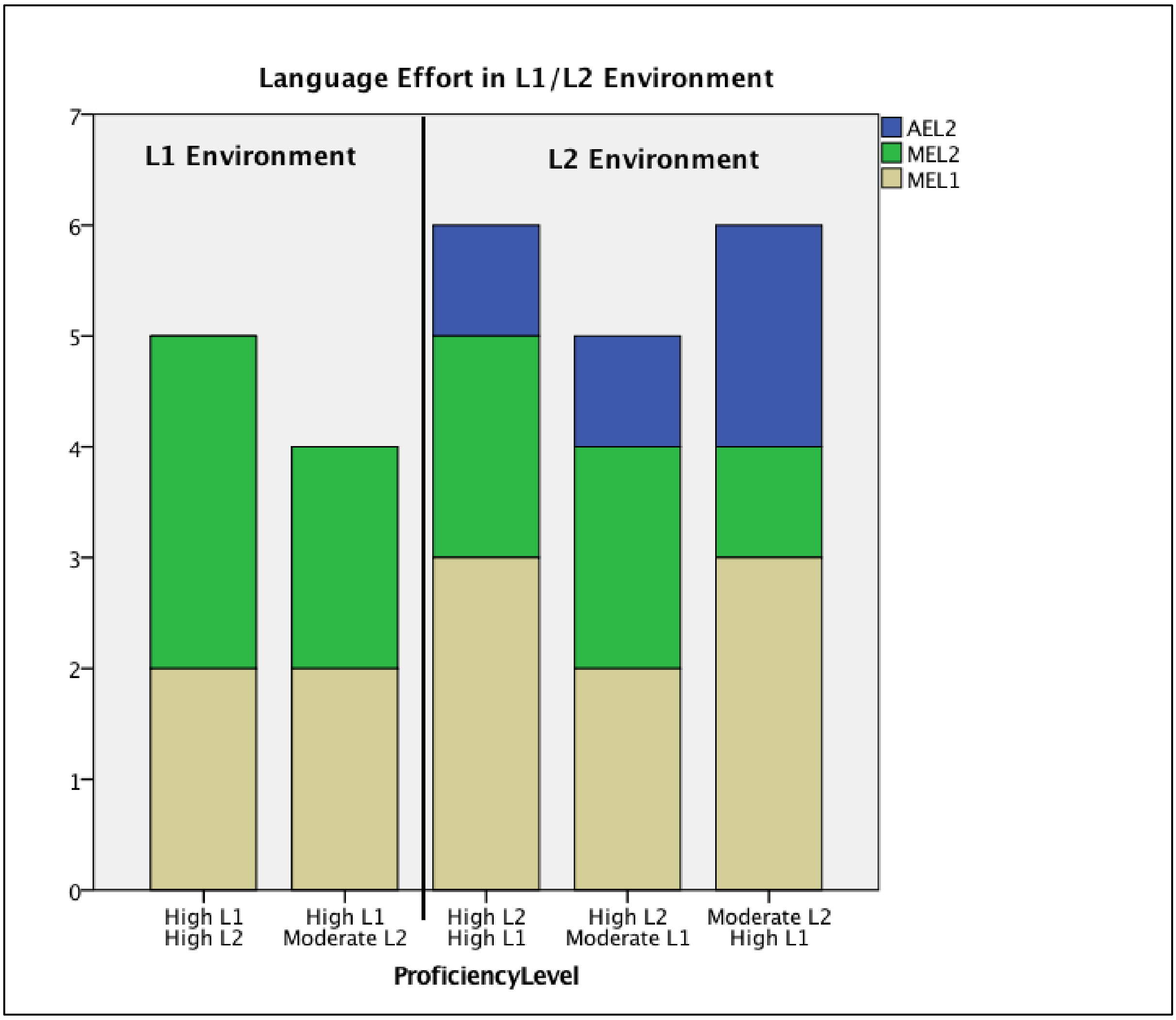


Figure 2.1 Language effort in different language environments (Heridina and Jessner, 2002)

There are several possibilities for bilinguals, as clearly shown in Figure 2.1 above. In an L1 environment, the first option for bilinguals is similar to monolinguals. When bilinguals are exposed to the L2 in an L1 environment, though there is definitely more language maintenance effort being made than by monolinguals, the L1 barely undergoes attrition, since language use and input are occupied by the L1. Also, the proficiency of L2 has no serious impact on L1 maintenance effort. Therefore, in an L1 environment, with maximum exposure and use of the L1, the L1 maintenance effort can still maintain high proficiency.

However, when the exposure environment changes to L2, the situation becomes far more complex, since the L1 is not supported naturally but L2 acquisition and maintenance are. From this, a greater than usual language effort is required to maintain L1 proficiency. On the other hand, L2, being naturally supported from both internal and external dimensions, could obtain acquisition effort and increases the maintenance effort to an adequate level easily, which gradually occupies language effort space that was originally belonging to L1. The L1 can only be maintained to a moderate level in the L2 environment given the same amount of language maintenance effort that keeps the L1 at a high proficiency level in the L1 environment. Thus, the L1 may undergo attrition with the corresponding L2 acquisition and proficiency effort.

2.3.3. The Regression Model

The regression model may be the oldest theoretical framework linked to language attrition. As opposed to the previous two models, which focus on theoretical concepts of the language system in neurolinguistics and psycholinguistics, the regression model pays more attention to phenomena that can be proved with evidence (de Bot *et al.*, 2007). The history of applying the regression model in language can be traced back to the early 1900s when Kussmaul (1910) used it to test aphasic phenomena. It was formulated by Jakobson (1941) during testing of pathological language loss compared with first language acquisition.

In Jakobson's (1941) work, the regression model is the supposed parallelism between language acquisition and language loss. The basic tenet of the regression model is that the order of language loss mirrors the order of acquisition. Specifically, for linguistic features, the first to be acquired is the last to attrite. It assumes that the most complex or difficult-to-process structures that are acquired later in the learning process are lost first, and that the less complex, easier-to-process structures that are acquired early largely remain resistant to loss. Though the model focused on pathological language loss initially, it assumes that there are universal principles at other linguistic levels as well (de Bot and Weltens, 1991).

The regression model mainly focuses on non-pathological language loss. Its tenability relies on the hierarchical level at which it is applied: 1) between languages, with respect to the order of acquisition and loss of language in multilinguals; 2) within languages, in acquisition, perception precedes production and spoken language proceeds written language, whereas in language loss the sequence is reversed; and 3) within sub-domains, as far as phonology, morphosyntax, and lexicon are concerned (de Bot and Weltens, 1991).

The intermediate position between pathological and non-pathological language loss is elderly speech. Evidence from several studies shows signs of regression in elderly speech. Concerning late bilinguals, language reversal is not a single phenomenon, but something related to language proficiency, which shows that reaching a "critical threshold" makes language proficiency relatively immune to attrition (Neisser, 1984). This is relevant to both L1 and L2. The misinterpretations of the elderly show remarkable similarities with those of young children. Evidence has also been found in young immigrant children who tend to revert to an L1 and lose an L2. These cases support the assumption that information acquired earlier is stored deeper and more strongly in memory (Clyne, 1981).

In more recent follow-up studies, the regression model has been supported consistently by evidence from both L1 attrition and L2 attrition. For example, regression patterns have been discovered in the syntax and semantics of numeral classifier systems in L2 learners of Chinese and Japanese (Hansen and Chen, 2001). Keijzer tested regression in L1 attrition and observed 9 linguistic features out of 15 in the L1 mirrored symmetries between attriters and acquirers (Keijzer, 2010). This supported the essential claim of the regression model that the last to be learned was the first to be attrited.

So far, we have discussed different theoritical models that are connected with L1 attrition. Though the three models make different assumptions about L1 attrition, similarities exist. First, they all assume that competence and interference between languages for bilinguals leads to language attrition. Second, language attrition is a reversible process by which either L1 or L2 could be attrited. Third, L1 attrition has been strongly linked with L2 proficiency and language dominance. To investigate L1 attrition further, we will discuss potential variables leading to L1 attrition.

2.4. Variables in L1 attrition

Reviewing previous research, several variables with potential impacts on L1 attrition have been studied, including language acquisition age, language proficiency, language contact and dominance, length of residence in an L2 environment, and level of education. In different contexts, these factors are given different names. For instance, language contact is also known as the amount and settings of use of languages (Köpke and Schimid, 2004). For the purpose of this thesis, variables that will be reviewed are 1) age, including age at the onset of L2 acquisition and age of arrival; 2) length of residence in an L2 environment; 3) L2 proficiency; and 4) contact with L1 and L2. Factors involved in sociolinguistics or psycholinguistics, such as attitude, personality, or motivation, will be excluded from the research.

2.4.1. Age

In Section 2.2.3, the age issue has already been delimited in the present thesis by restricting bilingualism to that of late/adult bilinguals. This study will focus on those who have been widely exposed to an L2 after completely acquiring L1. Hence, children, as early or simultaneous bilinguals, are excluded here.

Compared with early bilinguals, late bilinguals' L1s are less vulnerable to attrition and are more slowly affected by the acquisition of L2, especially after moving to an L2 environment. Various research has consistently reported evidence of language attrition among children up to 12 years old once they were relocated to a new language environment pre-puberty (Kaufman, 1991). Three studies focused on children from China, Russia, and the Ukraine who had been adopted by US families. The results indicated that these children experienced severe L1 attrition. Some of them even abandoned the L1 and completely replaced it with the L2 (Schumann, 1976; Slobin *et al.*, 1993)

Similar results were also observed in Korean-English bilinguals in the U.S. A sample of 240 Korean-English bilinguals, classified by different age of arrivals (AOA) in two ranges (1-7 years and 12-23 years), were asked to complete a hearing screening test, interview, self-rating language ability test, questionnaire, and speech production test in both Korean and English. Bilinguals with AOAs of 1-7 years had a distinct accent in L1 Korean production, while bilinguals with later AOAs, at 12-23 years, had L1 Korean levels that were the same as those of Korean monolinguals in general. For L2 production, bilinguals with AOAs of 1-7 years had near-native L2 pronunciation. Subjects with AOAs of 12-23 years had stronger accents in their L2s than those with AOAs of 1-7 years old. The majority of bilinguals, especially those who had early AOAs, reached a near-native level in L1, but not the same level as monolinguals. Phonology attrites in L1, and it can be argued that this deviation from L1 results indicates that the earlier the arrival, the stronger the attrition (Yeni-Komshian *et al.*, 2000).

This situation highlights the observation that "attrition of L1 among adults differs from the L1 attrition process among pre-pubescent children" (Ecke, 2004). For late bilinguals, the ability to maintain the L1 is far better than that of young children, since adult bilinguals have acquired the native language completely. Apart from this, another important difference is that for early bilinguals, both L1 and L2 are developing, so the L2 has the possibility of overtaking the L1 and becoming the dominant language. It is more difficult for an adult bilingual's L1, as an entrenched, well-developed, and frequently practiced system, to undergo attrition. This can only occur if variables such as L2 proficiency and L2 language contact change radically and chronically (Schmid *et al.*, 2004).

When late bilinguals are only exposed to an L2 environment, their L2 acquisition and maintenance will be strongly impacted by the environment, which naturally supports the L2. For bilinguals who immigrate permanently and are positively motivated to integrate in local life, the impact of the external environment is particularly strong. In that situation, adult bilinguals may achieve the same L2 proficiency as, or even outperform, early bilinguals. As Singleton (2003) argued, for L2 learners, there is no real evidence that early bilinguals acquire an L2 better than late bilinguals in the long run. This indicates some implications for L1 attrition, perhaps that L2 acquisition starting at a younger age would be a predictive factor when correlated with a higher level of L2. In this case, age would be a function that triggers the attrition of L1. However, in terms of late bilinguals, age may be outweighed by individual differences such as acquisition effort, maintenance effort, language contact, and length of residence. This causes considerable difficulties when researching attrition as an isolated variable.

2.4.2. Length of residence (LOR)

It is common sense that knowledge or skills will deteriorate gradually after long-term disuse. Human beings are born with the ability to learn languages, which is considered to be a skill. Hence, from this point of view, L1 attrition can be theoretically explained as result of long-term disuse of the native language. The length of time spent living in an L2 environment represents the length of exposure to a non-L1 domain. If one person is intensively exposed to an L2 environment, the L1 is not automatically supported by the surrounding environment. A change in language dominance will quickly become apparent as access to L1 gradually becomes less than access to L2, as L2 has no need to increase the competitive level to achieve a native-like standard (Schmid *et al.*, 2004).

An example of this comes from Sebastián-Gallés and Soto-Faraco (1999), who tested L1 perception among 51 early Catalan-Spanish bilinguals. All participants were born and raised in an L2 environment and had native-like proficiency in L2, buts their language dominances were different. Nineteen participants were dominant in Catalan and 32 were dominant in

Spanish. The processing of four Catalan contrasts, vocalic /e/-/ə/ and /o/-/ɔ/ and consonantal /ʃ/-/ʒ/ and /s/-/z/, were examined via a two-alternative forced choice test. The results showed that bilinguals with L2 Catalan dominance performed significantly worse when correctly identifying all contrasts except /s/-/z/, where they needed more information than L1 dominant bilinguals to make a correct choice. The findings of this perception study suggest that language dominance and language contact should be considered important factors in L1 attrition (Sebastián-Gallé and Soto-Faraco, 1999). A change in language dominance is not equal to language attrition, but language attrition is most likely preceded by a reversal in language dominance (Schmid *et al.*, 2004). In other words, once language dominance changes, L1 attrition will likely occur in the near future.

Conclusions in the research are diverse regarding the length of L2-environment residence that leads to L1 attrition. The majority of L1 attrition studies observed bilinguals with at least 10 years of living in an L2 environment (de Bot *et al.*, 1991; Jaspaert and Kroon, 1992; Schmid *et al.*, 2004; Mayr *et al.*, 2012). Some extreme cases recruited bilinguals with over 60 years of residential length in the L2 environment (Jaspaert and Kroon, 1992; Bullock and Gerfen, 2004a). Data reveal that language dominance switches for bilinguals after three to seven years' residence in an L2 environment, which is a sign of initial language attrition. As early as the 1980s, German-Swedish bilinguals who were native German speakers were found to experience attrition in German after six years of residence in Sweden. After four to five years, they demonstrated noticeably longer response times in L1 production compared to German monolinguals (Mägiste, 1979).One year later, they demonstrated slower reaction times in L1 German perception than monolinguals. Studies of Dutch immigrants in Australia also indicated that the first 5 to 10 years living in the L2 domain were critical for bilinguals demonstrating L1 attrition (de Bot and Clyne, 1989; Waas, 1996). Once the LOR is more than 10 years, the degree of language attrition tends to stabilise, language knowledge remains intact, and it becomes increasingly hard to identify the time effort after then (Waas, 1996; Köpke and Schimid, 2004).

However, LOR is not the only factor that is crucial for L1 attrition. L1 attrition is always paired with language proficiency. The findings also stated that more proficient language learners are capable of an initial retention plateau that is much greater than that of a less proficient learner (Weltens *et al.*, 1986; de Bot and Hulsen, 2002). In other words, languages may be less vulnerable after a person reaches a certain point of proficiency. Additionally, language contact is considered to be a significant factor in attrition. The research found that L1 proficiency declined in a linear fashion if L1 contact was reduced over time in immigrants, even for those who had native proficiency (de Bot and Clyne, 1989; de Bot *et al.*, 1991).

2.4.3. L2 proficiency

Knowledge or proficiency in L2 is generally considered as the core variable in L1 attrition. The observation is mainly based on the premise that L1 undergoes attrition in the context of L2 acquisition, and that the majority of factors in L1 attrition have direct relations with interference from L2. However, this issue, based on the contention of the present study, has not been addressed much until recently. The majority of empirical research studying L1 attrition from an L2 proficiency approach has paid much more attention to early bilinguals with an age of arrival of under twelve years old. Supportive arguments in adult bilinguals are limited, especially in phonology and phonetics.

Bilingual children are observed on the growth of L2 proficiency combined with a non-native level of L1 (Marino, 1983). It was reported that Chicano Spanish-English bilingual children in grade four had less accuracy in L1 than younger children in kindergarten in terms of comprehension and production, while the grade four bilinguals had a higher proficiency in the L2 than the kindergarten children. Another study on Mandarin-English bilingual children in the US showed a narrowing of the distance between L1 and L2 proficiency with an increasing age of onset until about age twelve, at which point the languages cross over (Jia and Aaronson, 1999). This leads to an assumption on language proficiency switching that depends on the age of arrival and the original L1 proficiency. Once the balance has switched, the L1 will develop in the same direction as the L2, but at a much-decreased rate. Similar phenomena can be found in the case of the Korean-English early bilinguals mentioned above, in that an increase in L2 proficiency may lead to a decrease in L1 proficiency, particularly in pronunciation. Results have also indicated, apart from AOA, in the interaction between languages, the languages interfere with one another rather than there being complete erosion on one side. That is to say, in the research. the increased proficiency of L2 and the disuse of L1 causes the attrition of L1 pronunciation (Yeni-Komshian *et al.*, 2000).

The above studies confirm the view that a high proficiency in L2 may be a direct indicator of greater competition reducing ability of L1, and thus L1 eventually would undergo attrition. However, when the AOA is greater than of twelve, or when dealing with late bilinguals, very few studies exist that can provide some clues to the factors leading to L1 attrition. A definite pattern of correlation between L2 proficiency and L1 attrition has been observed among late bilinguals, and evidence from studies investigating phonological changes when shifting between L1 and L2 are much stronger than evidence from those investigating syntax changes.

Major's (1992) research supported that greater L1 attrition implies a greater degree of L2 acquisition for late bilinguals. Participants who achieved a native-like level in L2 had an obvious attrition in L1. Five American English-Portuguese late bilinguals were observed for the aspiration of the voiceless stop /p t k/. The results indicated that all bilinguals suffered losses of native English proficiency that were caused by the strong influence of L2. The mean English VOT /p t k/ values of bilinguals were shorter (52, 65, 64 msec) than those of monolingual English speakers (78, 84, 93 msec), but their Portuguese productions were longer (31, 32, 55 msec) than those of Portuguese monolinguals (11, 15, 35 msec). Meanwhile, the research also examined L1 production in different speaking circumstances. It found that bilinguals tended to produce even shorter English VOT /p t k/ (43, 54, 50 msec) in casual conversations than in formal conversations (63, 76, 77 msec). Thus, research showed that L1 attrition was correlated with L2 proficiency rather than with the non-use of L1; the higher the L2 proficiency was, the greater the native L1 attrition. The research also suggested that it may be more likely for L1 to show signs of attrition in casual conversations as opposed to formal ones.

Empirical evidence from another study confirmed that a high proficiency in L2 impacted negatively on L1 maintenance. it investigated the use of overt pronouns among Greek-English late bilinguals. [+Topic Shift] is obligatory in Greek, but not in English. This study found that this obligatory feature associated with an overt subject pronoun in L1 Greek becomes optionally unspecified due to strong interference from near native proficiency of L2 English. It confirmed that near-native proficiency in L2 involves an interpretable feature associated with L1 loss in syntax (Sorace, 2000).

The evidence from both syntax and phonology support that L2 proficiency, under certain circumstances, is a predictive factor in L1 attrition, and that the greater the degree of mastery bilinguals have over L2, the greater probability there is that L1 will be affected negatively.

2.4.4. Language Contact

Language contact between the L1 and L2 has been mentioned several times above, along with LOR and L2 proficiency. It is a decisive variable in L1 attrition, since the majority of the research supports disuse in L1 and/or intensive L2 exposure over time as being directly linked to L1 attrition (Hulsen, 2000; Major, 2002; Köpke and Schimid, 2004). Almost all migrants face a decrease in the use of their L1. However, completely cutting off contact with their L1 is hard for late bilinguals, especially in the 21st century. Along with the decrease in use of L1, late bilinguals usually sharply increase their contact with the L2. For instance, the activation threshold model predicts that bilinguals may suffer from L1 attrition due to less L1 contact, which naturally involves increasing L2 exposure (Köpke and Nespoulous, 2001). Major (2002) also stated that L1 attrition is frequent in speakers who have continuous L2 exposure and also in those who use L1 less and less frequently. Hence, bilinguals' contact levels with L1 and L2 are usually studied in comparison.

Bullock and Gerfen (2004) examined phonetic and phonological attrition in L1 French in a French-speaking community, Frenchville, in Pennsylvania, USA. French in Frenchville is distinct from all other French varieties as a moribund language. The isolated geography and the fact that it is only spoken by the elderly has accelerated the loss of this specific variety of French.

Participants were siblings, aged 69 and 72 respectively, who had both lived in Frenchville for their whole lives and spoke French as their native language, but were illiterate in French. The language dominance in school was English, and they did not pass French on to the next generation. L1 French was only used in occasional communication between the two brothers. The data was collected from interviews. The results showed that the allophonic distinction between the mid-front rounded French vowels /œ/ and /ø/ had been lost by the brothers; they had merged to the English rhotacized schwa /ɚ/. Meanwhile, the retroflexed French lexical items were produced as non-retroflexed systematically. However, they still maintained a clear separation of rhotic phonemes in French and in English. Not only did this reveal a distinctive L1 attrition on certain phonemes that converged with similar L2 phonemes, but it also pointed out the relation between L1 attrition and language contact for L1 and L2.

Despite over 15 years of research, it is hard to find a widely accepted reference for how much disuse or how much L2 exposure is required for a language to be attrited among bilinguals (Hulsen, 2000). One reason is that the bulk of existing studies have presented evidence collected from self-reports about language contact, including use frequency, use amount, and language model setting. Hence, evaluations of language contact may vary. Another reason is that language contact is often connected with other sociolinguistic factors such as attitude (Seliger and Vago, 1991).

In sum, all variables discussed here form the impression that, although a high level of exposure in the L2 environment is demonstrated, adult bilinguals usually have far fewer opportunities to attrite their L1 compared with younger bilinguals. However, it cannot be said that L1 attrition in adult bilinguals is completely impossible. Variables such as language proficiency and language contact have a decisive impact on L1 attrition, as confirmed by previous studies.

2.5. Tone

In this section, an introduction to tone languages and to Mandarin tones will be given from a phonological perspective. Mandarin tones will be illustrated in light of relevant theories and models from the acoustic study of tone. Language families can be described in various ways. For instance, they can be classified by the number of native speakers, by their origins, and by linguistic features. The languages focused on in this research can be simply classified as tonal or non-tonal.

2.5.1. Tone languages

As it stated in *Tone* (Yip, 2002), tone languages account for 60% to 70% of the world's languages. The majority of tone languages are spoken in Asia, Africa, and Central America. While intonation exists in every language, and is used to expresses syntactic and contextual meanings, tone is used to distinguish different word meanings (Chao, 1930; Chao, 1968; Duanmu, 2002; Yip, 2002; Lin, 2007). Mandarin, the focus of the present thesis, is a typical tone language, and is the most widely spoken tone language worldwide.

Intonation and tone relate to the pitch of sound. To produce a sound, the vocal cords vibrate to release airflow. Acoustically speaking, the rate of vibration of the vocal cords is the fundamental frequency (F_0), which is measured in Hertz (Hz). F_0 is perceived as pitch by a listener, though the height of the F_0 is disproportionate to the pitch (Shih, 2000; Shi and Wang, 2006a). When pitch is used to distinguish words, it is called tone. Pitch contour describes tones by pitch movements such as rising, falling, and level.

Pitch register and pitch contour are two essential dimensions of pitch and vary across different tonal systems. Pitch register uses the relative pitch height, such as high, middle, and low, to distinguish different tones. For instance, Hausa, spoken in Nigeria, has a high tone, a middle tone, and a low tone.

2.5.2. Mandarin Tone

There are four tones in Mandarin. These are labelled as first tone (T1), second tone (T2), third tone (T3), and forth tone (T4). T1 is a level tone. T2 is a rising tone. T3 is a falling-rising tone. T4 is a falling tone. Mandarin tones have been transcribed in various ways. Three widely used Mandarin tone transcription systems are illustrated in Table 2.1.

The first system of tone description was designed by Chao. Chao's (1930) tone letters were a systematic transcription of Chinese tones, and were later adopted by the International Phonetic Association (IPA) (Shibles, 1994). These tone letter can be seen in Figure 2.2 below. It is still the most widely used method of tone transcription. He referred to music staves and used the numerical values one through five to describe tones, where one represents the lowest pitch value, and five is the highest pitch value on the right-hand side.

In Chao's system, the choice of five values was based on a balance between phonetic detail and phonological distinctions that is intentionally vague so as to assist subsequent studies (Chao, 1930; Duanmu, 2002; Zhu, 2008). On the other hand, for phonetic research, Chao's letters fail to provide sufficiently precise pitch values to support acoustic analysis. For phonological studies, Chao's letters are too precise, and could cause misunderstanding that pitch values [55] and [44] both represent high level tones. Hence, scholars have tried to improve on this and have represented several tone models from both phonetic and phonological perspectives in order to study tones systematically.

The second system is diacritics of Pīnyīn, which has been the official transcription system for Chinese in the People's Republic of China since 1958. Pīnyīn uses the Roman alphabet to represent Chinese phonemes and Chao's system as diacritics to denote tones (Chang *et al.*, 2011). It is clearly stipulated that the diacritics should be marked on rhymes of words.

The third system refers to tones using traditional Chinese tone categories represented by characters, in which only four categories are used to describe modern Chinese tones. It is used in the majority of Chinese dialect tone research since there are differences in dialect tones and Mandarin tones (Chang *et al.*, 2011). In this research, pitch contours, Chao's letters, and acoustic pitch values will be used to present and discuss tone issues.

Table 2.1 Three transcription system of Mandarin tones

	T1 Level	T2 Rising	T3 Falling-rising	T4 Falling
Chao’s tone letter in number	55	35	214	51
Pīnyīn diacritics	ˉ	ˊ	ˇ	ˋ
Traditional terms	阴平*(feminine level)*	阳平*(masculine level)*	上声*(rising)*	去声*(falling)*

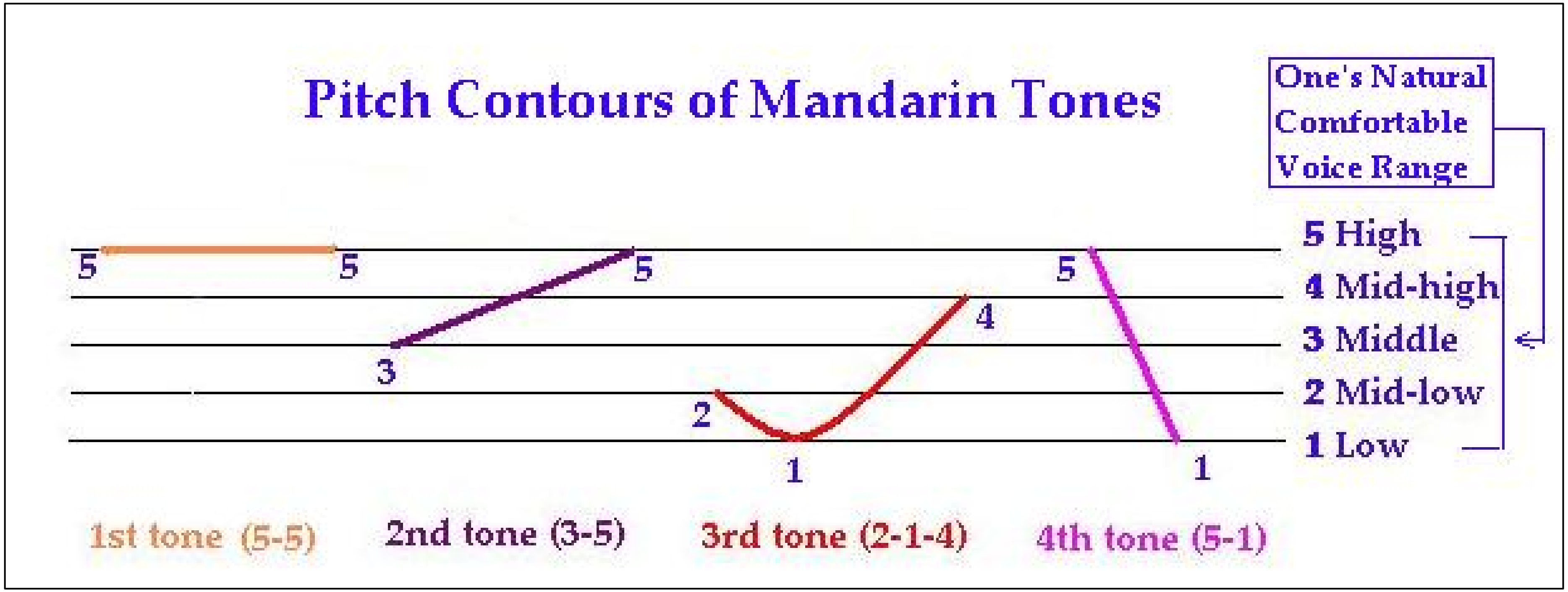


Figure 2.2 Chao’s Numbers (Zhang, 2018)

2.5.2.1. Tone sandhi and tone variation

Tone sandhi is one of the best known phonological rules in Mandarin, second only to the four tones, and mentioned in every L2 Mandarin textbook (Zhu, 2008). Tone sandhi involves the first tone 3 in a word changing to tone 2 when it is followed by another tone 3. There are no limitations concerning the application of tone sandhi to syntactic domains in Mandarin, whether to a word, a compound, or a phrase (Duanmu, 2002). The sandhi rule and examples are given in Table 2.2 below.

Table 2.2 T3S rule and example

Tone sandi	Example		
Rule	Word	Compound	Phrase
T3+T3→T2+T3	mǎ yǐ→ má yǐ 蚂蚁 *ant*	xǐ wǎn→xí wǎn 洗碗 *to wash dishes*	nǐ hǎo→ ní hǎo 你好 *How are you?*

Tone 4 variation

Further, tone variation exists and differs from tone sandhi where the original tone is the maintained, such as the falling tone T4 (Zhu, 2008). Tone 4 variation involves the first tone 4 in a word raising the pitch value of its end point from [51] to [53] when followed by another tone 4. In other words, the pitch value of T4+T4 is [53, 51], instead of [51, 51]. Tone 4 is most likely to maintain its pitch value [51] only before tone 3 or before neutral tones (Chao, 1968; Yip, 1980; Duanmu, 2002).

yi tone variation

There is another sandhi pattern related to the quantifier *yi* 一 'one'. The tone of *yi* is a high-level tone. A *yi* tone variation occurs when *yi* is followed by a T2 or a T3 and changes to a falling T4. When preceding a falling T4, the tone of *yi* changes to a falling T2, as exemplified below in Table 2.3.

Table 2.3 yi tone variations and example

yi tone variations	*yi* T1→T4 variation	*yi* T1→T2 variation
Rules	T1+T2/T3→T4+T2/T3	T1+T4→T2+T4
Examples	*yī* bǎi→*yì* bǎi 一百 *one hundred*	*yī* gè→*yí* gè 一个 *one*

2.5.2.2. The syllable in Mandarin

In the traditional system and the contemporary Pinyin system, a syllable in Chinese is represented using 23 initials and 39 finals. The syllable structure is (C)(G)V(X), where C is an optional consonant, G an optional glide, V a compulsory vowel, and X an optional consonant or vowel[1]. The vowel is either a monophthong or a diphthong, and the majority of Chinese words are monosyllabic with CV or CVC structures. Figure 2.3 presents a hierarchical tree showing the standard analysis of the Chinese syllable (Cheng, 1973; Lin, 1989; Duanmu, 2002; Lin, 2007). Some examples in Chinese are shown in Table 2.4.

```
        σ
      /    \
     I      F
     |     /  \
     |    M    R
     |    |    /\
     |    |   N  E
     |    |   |  |
   (C) (G)  V (X)
```

σ=syllable	
I=initial	E=ending
F=final	C=consonant
M=medial	G=glide
R=rime	V=vowel
N=Nucleus	X=consonant or vowel

Figure 2.3 Analysis of the Chinese syllable

Table 2.4 Some syllable structures and examples

Syllable	V	CV	GV	VC	CGV	CVC	CVV	GVC	CGVC
Example	é [ə:] 鹅 *goose*	bā [ba:] 八 *eight*	wá [wa] 娃 *child*	àn [an] 暗 *dark*	guā [kwa] 挂 *hang*	tāng [taŋ] 汤 *soup*	gǎi [gai] 改 *alter*	wǎn [wan] 碗 *bowl*	liǎng [ljaŋ] 两 *two*

2.5.2.3. Tone-bearing Unit

From the traditional view, tone is considered a property of the whole syllable. However, a consensus has not yet been reached concerning precisely which unit in a syllable bears a tone. There are four assumptions regarding tone-bearing units: the syllable (Wang, 1967; Chao, 1968), the rhyme (Yip, 1980; Bao, 1990; Yip, 2002), the mora (Hyman, 1985; Hayes, 1989), and a segment in the rime (Woo, 1969; Duanmu, 1990; Duanmu, 2002). These four assumptions are listed in Figure 2.4 below.

[1] If X is a consonant, the ending is the coda. If X is a vowel, then the ending is actually a nucleus, and forms a diphthong with the preceding vowel.

1. syllable	2. rhyme	3. mora	4. segment in the rime	
σ ↓ màn ↓ T	σ /\ O R ↓ ↓ m àn ↓ T	σ /\ μ μ ↓ ↓ mà n ↓ T	σ /\ O R | /\ m N Co | | à n ↓ T	σ=syllable T=tone root O=onset R=rime μ=mora N=nucleus Co=coda

Figure 2.4 Assumptions of tone-bearing units

In the first assumption, the tone is carried by the entire syllable node, representing the traditional view that tone belongs to units larger than segments. The second assumption proposes that tone is carried by the rhyme node, while onset does not bear a tone. Assumption three is that the first mora node in the syllable carries the tone. Assumption four is similar to assumption two, except the coda is not involved. The difference is that the tone-bearing units are the segments in the rime, specifically, the nucleus. Considering that the vowel is the only compulsory element in the syllable, assumption four is preferred; this coincides with the tone nucleus model for acoustic analysis (Zhang and Hirose, 2004; Hirose *et al.*, 2006).

2.5.2.4. Acoustic features

Physically, pitch is the perceptual interpretation of fundamental frequency(F_0). Hence, pitch contour, as the primary cue for Mandarin tones, can be represented by F_0 contours for acoustic analysis (Liu, 1924; Howie, 1976; Xu, 1997; Wang, 2007). Figure 2.5 below illustrates the four Mandarin tones in the monosyllable “ma”. In practice, F_0 is subjected to individual voice scope and changes within the tone contour. For instance, a female often has a higher F_0 than a male (Jongman *et al.*, 2000). Hence, F_0 needs to be normalised in acoustic analyses of Mandarin tones to eliminate these differences.

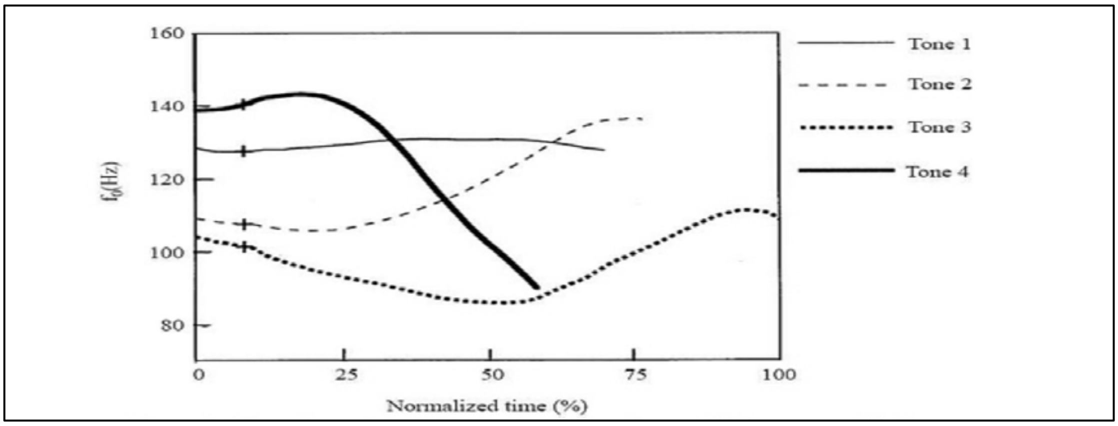


Figure 2.5 Fundamental frequency (F_0) contours for Mandarin four tones (Xu, 1997)

Rating tone on a five degree scale, also known as T-value transformation, was proposed in the early 1990s, and is one of the most widely-used methods to normalise F_0 acoustically (Shi, 1986). According to physical characteristics, F_0 is transformed into numeric degrees of one though five, into which have been adopted Chao's concepts. Figure 2.6 presents pitch contours with normalised F_0 for four tones in native norm (Wang *et al.*, 2003).

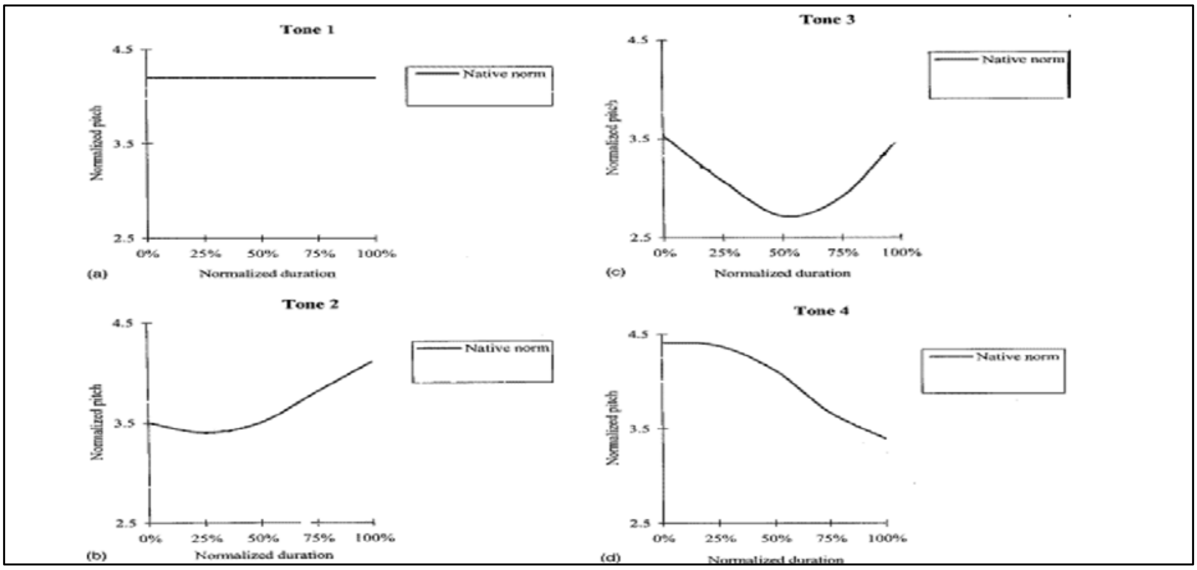


Figure 2.6 Pitch contours on the T-scale with the native norm (Wang et al, 2002)

Compared to other normalisation methods, such as semitone transformation (Baken, 1987; Hart *et al.*, 1990; Wu, 1997; Xu, 2006) and z-score transformation, T-value transformation not only eliminates individual differences, but also maintains the dynamic pitch track for Mandarin tones (Menn and Boyce, 1982; Rose, 1989; Zhu, 2008; Yang, 2015).

Pitch register refers to pitch height in Mandarin, since there is no register contrast. Some models (Bao, 1990; Yip, 2002) use both pitch contour and register as cues in tone analysis, because the phonological description for Mandarin tones is general. As the most complex tone among the four Chinese tones, tone 3 (with pitch value 21(4)) has a tone value of 21 in non-final position yielding a low falling tone, but it acquires a rise, shown by (4), in the final position of a phrase or followed by a neutral tone (Chao, 1968; Chen, 2000; Yip, 2002). Hence, the distinction between tone 3 and tone 4 relies on pitch height. Figure 2.7 below gives an example.

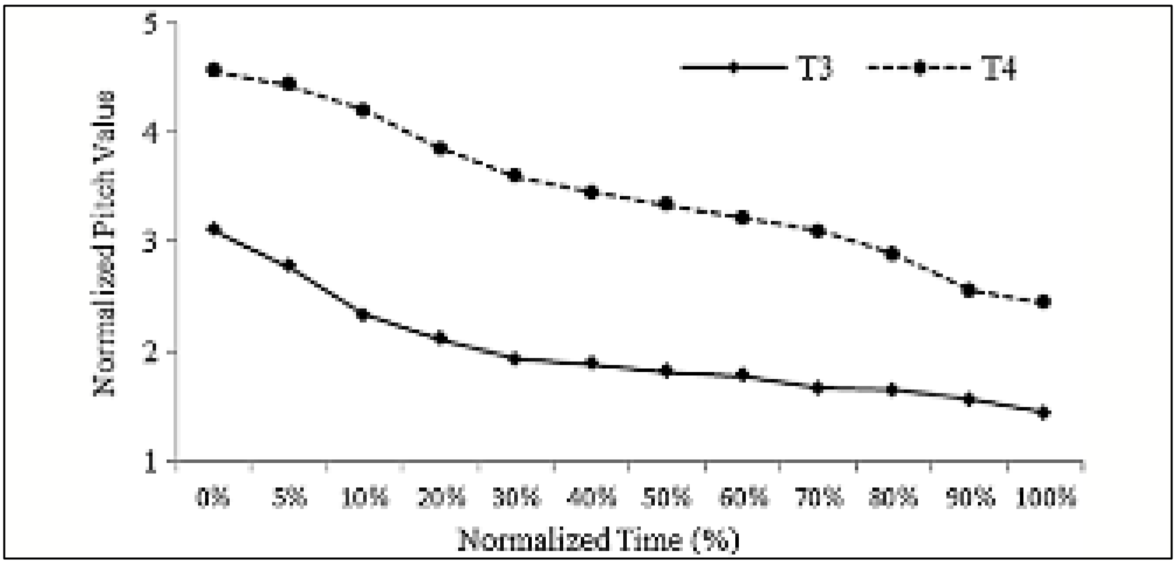


Figure 2.7 Contours for tone 3 and tone 4 (Yang, 2015)

Comparing Figure 2.7 and 2.8, it is clear that the pitch height for Mandarin tones is the second most important cue in acoustic analysis. This is different from phonological models such as Chao's (Figure 2.2). Several large-scale acoustic studies have analysed tonal paradigms for Mandarin tones (Liu, 1924; Lin, 1985; Shi, 1986; Shi and Wang, 2006a). Figure 2.8 illustrates the tonal distributions (maximum, average, and minimum F_0) for the four tones, carried by monosyllables and produced in isolation (Shi and Wang, 2006a). The production for each tone is dynamic in pitch height, and the middles lines with red circles are pitch contours with average F_0 heights. The upper line with collate points demonstrates pitch contours with the maximum F_0 height, while the bottom line with stars shows the minimum F_0 height. Any tone produced outside of the corresponding pitch height range is perceived as non-native like.

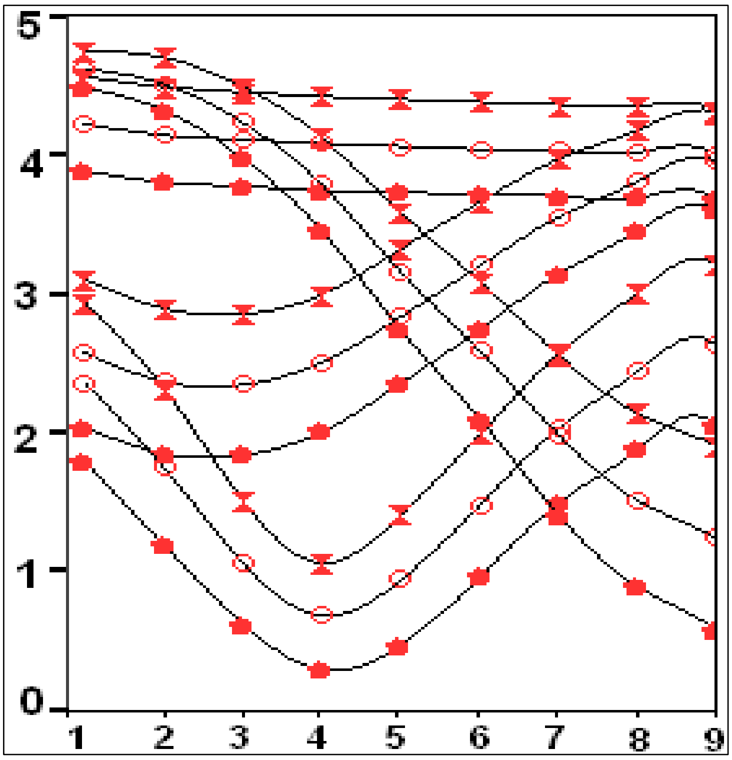


Figure 2.8 Main Distributions for Chinese four tones (Shi & Wang, 2006)

2.5.2.5. Contextual Tonal Variation

The four tones keep their pitch values when produced as monosyllables in isolation. In naturally occurring conversation, tone is affected by neighbouring tones when a tone-bearing lexical item is produced. The most well-known example is the tone sandhi. Several phonetic studies have revealed that tone categories have additional variations as a result of nearby contextual effects, known as tonal coarticulation (Xu, 1997). However, the effect of tonal coarticulation is minor on F_0 adjustments to preceding or following tones (Xu, 1999). Hence, F_0 realisation changes according to both processes by which contours for Mandarin tones are distinguished from the canonical contours of tones produced in isolation.

The difference between tone sandhi and tonal coarticulation is that tonal coarticulation only has a minor effect on partial contours rather than, for instance, changing the entire contour from rising to falling. Though general agreement has been reached, the results are varied on how much an articulatory F_0 transition participates in a syllable's entire contour (Howie, 1976). The transition proportion was about 30% of the whole contour in early studies. The transition had increased to 40% in latter studies (Rose, 1989), and even reached 50% in a study by Shih (1988). Xu (1997) observed the disyllabic non-word */mama/* with 16 possible combinations of the four tones in four carrier sentences. The results identified carry-over effects and anticipatory effects. Carry-over effects are assimilatory, which means that if the ending point of a tone is low, such as for T4, it will lower the F_0 contour of the following tone. If the ending point of a tone is high, such as for T1 and T2, it will raise the F_0 contour of the following tone. Anticipatory effects, however, are not always the same: if the starting point of a tone is low, such as for T2 and T3, the F_0 contour of the ending point of the preceding tone will be lowered. The magnitude of carry-over and anticipatory effects reduces over time. The rapid F_0 movement during the onset is reduced during the vowel. It is important to remember that the carry-over and anticipatory effects occur with syllables. The cross-syllabic carry-over and anticipatory effects are weak and unclear. Hence, in some circumstances, a reversed F_0 contour at the starting and/or ending point may be observed that is different from the main contour. For instance, a rising T2 could fall at the starting point if it is preceded by a falling T4 in natural speech. It is certain that coarticulation has an impact on F_0 realisation for Mandarin tones in production, regardless of the proportion in which it takes part.

Table 2.5 Articulatory F_0 transition observation by Xu (1997)

Disyllabic reading list	māmā	māmá	māmă	māmà	Carrier	1	wŏjiāo____liánluò.
	mámā	mámá	mámă	mámà		2	wŏjiāo____liànxí.
	mămā	mămá	mămă	mămà		3	wŏjiào____liánluò.
	màmā	màmá	màmă	màmà		4	wŏjiào____liànxí.

2.5.2.6. Tone Nucleus Model

In the majority of tonal research, a tone is divided into three parts – an onset, a central part (nucleus), and an offset – to study or eliminate variations produced by the nearby context (Xu, 1997). Previous studies fixed the duration of onset and offset in a given language. For instance, a vowel was measured between the 50 ms after the initial consonant burst and 50 ms before the cessation of significant vocal energy (Gottfried and Suiter, 1997), or between the first six and final eight pitch periods of the entire syllable (Lee *et al.*, 2008). However, the fixed duration contrasts with the changeable influence of the nearby context in connected speech.

To solve this problem, the tone nucleus model was proposed (Zhang and Hirose, 2004; Hirose *et al.*, 2006). This model dynamically adjusts the previous syllable division such that a syllable F_0 contour may be divided into three segments: the onset course, the tone nucleus, and the offset course (see Figure 2.9). The tone nucleus represents the underlying pitch targets and is obligatory. The onset and offset courses are the articulatory transitions. The tone nucleus model indicates that the nucleus is the essential part of the F_0 contour of the associated tone, as it is unaffected by changes in F_0 resulting from a voiced/voiceless onset, word boundary, sentence boundary, intonation, and stress. Both the onset and offset are optional and easily affected by the context.

Sub-syllable F_0 segments		
(1)	2	(3)
(Onset course)	Tone onset | Tone nucleus | Tone offset	(Offset course)
←	Syllable F_0 contour	→

Figure 2.9 Tone Nucleus Model

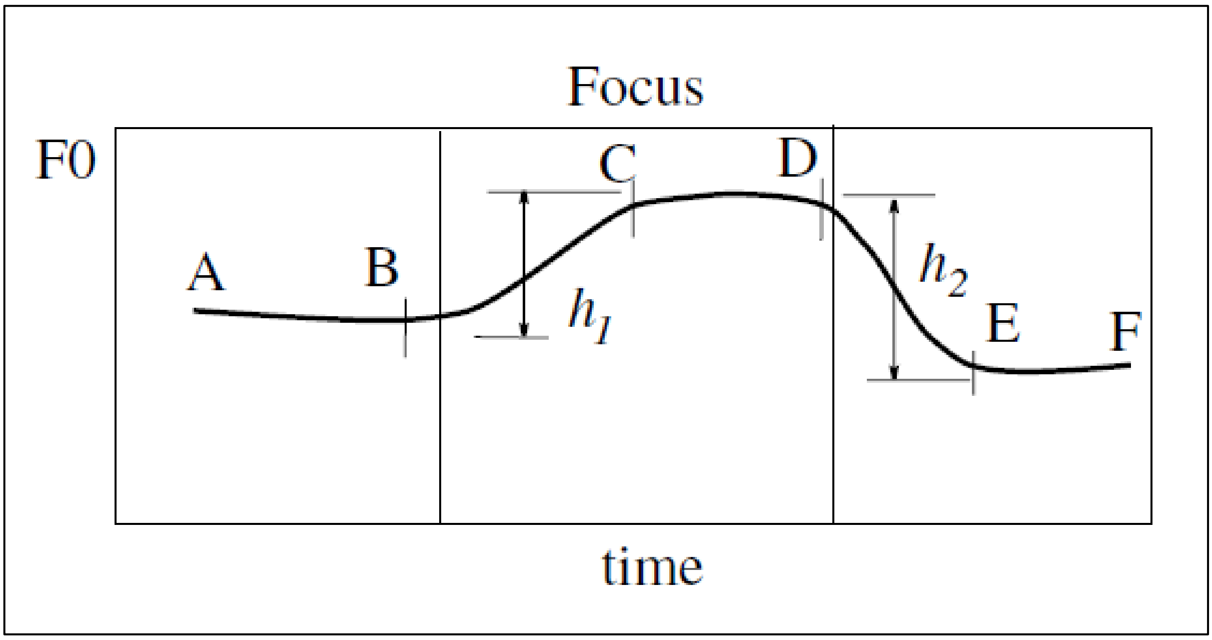


Figure 2.10 $\boldsymbol{F_0}$ *Contour for a continuum T1+T1+T1, focus on the second T1*

Figure 2.10 illustrates a typical F_0 contour for a three T1 sequence where the second T1 is the focus. It is easy to see that the focus leads to a substantial rise and a fall at BC and DE respectively. These kinds of F_0 contours are regarded as articulatory transitions based on the nucleus model. F_0 contours located at AB, CD, and EF are the tone nuclei of the three T1s. Considering the whole F_0 contour, the tone nuclei demonstrate a similarly level contour. The model suggests the level contours represented by AB, CD, and EF are justifiably regarded as the pitch contour of T1 (Zhang and Hirose, 2004).

The tone nucleus model can be applied to eliminate the variation of an onset and/or offset affected by surrounding prosodic features, which might create the opposite onset and/or offset contours compared with the core contour. Since register plays little role in Chinese, the register differences among contours AB, CD, and EF will not be elaborated on further here. Phonetic studies indicate that the expected tone contour starts when the rime starts, while the f_0 contour on onset is irregular (Howie, 1976; Rose, 1988; Xu, 1999). In this regard, 2.4 (b) and 2.4 (d) are better models than 2.4(a) and 2.4(c). As pointed out above, there is still not compelling evidence that the TBU is the rime or the moraic segment in the rime. Several studies have looked into variations of the onset and offset of a tone in order to answer this question (Duanmu, 1990; Gottfried and Suiter, 1997).

2.6. L1 tone attrition

The studies discussed above mainly focused on L1 attrition observed in phonetics, where the majority of participants were bilinguals of non-tone languages. Tone languages, such as Chinese, are rarely mentioned. Not only is there a lack of subjects, who lived in an L2 environment over certain time, for Standard Chinese (Mandarin) as an L1, but it is also notably difficult to capture and analyse the dynamic pitch contours for tone systems. With more and more tone language speakers immigrating to non-tone domains and the improvement of digital analysis methods, the number of studies on L1 tone attrition continues to increase.

The majority of L1 tone attrition studies observed early bilinguals' tone perceptions, while a few of them tested tone production in isolation (Piercea *et al.*, 2014b; Zhou and Broersma, 2014a). The data collected from early bilinguals or adoptees from L2 domains supports the previous models that early bilinguals demonstrate L1 attrition for tone perception, and that some even lose the ability to identify tones (Shittu and Tessier, 2015). In recent years, several studies have observed tone change among tone language speakers after they had moved to a different tone language domain. The results illustrate that the two tone systems merge (Yeh, 2011; Chang, 2014b; Qin and Mok, 2014). The following lists some representative cases to present a general view on L1 tone attrition.

Studies of L1 attrition focusing on tone perception usually pay more attention to early bilinguals than to whether the ability of perceiving tones is retained when the language environment is changed completely. A longitudinal study for tone perception was conducted among Chinese adoptees in the Netherlands (Zhou, 2010). Nine Chinese adoptees were adopted by Dutch families before the age of two and were tested after living in the Netherlands over five years. Seven Chinese-German early bilinguals, born and raised in the Netherlands, were recruited as the control group.

Participants were tested by three perception tasks, including an AX discrimination task, an AXB discrimination task, and a tone recognition task (TRT). Chinese adoptees demonstrated higher error rates in three tasks than the control group with error rates of 25%, 16%, and 31.6% compared to 4.3%, 4.1%, and 11% for AX, AXB, and TRT respectively. The results showed that Chinese adoptees attrited L1 tone perception, though they maintained their sensitivity to perceiving Mandarin tones to some degree.

The maintenance of tone perception is supported by a neurolinguistic study (Piercea *et al.*, 2014a). To test the maintenance of tone perception, 23 Chinese adoptees in a French-speaking environment, 12 Chinese-French early bilinguals, and 12 French monolingual children were observed. Chinese adoptees were exposed to a French-only environment starting before three years old, while early bilinguals started to learn French from three years old. Fifty-six syntactically acceptable sentences paired with hummed comparable sentences were tested, both of which were composed of three monosyllabic pseudowords. Participants were asked to recognise whether the final syllables for the paired sentences were the same or different.

The results indicated the neurological retention of an apparently attrited or lost language. The neural evidence examining brain activation to tonal contrasts supported that, even after several years of residence in the L2 environment and no L1 contact at all, Chinese adoptees still involved the brain's left hemisphere in processing lexical tone, just as the Chinese-French early bilinguals did. However, French monolinguals only recruited right hemisphere regions in the processing.

The phenomenon has not only been found in Chinese, but also in other tone languages, such as Niger-Congo spoken by the Yoruba (Shittu and Tessier, 2015). Shittu and Tessier tested 28 Yoruba-English early bilinguals aged 8 to 15 living in the L2 environment. They had restricted L1 exposure in that they rarely used Niger-Congo at home and never at school. Their parents, who used Yoruba daily at home and with friends, were considered to be the control group. An AX discrimination task, a tone identification task, and a lexical choice task were conducted for tone perception. Early bilinguals had reached 51%, 36.7%, and 53.8% accuracy rates in each task, similar to the control group, which reached 73.5%, 54%, and 96%. The data revealed intensive L1 attrition on tone perception among Yoruba-English early bilinguals, and also confirmed the maintenance of the ability of tone perception. Evaluating environmental factors, the study indicated the degree of attrition was observed in both L1 and

L2 contexts. Children with less L2 attrition had spent more time in an L2 context and less in an L1 context.

L1 attrition on tone perception was found among late bilinguals. Yeh and Lin (2015) examined language attrition and phonetic similarity on low-level tone in hai-lu Hakka[2], a very small dialect spoken in Taiwan. The study proposed that tonal attrition in hai-lu Hakka would be triggered by a decline in use and the interference from four tone standard Chinese. The 32 Hakka-Mandarin speakers involved in the study were grouped as follows: young non-daily users, young daily users, and older daily users. The three groups had average ages of 17.3, 38.9, and 59.1. All participants were exposed to Hakka and primarily spoke Hakka before the age of six. Old daily speakers had little Mandarin exposure compared to young non-daily users and young daily users, who had similar Mandarin exposure times. In other words, non-daily users and daily users were different in the degree of language attrition while the older users and young users contrasted in their use of L2 Mandarin.

Both perception and production for hai-lu Hakka tones were tested. The perception tasks were an ABX discrimination task, tonal identification task, and lexical recognition task. The results indicated that old daily users had the highest accuracy rates in three groups, which were 98.9%, 91.0%, and 94.6% for each perception task. Young daily users had slightly lower accuracy rates at 98.6%, 87.0%, and 90.6%, while young non-daily users had rates of 97%, 86.1%, and 76.0%. The differences in two of three perception tasks were minor; only the lexical recognition task had a significant difference between the young non-daily users and old daily users. The production task was reading a word list of 40 Hakka monosyllabic words. For Hakka tone production, young non-daily users had the lowest accuracy rate at 51.3%, much lower than the other two groups. Older participants had an accuracy rate of 91.7%, while younger daily user had a rate of 89.0%. Hakka low-level tone produced by young non-daily users were more likely to be produced as low-falling tones. Young non-daily users showed signs of L1 attrition in tone perception and production, though perception only showed minor attrition. The study suggested that L1 attrition among the young non-daily user group was correlated with decreasing use of Hakka rather than the increasing contact with

[2] Hakka is a native Chinese dialect, mainly spoken in Taiwan and south-east China. It used to be an important dialect in Taiwan. But the forced promotion of Taiwanese Guoyu by the Taiwan government decreased the usage so that currently only a small amount of young people can use it fluently.

Mandarin. Moreover, the study ascribed the low-falling error of low-level tone to minimise articulatory efforts instead of language internal efforts from Mandarin.

Similar tone attrition was found among Taiwanese-Mandarin speakers who were qualified as bilinguals (Chang, 2014b). Taiwanese has a different tonal system compared to Mandarin. The 27 participants were grouped by expected attrition degree: there was an L1 non-attriter group and an L1 attriter group. The L1 attriter group had acquired Mandarin as L2 and had resided in the L2 domain for more than five years. They were asked to complete film retelling and storytelling tasks in Taiwanese. Over 10 thousand tokens were recorded and all Taiwanese tones were analysed, particularly in Taiwanese for tone sandhi. The L1 attriter group had a significantly lower accuracy rate in tone production compared to the L1 non-attriter group. However, Taiwanese tone sandhi produced by L1 attriters maintained a similar accuracy rate as that produced by non-attriters. L1 attriters were still capable of switching tones from Mandarin to Taiwanese immediately. The study indicated that tone attrition among L1 attriters did not specifically involve losing a single tone, but rather the operating mechanism of tonal groups deteriorated because of a lack of L1 use. From this point of view, though Taiwanese-Mandarin speakers lived in an L2 tone domain, L1 attrition occurred mainly because of low L1 use rather than strong interference from L2 Mandarin (Chang, 2014a).

A very recent study also argued for correlations between L1 attrition and language dominance (Quam and Creel, 2017). To analyse the issue, 72 late Mandarin-English bilinguals participated in research where they were asked to complete one eye-tracked novel word-learning experiment, one eye-tracked familiar-word test, one multilingual naming test, and one bilingual dominance scale test. Participants had learned Mandarin from birth, though their English proficiency varied. The data were analysed for accuracy and reaction times for online recognition measurements of Chinese tone perceptions. The outcomes of the study indicated correlations between tone use and degree of Mandarin language dominance. Participants with low Mandarin dominance demonstrated slower exploitation of tone sandhi cues to anticipate the tone of the target words. In other words, bilinguals having more contact with L2 English demonstrated tone attrition in terms of lower word recognition success.

2.7. Summary

This chapter started by reviewing the development of research and definitions of language attrition, from the early 1980s to the most recent studies. Then, it focused on the pathway to L1 tone attrition and variables relevant to the research aims of the present thesis.

It reviewed the activation threshold model, the dynamic model of multilingualism, and the regression model, which are the theoretical guidelines for this work. Based on those models, the L1 of late bilinguals is considered as vulnerable if language and environmental domain are changed as mentioned above. Factors such as age and language contacts were evaluated as potential variables applying to L1 attrition in the present study.

Meanwhile, features of Mandarin tones were introduced, from phonological and acoustic approaches. The phonological model tone-bearing unit and the corresponding acoustic model, the tone nucleus model, were explained in detail in order to facilitate future study. L1 attrition was found in tone perception and production among early and late bilinguals. Previous studies revealed L1 attrition in phonetics, but also in phonological features such as tone. Tone attrition was found to correlate with age of arrival, length of residence, language proficiency, language contact, and language dominance.

However, there are two aspects not covered by previous studies. One is that the majority of the studies observed bilinguals with tone languages for both L1 and L2. Only Quama and Creelb (2017) have focused on Mandarin-English late bilinguals. Another aspect is that almost all data used for tone production analysis were produced in isolation, rather than from productions extracted from connected speech.

The present study aimed to investigate L1 tone attrition in tone perception and production among Mandarin-English late bilinguals. The models of the present study are guided by the activation threshold model, the dynamic model of multilingualism, and the regression model. Based on previous studies, ABX and multi tone recognition tasks were used for data collection for tone perception. Data for tone production was collected from naturally occurring speech through story-telling and interviews. These will be presented in detail in the following chapter.

Chapter 3. Methodology

3.1. Introduction

The study involved two types of participants: bilingual Chinese-English speakers and monolingual Chinese speakers. The participating bilinguals had spent varying lengths of time residing in an English-speaking country (the UK). The data were collected through a questionnaire on Mandarin and English use and two tasks that elicited the subjects' tone perception and production. Bilinguals were all tested by the Oxford Quick Placement Test (OQPT) to ensure that their English proficiency was university level, which for the OQPT is medium to advanced level.

The following hypotheses based on the research questions given in Chapter 3 were formulated:

1. Mandarin-English bilinguals will demonstrate attrition on three tones in Mandarin, namely T2, T3 and T4.

   1a. The order of attrition by degree expected is T3 > T2 > T4. (That is, tone attrition will mirror the acquisition order for children on L1 attested in the L1 acquisition literature.)

   1b. This will be demonstrated on both production and perception tasks.

2. Attrited T3 will be produced with either half rising part or falling part.
3. Amount of use of L1 and/or L2 will affect attrition, as measured by years of UK residence and interaction in the dominant language, English.
4. Tone attrition will be in more evidence in casual contexts than in formal situations.

3.2. Participants

All participants were native speakers of Standard Chinese, i.e. Mandarin. Since Standard Chinese is based on the northern Chinese dialect, all participants were from the north of China, specifically Beijing, to ensure that they had no exposure to other dialects. Participants from areas surrounding Beijing were also suitable for the research because there is no difference in Chinese tones. The age range of the participants was 20-35 years and there was a roughly equal numbers of males and females. Bilinguals were selected from among university students or adult residents who had lived in the UK for varying lengths of time. Monolinguals had lived all their lives in Mainland China, travelling to other countries no more than two weeks at a time, and had relative minimal exposure to English – between 3-8 hours per week from primary school to university – compared with the exposure to L1 Chinese.

English language teaching is not officially required in kindergartens. In some large cities and advantaged areas, children learn simple English songs or a small number of vocabulary items. However, their proficiency in English is insufficient for evaluation (Hu, 2002). The recommended starting grade for English learning is Primary Grade Three. The exposure to English can be described as minimum at this level. The exposure amount from primary school to university shows a positive curve, which reaches a peak in high school (7.5 hours per week) and gradually reduces in university (3-4 hours per week). Hence, children's exposure to L2 English can be considered as minimal (Hu, 2005).

Since there are various speaking circumstances, the delimitation of bilingualism in this thesis is necessary, as recommended in previous literature (Ng and Wigglesworh, 2007). Bilinguals in the present study are late bilinguals who have acquired their native language prior to learning English (and in some cases other languages) after childhood. Their L2 was initially acquired from the classroom, and they later moved to the UK. Their L2 is held to be stable, and the criterion for eligibility was an intermediate or advanced level of L2. They were also circumstantial bilinguals using L2 actively, and at the time of testing they had been living continuously in an L2 environment over a certain period of time.

Bilingual participants were grouped by the length of residence in an L2 English environment. All participants had their formal first L2 English exposure at primary school,[3] with more than 10 year of English studying experience continuously (Wang, 2007). The majority of participants had no previous experience residing in an English environment longer than four weeks before they moved to the UK.

Group 06M consisted of 10 new-arrival bilinguals, who had arrived in the UK no more than six months prior to testing. They were studying in different schools within Newcastle University. Group 13M was 10 bilinguals who had spent 13-24 months in the UK

[3] In 2001, the Ministry of Education announced that English classes would begin in grade three of primary school with a view to starting classes from grade one in the future.

continuously by the time of testing. Group 36M was 10 bilinguals with 30-48 months of experience in the UK and no more than four weeks spent in China during that time. Group 60M was 10 bilinguals with over 60 months of experience in an English-speaking environment. None of the speakers in any of these groups had spent more than a month back in China each year.

The 10 adults who participated in the study as the control group were not monolingual, because since the 1980s, English or Japanese learning has been compulsory in the Chinese education system from elementary school up until university. English is the most popular foreign language, and all those in the study had learned English since Grade Three, at around 10 years old.

The study total considered participants with low English proficiencies to be monolinguals, which meant that their exposure to English had been less than 1.5 hours per day during their schooling. The subjects were residents in Mainland China who studied or graduated from universities but not with an English or English literature or linguistics related major. They had no regular use of English at work/home had not spent any substantial time in English-speaking countries, as confirmed by the questionnaire and interview they were given.

All participants involved in this study took part on a voluntary basis without financial compensation. The researcher provided an information sheet and a consent form, which were read and signed by the participants. The participants were then debriefed in written and oral form after data collection. All information sheets were in English and in Mandarin. Participants' identities were protected confidentially, and their names were replaced by a code using the format of group name and two numbers representing the order in which they took the experiment. The shortest residential length among participants was used to name groups. For instance, G13M01 represents the first participant in Group 13M, who lived in an L2 English environment for between 13 and 24 months. The code 60M10 represents the tenth participant in Group 60M, who arrived in the UK more than five years prior to testing.

3.3. Tasks & Materials

The study aimed to examine both perception and production of tones in Standard Mandarin. The stimuli were created to elicit data on participants' perceptions and production regarding tones in mono-morphemic words and compounds. The session contained seven parts: two perception tasks, three production tasks, the English level test, and a questionnaire. Please refer to 7.5. (Stimuli Materials) in the Appendices.

3.3.1. Perception Tasks –Task 1

Two lexical tasks elicited participants’ perception of Mandarin tones. Triangulation was used to ensure the accuracy of the task. Participants were asked to choose the correct tones from three options in Task 1A and to distinguish different tones in Task 1B. For the perception tasks, 198 words – 99 words for each perception task – were selected from latest Modern Chinese Vocabulary Retrieval System (Xiao, 2012).

Words in the two perception tasks were disyllabic or trisyllabic words. In order to create valid tokens, each syllable was CV(C) structure. All five vowels of Chinese – /a/, /i/, /e/, /o/, /u/ – were chosen. All four tones in different combinations and phrases were included in two tasks. The orders of combination and phrases were mixed and arranged randomly to avoid regular patterns.

All words were clearly articulated and recorded by a trained female native Chinese speaker with a normal speaking speed. The recordings were checked by a professional native Chinese speaker who had taught Chinese for over 10 years. The number of the word was pronounced to ensure that the subjects followed the listening order.

Task 1A was a multiple-choice perception task that asked the participants to choose the correct tone from three different options for each word thy listened to. For example, word ‘gān 干 k ū 枯’ was used to test tone perception of T1. Three different pronunciations (*A gānkū /B gǎnkū/C gànkū*) were played to participants, who were asked to choose the correct tone use while listening. These were compounds of varying numbers of syllables. The task contained 99 words with possible combinations of the four tones, including those listed in Table 3.1 and 3.2.

The 99 words tested included 16 T1, 16 T2, 16 T3, 16T4, 24 T3 sandhi, 18 T2 variations, and 18 T4 variations. An answer sheet with five columns was given to the participants, who had to choose one correct pronunciation from the three options for each test item. An example was given before the task started. Table 3.1 and Table 3.2 below show tone combinations. ‘X’ here indicates tested tone pairs in the task. Black cells are where no tone pair was tested or analysed. This is because some tone pairs, e.g. T3T3 and tone sandhi, are listed in Table 3.2 as tone variations instead of regular tone combinations.

Table 3.1 Tone Combinations tested

	T1	T2	T3	T4
T1	X	X	X	X
T2	X	X	X	X
T3	X	X		X
T4	X	X	X	

Table 3.2 Tone Variations tested

	T2	T3	T4
T1 (*yi* tone variations)	X	X	X
T3 (Tone sandhi)		X	
T4 (Tone 4 variation)			X

Task 1B was an ABX perception task where participants were asked to listen to a recording and point out whether X's tone was the same as A's or B's. Similar to Task 1A, Task 2 B has 99 words with all combinations of all four tones, including 16 T1, 16 T2, 16 T3, 16 T4, 24 T3 tone sandhi, 18 T2 variety, and 18 T4 variety. For instance, word 'zhǔzhǐ 主旨 'was tested as T3 sandhi. Two options (*A zhúzhǐ/B zhǔzhǐ*) were played followed by *X zhúzhǐ* on the recording, and the participant was asked whether the last tone was the same as or different from the first tone they heard. The difference, compared with Task 1A, was the tested words: for instance ' zhǔzhǐ 主旨 ', were not shown on the answer sheet listed in Stimuli Material in the Appendices.

Participants were asked to circle either A or B. An example was given before the task started. The perception answer sheets are included in Appendices 7.6.1 and 7.6.2.

3.3.2. Production Tasks – Task 2

Production tasks examined the tonal production and pronunciation consistency among the participants and were designed to provide data to acoustically evaluate participants' pronunciation of Mandarin tones. There were three tasks: reading aloud, story-retelling, and video description, which were intended to stimulate speakers to speak both formally and informally.

The order of the production tasks was as follows: Task 2A, Reading aloud; Task 2B, Retelling the story; and Task 2C, Describing videos, simulating formal, semi-formal and casual speaking circumstances. Major (1992) and Köpke (2007a)'s order were from more formal to less formal, and I followed their orders. Of course such an order could have alerted my participants to the purpose of the study and resulted in monitored speech, but there is no clear evidence it did.,

Task 2A asked participants to read a story called *Mogao Ku (*Mogao Grottoes/Caves) (Yi, 2016), which describes an ancient and famous Chinese attraction. The story was selected from a textbook of 6^{th} grade Chinese (Wen, 2015), containing 605 single characters that were composed of 186 words and compounds. Apart from 37 neutral tones, Task 2A tested 79 first tones, 80 second tones, 69 third tones, and 114 fourth tones with 19 third tone sandhi, 3 second tone variations, and 20 fourth tone variations.

After reading, participants were asked to do Task 2B, a re-telling of Task 2A. In the retelling process, participants were given important key works, compounds and phrases in the story, reminding and helping them to retell the story as much as they could. The tested tones were 71 T1s, 52 T2s, 46 T3s, and 95 T4s, including 10 T3 sandhi, 3 T2 variations, and 20 T4 variations, which were embedded in words.

Participants were asked to describe two videos in Chinese in Task 2C while watching them in sequence. In this section, the researcher played two videos related to well-known disasters, which participants would be familiar with. The purpose of using disaster videos was to force participants to deliver tones naturally without deliberate control (Labov and Waletzky, 1967). Labov and Waletzky (1967) reported that he asked interviewees to talk about a personal life-threatening experience, and he observed that when these speakers were distressed, they did not monitor their speech and spoke more naturally. The study suggests that when second language speakers are engrossed in speaking about a topic, they too will be more likely to speak naturally (Labov and Waletzky, 1967).

Each video was no longer than three minutes. One video showed surveillance recordings of a Sichuan Ya'an earthquake taken in different places. The other video was a recording of 9/11, taken by a witness at the location of the scene. Videos only contained background sounds, such as vehicle noises and peoples' cries. Neither contained any sentences that would have interrupted the participant's description. Both videos were published on a public online service and were legally downloaded by the researcher.

All participants performed all three tasks in the same order. A brief introduction was given by the researcher before the production tasks, and participants were told again that they had the right to terminate the activity at any time without giving a reason. All three production tasks were audio-recorded. The data was acoustically analysed by Praat and then in SPSS in both qualitative and quantitative approaches.

3.3.3. Questionnaire

The aim of the questionnaire was to ensure the equality of age and gender among participants. This information was asked in the first and second questions. The questionnaire was also used to collect information on the daily use of native and second languages according to participants' self-rankings.

The questionnaire had two sections with 27 questions in each section: Section A was personal information, including name, age and gender, place of birth, and current resident place. Section B was the knowledge and use of languages, including information of native language variety, second language, other foreign languages, as well as the language environment. Questions about second languages were more specific, including general language level (see below), entire learning time, daily use time, and so on. The questionnaire was written in both Chinese and English for the convenience of the participants. The language they used to answer the questionnaire was the same as the language shown on the questionnaire (Chinese or English).

3.3.4. English Proficiency Test

The study used scores from two English tests to evaluate participants' English proficiencies. The minimum English proficiency level for all participants was intermediate, including lower intermediate. One test used was the International English Language Test System (IELTS), which is used generally in the People's Republic of China for those who would like to study in or immigrate to the UK and refers to the English proficiency of participants before they have arrived in an L2 environment. Participants were asked their score on the questionnaire. The equivalent English test – *Test of English as a Foreign Language* (TOEFL) – was also acceptable and was translated into relevant scores on the IELTS. The score scales go from the 1 as the lowest value to 9 as the highest, as shown in the following Table 3.3.

Table 3.3 IELTS score scale

Bandscore	Skill level	Key points
Band 9	Expert user	accurate full understanding
Band 8	Very good user	rare errors uses complex language well
Band 7	Good user	only occasional errors uses complex language quite well in most situations
Band 6	Competent user	some errors uses come complex language which is best in familiar situations
Band 5	Modest user	frequent errors has difficulties with complex language

The second measure was the Oxford Quick Placement Test (UCLES, 2001). It is a paper and pen test used to evaluate participants' English. This test was used in the present study as a measure of participants' current English levels. The OQPT has 60 questions. Scores represent different levels, which are shown in Table 3.4 along with the Common European Framework of Reference (CEFR)/Council of Europe levels (Goullier, 2007). [4] CEFR is used as a reference for a comparison of IELTS and OQPT in Chapter 5.

Table 3.4 Oxford Quick Placement levels

Level	Paper and pen test score	Council of Europe Level
0 beginner	0-17	A1
1 elementary	18-29	A2
2 lower intermediate	30-39	B1
3 upper intermediate	40-47	B2
4 advanced	48-54	C1
5 very advanced	54-60	C2

Pronunciation for L2 was not assessed in using these two well-known and widely used English proficiency measurements. The IELTS speaking test (IELTS, 2019) does evaluate L2 oral proficiency but not L2 pronunciation. The IELTS speaking test is designed to assess a wide range of skills, including ability to communicate, use of appropriate language, coherent organisation of ideas, analysis and discussion.

3.4. Equipment and Materials

The equipment used to collect data was a stereo audio recorder (Sony ICD-PX240), a headphone, and a laptop. All testing materials were given to participants step by step.

[4] http://www.coe.int/t/dg4/linguistic/source/framework_en.pdf

Listening materials for Task 1A and 1B were prepared by the researcher and recorded by a professional Chinese broadcaster who had been awarded with an A-level certificate in Chinese. Each recording was approximately 15 minutes long. Answer sheets were designed by the researcher to suit the tests and were given individually for the two perception tests and the OQPT. The questionnaire was available in two formats: an online survey via Survey Monkey and a printed version, chosen depending on participants' willingness and technical ability.

All materials used for the stimuli were modified to suit the web format and uploaded online. Therefore, some participants and the control group who were only available via long distance completed all stimuli online. This was monitored via Skype by the researcher. The purpose of monitoring was to ensure that no additional variables were involved. The long-distance experiments were conducted under the same requirements as the experiments in person. Long-distance participants were instructed to download Praat to their own laptops as the recording software for production tasks.

3.5. Participants

3.5.1. Participant recruitment

Potential candidates for both bilingual and monolingual groups were recruited through personal contacts, online social circles, newsletter items, and fliers distributed in the library at Newcastle University and Tianjin Foreign Studies University.

The research was framed in the information sheet for the participants as a study to test language change among late/adult bilingualism order to avoid alerting participants to the study's purpose and mentioning the potentially sensitive issue of language attrition. Vague statements for participants regarding the purpose of research are supported by the literature (Wray and Trott, 1998) to avoid situations in which participants attempt to either please or mislead the researcher.

At the first contact, participants were asked several questions about general biographical data as well as information on their L2 acquisition. If the participant met the requirements and was willing to participate in a "linguistic experiment related to language change", they were told what they would be contacted by the researcher later to confirm the time and venue. In the second contact, the time and venue were confirmed with participants, and they were told the experiment duration and the general purpose of the research.

3.5.2. Selection Criteria

The primary subjects were 50 Chinese-English bilinguals drawn from universities in Newcastle and the surrounding areas and 10 native Mandarin speakers from northern China as a control group. Appendix 7.5 provides an overview of basic background data for each group, which is discussed here and referenced in the following chapters.

In order to be eligible, the bilingual participants had to meet certain criteria in addition to the late bilingual and L2 proficiency criteria described above. First, a minimum age of arrival (AOA) was set at 10 years to ensure participants had acquired their first language, Mandarin, completely. The minimum AOA refers to other studies of adult immigrants (de Bot *et al.*, 1991; Schmid and Köpke, 2013), and corresponds with the English learning situation in China. This is very important for Group 60M, who were expected to have resided in an L2 environment for more than five years. Some of them had immigrated during their late childhood/early puberty.

Second, although the maximum age at the time of testing was not restricted in the research, aging itself may have had an impact on language proficiency and usage (Goral, 2004; de Bot and Makoni, 2005). The majority of the participants were selected from different universities and were therefore students, and although the maximum age was set at 50, it turned out that maximum age was not reached as the oldest participant was 35 years old at the time of taking part in the experience.

Third, the minimum proficiency in English was intermediate, which is the equivalent to IELTS 6 (out of 9) or OQPT 35 (out of 60). This was the minimum requirement, which is in line with the literature on SLA and first language attrition that bilinguals' L1 proficiency is related to L2 proficiency (de Bot *et al.*, 1991; Opitz, 2011). Meanwhile, Chinese students who were attending language courses were excluded from the testing because of their likely metalinguistic awareness. Participants who were attending or had attended linguistics-related courses also did not meet the selection criteria due to the fact that they may possess relevant professional knowledge and enhanced metalinguistic awareness that would have affected the results.

All participants' general proficiency in their Mandarin was also assessed in order to limit extra factors. The proficiency for all participants in Chinese was examined by the Putonghua Shuiping Ceshi (PSC)[5], which is compulsory for all university students in China. The aim of the PSC is to assess the degree of standardization achieved by the person tested in their use of Mandarin in terms of phonetics, vocabulary, and grammar. The test has reading, writing, and listening sections. Table 3.5 gives more details. The proficiency in Mandarin required for all participants to be included in the study was First Class, which is the highest proficiency level in the PSC.

Table 3.5 Levels for PSC

Levels	Description
1st	Pronunciation, vocabulary and grammar use are correct. Tones are produced naturally. Expression is fluent in reading and talking. Very few words and the tones are incorrect. The total incorrect rates at this level between 3% and 9%.
2nd	Pronunciation, vocabulary and grammar use are correct in most circumstances. Tones are produced naturally. Expression is fluent in reading and talking. Occasionally, a few difficult sounds (front and back nasal sounds and rhotic sounds) are incorrect. The vocabulary and grammars have some mistakes. The total incorrect rates is between 10% and 20%
3rd	There are mistakes in using tones, vocabulary, and grammar sue. The dialect tones are obvious. Total incorrect rates is between 21% and 40%.

Lastly, in terms of regions of origin, the bilingual and the monolingual group came from the same region to avoid the extra variable of L1 variety differences. The purpose of the research is to test standard Chinese tones, which are based on northern Mandarin – specifically the Beijing dialect. Therefore, the most suitable participants, both the control group and bilingual participants, were from Beijing. Those who were from other cities in northern China, provided their L1 was Mandarin and they scored at the 1st proficiency level, were also acceptable since there was no difference in Chinese tones.

3.5.3. Participant Information

Gender

There were 10 participants in each group with comparable numbers of each gender. In the control group, there were five female participants and five male participants. Bilingual group 06M, 13M, and 36M each contained six female participants and four male participants. Group

[5] Putonghua Shuiping Ceshi is a national assessment framework to examine the proficiency in Standard Chinese.

60M, like the control group, comprised five male and five female participants. Table 3.6 provides details.

Table 3.6 Gender of participants for all five groups

	Control Group	Group 06M	Group 13M	Group 36M	Group 60M
Female	5	6	6	6	5
Male	5	4	4	4	5

Residential Length

Table 3.7 illustrates the length of residence (measured in months) in an L2 English environment for all participants specifically in the UK. Monolinguals – the control group – had no experience of living in an English-speaking environment. Participants in Group 06M were relatively new arrivals to the U.K. The majority had lived for no more than six months in an English-speaking environment. Two participants had 7-month and 12-month stays respectively. Ten participants in Group 13M had lived in the UK for between 13 and 24 months, while three had lived in the UK for 13 months, one for 15 months, three for 18 months, and three for 24 months. Group 48M lived in the UK for between 30 and 48 months. Among the ten participants, one participant had lived there for 30 months, five participants for 36 months, and the remaining four participants for 48 months. Participants recruited for Group 60M had the longest length of residence of all four bilingual groups, namely over 60 months. Four of them had lived in the UK for 60 months, three for 72 months, one for 96 months, and the remaining two for over 120 months (ten years). Tale 3.7 lists details for each participant's residential length in months.

Table 3.7 Residential length for each participant in months

Participants NO.	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Ave.
Control Group	0	0	0	0	0	0	0	0	0	0	0
Group 06M	6	6	6	6	12	6	6	6	7	6	6.7
Group 13M	18	18	15	12	12	24	18	12	24	24	17.7
Group 36M	36	48	36	30	36	48	36	36	48	48	40.2
Group 60M	60	72	60	60	60	72	96	120	72	120	79.2

Age, Age of Arrival (AOA) and Age of L2 Exposure

In the research, participants' actual ages, AOA, and L2 exposure ages were documented. These are presented in Tables 3.8 and 3.9 below. Table 3.8 shows actual ages individually. The average age of the control group was 21.8 years old. The averaged actual ages of each bilingual group increased gradually, and were 22.8, 24.5, 26.1, and 27 respectively. The mean

AOAs of Groups 06M, 13M, and 36M were very similar, namely 22.4, 22.6, and 22.4 respectively. Group 60M had a lower AOA of 20.10. Table 3.9 shows individual AOA.

Table 3.8 Age at the experiment

Participant NO.	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Ave.
Control Group	20	22	21	20	22	19	19	26	30	19	21.8
Group 06M	21	27	21	22	24	22	21	24	25	21	22.8
Group 13M	27	20	28	34	19	25	25	23	20	24	24.5
Group 36M	26	27	28	27	25	25	25	26	27	25	26.1
Group 60M	24	29	29	27	27	27	27	25	28	27	27.0

Table 3.9 Age of arrival (AOA)

Participant NO.	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Ave.
Control Group	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Group 06M	21	27	21	21	23	23	20	23	25	20	22.4
Group 13M	25	18	26	33	18	23	23	22	18	20	22.6
Group 36M	23	21	25	24	22	21	22	23	22	21	22.5
Group 60M	19	23	24	22	22	22	19	13	22	17	20.3

The L2 exposure ages at home and at school for each participant are illustrated below. Table 3.10 shows L2 exposure ages at home. Only around 50% of participants had indicated their L2 exposure ages at home because learning English at home was not common in the childhoods of the participants. Only three participants in the control group indicated their L2 exposure ages at home, which were six, nine, and six years old. Hence, the average at-home exposure age was seven years. Group 06M had an average L2 exposure age of 6.2 years old, with two participants first exposed at age 6, one at age 7, one at 8, two at age 11, and one at age 13. Three participants did not indicate L2 exposure ages. Group 13M also had three participants for whom AOA data was missing. The averaged exposure age of 8.83 years old is based on one participant at age 5, one at 6, one at 7, one at 8, one at 9, and two at 12. Only two participants from Group 36M stated their initial L2 exposure age, identifying these as age five and eight years old respectively. The average L2 exposure age of Group 36M was eight years old. Group 60M had an average of 7 years old, with one participant exposed to the L2 at age 2, one at 5, one at 6, two at 8, one at 9, and one at 12. The other two participants did not indicate L2 exposure age.

Table 3.10 L2 Exposure age at home

Participant NO.	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Ave.
Control Group	N/A	N/A	6	9	N/A	N/A	6	N/A	N/A	N/A	7
Group 06M	N/A	6	N/A	N/A	11	11	6	7	8	13	6.2
Group 13M	N/A	9	12	12	8	N/A	N/A	6	5	7	8.83
Group 36M	N/A	5	N/A	N/A	N/A	11	N/A	N/A	N/A	N/A	8
Group 60M	8	5	8	N/A	9	6	N/A	11	N/A	2	7

On average, the L2 exposure ages at school of the five groups were between 9 years old and 12 years old. However, individual L2 exposure ages at school were diverse. The average age in the control group was 9.33 years old, with large fluctuations. The youngest age of exposure to L2 English was 6, while the oldest was 14. There was one datum not provided. Group 06M had an average exposure age of 9.6 years old, with one at age 6, two at 7, one at 8, one at 9, two at 11, and two at 12. Group 13M had an average L2 exposure age of 11.11 years old, with one at age 6, one at 8, one at 9, one at 11, one at 12, two at 13, and two at 14. Though there was one participant who did not indicate the L2 exposure age, the average age of Group 13M was still the highest among the five groups. Group 36M had an average of 10.5 years old, with exposure ages ranging from 7 to 13 years. Like Group 36M, the L2 exposure age of participants from Group 60M ranged from 7 to 13 years old, with the average age being 10.44. One participant did not provide data. L2 exposure ages at school for each participant are listed below in Table 3.11.

Table 3.11 L2 Exposure age at school

Participant NO.	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**Ave.**
Control Group	8	12	9	9	13	N/A	6	7	14	6	9.33
Group 06M	9	12	12	8	11	11	7	7	6	13	9.6
Group 13M	14	9	14	13	8	11	13	N/A	6	12	11.11
Group 36M	10	7	12	13	9	13	11	8	12	10	10.50
Group 60M	11	13	10	12	13	7	9	11	N/A	8	10.44

Daily Usage of Languages

The results for language of daily use are stated in time percentage for L1 Chinese and L2 English. The hours of usage for one language may exceed 24 hours in a day because the study surveyed in detail when participants used each language, and some activities were carried out at the same time. For instance, a bilingual participant could be watching a Chinese TV show while responding to a friend’s message in English or listening to the radio in Chinese and shadowing it in English to practice English. Hence, in some cases, the language of daily use figures exceeded 24 hours per day. Therefore, a time percentage was used in analysis.

In Table 3.12, the daily use of L1 Chinese demonstrates a U shape for the five groups. The control group had an average of 89.52%exposure time to L1 Chinese, ranging from a minimum of 66.67% usage to the remarkable maximum of 100%. Group 06M, as new arrivals, had only 52.55% usage of native Chinese per day on average, and the majority used Chinese for less than 60% daily. Group 13M had the lowest use of Chinese per day among all five groups, amounting to an average of only 39.46% per day. Similar with Group 06M, the majority of participants from Group 13M used Chinese for less than 60% per day. Group 36M showed a small increase in Chinese usage compared to Group 13M, with an average of 45.12% per day. Group 60M, with the longest length of residence in an L2 English environment, had the largest amount of Chinese usage time among the four bilingual groups, which was not as expected. The average amount of Chinese usage was 56.83% per day, ranging from a minimum of 25% to a maximum of 87.23% per day.

Unlike L1 daily usage, the usage of L2 English daily in Table 3.13 increases gradually. The control group had minor exposure to the L2, with an average of 10.48% per day. Group 06M had an average of 47.45% per day of exposure to L2 English, with large differences in individual daily usage. The shortest amount of exposure took only 11.90% daily, while the longest exposure took 76.9%. Group 13M had an average of 60.54% daily L2 exposure, which was the longest among the four bilingual groups. Four participants had less then 50.00% of daily L2 usage and two participants' L2 daily usage was greater than 75%. Group 36M had an average of 54.88% daily L2 usage. The majority of participants had a L2 daily usage of around 50%, while the minimum L2 daily usage took part in, remarkably, only 11.11% per day. Group 60M had an average of 43.17% daily L2 usage, ranging from 12.77% to 75.00%.

Table 3.12 L1 Chinese daily usage

Participant NO.	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**Ave.**
Control Group	100.00%	90.00%	76.47%	86.15%	82.51%	66.67%	95.83%	100.00%	95.83%	83.33%	89.52%
Group 06M	39.02%	23.08%	41.86%	46.88%	88.10%	70.37%	41.94%	68.09%	56.70%	72.73%	52.55%
Group 13M	35.29%	46.15%	65.00%	20.70%	40.00%	53.57%	17.86%	54.95%	40.79%	50.00%	39.46%
Group 36M	41.67%	49.15%	35.80%	45.51%	33.33%	34.43%	18.42%	88.89%	36.59%	67.68%	45.12%
Group 60M	35.00%	68.00%	80.20%	56.25%	25.00%	53.42%	87.23%	38.46%	55.80%	46.69%	56.83%

Table 3.13 L2 English daily usage

Participant NO.	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**Ave.**
Control Group	0.00%	10.00%	23.53%	13.85%	17.49%	33.33%	4.17%	0.00%	4.17%	16.67%	10.48%
Group 06M	60.98%	76.92%	58.14%	53.13%	11.90%	29.63%	58.06%	31.91%	43.30%	27.27%	47.45%
Group 13M	64.71%	53.85%	35.00%	79.30%	60.00%	46.43%	82.14%	45.05%	59.21%	50.00%	60.54%
Group 36M	58.33%	50.85%	64.20%	54.49%	66.67%	65.57%	81.58%	11.11%	63.41%	32.32%	54.88%
Group 60M	65.00%	32.00%	19.80%	43.75%	75.00%	46.58%	12.77%	61.54%	44.20%	53.31%	43.17%

English Proficiency

The English proficiency of participants was measured twice. The first measurement of English proficiency had been taken prior to their trip abroad for study. Thus, the IELTS was used as the first English proficiency test, since it is compulsory for Chinese students who wish to study in the UK. The second measure of English proficiency was taken at the time of the experiment. It aimed to examine bilinguals' actual English levels after living in the UK for a certain time. The OQPT was used for the second measurement. It was impossible for the researcher to use the IELTS to test all bilinguals again. Thus, the study used the OQPT, which is widely used in the L2 learning literature

The IELTS uses nine-band scales to identify proficiency levels clearly. The OQPT has six-band scales to classify levels of English proficiency quickly and reliably. Since these two tests have different scales, the results were interpreted using the Common European Framework of Reference for Language (CEFR). A detailed description of CEFR levels can be found in Appendix 7.7. A one-way ANOVA was used to compare English proficiency levels between groups. and it indicated no significant differences in English proficiency on the IELTS.

Table 3.14 IELTS results

Participant NO.	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**Ave.**
Control Group	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Group 06M	6.5	8	7.5	6.5	7.5	6	6.5	6.5	7	6.5	6.5
Group 13M	8	6.5	7	105(7.5)	7	6	7	8	7	8	8
Group 36M	7	7	7	7	7	8	6.5	6.5	7	6.5	7
Group 60M	7.5	7	7	7.5	5.5	7.5	6.5	N/A	770 (7)	6	7.5

Table 3.15 demonstrates the results of the second measurement of English proficiency. The level of English proficiency of the control group was lower than the other four bilingual groups. The English proficiency of each participant interpreted in terms of a CEFR level is illustrated in Appendix 7.7.

Table 3.15 OQPT results

Participant NO.	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**Ave.**
Control Group	28	29	37	39	38	42	41	26	31	41	35.2
Group 06M	48	54	38	36	53	39	40	38	49	47	44.2
Group 13M	52	35	43	57	46	41	31	56	43	52	45.6
Group 36M	50	41	46	45	50	56	49	44	49	35	46.5
Group 60M	46	54	48	40	41	47	49	57	33	41	45.6

3.5.4. Data Collection Procedure

The majority of data collection was conducted in a quiet and soundproof room. The researcher went back to China to collect data from the control group. Five participants' data was collected online, and they were asked to complete the experiments in a quiet room of their choosing and finish the tasks with no interruption. The researcher monitored those experiments via Skype in their entirety. However, the data collected online were considered to be backups and ultimately not analysed.

Before the experiment began, participants were asked to read an information sheet that provided very brief information about the research, procedures and stimuli, benefits and risks, confidentiality, data storage and usage, and dissemination of results. If participants were willing to continue, they were asked to read the risk assessment again and sign the consent form. It was reiterated to the participants that they had the right to quit the experiment at any time and that their data would then be destroyed immediately.

Once the participants agreed and were ready to continue with the experiment, they started by listening to the two perception tests. An example was given to the participants before the full recording to ensure full understanding of the procedure and that participants were not anxious during the tests. Participants were given a two-minute break before they started Task 1B.

After approximately 30 minutes of listening, participants were given a five-minute break to relax. Then the researcher explained the procedure of the production tasks step by step and mentioned that a digital recorder would record all production. The researcher interacted with participants for a while to lower their stress before they started.

The reading material of Task 2A was given to participants, who were asked to read clearly in Chinese using their normal reading speed. Moreover, they were instructed to keep reading continuously even if they thought any mistakes had occurred and told there was no need to pause and restart. They were, however, encouraged to correct any sound that they thought was a mistake and then continue to read. Task 2A was generally completed in 3-4 minutes. The reading material of Task 2A was taken from participants immediately when Task 2A was completed. A one-minute break was then given. Then participants started Task 2B, retelling the story they had just read. A list of key words and phrases was handed to the participants, who were requested to retell the story using their own words. The list was to help them to remember. They were told that it was not necessary to include all of the key words and phrases. However, all participants used all key words and phrases given in the retelling of their stories, which made it easier to compare the data collected from Tasks 2A and 2B. The completion time of Task 2B was also 3-4 minutes. As in Task 2A, the list of key words and phrases was taken from them after their retelling, and a one-minute break was given.

Then participants moved on to Task 2C, where they were asked to describe two short videos in Mandarin after a briefing by the researcher on how to describe the videos. They were encouraged to describe everything shown. However, they were not restricted to describing what was in the videos; they were also encouraged to produce their own thoughts and made their own comments through personal experience related to the videos.

Participants were told what they would be seeing and were informed that the two videos contained some screaming from people in the video in the distance, which would elicit an emotional reaction. Meanwhile, the researcher told them that they would be asked to describe the videos as much as they could without too many pauses between sentences. After the researcher confirmed their willingness, they were shown the two videos. Participants were also asked to wear headphones to block out the audio, partly because in Video Two, there were potentially distressing contents, but also because the speaking volume of participants automatically increased while they listened to a noisy video (Spolsky and Sigurd, 1968). Task 2C was completed within six minutes.

The production tasks as a whole generally took between 11 to 15 minutes. Section 3.3.2 (page 46) explains the procedure. When participants completed the production tasks, they were informed that the main part of the current experiment had been completed. They were given a two-minute break to rest and then asked to complete the English test. The OQPT English test was timed and 20 minutes were allowed to the participants, followed by a two-minute break.

Then, the last part of the testing instrument, the questionnaire, was given to participants, who had the choice of complete it online or in written hand copy form. The time of completion was also restricted to 20 minutes. Two thirds of participants used printed versions of the questionnaire and the other one third used the online questionnaire. Some participants did the experiment in person but completed the survey online due to a personal preference for typing over writing.

Once they completed the experiment, participants were given a debriefing sheet about the purpose of the research, the researcher’s signature, and the contact information of the researcher. If they were interested in the results and analysis, they could email to the researcher, who would then inform them by post or email once the results and analysis were complete. The whole experiment took 1 hour and 40 minutes on average, ranging from 1 hour and 20 minutes to 2 hours.

For long-distance participants, the instructions for the experiment were given by the researcher via a Skype face-to-face meeting as stated above. Participants were asked to complete the stimuli in a quiet or soundproofed room. Their productions were recorded via Praat to ensure quality of sound. During the experiment, the researcher was observing via muted Skype to ensure the procedure were followed.

3.6. Summary

This chapter introduced and discussed the methodology designed for the study, the experiment procedure, and difficulties and problems that occurred in the actual process. Based on previous research, stimuli included tasks for L1 tone perception and production as well as a questionnaire on language exposure and backgrounds. Criteria in terms of age, gender, and language proficiency for subjects were determined at participants’ recruitment to avoid extra variables that could influence the results.

The following chapter, Chapter 4, presents the results of all data collection phases for the bilingual and monolingual groups.

Chapter 4. Results

This and the following chapter present and discuss the data elicited with reference to the four hypotheses posed in the previous chapter, which are listed again below for ease of reference:

1. Mandarin-English bilinguals will demonstrate attrition on three tones in Mandarin, namely T2, T3 and T4.

   1a. The order of attrition by degree expected is T3 > T2 > T4. (That is, tone attrition will mirror the acquisition order for children on L1 attested in the L1 acquisition literature.)

   1b. This will be demonstrated on both production and perception tasks.

2. Attrited T3 will be produced with either half rising part or falling part.

3. Amount of use of L1 and/or L2 will affect attrition, as measured by years of UK residence and interaction in the dominant language, English.
4. Tone attrition will be in more evidence in casual contexts than in formal situations.

This chapter presents the data from five groups of bilinguals and monolinguals for three stimuli sections: the language and background questionnaire, perception tasks, and production tasks. In each section, the data is listed separately by group. Analysis and discussion will be presented in the Chapter 5.

4.1. Language and Background Questionnaire

The results of the questionnaire are presented below in four categories: gender, length of residence in L2 environment, age (including actual age, age of arrival (AOA), and age of L2 exposure), language of daily use, and English proficiency. Appendix 7.7.presents detailed p-values.

Gender

In order to exclude the gender issue, participants in each group were recruited based on roughly equal numbers of males and females. Please refer to Table 3.6 above. There were no significant differences based on gender.

Residential Length

Significant differences exist not only between the control group and each bilingual group, according to an independent t-test, but also within the four bilingual groups, according to multi-comparison. The *p*-values are all less than 0.05.

Actual Age

No significant differences, as we will see, were detected when comparing the control group with either Group 06M or Group 13M separately. Significant differences exist for Group 36M (p-value=0.002) and Group 60M (p-value=0.000) when compared with the control group via an independent t-test.

AOA

Since the control group had no AOA, a one-way ANOVA was used to test differences between bilingual groups. There were no significant differences between the four bilingual groups in multiple comparisons.

L2 Exposure Age

No significant differences were detected via an independent t-test comparing the control group and the other four bilingual groups respectively on L2 exposure ages at home or at school.

Daily Usage of Languages

The bilingual groups 06M, 13M, and 36M had significant differences in daily L1 Chinese usage compared with the control group. The *p*-values were 0.032, 0.007, and 0.009 respectively. However, the bilingual group 60M showed no significant difference in daily L1 use compared with the monolingual control group. The *p*-value was 0.234.

It is apparent that significant differences existed in L2 daily usage between the control group and the four bilingual groups, 06M, 13M, 36M and 60M, for which the *p*-values were 0.002, 0.001, 0.000, and 0.001 respectively.

English Proficiency

The English proficiency of the four bilingual groups differed from the control group significantly, such that the p-value for each bilingual group was less than 0.05. Detailed results of the pre-test and post-test and statistical analysis are given in Table 3.14, Table 3.15

above and Appendix 7.7. The English proficiency of each participant interpreted in terms of a CEFR level is illustrated in Appendices 7.8

4.1.1. Summary

This chapter presents the results and includes the data for tone perception and production and linguistic backgrounds for monolingual and bilingual participants. The analysis applies one-way ANOVAs and independent t-test in order to compare data through a quantitative approach within groups and tasks. The four bilingual groups retained their abilities to perceive tones as compared to the control group. The bilingual groups demonstrated low error rates in perceiving tone pairs, tone sandhi, and tone variations, with no significant differences detected when compared to the control group.

Bilingual groups had different tone productions compared to the control group. The difference is demonstrated on tone 3 of Groups 36M and 60. These two groups tended to produce tone 3 with shortened or no rising part during the tasks. Apart from tone 3, there are no major significant differences detected on other tones, tone sandhi, and tone variations.

Within each group, the numbers of male and female participants were generally equal. All participants were from same generation and had similar AOAs. L2 study requirements are strict in China’s domestic education system, so participants were exposed to the L2 at school at about the same age. The majority of them were exposed more to an L2 environment at school verses at other places. Bilinguals maintained English proficiencies at an intermediate level after moving to the L2 domain, regardless of the length of residence. However, language contacts for both L1 and L2 were diverse. The control group had maximum L1 contact and minimum L2 contact. L1 contacts of the four bilingual groups demonstrated a U shape, while L2 contacts showed an inverted U shape.

The data presented above will be discussed in Chapter 6 in terms of L1 attrition in Mandarin tones and the potential factors that lead to attrition.

4.2. Tone Perception

The perception element contained two tasks. Each task consisted of 99 tonal combinations, including tone pairs, tone phrases, tone sandhi, tone 4 variation, and *yi* tone variations. Table 4.1 below presents the different combinations of the four tones, marked with X. Black cells are tone sandhi T3T3 and tone 4 variation T4T4, which are excluded from regular tone pairs. In Table 4.1 and 4.2, black cells present invalid tone variations.

Table 4.1 Tone pairs tested

Tone pairs				
	T1	T2	T3	T4
T1	X	X	X	X
T2	X	X	X	X
T3	X	X		X
T4	X	X	X	

Table 4.2 Tone variations tested

Tone Variations			
	T2	T3	T4
T1(*yi* tone variations)	X	X	X
T3		X	
T4			X

Task 1A was a multiple-choice task involving choosing the appropriate tones from among three options while listening to a recording. In this task, 28 tone pairs, 26 T3 sandhi, 20 T4 variations, and 3 *yi* tone variations were randomly inserted into 99 tonal combinations. In total, each group (N=10) had 280 tone pairs, 260 T3 tone sandhi, 200 T4 variations, and 30 *yi* tone variations.

Task 1B was an ABX discrimination task with two types of options: ABA pairs and ABB pairs. Participants needed to decide whether X was the same tone as A or B. There were 99 total tonal combinations, including 28 tone pairs, 26 T3 sandhi, 23 T4 variations, and 2 *yi* tone variations.

4.2.1. Data Analysis

An appropriate choice for a tone combination was marked as 0, while an incorrect choice was marked as 1. The results for tone perception are presented separately as an error rate in figures and tables and were analysed using a series of independent t-tests in SPSS comparing the control group and the other four bilingual groups respectively. The error rate of a tone pair or a tone variation is the sum of incorrect marks divided by the total possible marks for the tone pairs or tone variations. Thus, a high score presented by any bilingual group indicated attrition.

4.2.2. Task 1A: Multiple Choice

The results of Task 1A are presented in two separate sections: tone pairs are shown in Figure 4.1 and tone variations are shown in Figure 4.2. Tone pairs are combinations of four tones. Tone sandhi T3T3 and tone 4 variation (T4T4) are tone variations instead of tone pairs. Detailed error rates are shown in Table 4.3 and Table 4.4. Tone pairs with a 100% accuracy rate will not be presented. Diagonal down cell insure tone pairs are perceived correctly for a corresponding group. Tone pairs with 100% correct perception are represented by slashes.

All five groups presented low error rates in all tested tone pairs. The majority of tone pairs' error rates were 5% or less. Group 13M had 10% error rates for both T22 and T43 pairs. Group 36M showed 9% and 10% error rates for T22 and T42 pairs respectively. Group 60M only had a 10% error rate for T24 pairs. There were no significant differences in all tone pairs tested via an independent t-test.

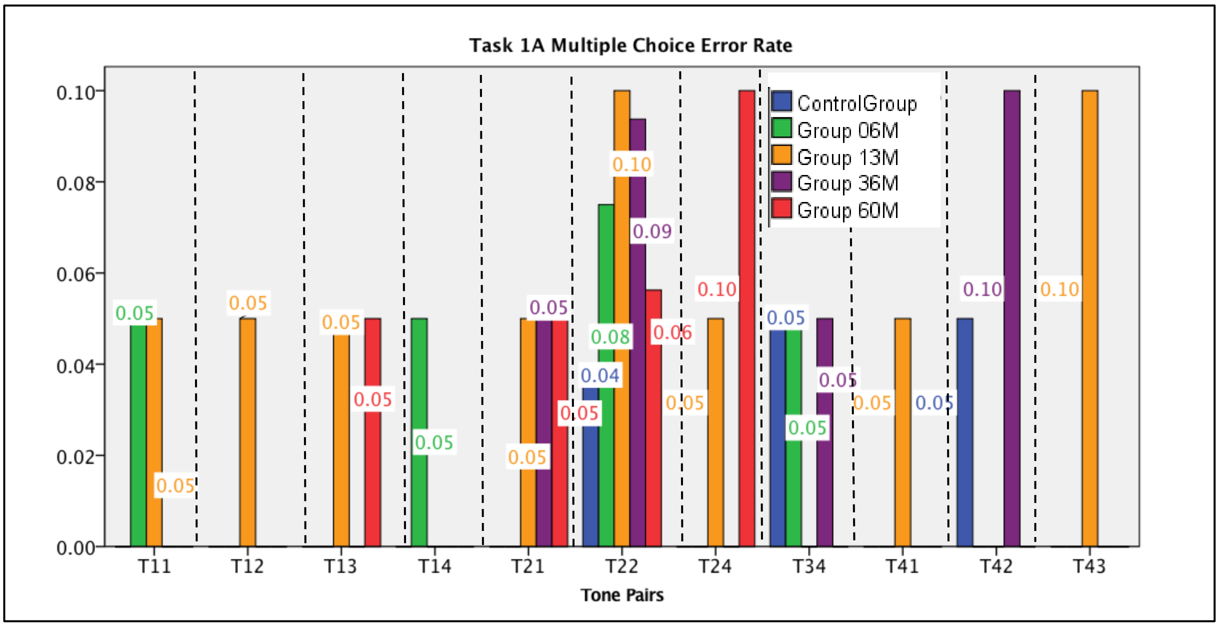


Figure 4.1 Task 1A multiple choice tone pair error rate in proportions

Table 4.3 Task 1A multiple choice: error rate of tone pairs

Tone Pairs	Control Group	Group 06M	Group 13M	Group 36M	Group 60M
T22	0.04	0.08	0.10	0.09	0.06
T21			0.05	0.05	0.05
T34	0.05	0.05		0.05	
T11		0.05	0.05		
T13			0.05		0.05
T12			0.05		
T24			0.05		0.10
T14		0.05			
T42	0.05			0.10	
T41			0.05		
T43			0.10		

Unlike the tone pair data, the perception of tone variation data from in Task 1A's multiple choice test showed diverse results. Tone sandhi T33 had the highest error rates among all tone variations. The error rates of all five groups on tone sandhi were around 30%. Group 13M made the most errors, with errors totalling exactly 30%. Group 36M had the lowest error rate among the four groups, which was 26%. Since the numbers of all five groups were close to each other, there were no significant differences between the four bilingual groups and the control group.

The error rate for Tone 4 variation showed a descending curve in general, from the control group's 8% to the lowest rate of 3% for Group 60M. Group 13M was the only group that showed a 10% error rate for *yi* T1→T2 variation. On the contrary, Groups 13M and 36M made no errors in the perception of *yi* T1→T4 variation. The other three groups each demonstrated a 5% error rate. Significant differences did not exist for tone sandhi or tone variations between the control group and the other four groups respectively.

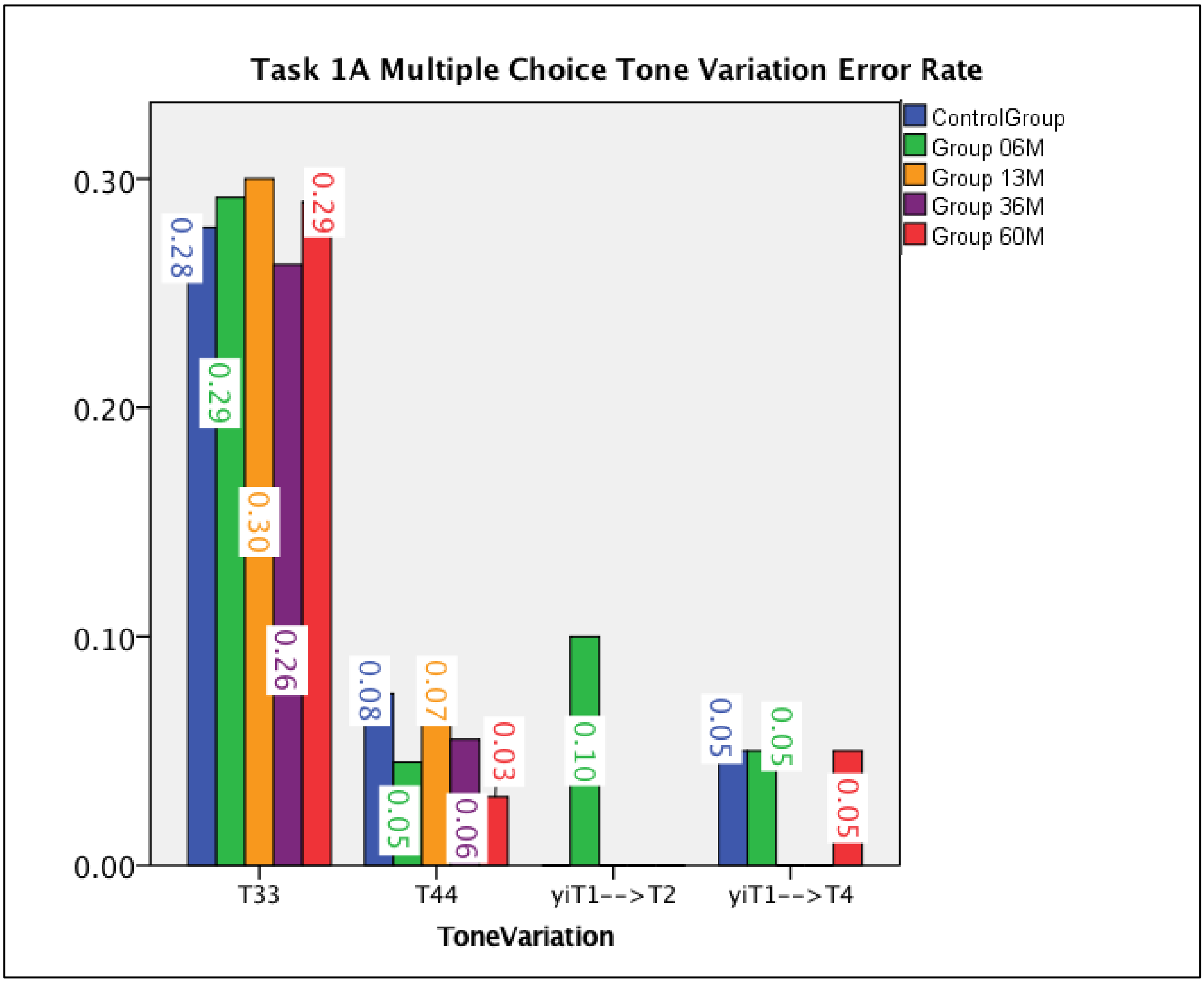


Figure 4.2 Task 1A multiple choice tone variation error rate

Table 4.4 Task 1A multiple choice: error rate of tone sandhi and tone variations

			Control Group	Group 06M	Group 13M	Group 36M	Group 60M
Tone sandhi		T33	0.28	0.29	0.30	0.26	0.29
Tone variations		T44	0.08	0.05	0.07	0.06	0.03
	yi	T1→T2	0.00	0.10	0.00	0.00	0.00
		T1→T4	0.05	0.05	0.00	0.00	0.05

4.2.3. Task 1B: ABX

In Task 1B, the perception of the majority of tone pairs showed low error rates among all five groups. The control group made some errors in detecting T13, T22, and T23, which amounted to 15%, 6%, and 5% respectively. Group 06M's perception errors for T22, T23, T34, and T41 were less than or equal to 5%. For T43, Group 06M presented the highest error rate, at 10%. Group 13M had incorrect perceptions of seven tone pairs, which was the highest among the five groups. The perception errors occurred for T13, T21, T22, T34, T42, and T43 with a 5% error rate, and a 10% error rate for T41. Group 36M had the smallest number of incorrectly perceived tone pairs. The error rate for T22 was only 2%, while the other two pairs with errors, T23 and T32, had 5% error rates. Group 60M perceived the majority of tone pairs with a 100% accuracy rate. Perception errors in Group 60M occurred for T12, T14, T22, and T23, which had a 5%, 10%, 4%, and 5% error rates respectively.

An independent t-test showed no significant differences when comparing the results for the control group with those for each of the four bilingual groups.

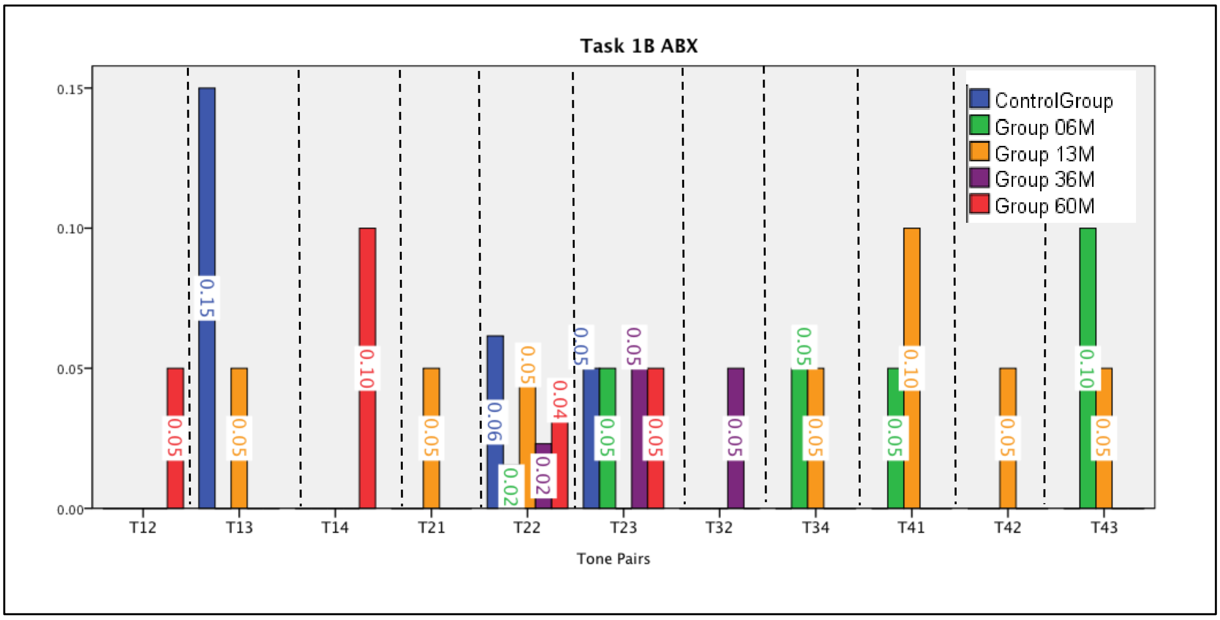


Figure 4.3 Task 1A ABX tone pair error rate

Table 4.5 Task 1B ABX: Error Rate of Tone Pairs

Tone Pairs	Control Group	Group 06M	Group 13M	Group 36M	Group 60M
T12					0.05
T13	0.15		0.05		
T14					0.10
T21			0.05		
T22	0.06	0.02	0.05	0.02	0.04
T23	0.05	0.05		0.05	0.05
T32				0.05	
T34		0.05	0.05		
T41		0.05	0.10		
T42			0.05		
T43		0.10	0.05		

Figure 4.3 illustrates the results for the incorrect perception of tone pairs tested by the ABX task. It is clear that the majority of tone pairs were perceived correctly by all five groups, and that the error rates for tone perception were very low. The control group showed 15%, 6%, and 5% error rates for T13, T22, and T23 respectively. Group 06M had a 2% error rate for T22 and 5% error rates for T23, T34, and T41. Group 13M had the most incorrect responses in this task compared with the other four groups, with 5% error rates for T13, T21, T22, T34, T41, T42, and T43. Group 36M only incorrectly perceived the tones in the T22, T23, and T32 pairs, with error rates of 2%, 5%, and 5% respectively. Group 60M made errors in the perception of T12 with an error rate of 5%, T14 with an error rate of 10%, T22 with an error rate of 4%, and T23 with an error rate of 5%.

Error rates for tone sandhi and tone variations in the ABX task are illustrated in Figure 4.4 and Table 4.6. Similar to the Task 1A multiple choice task, the control group and the four bilingual groups made some errors in the perception of tone sandhi, with respective error rates of 17%, 13%, 20%, 20%, and 15%. The error rates for the perception of T4 variation were much lower than for tone sandhi: they were all under 10%. Meanwhile, *yi* tone variations presented two different results: all participants perceived T1 to T2 *yi* variation with 100% accuracy, while T1 to T4 *yi* variation yielded 10% or 20% error rates for different groups. There were no significant differences in tone pairs and tone variation from Task 1B.

4.2.4. Summary

The control group and each of the four bilingual groups presented similar error rates in both Task 1A multiple choice and Task 1B ABX. In each task, the error rates for normal tone pairs were generally lower than for tone sandhi and tone variations. The majority of tone pairs' error rates were lower than 10% in both tasks. Error rates for tone sandhi and tone variations were varied. However, there were no significant differences between the control group and each bilingual group in any of the perception tasks.

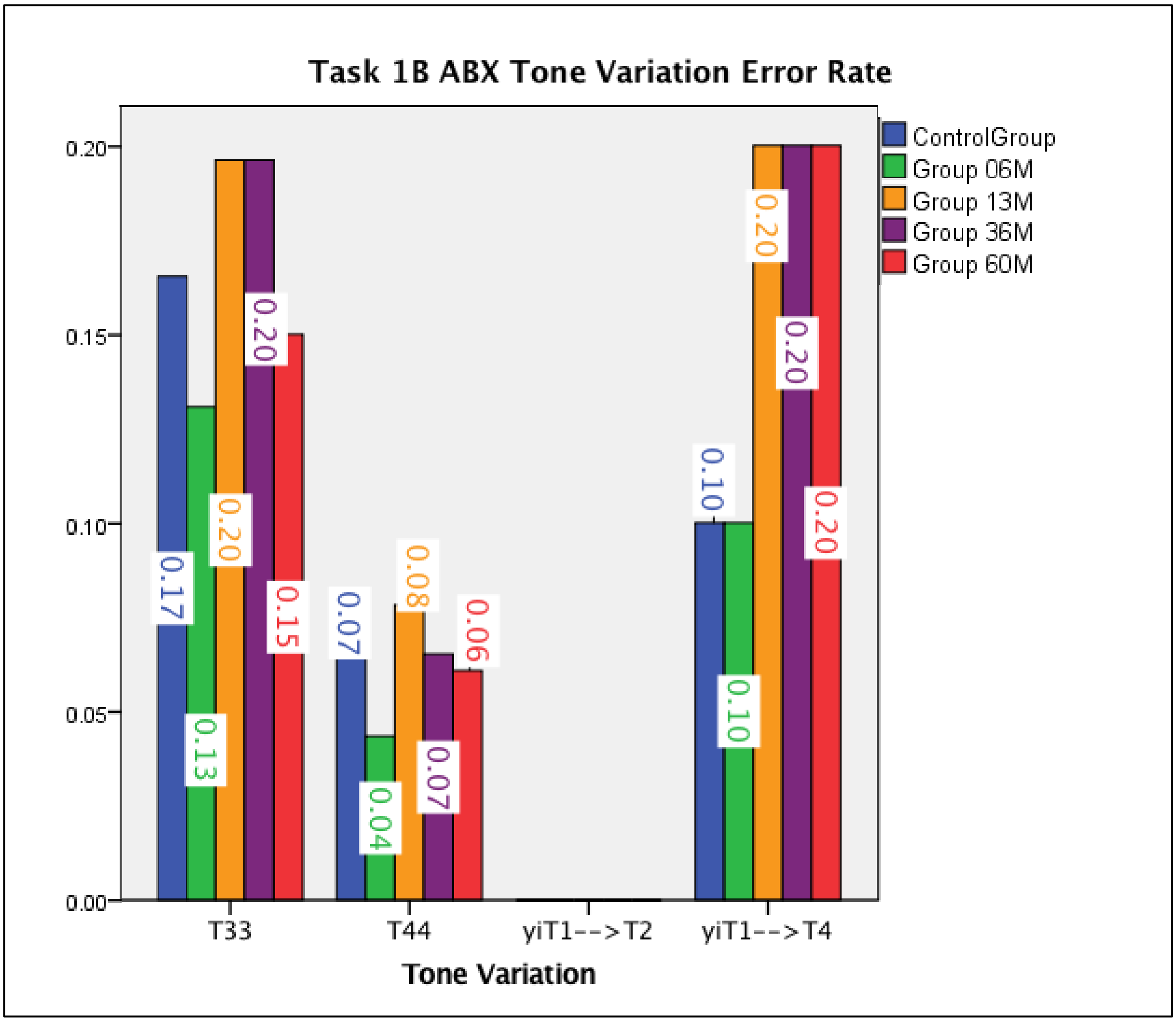


Figure 4.4 Task 1B ABX tone variation error rate

Table 4.6 Task 1B ABX: error rate of tone sandhi, and tone variations

			Control Group	Group 06M	Group 13M	Group 36M	Group 60M
Tone Sandhi	T33		0.17	0.13	0.20	0.20	0.15
Tone Variation	T44		0.07	0.04	0.08	0.07	0.06
	yi	T1→T2	0.00	0.00	0.00	0.00	0.00
		T1→T4	0.10	0.10	0.20	0.20	0.20

4.3. Tone Production

The results for tone production are presented below by task: the Task 2A read-aloud task involving reading a story, the Task 2B story retelling task, and the Task 2C video description task. The results for each tone are explained, followed by the results for tone variation and tone sandhi production.

4.3.1. Data analysis

From every participant, 10 samples were collected for each tone to provide 10*4*50 = 2000 valid samples. All samples were manually extracted. Syllables starting with nasal or lateral consonants or with no consonants were not included in the analysis because they have significant acoustic differences in pitch contour as compared with other consonants (Howie, 1976; Shi, 1987). Figure 4.5 demonstrates an example spectrogram of Tone 4.

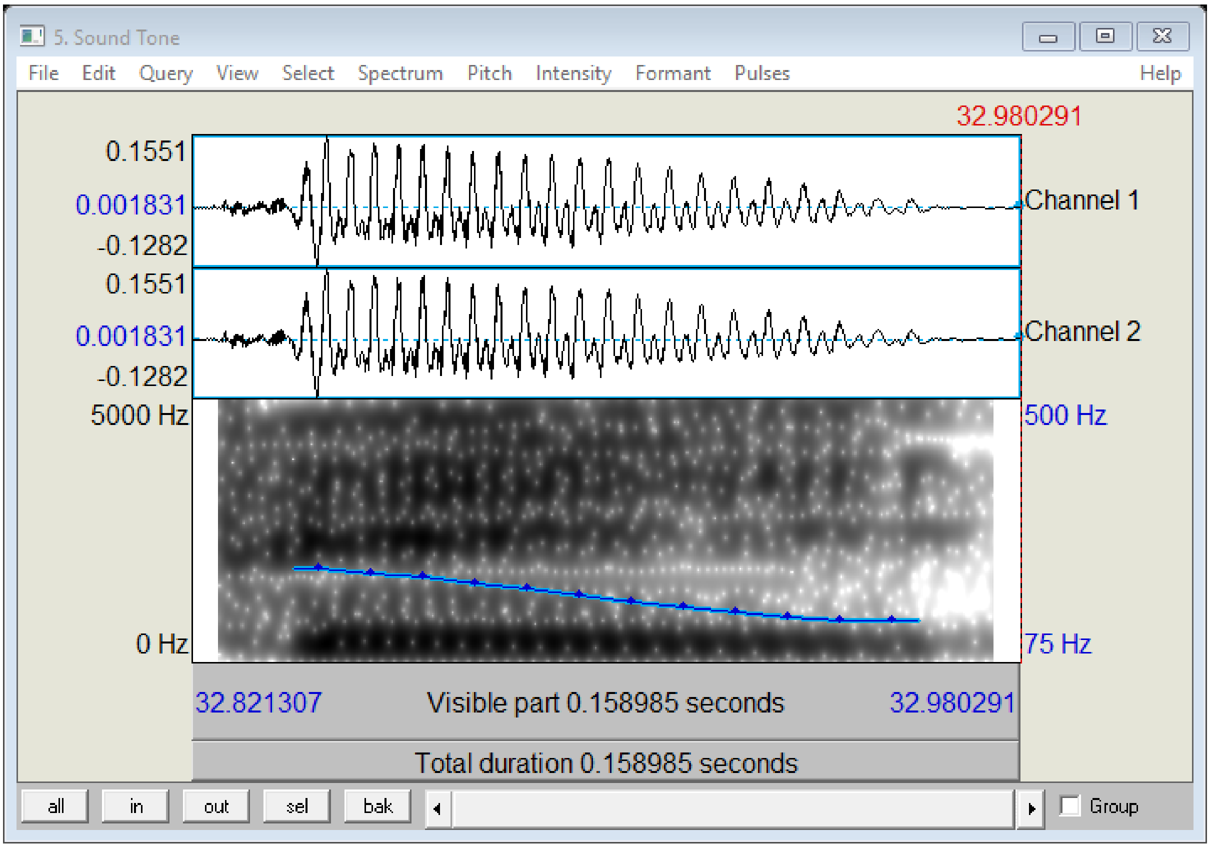
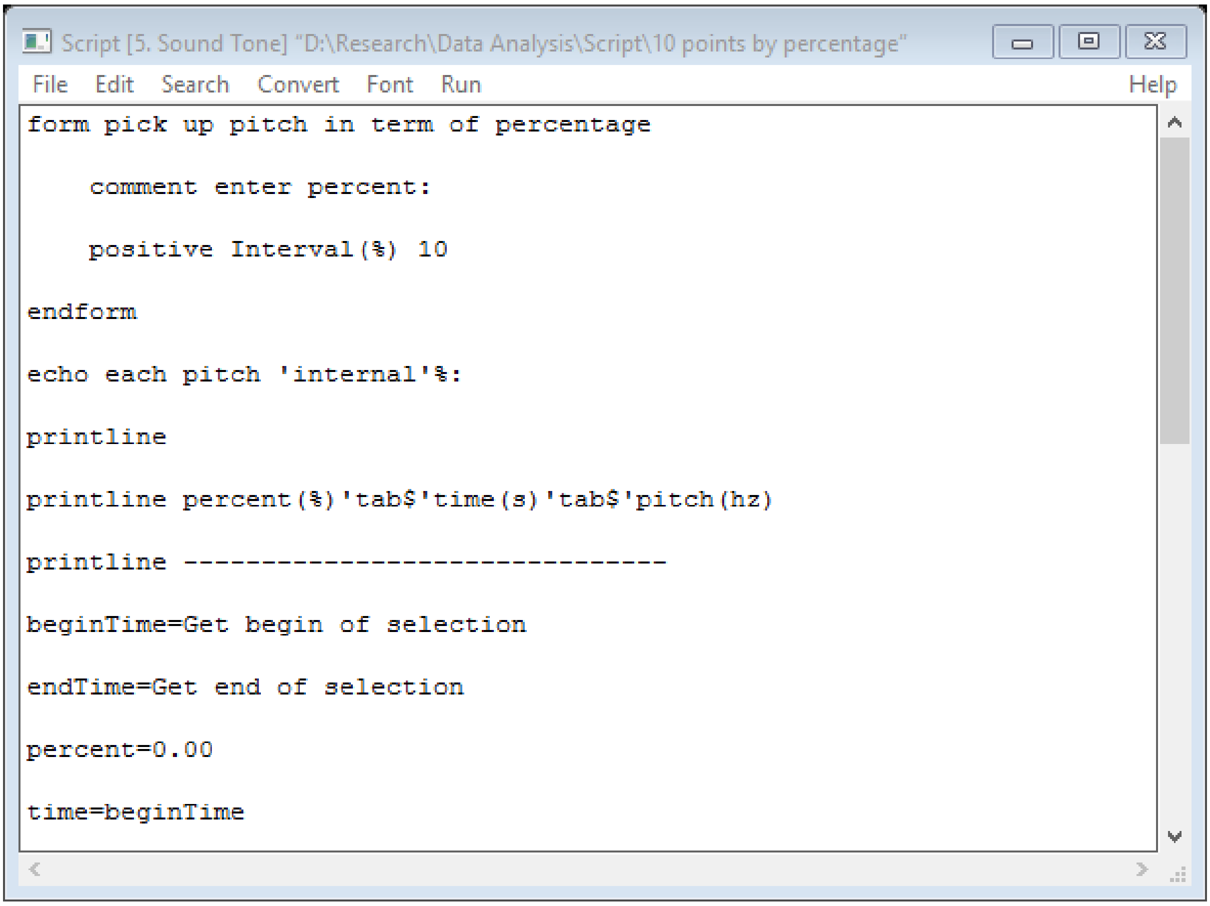


Figure 4.5 Example of manually extracted Tone 4 spectrogram

Only the nucleus in the syllable carries a tone, and this is extracted from the second glottal pulse. The first glottal pulse is always excluded in acoustic measurement because the tongue is not in position and the amplitude is too small to be heard when producing the vowel (Lisker

& Aramson, 1963; Baken, 1987; Zhu, 2008). In a linguistic context, this feature is more apparent in acoustic analysis. The end points are different for different tones. For T1 and T4, the tone ends at regular intervals at the end of the pitch contour of the nucleus. The end points of T2 and T3 are the peak of the pitch contour of the nucleus.

Each token was analysed in Praat. The pitch range of each subject was between 50Hz and 500Hz, and was hand-adjusted in some cases using narrow band spectrograms. An F_0 measurement was taken at every 10% of a tone nucleus duration by running a Praat script, namely Ten Points, based on the concept of Five Degrees of Tone (T-value) (Shi, 1986), T-value script (Shi and Wang, 2006b) and the Time Normalized f_0 script (Xu and Xu, 2005). Please see Figure 4.6 below.




```
form pick up pitch in term of percentage

    comment enter percent:

    positive Interval(%) 10

endform

echo each pitch 'internal'%:

printline

printline percent(%)'tab$'time(s)'tab$'pitch(hz)

printline -------------------------------

beginTime=Get begin of selection

endTime=Get end of selection

percent=0.00

time=beginTime
```

Figure 4.6 Praat Script Ten Points

The first F_0 measurement ($1F_0$) was at 5% of the normalized duration to eliminate the carry-over effect. The $2F_0$ to $9F_0$ measurements were at 15%, 25%, 35% … 65%, 75%, and 85% of the normalized time of the nucleus. $10F_0$ is at 95% of the normalized time, and aims to eliminate the influence of the following tones as well. Please see Figure 4.7 below. Thus, this yielded 10 f_0 measurements, which were normalized as in Equation 4.1 below to calculate the t-value.

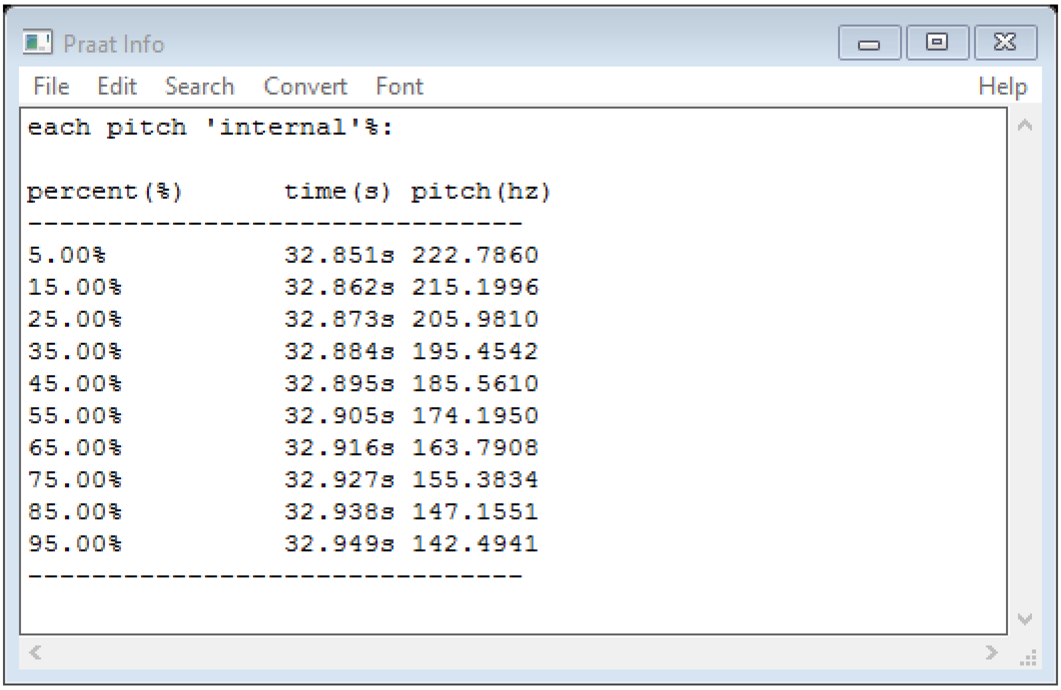


Figure 4.7 Example pitches of ten measurement

Equation 4.1 : T-value calculation (Shi and Wang, 2006a; Liang and Meng, 2013)

$$T_{f_0} = \left\{ {log10 f_i - log10(f_{min} - f_{st.s})} \middle/ {log10(f_{max} + f_{st.s}) - log10(f_{min} - f_{st.s})} \right\} * 5$$

In Equation 4.1, f_i is not a single F_0 value from a participant. It is the averaged F_0 value at one F_0 measurement of 10 samples from a participant, represented by the lower case “f_0”. An example is shown in Table 4.17 below.

Hence, for one participant in a task, there are forty averaged f_0 values for all four tones. f_{min} presents the minimum f_0 value, f_{max} is the maximum f_0 value, and $f_{st.s}$ is the sample standard deviation f_0 value of the forty averaged f_0. The use of $f_{st.s}$ is to raise and lower the maximum and minimum f_0 values, which could provide more appropriate results for large data analysis. T_{f_0} presents the T-value, which uses a normalized 1-5 numerical scale based on the traditional tone pitch range proposed in Chao’s Letters (1948, 1968).

Table 4.7 Example $\boldsymbol{F_0}$ measurements of Tone 4

Example Participant	Token 1	Token 2	Token 3	Token 4	Token 5	Token 6	Token 7	Token 8	Token 9	Token 10	Ave.		T-value
Tone 1													
$1F_0$	166.34	158.55	131.13	119.96	126.64	148.16	173.45	195.10	137.92	122.38	147.96	$1f_0$	3.89
$2F_0$	166.05	158.16	131.27	119.94	126.44	148.50	173.76	195.05	137.81	122.18	147.92	$2f_0$	3.89
$3F_0$	165.58	157.65	131.28	119.96	126.08	149.02	173.93	194.97	137.61	121.85	147.79	$3f_0$	3.88
$4F_0$	165.01	157.23	131.27	120.02	125.75	149.68	174.23	194.86	137.31	121.41	147.68	$4f_0$	3.88
$5F_0$	164.70	157.37	131.46	120.15	125.85	150.44	174.99	194.70	136.89	121.05	147.76	$5f_0$	3.88
$6F_0$	165.07	158.10	131.86	120.42	126.28	151.19	176.24	194.68	136.43	120.95	148.12	$6f_0$	3.90
$7F_0$	166.21	158.95	132.17	120.80	126.52	151.68	177.39	194.67	136.03	121.19	148.56	$7f_0$	3.92
$8F_0$	167.75	159.38	132.40	120.79	126.45	151.83	177.92	194.52	135.92	121.61	148.86	$8f_0$	3.93
$9F_0$	167.85	159.47	132.74	120.96	126.21	151.64	177.92	194.37	135.77	121.85	148.88	$9f_0$	3.93
$10F_0$	169.10	159.43	132.86	121.32	126.16	151.53	177.87	194.27	135.55	121.96	149.00	$10f_0$	3.94
Tone 2													
F1	103.17	119.13	109.20	100.61	123.00	112.24	104.65	101.77	106.26	107.03	108.71	$1f_0$	1.99
F2	103.30	120.06	109.76	100.45	123.34	112.25	104.77	101.94	106.34	107.43	108.97	$2f_0$	2.01
F3	103.50	121.36	111.52	100.26	124.15	112.27	104.96	102.04	106.43	108.59	109.51	$3f_0$	2.04
F4	103.78	123.25	115.91	100.07	125.77	112.40	105.24	101.66	106.30	110.92	110.53	$4f_0$	2.10
F5	104.29	125.91	123.55	100.00	128.65	112.72	105.66	100.90	105.96	114.56	112.22	$5f_0$	2.19
F6	105.09	129.51	133.24	100.03	132.69	113.21	106.28	100.02	105.74	119.60	114.54	$6f_0$	2.31
F7	106.17	133.70	142.86	100.13	137.32	113.86	107.10	99.48	106.45	126.06	117.31	$7f_0$	2.46
F8	107.37	136.97	150.41	100.20	136.60	113.83	108.01	99.33	108.64	132.51	119.39	$8f_0$	2.57
F9	107.37	137.56	151.86	100.22	140.14	114.32	108.07	99.38	109.41	136.84	120.52	$9f_0$	2.63
F10	108.23	139.98	155.10	100.24	143.22	114.77	108.76	99.50	111.47	137.66	121.89	$10f_0$	2.70
Tone 3													
F1	107.25	101.21	101.30	104.22	103.34	101.09	104.02	110.07	111.34	101.09	104.49	$1f_0$	1.75
F2	106.36	100.89	101.59	104.18	103.16	101.06	103.88	109.59	110.08	100.97	104.18	$2f_0$	1.73
F3	103.71	100.35	101.99	104.08	102.80	100.98	103.61	108.38	105.51	100.76	103.22	$3f_0$	1.67

F4	100.10	99.63	102.25	103.90	102.21	100.69	103.21	106.39	99.96	100.69	101.90	$4f_0$	1.59
F5	97.63	99.17	102.32	103.63	101.53	100.12	102.72	104.42	97.41	100.63	100.96	$5f_0$	1.54
F6	96.54	99.19	102.29	103.23	100.66	99.31	102.16	103.01	96.86	100.38	100.36	$6f_0$	1.50
F7	95.87	99.58	102.35	103.10	99.36	98.32	101.54	102.45	96.65	99.90	99.91	$7f_0$	1.47
F8	95.10	100.04	102.47	103.10	97.83	98.27	100.90	102.72	96.06	99.31	99.58	$8f_0$	1.45
F9	94.48	100.21	102.55	102.70	97.55	97.67	100.60	103.52	94.94	98.78	99.30	$9f_0$	1.44
F10	94.31	100.44	102.62	102.33	96.64	97.08	100.34	103.72	94.37	98.51	99.04	$10f_0$	1.42
Tone 4													
F1	162.44	150.30	173.96	156.42	153.35	145.60	166.46	162.26	159.66	137.06	156.75	$1f_0$	4.25
F2	161.96	149.51	171.89	155.63	151.92	144.82	165.99	160.46	157.55	135.84	155.56	$2f_0$	4.20
F3	161.21	147.74	166.35	153.72	148.92	143.78	165.34	156.48	152.20	133.14	152.89	$3f_0$	4.09
F4	160.08	144.64	156.66	149.40	143.86	142.46	164.43	149.54	143.96	128.23	148.33	$4f_0$	3.91
F5	158.58	140.33	144.56	143.41	137.58	140.83	163.53	141.84	135.16	122.04	142.79	$5f_0$	3.67
F6	157.02	135.61	132.23	135.97	131.64	138.80	162.99	134.81	127.52	115.95	137.25	$6f_0$	3.43
F7	155.58	131.18	121.06	128.11	126.80	138.20	162.91	128.80	121.73	110.87	132.52	$7f_0$	3.21
F8	154.95	127.61	112.20	121.04	123.24	137.91	162.87	123.87	118.10	106.87	128.87	$8f_0$	3.04
F9	154.66	127.28	106.92	119.02	122.99	136.52	163.05	120.75	116.60	105.96	127.38	$9f_0$	2.97
F10	153.90	125.39	105.90	115.55	121.10	135.48	163.54	119.73	116.16	103.94	126.07	$10f_0$	2.91
										MAX f_0	156.75		
										MIN f_0	99.04		
										STD.S	20.37		
Equation	$T_{f_0} = \{ {log10 f_i - log10(f_{min} - f_{st.s})} \big/ {log10(f_{max} + f_{st.s}) - log10(f_{min} - f_{st.s})} \} * 5$ *(Shi and Wang, 2006a)*												

4.3.2. Task 2A: Reading aloud

In this section, the results are illustrated in two parts. The first part is the T-value results for the four tones and the second part is the results of the tone sandhi and tone variations. For each tone, an independent sample t-test was conducted to compare every f_0 measurement between one bilingual group and the control group. Since there is no comparison within groups, ANOVA was not used in this research. In all figures of pitch track provided in the thesis, the x-axis represents the 10 averaged f_0 measurements. The y-axis is the T-value, which ranges from 1 to 5.

Tone 1

Table 4.8 shows the T-value of Task 2A Tone 1 for each group, and the significant differences revealed by the independent-sample t-test for each bilingual group compared with the monolingual control group. Figure 4.8 demonstrates the pitch track of tone 1 for the four bilingual groups and the monolingual control group.

All five groups produced tone 1 as level. The control group speakers produced T1 with the highest T-value of 3.943 and the lowest of 3.887. The remaining T-values vary between these extremes with minor differences. Group 06M overlapped with the control group in the first three measurements, as shown in Figure 4.8, while the remaining measurements had a lower register. Group 13M, unlike Group 06M, had a higher register than the control group in the first six measurements. The last three measurements overlapped with the control group. Groups 36M and 60M had a similarly level contour as the control group, but with higher registers. The T-values of the majority of measurements for Group 36M were higher than 4, but most of the measurements of Group 60M were around 3.9.

Though tone 1 as produced by bilingual groups 06M, 13M, 36M, and 60M was slightly different than that of the control group, there were no significant differences in the measurements between each bilingual group and the control group.

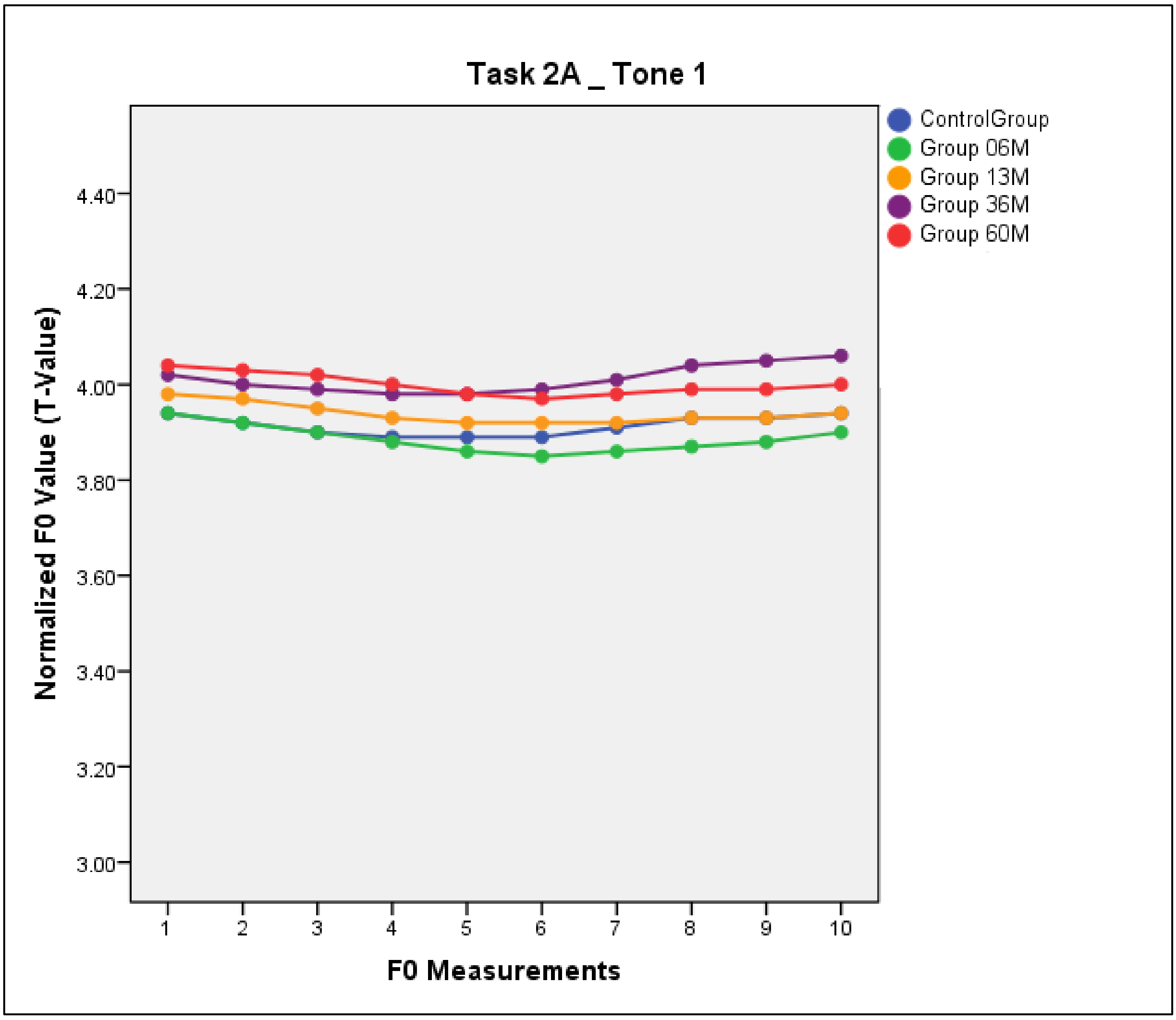


Figure 4.8 Pitch contours for Task 2A Tone 1

Table 4.8:T-values and significant differences for Task 2A Tone 1

Task 2A_Tone 1		$1T_{f_0}$	$2T_{f_0}$	$3T_{f_0}$	$4T_{f_0}$	$5T_{f_0}$	$6T_{f_0}$	$7T_{f_0}$	$8T_{f_0}$	$9T_{f_0}$	$10T_{f_0}$
Chinese Monolinguals	Control Group	3.943	3.924	3.902	3.888	3.887	3.894	3.905	3.926	3.930	3.942
Chinese-English Bilinguals	Group 06M	3.940	3.920	3.900	3.878	3.858	3.850	3.858	3.875	3.881	3.900
	Group 13M	3.982	3.973	3.952	3.935	3.921	3.918	3.923	3.931	3.934	3.938
	Group 36M	4.021	4.004	3.991	3.981	3.980	3.991	4.014	4.035	4.046	4.055
	Group 60M	4.039	4.031	4.017	3.996	3.980	3.974	3.979	3.989	3.991	3.998

Tone 2

It is clear from Figure 4.9 that tone 2 production by all five groups has identical rising contours. The control group produced T2 starting at T-value 2.410 and ending at 3.160. Group 06M matched the first two measurements of the control group, but the magnitude of the rise was sharper than the control group from the third measurement, ending at 3.219. Group 13M had nearly the same contour as the control group, with 2.404 at the start and 3.219 at the end. Group 36M had a similar rising contour with the highest register among the five groups. The starting T-value was 2.525, and the ending T-value was 3.248. Group 60M had a relatively gentle rising pitch contour compared with the control group and the other bilingual groups, which started at 2.512 and ended at 3.031.

There were no significant differences between the control group and each bilingual group in an independent t-test, though the contours are different from each other.

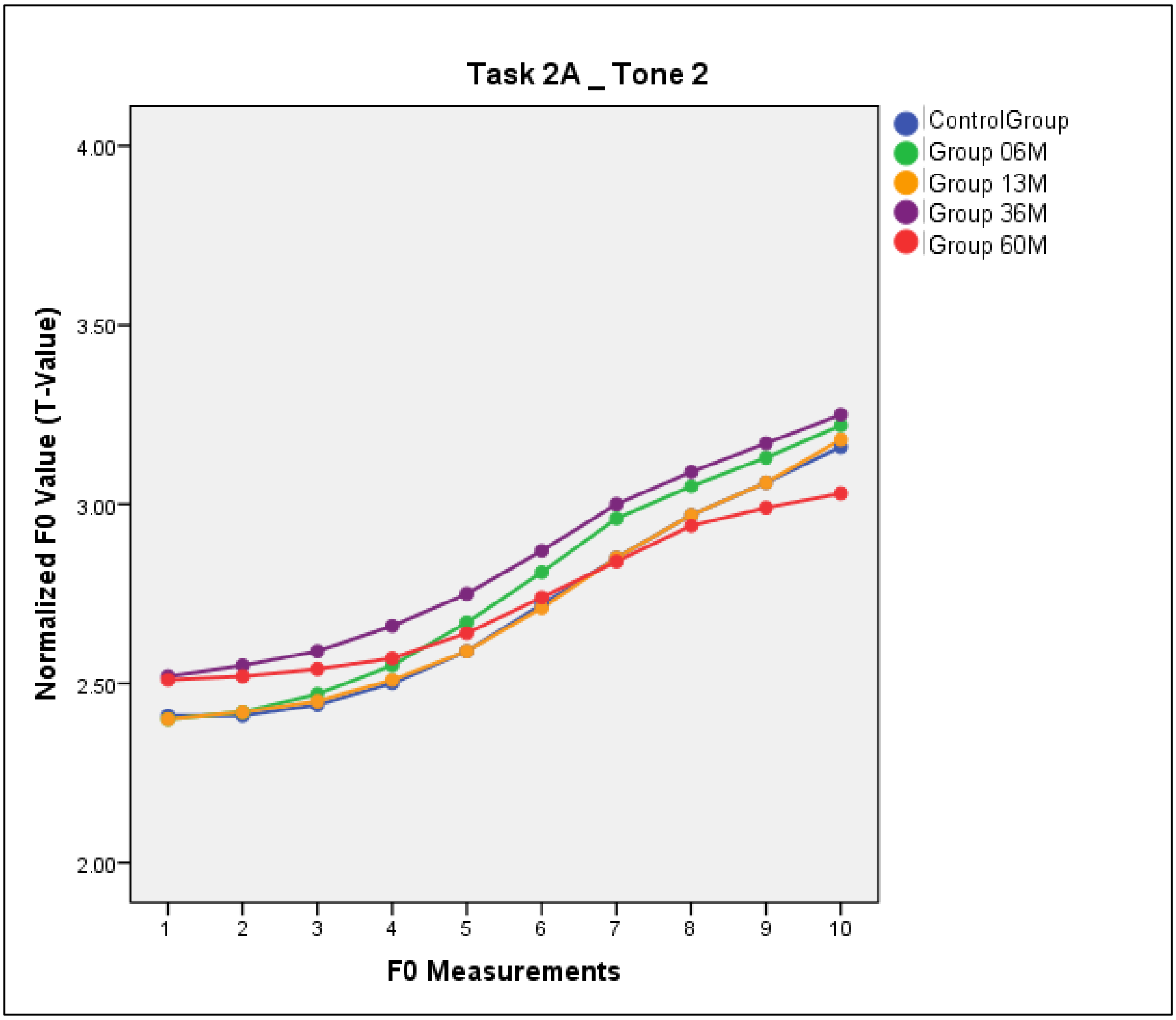


Figure 4.9 Pitch contours for Task 2A Tone 2

Table 4.9 T-values and significant differences for Task 2A Tone 2

Task 2A_Tone 2		$1T_{f_0}$	$2T_{f_0}$	$3T_{f_0}$	$4T_{f_0}$	$5T_{f_0}$	$6T_{f_0}$	$7T_{f_0}$	$8T_{f_0}$	$9T_{f_0}$	$10T_{f_0}$
Chinese Monolinguals	Control Group	2.410	2.415	2.441	2.495	2.590	2.719	2.851	2.967	3.064	3.160
Chinese-English Bilinguals	Group 06M	2.404	2.422	2.474	2.555	2.671	2.812	2.955	3.049	3.126	3.219
	Group 13M	2.404	2.415	2.452	2.511	2.595	2.712	2.850	2.970	3.061	3.178
	Group 36M	2.525	2.548	2.591	2.659	2.753	2.872	2.998	3.095	3.172	3.248
	Group 60M	2.512	2.521	2.538	2.574	2.641	2.736	2.842	2.937	2.986	3.031

Tone 3

From Figure 4.10 it can be seen that the pitch track of the control group was a typical curve, starting in a high position, sharply falling to the 7th f_0 measurement as the lowest pitch point, and rising to the end point. Groups 06M and 13M had similar pitch tracks to the control group. The differences are that these two bilingual groups gradually lowered the starting points while the main body of the pitch contours was raised higher than the control group. The longer their residential length, the higher the main body was. Thus, Group 13M's main body is higher than that of Group 06M. Though the lowest pitches of Groups 06M and 13M were still at the 7th f_0 measurement, their rising parts were slightly lowered. For Group 13M, the rising part of tone 3 is almost level. Groups 36M and 60M showed more differences in pitch contours than did the control group. These are listed below in Figures 4.11 and 4.12.

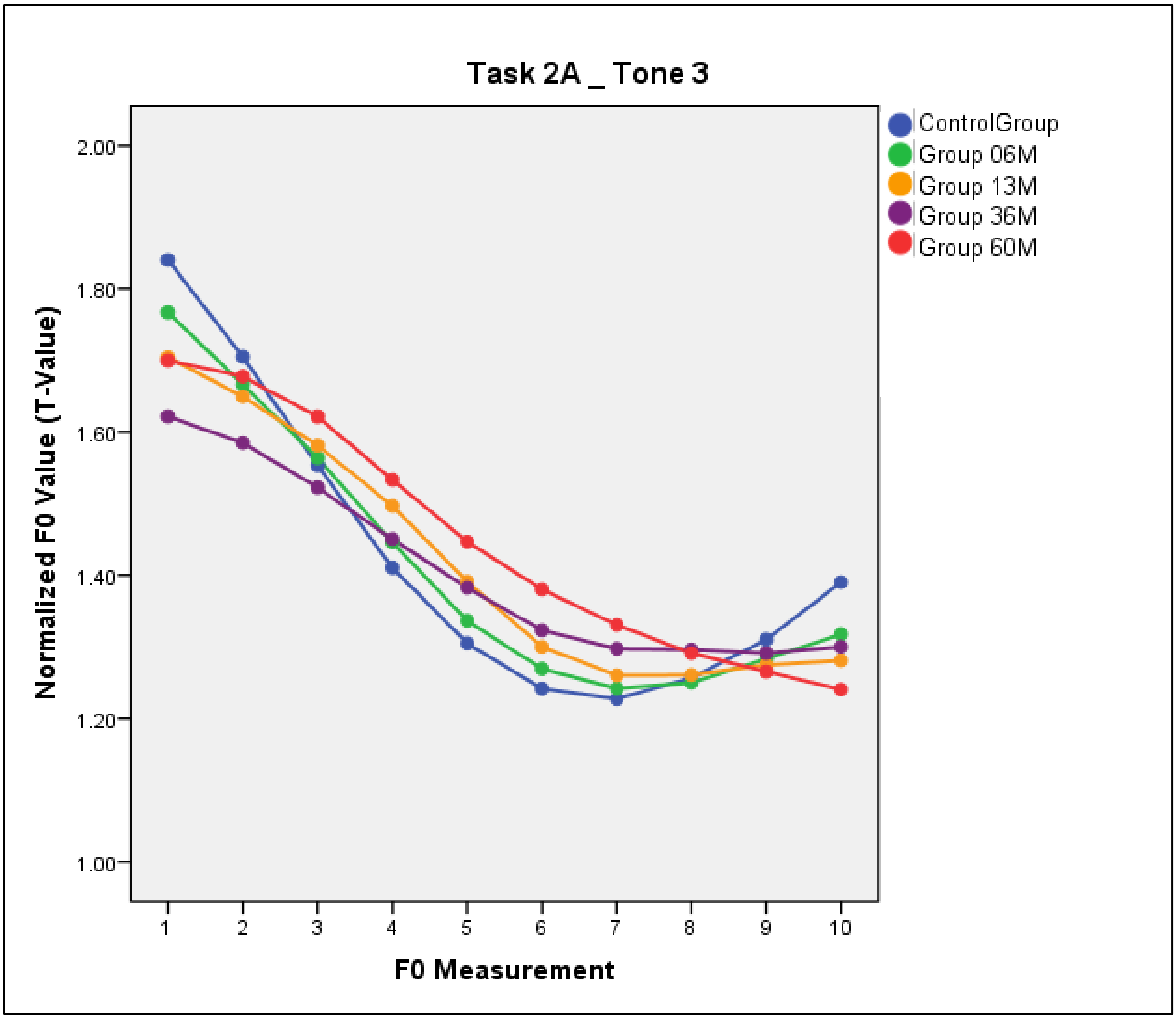


Figure 4.10 Pitch contours for Task 2A Tone 3

Table 4.10 T-values and significant differences for Task 2A Tone 3

Task2A_Tone 3		$1T_{f_0}$	$2T_{f_0}$	$3T_{f_0}$	$4T_{f_0}$	$5T_{f_0}$	$6T_{f_0}$	$7T_{f_0}$	$8T_{f_0}$	$9T_{f_0}$	$10T_{f_0}$
Chinese Monolinguals	Control Group	1.840	1.705	1.553	1.410	1.305	1.242	1.227	1.256	1.310	1.390
Chinese-English Bilinguals	Group 06M	1.767	1.666	1.564	1.446	1.336	1.269	1.242	1.250	1.283	1.317
	Group 13M	1.704	1.649	1.581	1.497	1.391	1.300	1.260	1.261	1.275	1.281
	Group 36M	1.621	1.585	1.522	1.450	1.382	1.323	1.297	1.296	1.291	1.300
	Group 60M	1.700	1.677	1.621	1.533	1.447	1.380	1.330	1.291	1.265	1.240

The main body of Group 36M follows the pattern that the greater the length of residence, the higher the pitch track. However, compared to the control group and bilingual groups 06M and 13M, it is clear that pitch contours produced by Group 36M speakers are smoother and shortened in the rising contour. Two measurements for Group 36M demonstrate significant differences compared to the control group. The first one is the starting point $1f_0$, which has the lowest f_0 value among the five groups. It is significantly lower than the corresponding measurement from the control group (p=0.028). Another significant difference is in $7f_0$ (p=0.05) as measured in Group 36M verses the control group, as illustrated in Table 4.10. Meanwhile, from Figure 4.11, it is clear that the f_0 with the lowest pitch value for Group 36M moves to the $9f_0$ due to the shortened rising contour. This will be discussed in detail in Chapter 5.

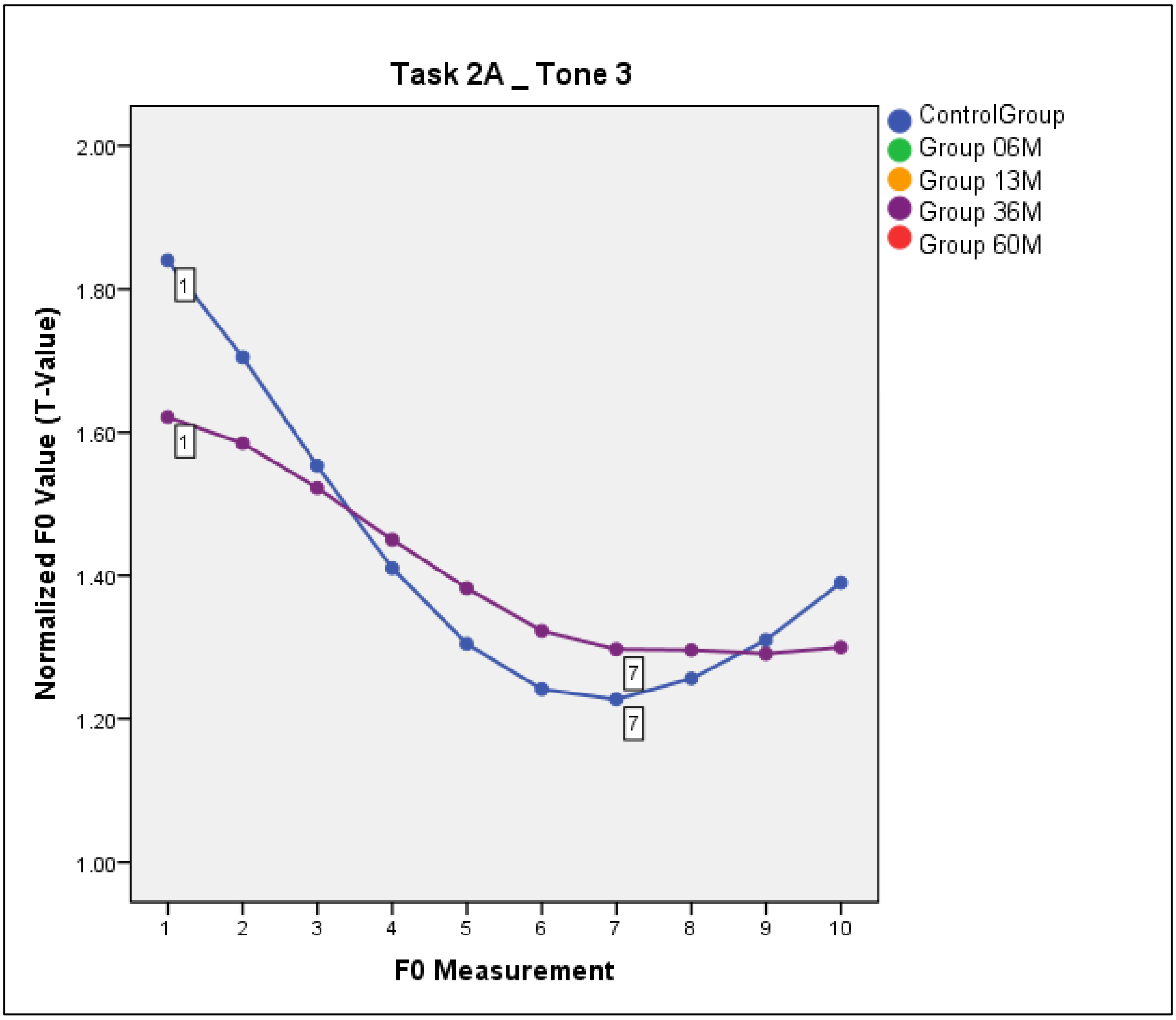


Figure 4.11 Pitch contours for Task 2A Tone 3: Control Group vs Group 36M

The main contour of Group 60M follows the pattern mentioned above and has the highest pitch track in general. However, the starting point of Group 60M is not, as was expected, the lowest. It has the second lowest pitch value, which is not significantly different from the control group. Meanwhile, the lowest pitch point moves to the ending point $10f_0$ of Group 60M. In other words, there were no rising parts produced by Group 60M speakers. The significant differences between Group 60M and the control group are in the $5f_0$, $6f_0$, and $7f_0$ measurements (p=0.016, 0.004, 0.013), which means that pitch heights for Group 60M at these three measurements are significant higher than they are for the control group. However, the significantly higher pitch heights are also caused by shorter rising parts. This will be discussed in Chapter 5.

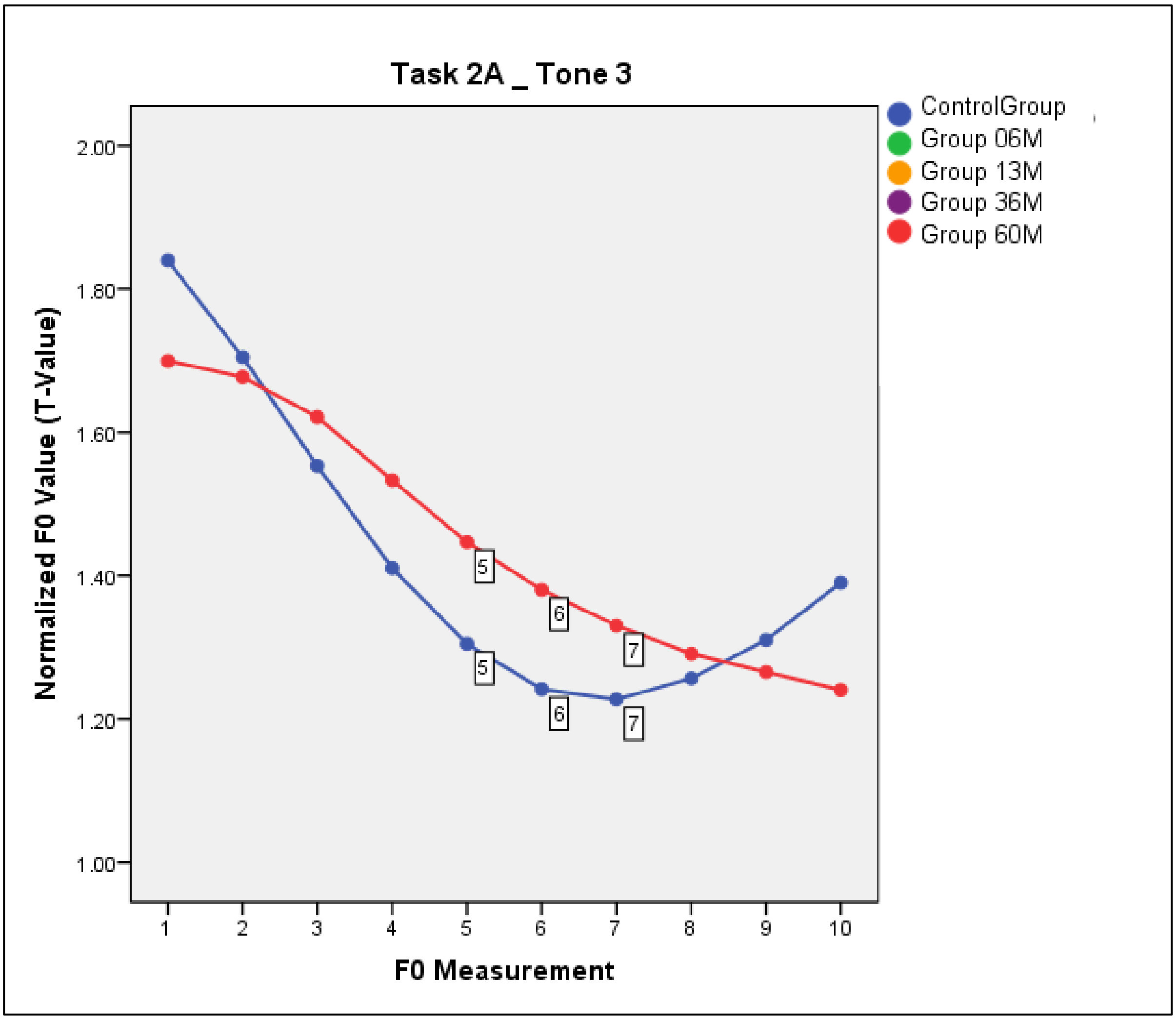


Figure 4.12 Pitch contours for Task 2A Tone 3: Control Group vs. Group 60M

Due to the Time Normalized f_0 Script (Xu and Xu, 2005), the time for producing a tone is normalized in a unit. Hence, each tone can be seen as being produced in the same time period. Within the same time period, the control group produced the falling and rising parts that formed a complete tone 3. However, Group 36M and Group 60M produced only the falling parts in the same time period. The falling pitch contours for Group 36M and Group 60 were strengthened to fill the time period. Therefore, Group 36M and Group 60 formed higher contours than the control group.

Figure 4.13 demonstrates the simplified tone 3 contours for the five groups in Task 2A. The starting measurement $1T_{f_0}$(maximum f_0), turning point (minimum f_0), and ending measurement $10T_{f_0}$ were kept in order to demonstrate simplified falling and rising parts. It is clear that pitch register differences do exist at the start, especially between the control group and Group 36M. However, contours of the falling part at its lowest point overlapped with each other, which means that pitch registers for the five groups were similar to each other. There are no significant differences in the degree of initial fall (ΔT_{f_0}) when comparing the control group and each bilingual group.

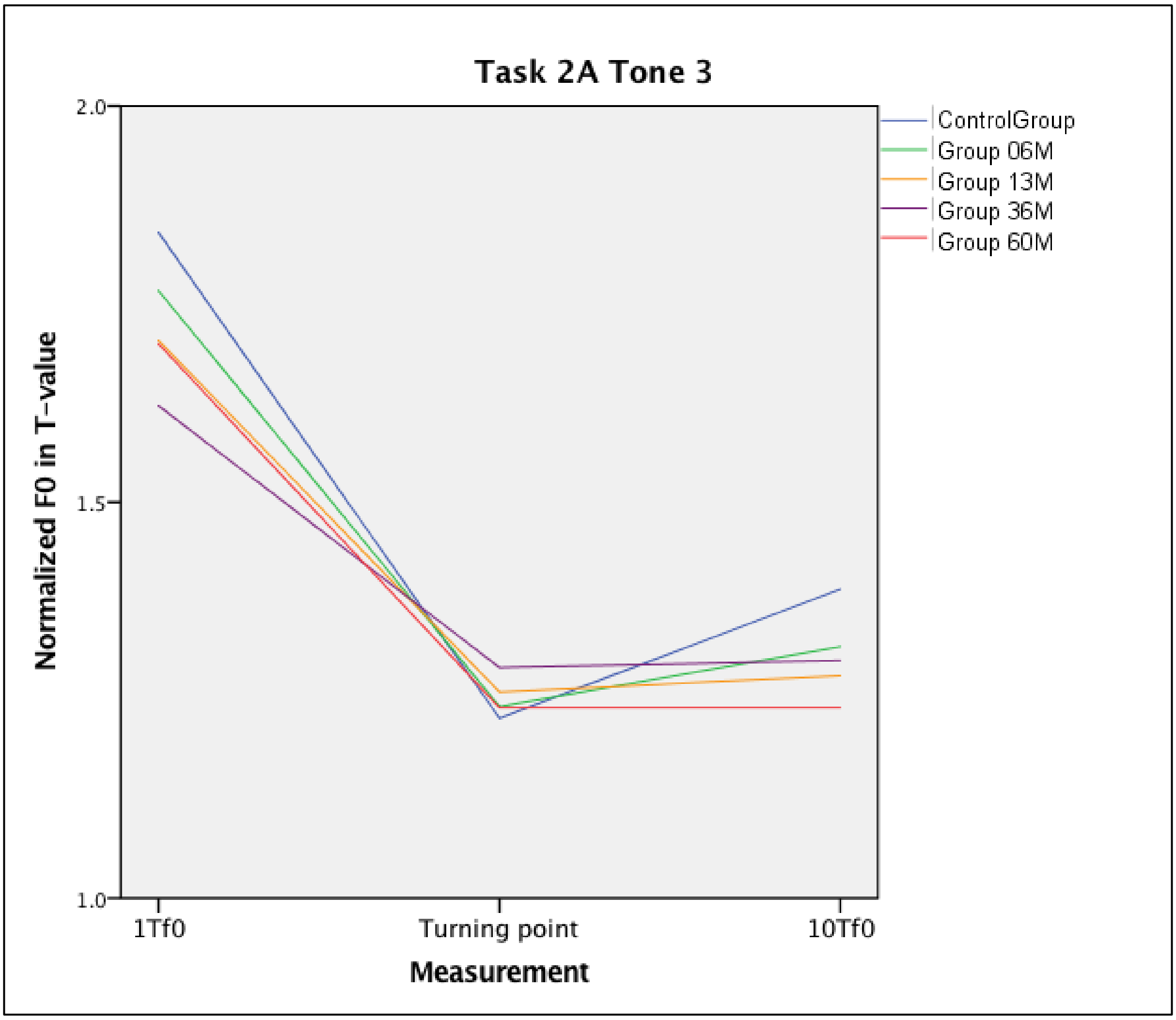


Figure 4.13 Simplified tone 3 contours for five groups for Task 2A

Table 4.11 T-values and significant differences for simplified tone 3 for five groups for Task 2A

	Starting $1T_{f_0}$	Turning point (Min T_{f_0})	Ending $10T_{f_0}$		
Control Group	1.84	1.23	1.39		
Group 06M	1.77	1.24	1.32		
Group 13M	1.7	1.26	1.28		
Group 36M	1.62	1.29	1.3		
Group 60M	1.70	1.24	1.24		

Tone 4

Figure 4.14 demonstrates T4 production for all five groups, which are all falling pitch contours. The control group had the highest starting T-value: 4.046. The contour's end point dropped to 2.754. Group 06M had a similar pitch contour, but a lower register than the control group. Group 13M overlapped in the first five measurements with Group 06M, while the remaining five measurements had higher T-values than Group 06M. Group 36M and 60M had similar pitch contours with most measurements overlapping each other.

In general, the four bilingual groups showed no significant differences compared with the control group. The only two exceptions exist in $2f_0$ (p-values=0.041) and $3f_0$ (p-values=0.041) measurements from Group 06M, which are significantly different from the control group.

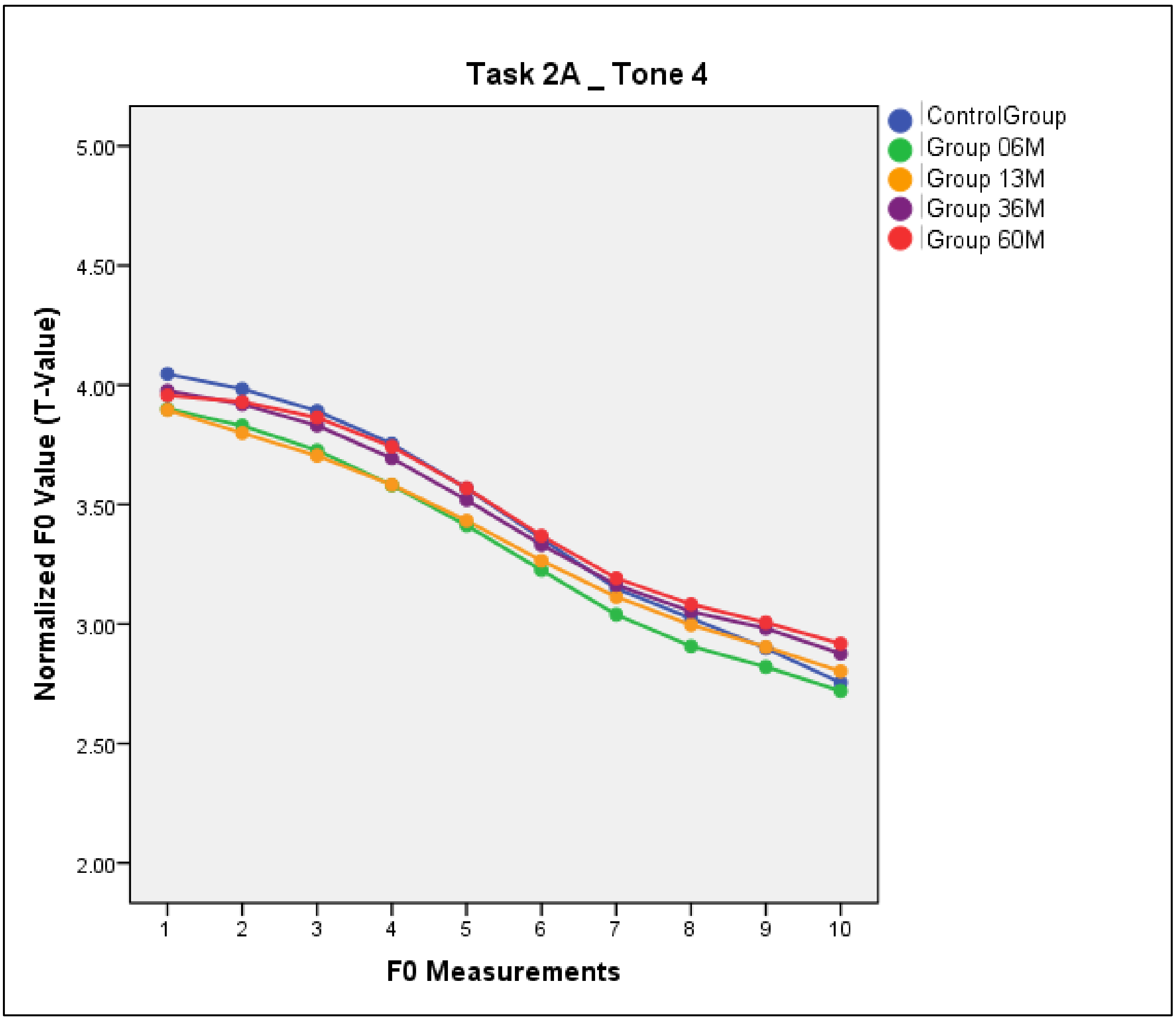


Figure 4.14 Pitch contours for Task 2A Tone 4

Table 4.12 T-values and significant differences for Task 2A Tone 4

Tone 4		$1T_{f_0}$	$2T_{f_0}$	$3T_{f_0}$	$4T_{f_0}$	$5T_{f_0}$	$6T_{f_0}$	$7T_{f_0}$	$8T_{f_0}$	$9T_{f_0}$	$10T_{f_0}$
Chinese Monolinguals	Control Group	4.046	3.983	3.891	3.754	3.567	3.358	3.148	3.024	2.899	2.754
Chinese-English Bilinguals	Group 06M	3.899	3.829	3.727	3.580	3.412	3.225	3.039	2.907	2.821	2.720
	Group 13M	3.896	3.799	3.704	3.582	3.432	3.265	3.113	2.996	2.904	2.802
	Group 36M	3.976	3.919	3.830	3.694	3.519	3.332	3.164	3.052	2.982	2.876
	Group 60M	3.956	3.929	3.864	3.742	3.568	3.369	3.191	3.083	3.006	2.918

Tone 4 Variation (T44)

Recall that T4 is a falling tone and that there are two T4 syllables. The first T4 is pronounced with a higher ending, while the second T4 is pronounced with a lower starting and ending point. Figure 4.15 states the T-value of 20 measurements of adjacent T4 syllables, in which the first 10 f_0 measurements stand for the first T4 and the second 10 f_0 measurements state the second T4.

The control group showed this expected T44 variation. The first T4 started with T-value 4.184, which is similar to the normal T4, but ended at 3.429, which is much higher than the normal T4 ending T-value. The starting point of the second T4 ($11T_{f_0}$) was only slightly higher than the ending of the first T4 ($10T_{f_0}$). However, its end was around T-value 2, which is also similar to the normal T4. Bilingual Groups 06M, 13M, 36M, and 60M had similar pitch contours to the control group, with a higher ending for the first T4 and a lower starting point for the second T4. The difference in the T-values at each measurement is minor and no significant differences exist. Table 4.13 shows this in detail.

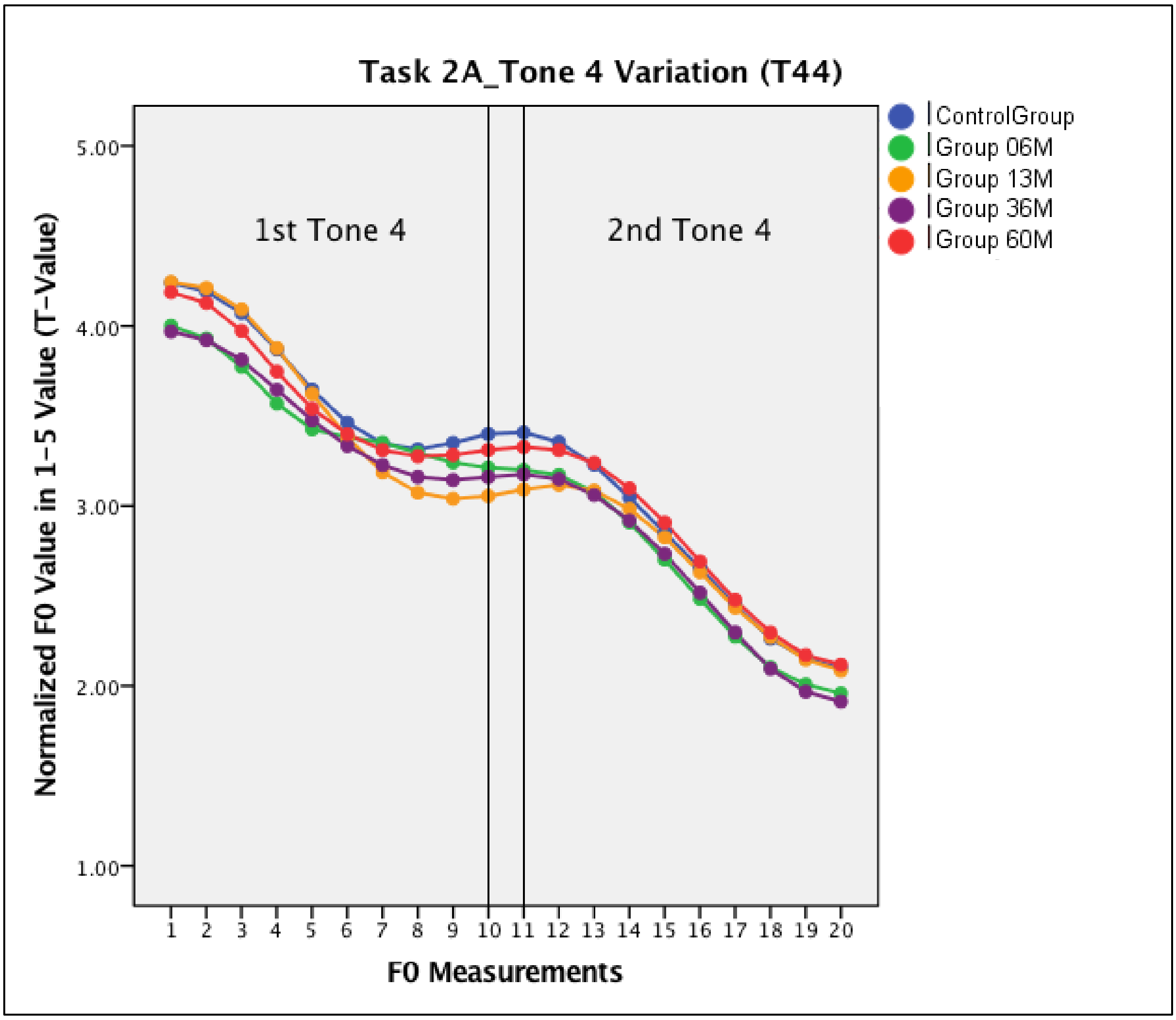


Figure 4.15 Pitch contours for Task 2A tone 4 variation

Table 4.13 T-values and significant differences for Task 2A Tone 4 variation

Task 2A_ Tone 4 variation 1st T4		$1T_{f_0}$	$2T_{f_0}$	$3T_{f_0}$	$4T_{f_0}$	$5T_{f_0}$	$6T_{f_0}$	$7T_{f_0}$	$8T_{f_0}$	$9T_{f_0}$	$10T_{f_0}$
Chinese Monolinguals	Control Group	4.183	4.134	4.010	3.816	3.609	3.450	3.365	3.350	3.385	3.429
Chinese-English Bilinguals	Group 06M	4.001	3.93	3.773	3.568	3.426	3.381	3.352	3.294	3.241	3.212
	Group 13M	4.283	4.249	4.122	3.909	3.674	3.456	3.283	3.187	3.167	3.188
	Group 36M	4.083	4.028	3.900	3.710	3.513	3.357	3.248	3.182	3.173	3.195
	Group 60M	4.129	4.070	3.918	3.699	3.505	3.377	3.298	3.269	3.276	3.300

Task 2A_ Tone 4 variation 2nd T4		$11T_{f_0}$	$12T_{f_0}$	$13T_{f_0}$	$14T_{f_0}$	$15T_{f_0}$	$16T_{f_0}$	$17T_{f_0}$	$18T_{f_0}$	$19T_{f_0}$	$20T_{f_0}$
Chinese Monolinguals	Control Group	3.433	3.372	3.250	3.089	2.917	2.742	2.561	2.389	2.283	2.231
Chinese-English Bilinguals	Group 06M	3.200	3.171	3.077	2.908	2.701	2.483	2.274	2.102	2.008	1.958
	Group 13M	3.225	3.256	3.235	3.134	2.976	2.784	2.591	2.422	2.281	2.215
	Group 36M	3.195	3.141	3.027	2.877	2.712	2.530	2.338	2.161	2.055	2.006
	Group 60M	3.315	3.298	3.231	3.093	2.907	2.694	2.486	2.309	2.188	2.136

Tone Sandhi

Figure 4.16 presents Tone Sandhi data from Task 2A. It is clear that all five groups produced tone sandhi following the rule that when T3 is followed by another T3, the first T3 changes to T2. The control group produced tone sandhi with the expected obvious rising contour. Group 06M had a relatively smooth rising contour compared with the control group. The T-values of the first five measurements were much higher than the control group, but they approached those of the control group from the sixth measurement and overlapped at the eighth. The tone sandhi contour produced by Group 13M had a similar tendency to that of Group 06M. The first four measurements had higher T-values than the control group, but the contour crossed that of the control group at the fifth measurement and then rose less sharply. Group 36M had the highest T-values for the majority of measurements among all five groups, but the ending T-value of 2.869 was slightly lower than that of Group 06M. Group 60M, on the contrary, had the lowest T-values for the majority of measurements, with the first three overlapping with the control group. The T-values of each measurement for all five groups ranged between 1.6 and 3. Moreover, no significant differences were evident in independent t-tests.

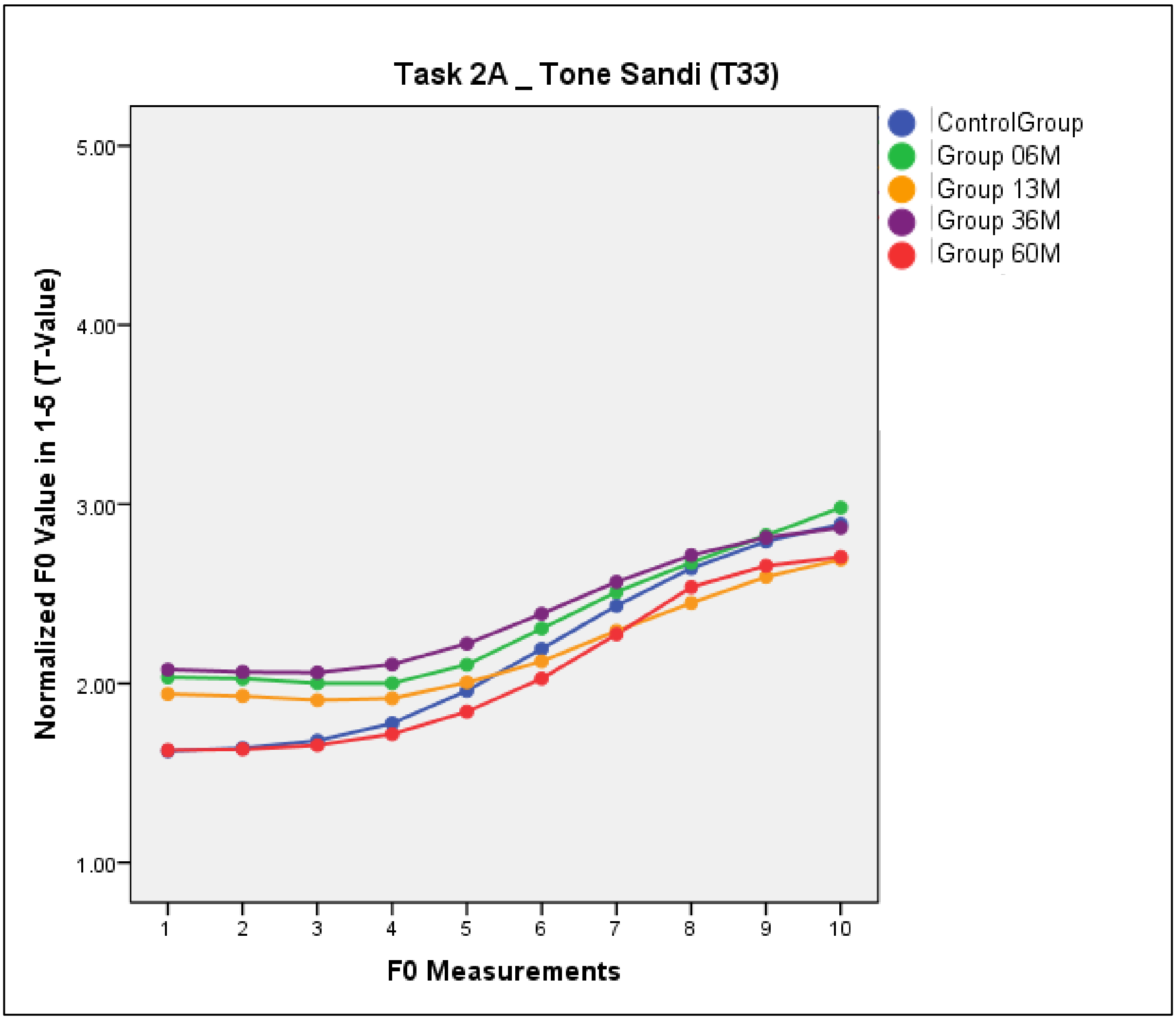


Figure 4.16 Pitch contours for Task 2A tone sandhi

Table 4.14 T-values and significant differences for Task 2A tone sandhi

Task 2A_Tone sandhi		$1T_{f_0}$	$2T_{f_0}$	$3T_{f_0}$	$4T_{f_0}$	$5T_{f_0}$	$6T_{f_0}$	$7T_{f_0}$	$8T_{f_0}$	$9T_{f_0}$	$10T_{f_0}$
Chinese Monolinguals	Control Group	1.623	1.638	1.681	1.777	1.960	2.193	2.433	2.643	2.792	2.889
Chinese-English Bilinguals	Group 06M	2.034	2.027	2.001	2.000	2.105	2.306	2.511	2.674	2.826	2.981
	Group 13M	1.941	1.930	1.907	1.917	2.005	2.123	2.293	2.449	2.594	2.692
	Group 36M	2.077	2.063	2.060	2.106	2.221	2.389	2.567	2.715	2.814	2.869
	Group 60M	1.627	1.632	1.655	1.717	1.842	2.027	2.274	2.537	2.656	2.706

yi Variation

yi variation is described below in two parts. The first part considers the change from T1 to T4 when *yi* precedes T1, T2, or T3. The second part describes the change from T1 to T2 when preceding T4.

From Figure 4.17 below, it can be seen that all five groups produced the *yi* T1→T4 tone as a falling tone, though the ends of the contours were much higher than the normal T4. The control group produced the *yi* T1→T4 tone starting at T-value 3.595 and ending at T-value 3.395. Group 06M had a relatively level contour from the beginning (T-value of 3.178) to the sixth measurement (T-value of 3.174), and then dropped from there to the end (T-value of 2.978). Group 13M had a very similar contour to the control group, with slightly lowered T-values from the sixth measurement until the end. Group 36M had the highest T-values for each measurement among the five groups, with a declining tendency. It started at T-value 3.839 and ended at 3.533. Group 60M had the most obvious falling contour among the groups, staring at T-value 3.386 and ending at 2.920.

The *yi* T1→T4 tone contours appear dissimilar in the figure, but there are no significant differences in the majority of measurements. Significant differences only exist in the last two measurements between the control group and Group 60M, according to an independent t-test with p-values of 0.044 and 0.040.

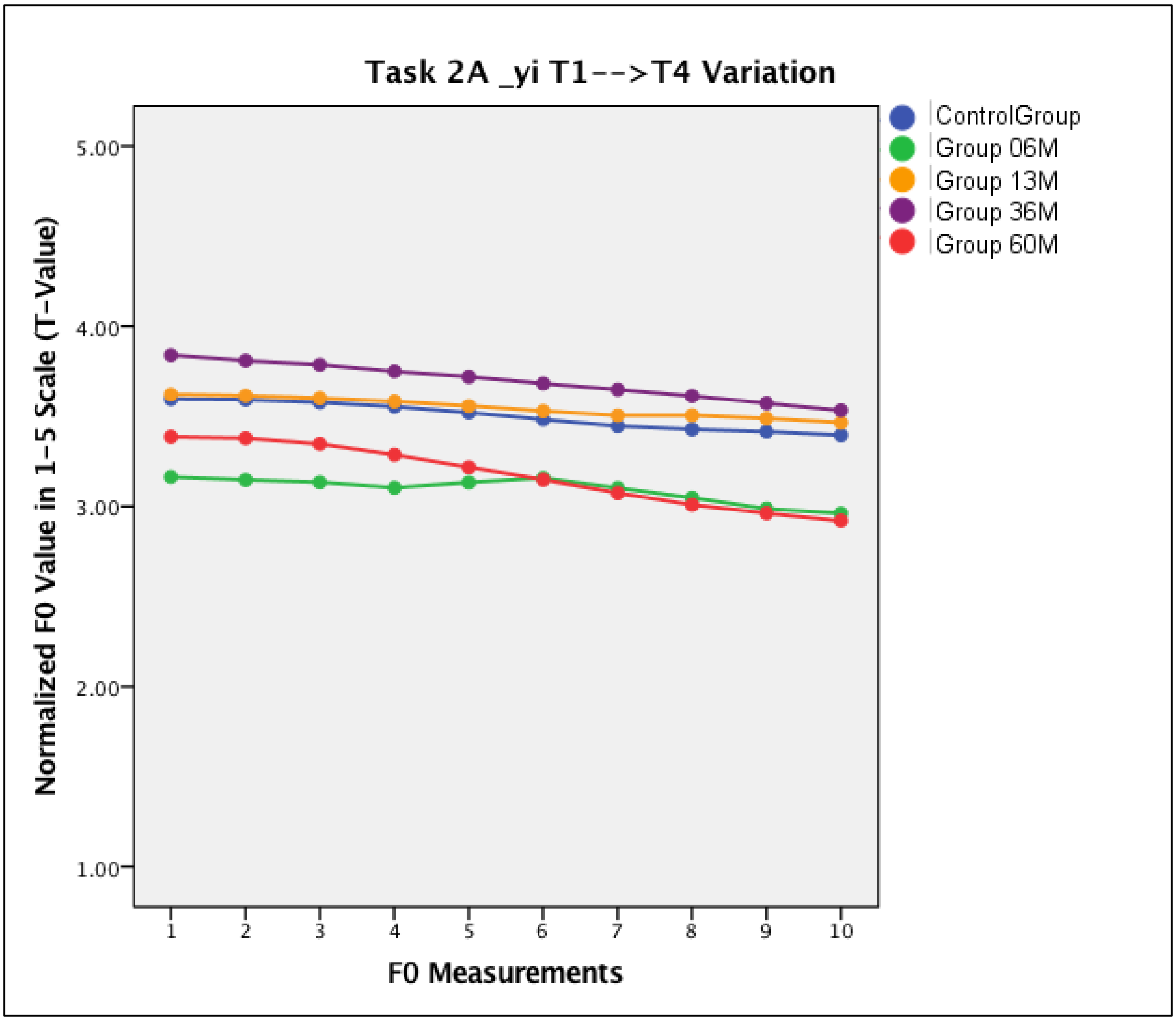


Figure 4.17 Pitch contours for Task 2A yi T1→ T4 variation

Table 4.15 T-values and significant differences for yi T1 →T4 Variation

Task 2A_ *yi* T1→T4 variation		$1T_{f_0}$	$2T_{f_0}$	$3T_{f_0}$	$4T_{f_0}$	$5T_{f_0}$	$6T_{f_0}$	$7T_{f_0}$	$8T_{f_0}$	$9T_{f_0}$	$10T_{f_0}$
Chinese Monolinguals	Control Group	3.595	3.592	3.577	3.553	3.520	3.482	3.445	3.427	3.414	3.395
Chinese-English Bilinguals	Group 06M	3.178	3.162	3.149	3.119	3.149	3.174	3.119	3.063	3.002	2.978
	Group 13M	3.621	3.614	3.601	3.582	3.558	3.529	3.504	3.505	3.488	3.464
	Group 36M	3.839	3.809	3.786	3.750	3.719	3.682	3.648	3.612	3.572	3.533
	Group 60M	3.386	3.378	3.346	3.286	3.217	3.149	3.074	3.008	2.962	2.920

Figure 4.18 shows the second part of *yi* T1→T2 variation. All five groups produced a proper rising *yi* T1→T2 tone. The contour of the control group stayed in the centre of the five contours, with a rising tendency. It started at T-value 1.697. This is much lower than the normal T2 production, which starts at T-value 2.5. With a slight rise, the *yi* T1→T2 tone produced by the control group ended at T-value 1.827. Group 06M had a very similar contour to the control group, but a greatly lowered register. Group 06M's T-values were the lowest among the five groups, starting at 1.287 and ending at 1.411. Group 13M had a higher register contour than the control group, but its rising tendency was even smoother, and was almost like a level contour. The difference between the first T-value measurement and the last measurement is only 0.12. The contour of Group 36M was highest, with the T-value of each measurement over 2. Group 60M's contour was very close to that of the control group, overlapping with it in the last three measurements.

Though the contours are nearly parallel to each other with different register gaps, only one significant difference was detected at measurement $10T_{f_0}$ between the control group and Group 06M. The *p*-value was 0.043.

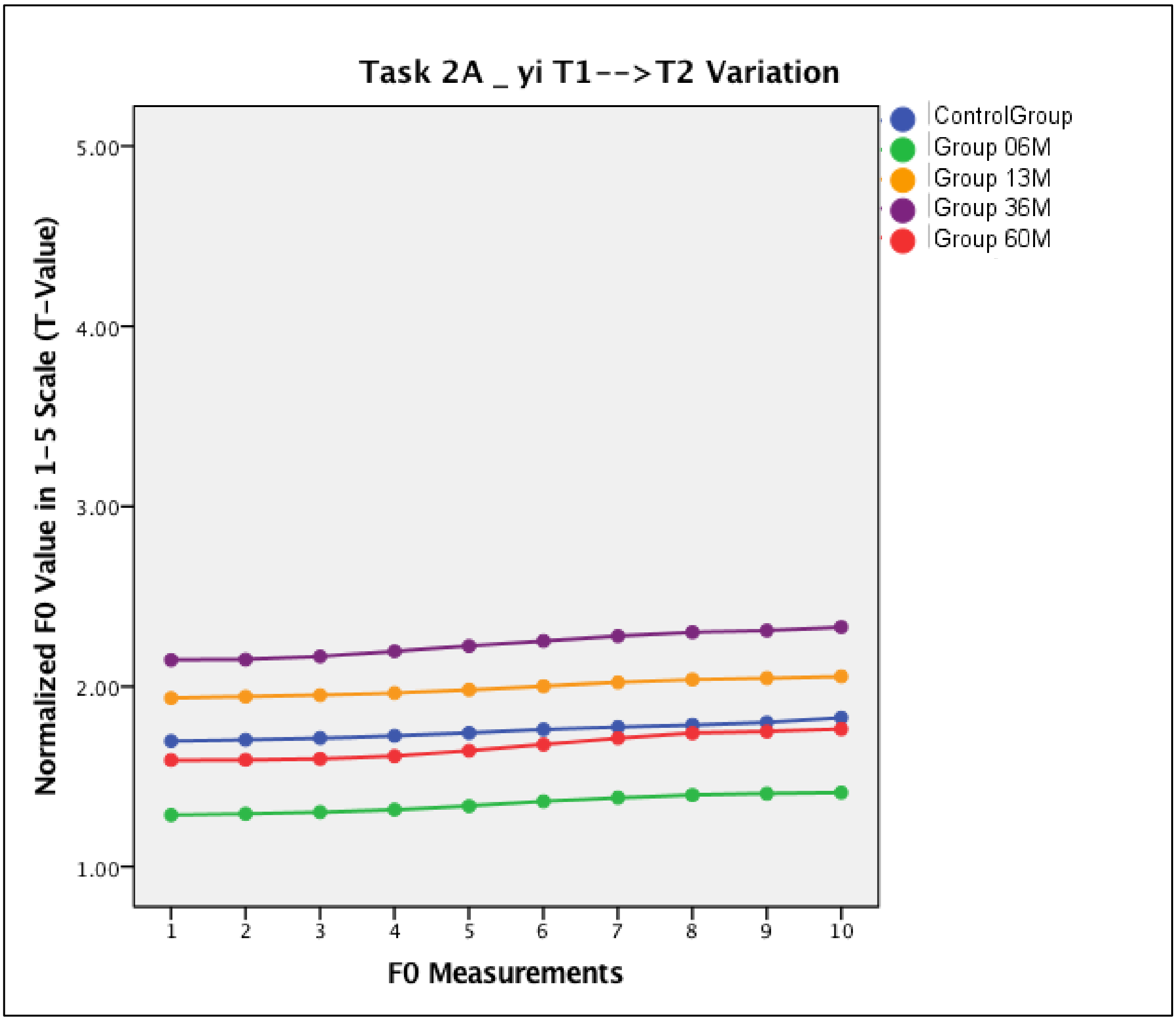


Figure 4.18 Pitch contours for Task 2A yi T1→ T2 variation

Table 4.16 T-values and significant differences of yi T1→T2 variation

Task 2A_*yi* T1→T2 variation		$1T_{f_0}$	$2T_{f_0}$	$3T_{f_0}$	$4T_{f_0}$	$5T_{f_0}$	$6T_{f_0}$	$7T_{f_0}$	$8T_{f_0}$	$9T_{f_0}$	$10T_{f_0}$
Chinese Monolinguals	Control Group	1.697	1.704	1.713	1.726	1.743	1.762	1.775	1.786	1.801	1.827
Chinese-English Bilinguals	Group 06M	1.287	1.293	1.302	1.316	1.337	1.363	1.382	1.398	1.406	1.411
	Group 13M	1.936	1.944	1.952	1.964	1.981	2.002	2.023	2.039	2.046	2.056
	Group 36M	2.148	2.150	2.167	2.195	2.225	2.252	2.280	2.301	2.311	2.330
	Group 60M	1.591	1.592	1.598	1.614	1.643	1.679	1.713	1.742	1.751	1.764

4.3.3. Task 2B: Retelling the story

Task 2B was to retell the story that was read in Task 2A. The results of this task are listed below, describing individual production of the four tones in the first section, and tone variation in the second section.

Tone 1

It is clearly shown in Figure 4.19 that all five groups produced T1 as a level tone in Task 2B. The T-value of each measurement ranged from 3.75 to 3.99. There were slight differences between each group's T1 production. The control group produced T1 as a level tone that slightly rose at the end. Group 06M had a higher starting point than the control group, but the last measurement $10T_{f_0}$ overlapped with the control group. The T1 produced by Group 13M was also level but rose at the end. Group 36M had a similar T1 contour to the control group. However, its register was higher. Its starting and ending measurements overlapped with those of Group 13M. Meanwhile, Group 60M had a similar downward T1 contour to Group 06M.

The only significant difference, when comparing the bilingual groups to the control group, was at the first f_0 measurement of Group 06M, where the p-value was 0.044. The other three bilingual groups had no significant differences between their T-value and those of the control group at each measurement.

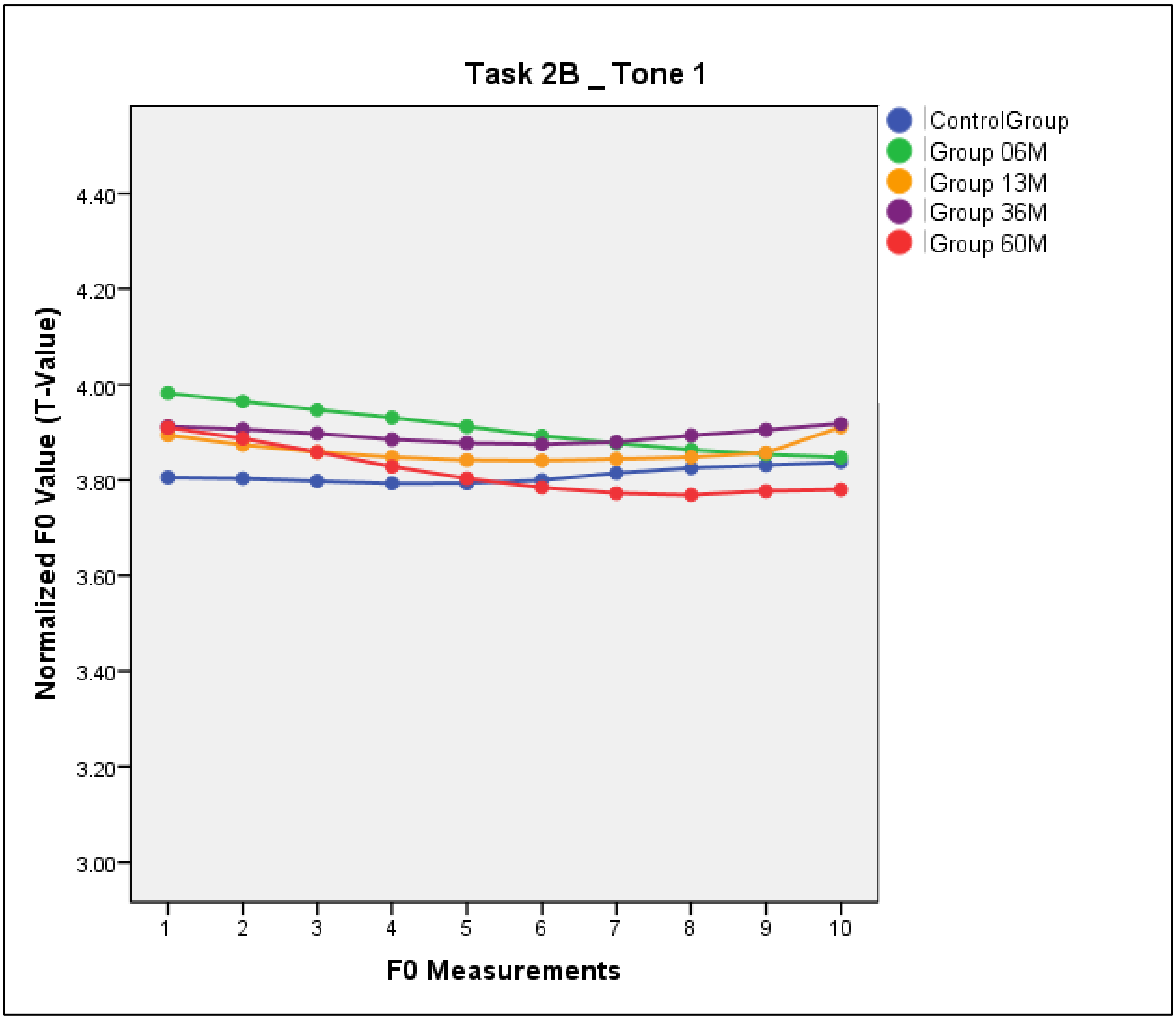


Figure 4.19 Pitch contours for Task 2B Tone 1

Table 4.17 T-values and significant differences for Task 2B Tone 1

Task 2B_Tone 1		$1T_{f_0}$	$2T_{f_0}$	$3T_{f_0}$	$4T_{f_0}$	$5T_{f_0}$	$6T_{f_0}$	$7T_{f_0}$	$8T_{f_0}$	$9T_{f_0}$	$10T_{f_0}$
Chinese Monolinguals	Control Group	3.806	3.803	3.798	3.793	3.793	3.800	3.815	3.826	3.831	3.838
Chinese-English Bilinguals	Group 06M	3.982	3.965	3.947	3.930	3.912	3.892	3.877	3.864	3.854	3.848
	Group 13M	3.894	3.874	3.859	3.848	3.842	3.841	3.844	3.848	3.857	3.911
	Group 36M	3.912	3.906	3.897	3.885	3.877	3.875	3.880	3.893	3.905	3.918
	Group 60M	3.910	3.887	3.859	3.829	3.803	3.784	3.772	3.769	3.777	3.780

Tone 2

Figure 4.20 shows that all five groups produced T2 as a rising tone. The control group produced a rising T2 with a starting T-value of 2.551 and an ending value of 3.246. The rising contour is very apparent. Group 06M produced rising T2 with a lower register than that of the control group. It started at T-value 2.383 and finished at 2.919. Group 13M had the lowest starting measurement at only 2.338, but the end, at 3.108, was much higher than that of Group 06M. The T2 contour produced by Group 36M, similar to that of Group 13M, started at 2.388 and completed at 3.189. It had a good rising track. Group 60M had a higher starting T-value than the control group, but it overlapped the control group in latter measurements. There were no significant differences between any of the f_0 measurements of the bilingual groups and those of the control group. The detailed T-values and *p*-values are listed in Table 4.18 below.

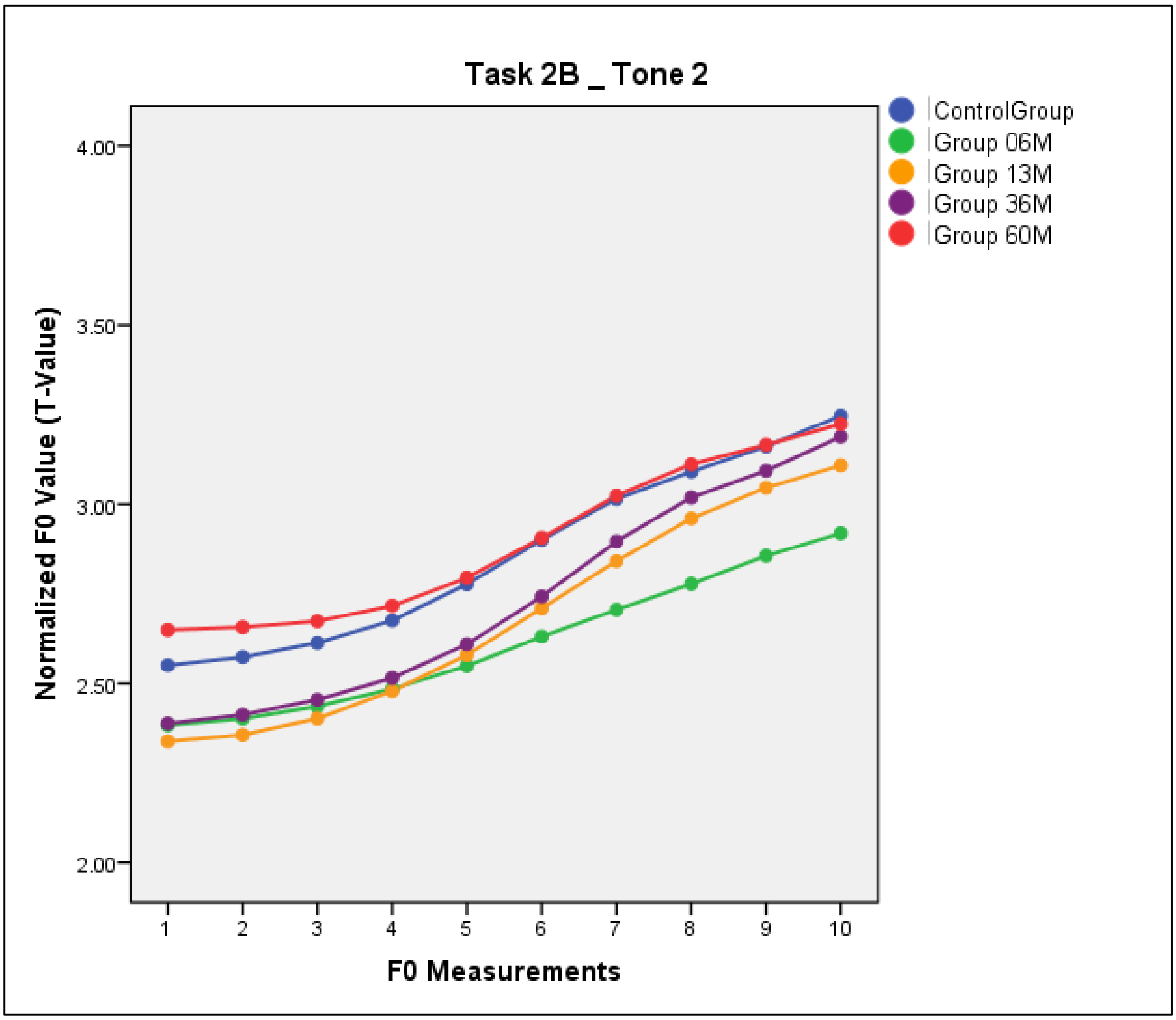


Figure 4.20 Pitch contours for Task 2B Tone 2

Table 4.18 T-values and significant differences for Task 2B Tone 1

Task 2B_Tone 2		$1T_{f_0}$	$2T_{f_0}$	$3T_{f_0}$	$4T_{f_0}$	$5T_{f_0}$	$6T_{f_0}$	$7T_{f_0}$	$8T_{f_0}$	$9T_{f_0}$	$10T_{f_0}$
Chinese Monolinguals	Control Group	2.551	2.573	2.613	2.676	2.777	2.901	3.015	3.091	3.162	3.246
Chinese-English Bilinguals	Group 06M	2.383	2.402	2.436	2.485	2.549	2.631	2.706	2.778	2.856	2.919
	Group 13M	2.338	2.356	2.402	2.479	2.580	2.710	2.841	2.960	3.046	3.108
	Group 36M	2.388	2.413	2.454	2.515	2.609	2.742	2.896	3.019	3.093	3.189
	Group 60M	2.649	2.657	2.674	2.716	2.795	2.906	3.024	3.112	3.166	3.224

Tone 3

The contours of T3 in Task 2B, similar to T3 in Task 1B, demonstrated two different tendencies. The control group, in blue in Figure 4.21, produced T3 with a falling part and a rising part. The rising part is obvious. The sixth f_0 measurement ($6T_{f_0}$) is the turning point from falling to rising. Group 06M had the lowest starting point among the five groups. Its falling part was longer than that of the control group until the $8T_{f_0}$measurement, and then it rose slightly up at the end. Group 13M had a T3 contour similar to the control group. The rising part clearly started from the $7T_{f_0}$ measurement. Group 36M produced T3 with the highest starting point. The falling part continued to $8T_{f_0}$, and the rising part was almost level. Group 60M had no rising part, as can be seen clearly in Figure 4.21.

The tones produced by all four bilingual groups had an apparent falling part. Group 06M and 13M demonstrated a clear rising part from $8T_{f_0}$ and $7T_{f_0}$. However, it is hard to see the rising contour of Group 36M, and there is no rising part for Group 60M. The T3 contours produced by Groups 36M and 60M can be seen group in Figure 4.19 and Figure 4.20 below to have significant differences compared with the control. The significant differences between the control group and Group 36M are evident in the $4T_{f_0}$, $5T_{f_0}$, and $6T_{f_0}$ measurements. The corresponding *p*-values are 0.048, 0.028, and 0.019. The significant differences between Group 60M and the control group can be seen at the $5T_{f_0}$, $6T_{f_0}$, and $7T_{f_0}$ measurements with *p*-values of 0.013, 0.002, and 0.008 (for details, see Table 4.19).

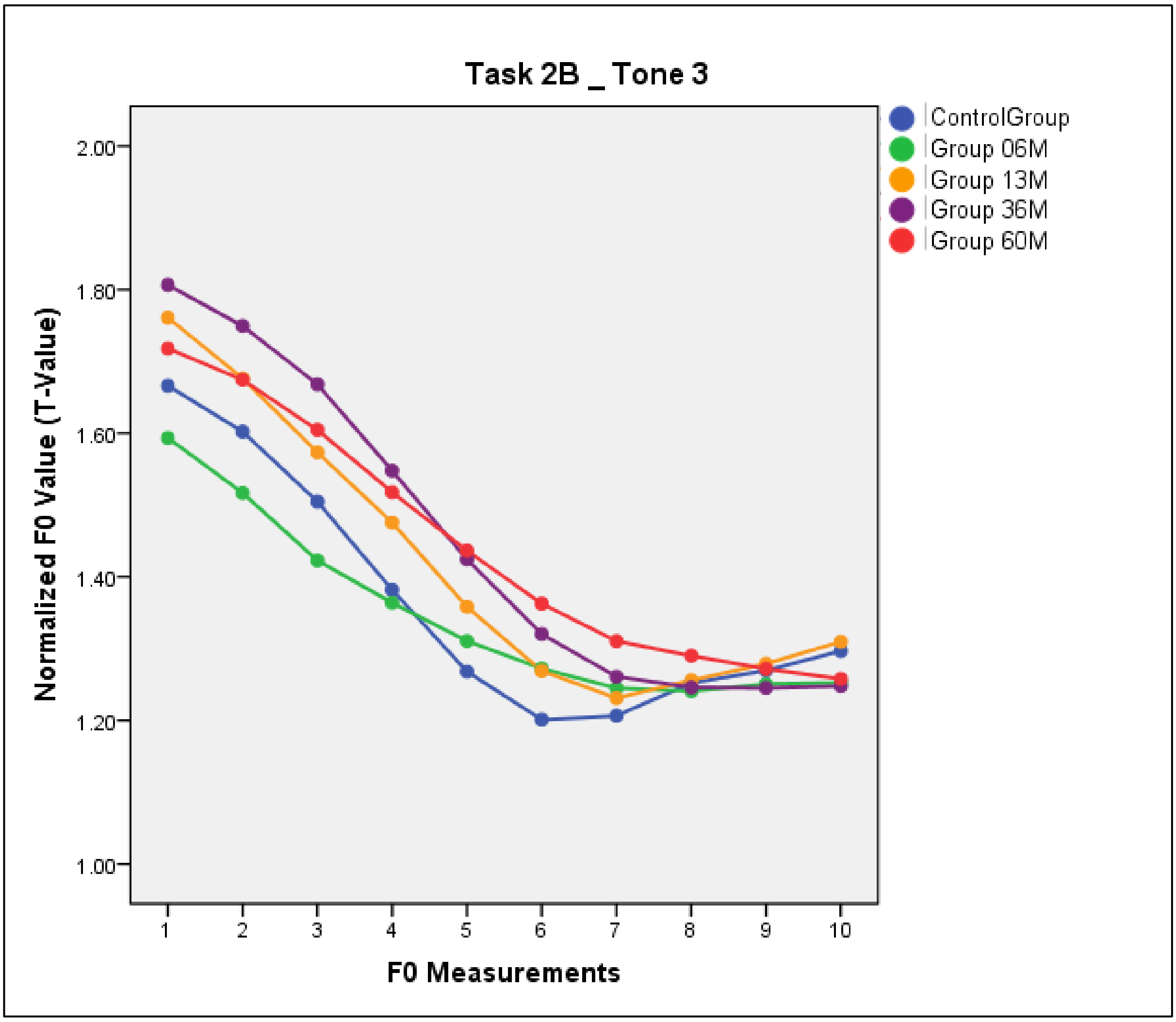


Figure 4.21 Pitch contours for Task 2B Tone 3

Table 4.19 T-values and significant differences for Task 2B Tone 3

Task 2B_Tone 3		$1T_{f_0}$	$2T_{f_0}$	$3T_{f_0}$	$4T_{f_0}$	$5T_{f_0}$	$6T_{f_0}$	$7T_{f_0}$	$8T_{f_0}$	$9T_{f_0}$	$10T_{f_0}$
Chinese Monolinguals	Control Group	1.666	1.602	1.505	1.382	1.268	1.201	1.206	1.252	1.269	1.297
Chinese-English Bilinguals	Group 06M	1.593	1.517	1.423	1.364	1.311	1.272	1.245	1.241	1.250	1.252
	Group 13M	1.761	1.676	1.573	1.476	1.358	1.269	1.231	1.256	1.279	1.310
	Group 36M	1.806	1.749	1.668	1.548	1.424	1.320	1.261	1.246	1.245	1.248
	Group 60M	1.718	1.674	1.605	1.518	1.436	1.363	1.310	1.290	1.272	1.258

As can be seen clearly in Figure 4.22 below, Group 36M produced tone 3 with a higher pitch height in general compared to the control group. Tone 3 as produced by two groups had parallel falling contours from the starting measurement to measurement $6T_{f_0}$. The contours intersected at measurement $8T_{f_0}$ and Group 36M's contour continually fell, which was much different from the control group's rising contour. Measurements $4T_{f_0}$, $5T_{f_0}$, and $6T_{f_0}$ for Group 36M were significantly higher than the corresponding measurements for the control group. Meanwhile, the rising part of tone 3 contour produced by Group 36M was shortened and almost level. On the contrary, the rising part produced by the control group was apparent.

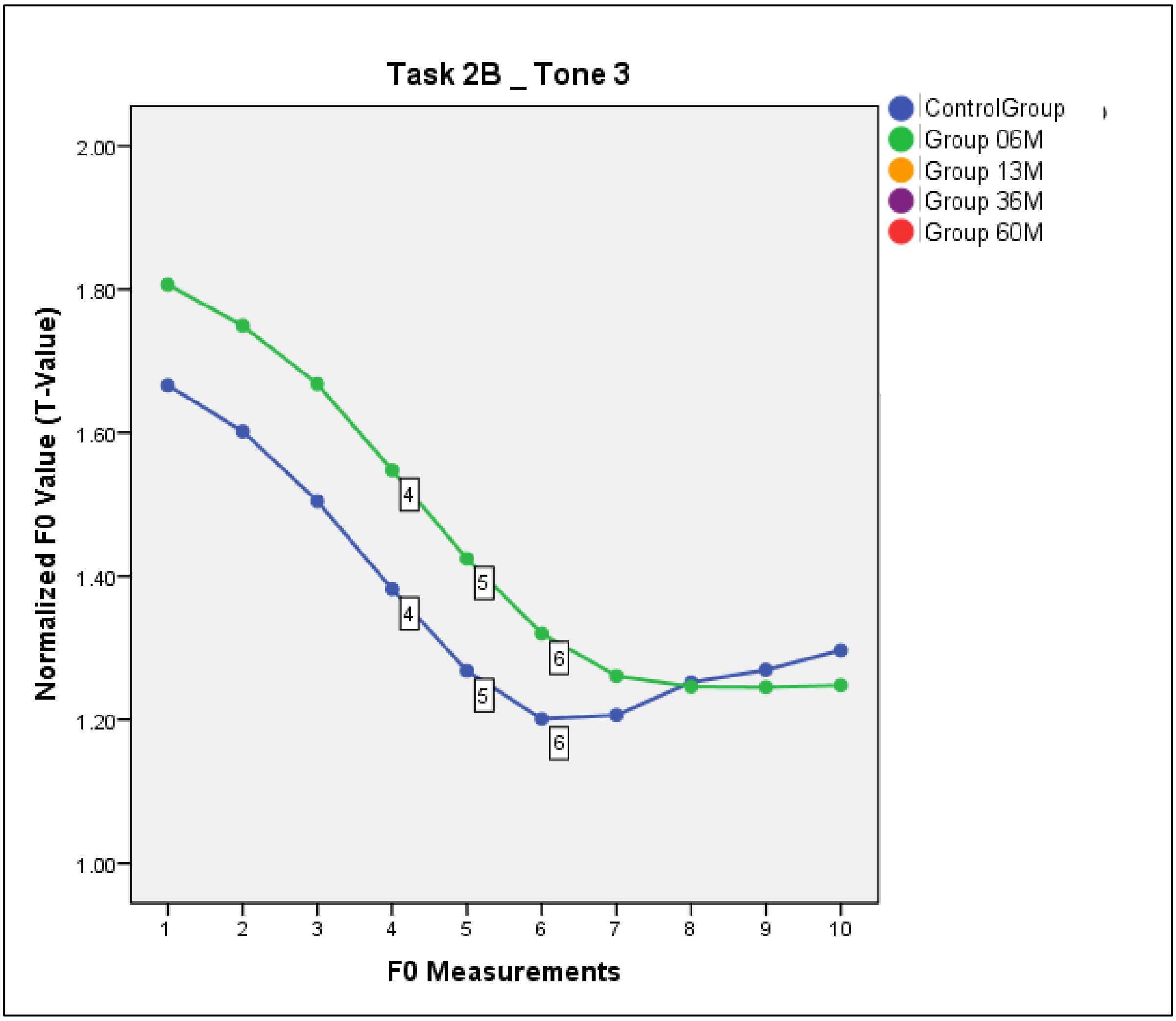


Figure 4.22 Pitch contours for Task 2B Tone 3: Control Group vs. Group 36M

Tone 3 as produced by Group 60M, similar to Group 36M, had a significantly higher pitch height than the control group. The whole contour produced by Group 60M was falling, unlike the control group's falling and then rising contour. In other words, Group 60M omitted the rising part of tone 3 production. Thus, contours for two groups overlapped on measurement $9T_{f_0}$.

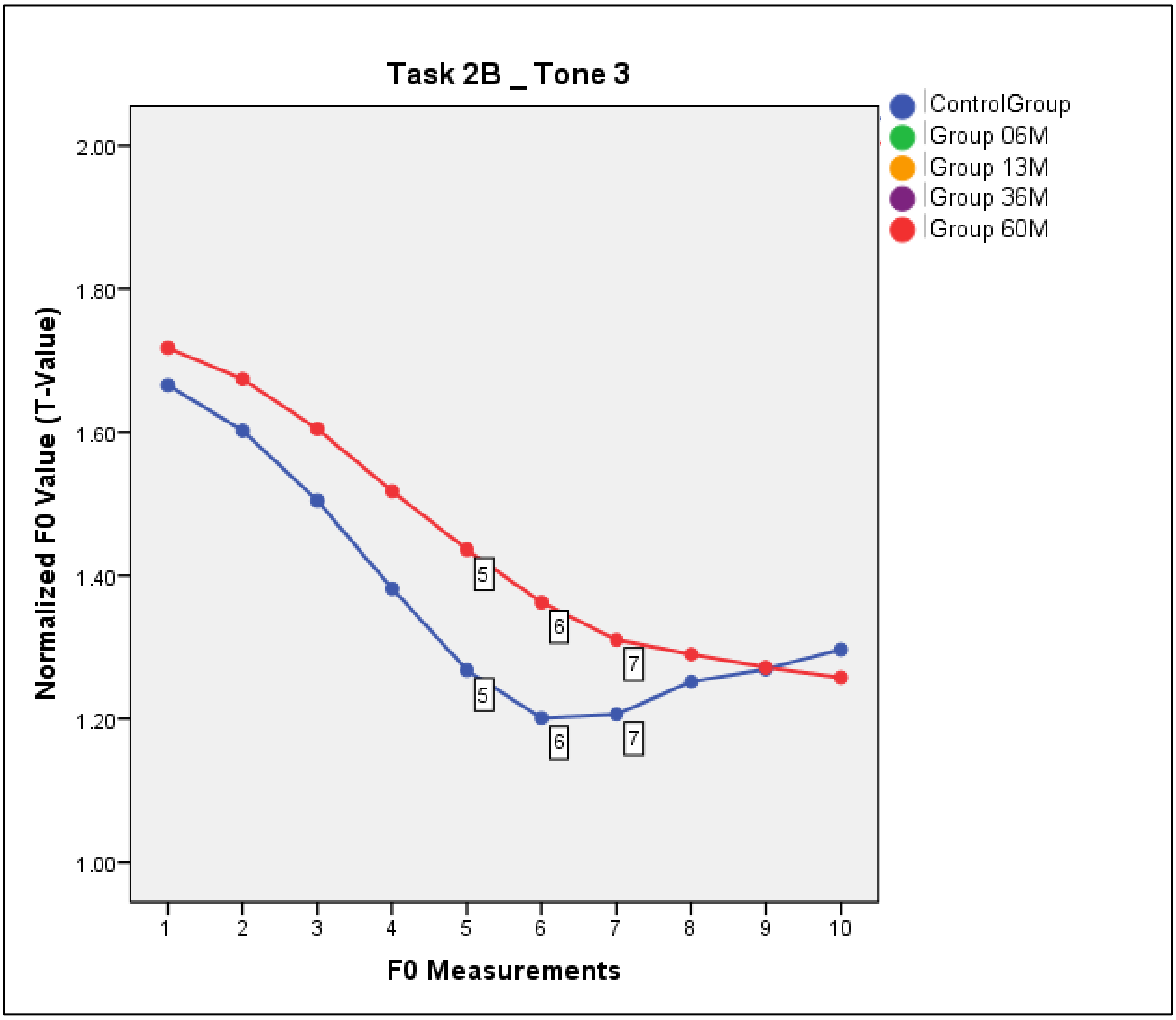


Figure 4.23 Pitch contours for Task 2B Tone: Control Group vs. Group 60M

Figure 4.24 demonstrates the simplified three measurements of tone 3 contours for the five groups. All five groups demonstrated falling parts from the start measurement to the turning point. There are no significant differences at these two points when comparing the control group and the other four groups. The control group and Group 06M performed rising parts clearly. Group 13M demonstrated a lowered rising part. Group 36M and Group 60M had no rising parts, which was a significant difference compared to control group.

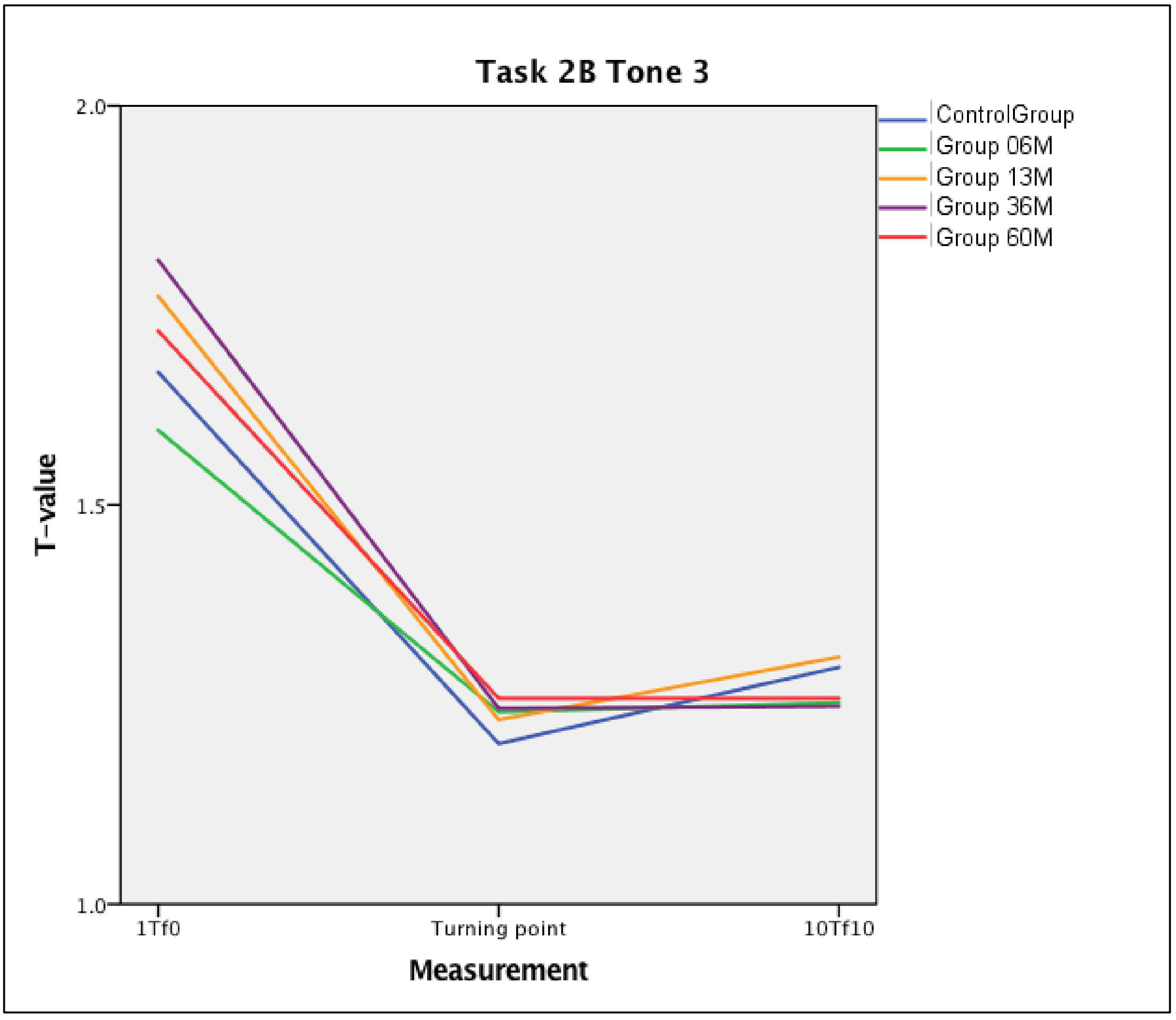


Figure 4.24 Simplified tone 3 contours for five groups for Task 2B

Table 4.20 T-values and significant differences for simplified tone 3 for five groups for Task 2B.

	Starting $1T_{f_0}$	Turning Point (Min T_{f_0})	Ending $10T_{f_0}$		
Control Group	1.666	1.201	1.297		
Group 06M	1.593	1.241	1.252		
Group 13M	1.761	1.231	1.310		
Group 36M	1.806	1.245	1.248		
Group 60M	1.718	1.258	1.258		

Tone 4

T4 as produced by all five groups had falling contours. The control group uttered T4 with a starting T-value of 3.972 and an ending one of 2.836. Group 06M had nearly the same T4 contour as the control group. T4 as produced by Group 13M was slightly lower than that of the control group, coinciding at the final three measurements. Groups 36M and 60M demonstrated higher starting points for T4. Group 36M maintained a higher pitch track to the end, but Group 60M lowered the latter part.

There were no significant differences at each measurement between the control group and the other four groups according to independent t-tests.

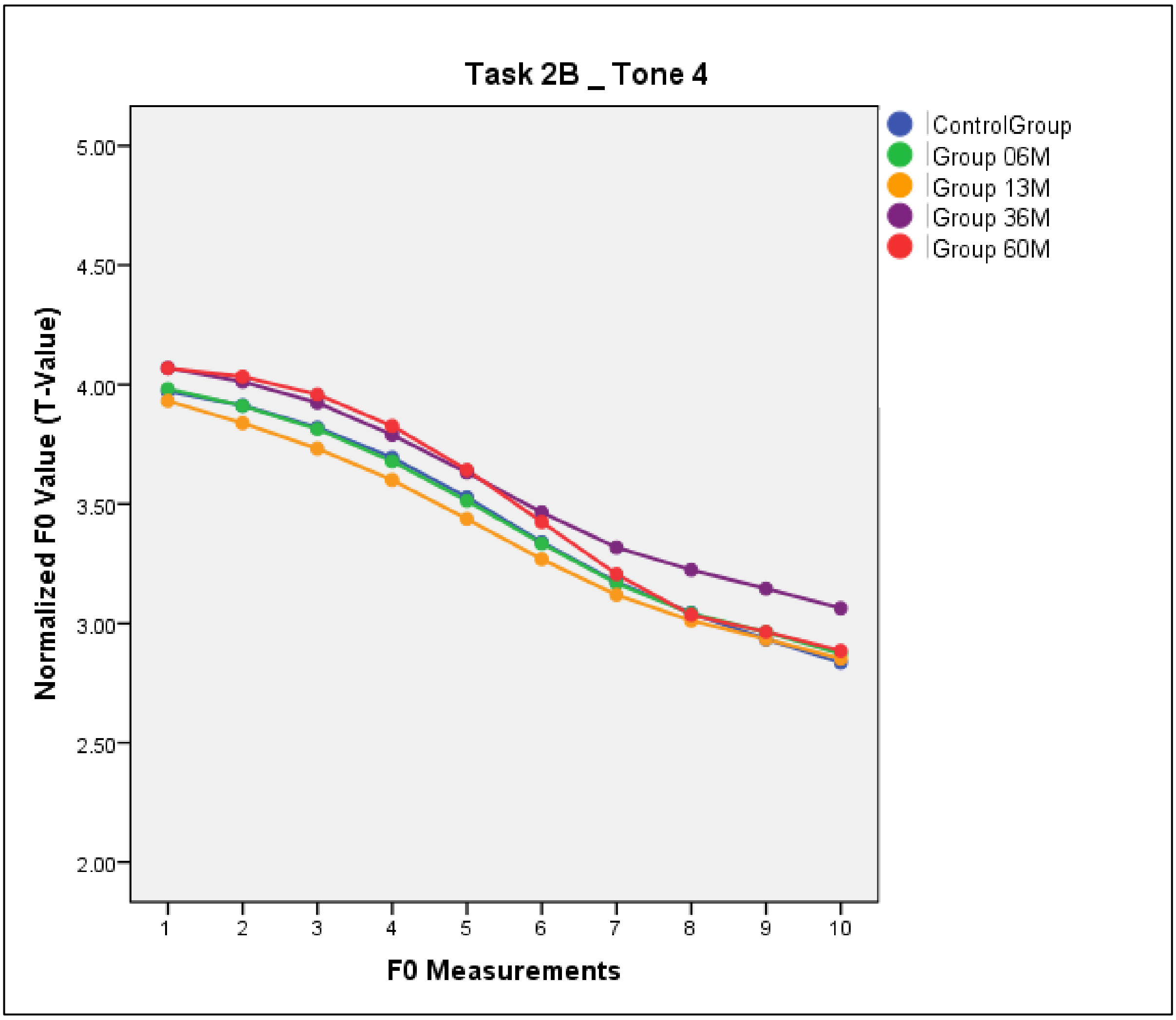


Figure 4.25 Pitch contours for Task 2B Tone 4

Table 4.21 T-values and significant differences for Task 2B Tone 4

Task 2B_Tone 4		$1T_{f_0}$	$2T_{f_0}$	$3T_{f_0}$	$4T_{f_0}$	$5T_{f_0}$	$6T_{f_0}$	$7T_{f_0}$	$8T_{f_0}$	$9T_{f_0}$	$10T_{f_0}$
Chinese Monolinguals	Control	3.972	3.912	3.821	3.694	3.528	3.340	3.173	3.043	2.934	2.836
Chinese-English Bilinguals	Group 06M	3.982	3.911	3.814	3.678	3.513	3.334	3.168	3.041	2.964	2.873
	Group 13M	3.931	3.838	3.732	3.601	3.437	3.269	3.119	3.012	2.934	2.852
	Group 36M	4.069	4.012	3.924	3.789	3.631	3.465	3.318	3.224	3.146	3.064
	Group 60M	4.068	4.033	3.959	3.827	3.643	3.425	3.206	3.036	2.965	2.886

Tone 4 Variation

T44 production in Task 2B for the five groups is illustrated in Figure 4.26 below. The control group produced a standard T44 with the first T4 starting at T-value 4.233 and ending at 3.271. The second T4 started lower with a T-value of 3.301 and ended with a T-value of 2.132. T44 as produced by the bilingual groups also followed T4 variation rules. Group 06M overlapped with the control group in the first five measurements. The transition was smooth from the first T4 to the second T4, which ended at 2.569. Group 13M's contour slightly rose at the end of the first T4, and this was followed by a falling second T4. As for Group 13M, the rising ending of the first T4 as produced by Group 36M extended to the 13T_{f_0} measurement of the second T4. Group 60M had an apparent rise from the first T4 to connect to the second T4. Comparing the control group with each bilingual group, there were no significant differences.

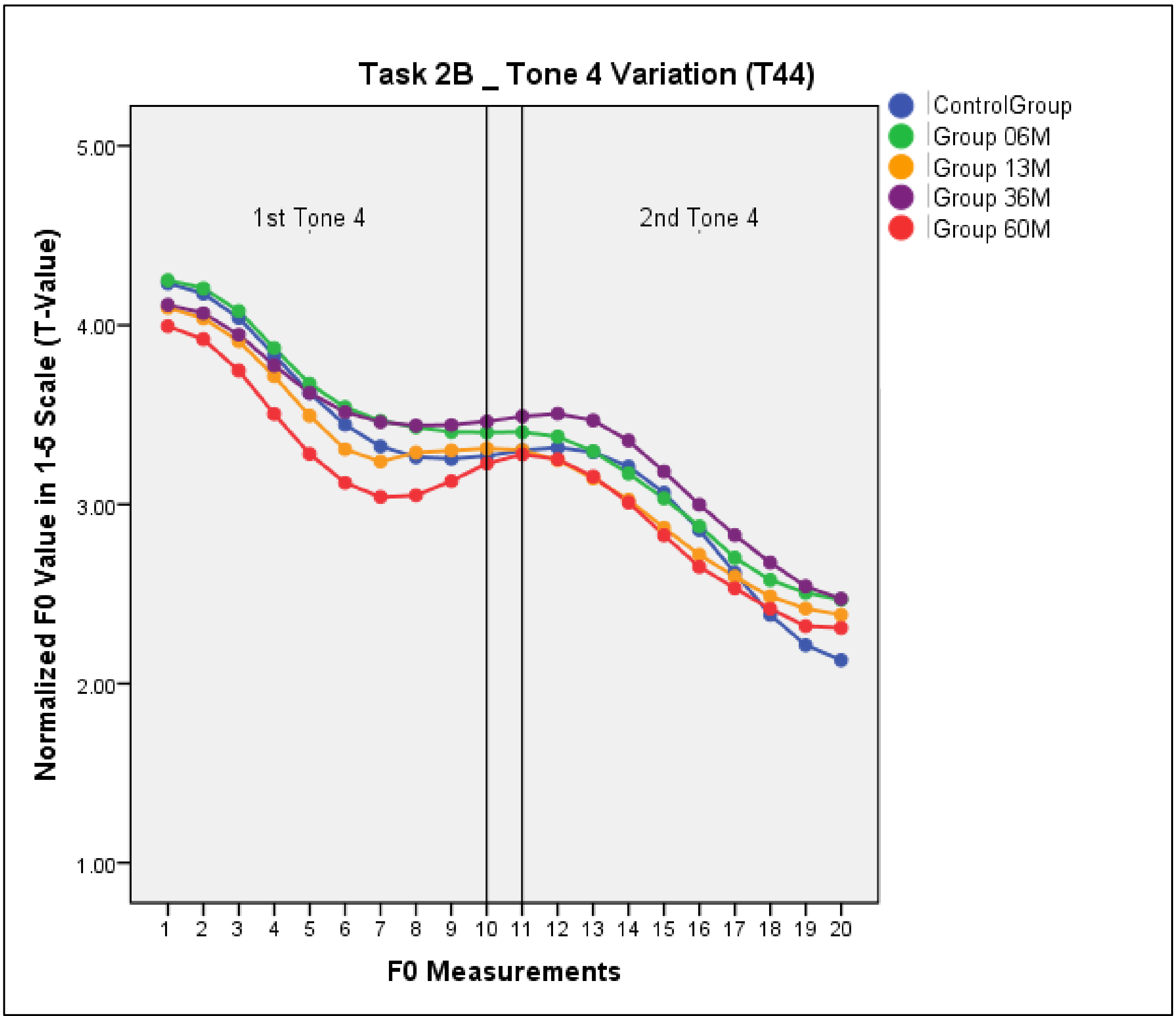


Figure 4.26 Pitch contours for Task 2B Tone 4 variation

Table 4.22 T-values and significant differences of Task 2B Tone 4 variation

Task 2B_ Tone 4 variation 1st T4		$1T_{f_0}$	$2T_{f_0}$	$3T_{f_0}$	$4T_{f_0}$	$5T_{f_0}$	$6T_{f_0}$	$7T_{f_0}$	$8T_{f_0}$	$9T_{f_0}$	$10T_{f_0}$
Chinese Monolinguals	Control Group	4.233	4.176	4.040	3.833	3.620	3.444	3.324	3.264	3.254	3.271
Chinese-English Bilinguals	Group 06M	4.250	4.206	4.079	3.871	3.673	3.542	3.466	3.429	3.404	3.401
	Group 13M	4.097	4.039	3.911	3.715	3.494	3.307	3.239	3.289	3.301	3.312
	Group 36M	4.113	4.067	3.947	3.776	3.621	3.515	3.459	3.439	3.443	3.462
	Group 60M	3.994	3.921	3.746	3.504	3.282	3.121	3.041	3.051	3.131	3.228
Task 2B_ Tone 4 variation 2nd T4		$11T_{f_0}$	$12T_{f_0}$	$13T_{f_0}$	$14T_{f_0}$	$15T_{f_0}$	$16T_{f_0}$	$17T_{f_0}$	$18T_{f_0}$	$19T_{f_0}$	$20T_{f_0}$
Chinese Monolinguals	Control Group	3.301	3.317	3.292	3.211	3.065	2.857	2.618	2.385	2.215	2.132
Chinese-English Bilinguals	Group 06M	3.403	3.378	3.296	3.172	3.033	2.879	2.702	2.578	2.507	2.469
	Group 13M	3.303	3.247	3.147	3.025	2.869	2.719	2.596	2.487	2.419	2.384
	Group 36M	3.491	3.506	3.468	3.355	3.183	2.999	2.829	2.675	2.543	2.473
	Group 60M	3.279	3.252	3.156	3.011	2.828	2.651	2.532	2.417	2.321	2.311

Tone Sandhi

Figure 4.27 presents tone sandhi data from Task 2B. All five groups followed the standard tone sandhi rules, changing the first T3 to a rising T2. The control group had a more obvious rising contour than the bilingual groups. Group 06M produced tone sandhi as a level tone rising very slightly from $5T_{f_0}$ to the end. Group 13M also had a rise from $5T_{f_0}$, but its rising part was more distinct than that of Group 06M. Group 36M and 60M overlapped in the first three measurements, with Group 60M lower than Group 36M in the following rising part. No significant differences were evident in independent t-tests.

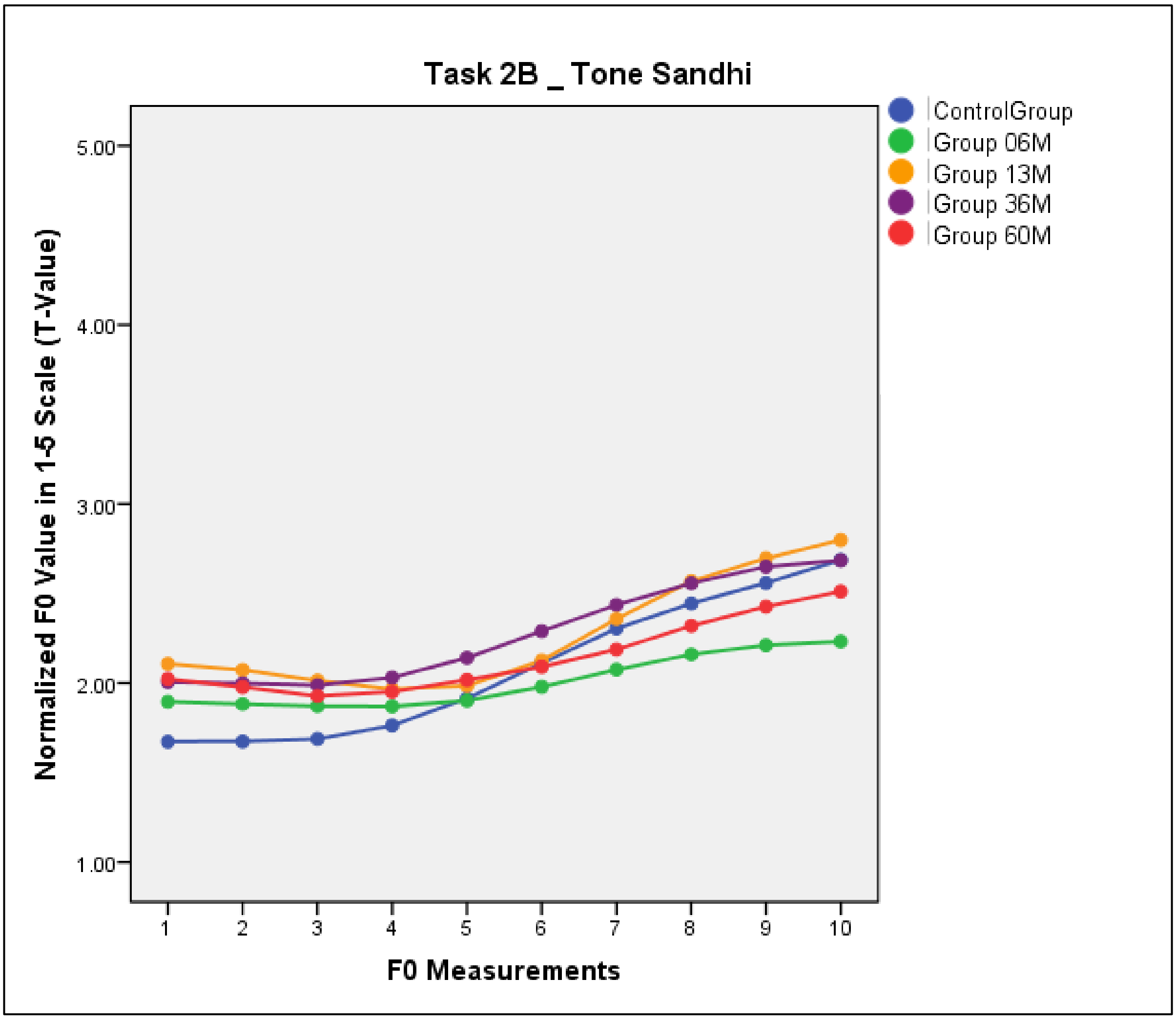


Figure 4.27 Pitch contours for Task 2B tone sandhi

Table 4.23 T-values and significant differences for Task 2B tone sandhi

Task 2B_ Tone sandhi		$1T_{f_0}$	$2T_{f_0}$	$3T_{f_0}$	$4T_{f_0}$	$5T_{f_0}$	$6T_{f_0}$	$7T_{f_0}$	$8T_{f_0}$	$9T_{f_0}$	$10T_{f_0}$
Chinese Monolinguals	Control Group	1.673	1.674	1.688	1.763	1.914	2.111	2.305	2.444	2.559	2.688
Chinese-English Bilinguals	Group 06M	1.896	1.883	1.871	1.870	1.902	1.979	2.075	2.160	2.211	2.233
	Group 13M	2.108	2.073	2.014	1.966	1.985	2.126	2.359	2.569	2.696	2.799
	Group 36M	2.006	1.999	1.989	2.031	2.141	2.290	2.437	2.557	2.649	2.685
	Group 60M	2.023	1.977	1.928	1.952	2.018	2.091	2.188	2.319	2.427	2.511

yi variation

From Figure 4.28 below, it can be seen that *yi* T1→T4 variation was produced as a falling tone by all five groups. The control group produced *yi* T1→T4 variation with a starting T-value of 3.399 and ending at T-value 3.150. The difference between the starting and ending points was small. Group 06M had a relatively level contour from the beginning to the end, with a height difference of T-value 0.066. Group 13M had a similarly level contour to Group 06M, but with slightly lowered T-values. Group 36M had the most obvious falling *yi* tone. The difference between $1T_{f_0}$ and $10T_{f_0}$ was 0.497, which was the largest T-value difference among the five groups. Group 60M had a relevant falling *yi* tone, starting at T-value 3.757 and ending at 3.414. According to independent t-tests, there were no significant differences at any measurement.

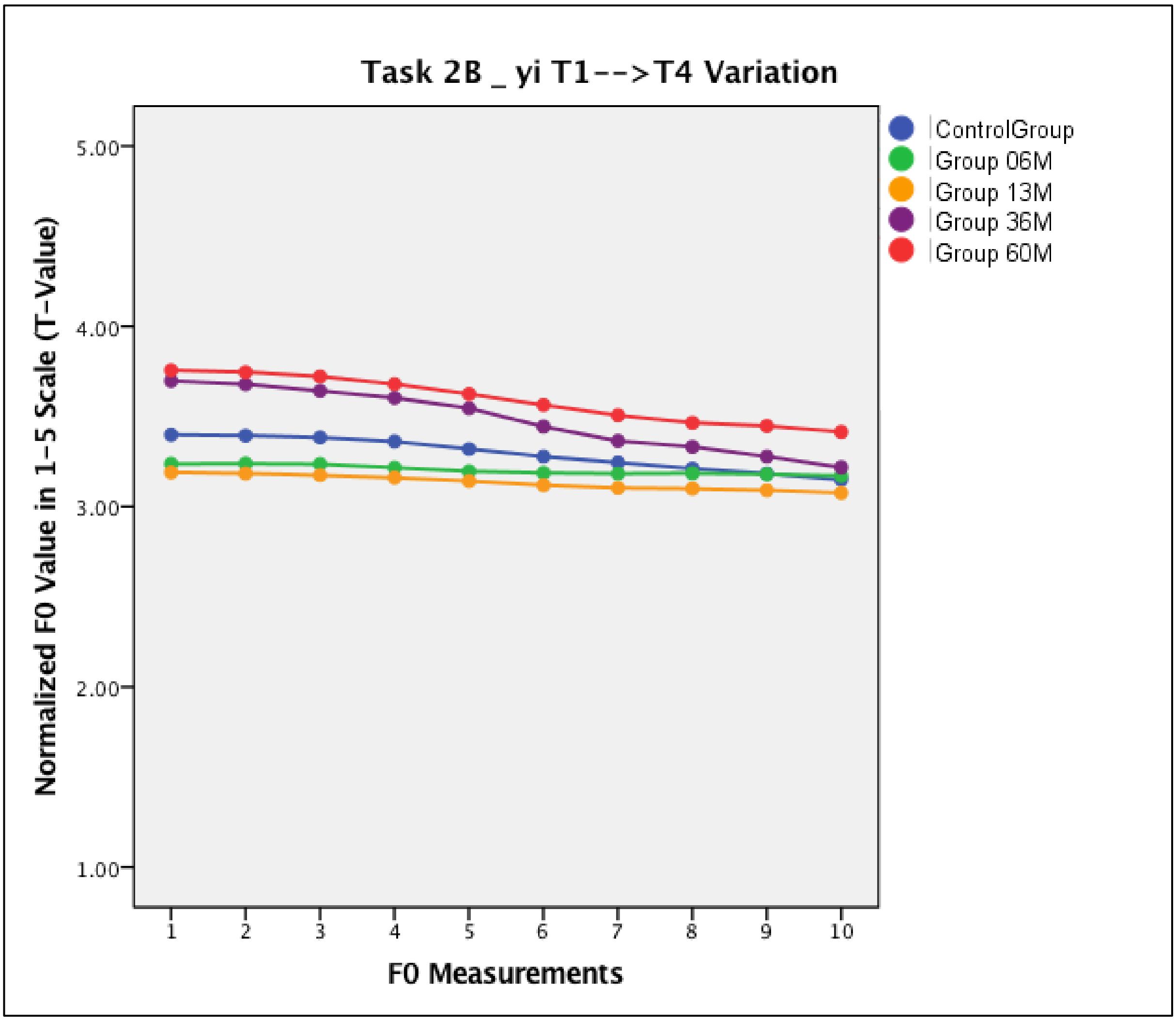


Figure 4.28 Pitch contours for Task 2B yi T1→T4 variation

Table 4.24 T-values and significant differences for Task 2B yi T1→T4 variation

Task 2B_*yi* T1→T4 variation		$1T_{f_0}$	$2T_{f_0}$	$3T_{f_0}$	$4T_{f_0}$	$5T_{f_0}$	$6T_{f_0}$	$7T_{f_0}$	$8T_{f_0}$	$9T_{f_0}$	$10T_{f_0}$
Chinese Monolinguals	Control Group	3.399	3.394	3.384	3.361	3.320	3.278	3.244	3.211	3.183	3.150
Chinese-English Bilinguals	Group 06M	3.237	3.239	3.236	3.216	3.196	3.187	3.183	3.185	3.180	3.171
	Group 13M	3.190	3.184	3.174	3.161	3.142	3.119	3.104	3.100	3.091	3.076
	Group 36M	3.697	3.679	3.642	3.603	3.546	3.444	3.364	3.332	3.278	3.218
	Group 60M	3.757	3.746	3.722	3.680	3.625	3.564	3.507	3.466	3.448	3.414

Figure 4.29 illustrates the T1→T2 *yi* variation. All five groups followed the tone sandhi rules and produced a rising *yi* tone. The control group produced T1→T2 *yi* variation with a slightly rising tendency. Group 06M produced the most obvious rising tone among the five groups. Group 13M had a very similar contour to the control group, but a slightly lowered register. Group 36M's *yi* variation had an obvious rising contour that was similar to Group 06M, but much lowered register. Group 60M had the highest contour for *yi* variation, and its rising tendency was relatively smooth.

Though the contours were produced at different registers, there were no significant differences between the control group and the bilingual groups.

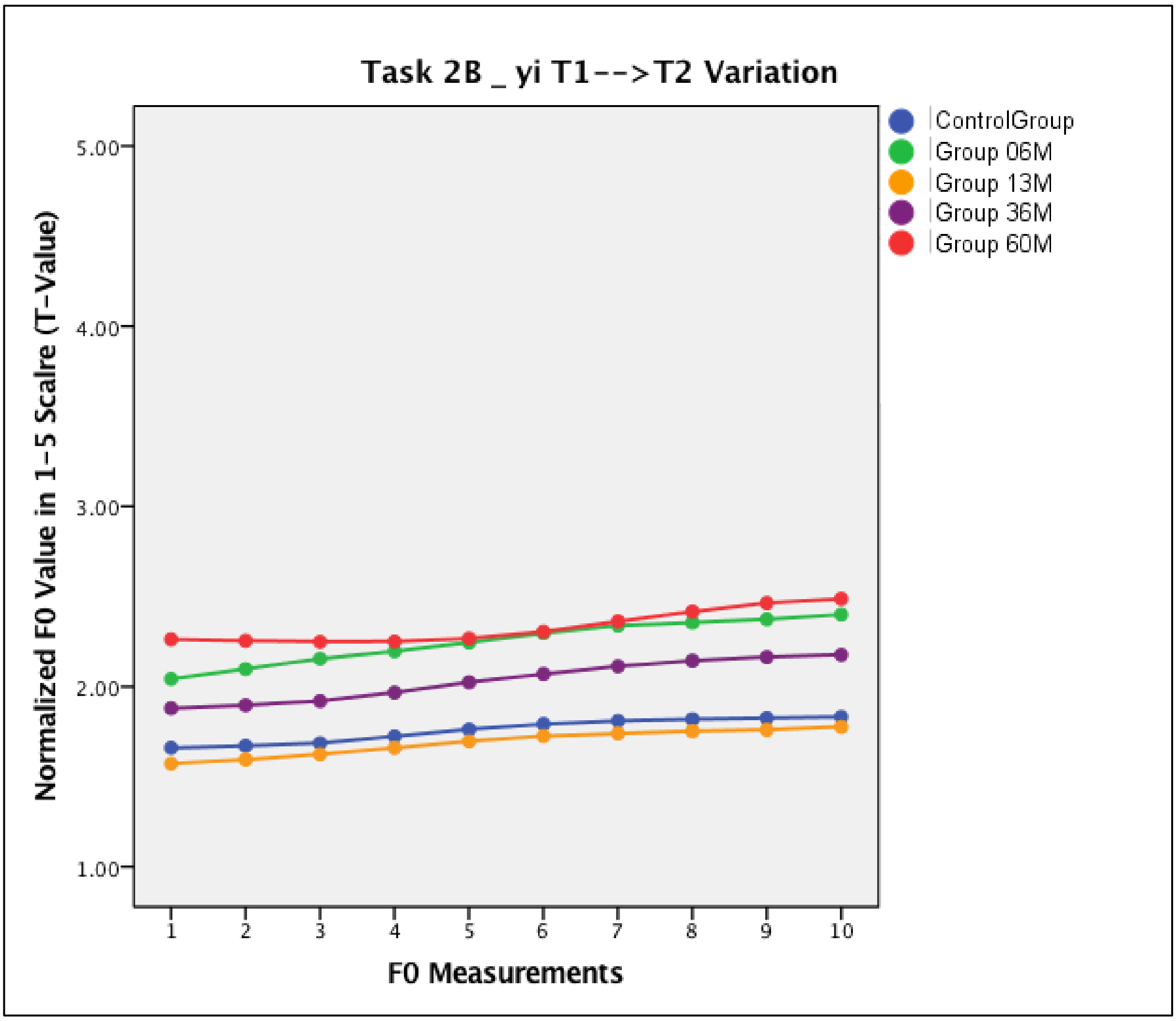


Figure 4.29 Pitch contours for Task 2B yi T1→ T2 variation

Table 4.25 T-Values and Significant differences for Task 2B yi T1→T4 variation

Task 2B_*yi* T1→T2 variation		$1T_{f_0}$	$2T_{f_0}$	$3T_{f_0}$	$4T_{f_0}$	$5T_{f_0}$	$6T_{f_0}$	$7T_{f_0}$	$8T_{f_0}$	$9T_{f_0}$	$10T_{f_0}$
Chinese Monolinguals	Control Group	1.660	1.671	1.686	1.724	1.762	1.792	1.809	1.819	1.825	1.832
Chinese-English Bilinguals	Group 06M	2.043	2.097	2.154	2.196	2.244	2.296	2.338	2.355	2.373	2.400
	Group 13M	1.572	1.595	1.624	1.659	1.697	1.725	1.739	1.752	1.760	1.776
	Group 36M	1.879	1.897	1.919	1.967	2.024	2.069	2.113	2.143	2.164	2.176
	Group 60M	2.262	2.254	2.249	2.250	2.267	2.305	2.362	2.416	2.464	2.487

4.3.4. Task 2C: Describing Videos

Tone 1

In Task 2C, T1 was produced with a level contour by the five groups. The control group produced T1 with a lower register, with the T-values of the 10 measurements between 3.8 and 3.9. Bilingual groups 06M, 13M, and 36M had similar T1 production. At a higher register, the pitch tracks of these three groups nearly matched those of the control group at every measurement. Group 60M, in contrast with the other three bilingual groups, produced a lower T1. The pitch track of Group 60M was at the same level as the control group.

Though the control group and the four bilingual groups produced T1 at two main pitch registers, there were no significant differences at each f_0 measurement. The T-values of the f_0 measurements ranged between 3.8 and 4.0 (details are listed in Table 4.26 below).

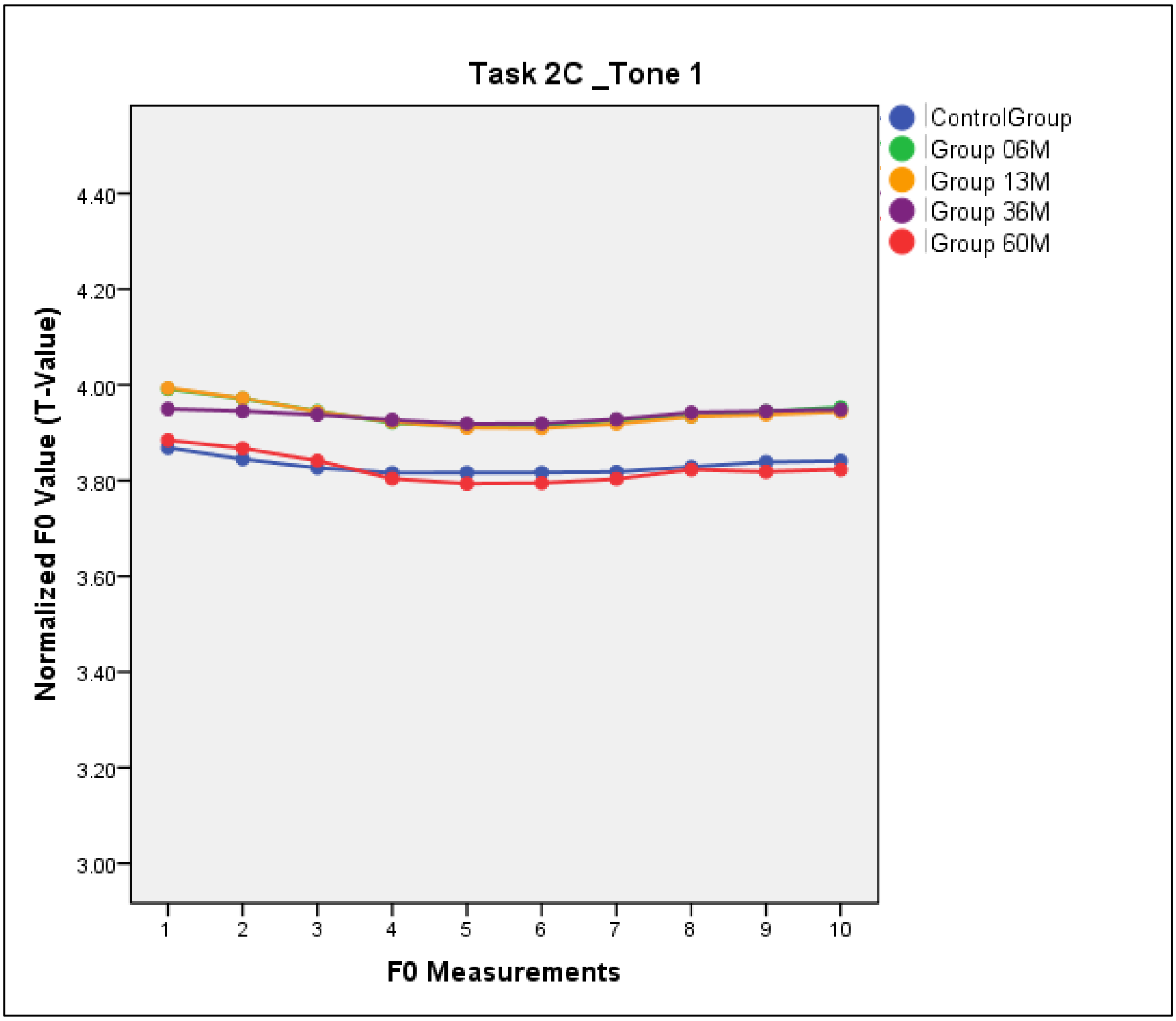


Figure 4.30 Pitch contours for Task 2C Tone 1

Table 4.26 T-values and significant differences for Task 2C Tone 1

Task 2C_Tone 1		$1T_{f_0}$	$2T_{f_0}$	$3T_{f_0}$	$4T_{f_0}$	$5T_{f_0}$	$6T_{f_0}$	$7T_{f_0}$	$8T_{f_0}$	$9T_{f_0}$	$10T_{f_0}$
Chinese Monolinguals	Control Group	3.868	3.845	3.826	3.816	3.816	3.817	3.818	3.829	3.839	3.841
Chinese-English Bilinguals	Group 06M	3.991	3.971	3.945	3.921	3.914	3.916	3.925	3.935	3.944	3.953
	Group 13M	3.994	3.972	3.943	3.923	3.910	3.909	3.919	3.934	3.938	3.943
	Group 36M	3.949	3.945	3.938	3.927	3.919	3.919	3.928	3.942	3.945	3.948
	Group 60M	3.887	3.869	3.843	3.805	3.795	3.797	3.806	3.826	3.821	3.825

Tone 2

Figure 4.31 below shows T2 production in the task. It is clear that all five groups produced a rising T2s as in Tasks 2A and 2B. The pitch contour of T2 produced by the control group rose smoothly until $5T_{f_0}$, after which there was a relatively sharp rise. Group 06M coincided with the control group in the first half of the pitch track. The second half of the contour was lower than the control group, but nevertheless still rising. The pitch contours of Groups 13M, 36M, and 60M approximately coincide at $3T_{f_0}$, $4T_{f_0}$, and $5T_{f_0}$. Group 13M ends with the highest T-value, followed by Groups 36M and 60M.

In comparison with the control group, there were no significant differences across the whole contour of the four bilingual groups, though the T-value vary at each f_0 measurement.

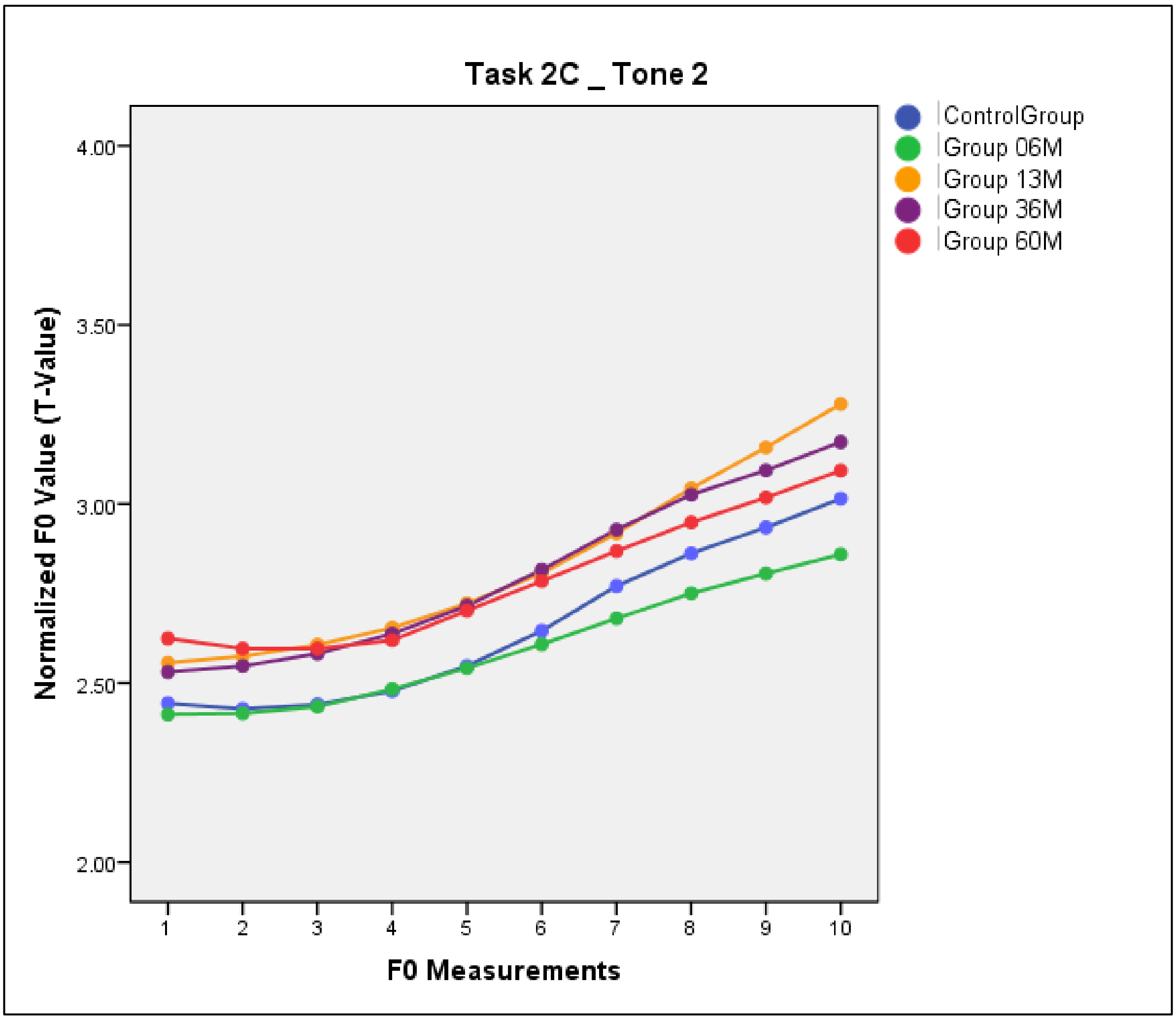


Figure 4.31 Pitch contours for Task 2C Tone 2

Table 4.27 T-values and significant differences for Task 2C Tone 2

Task 2C_Tone 2		$1T_{f_0}$	$2T_{f_0}$	$3T_{f_0}$	$4T_{f_0}$	$5T_{f_0}$	$6T_{f_0}$	$7T_{f_0}$	$8T_{f_0}$	$9T_{f_0}$	$10T_{f_0}$
Chinese Monolinguals	Control Group	2.444	2.428	2.440	2.478	2.548	2.646	2.771	2.862	2.935	3.015
Chinese-English Bilinguals	Group 06M	2.413	2.416	2.434	2.483	2.542	2.608	2.681	2.750	2.806	2.859
	Group 13M	2.557	2.575	2.607	2.654	2.722	2.807	2.918	3.044	3.158	3.279
	Group 36M	2.531	2.548	2.582	2.638	2.716	2.816	2.929	3.026	3.094	3.173
	Group 60M	2.625	2.596	2.596	2.620	2.702	2.785	2.868	2.949	3.018	3.093

Tone 3

In this task, T3 contours were more centralized than in the previous two tasks. The control group produced a proper T3 with a falling part and a rising part. The rising part encompassed the last three measurements of $8T_{f_0}$, $9T_{f_0}$, and $10T_{f_0}$, and so was less obvious than in Task 2A and 2B. Group 06M had a similar pitch contour to the control group, though the rising part started from $7T_{f_0}$. Groups 13M, 36M, and 60M followed the rule that their contours had higher registers according to the length of residence. Group 13M's T3 production had the highest starting T-value at 1.786, then dropped to 1.198 before slightly rising at the end. Group 36M had only the rising part with a higher register than the control group. Group 60M, just like Group 36M, had no rising part at all. Figure 4.32 presents more information.

Table 4.28 illustrates the T-values and significant differences for each measurement. There were no significant differences between the control group and the bilingual groups 06M and 13M. Significant differences existed at $6T_{f_0}$ between the control group and Group 36M. The *p*-value was 0.040. Group 60M had three measurements, $4T_{f_0}$, $5T_{f_0}$, and $6T_{f_0}$, that were significantly different from the control group. The *p*-values were 0.035, 0.030, and 0.029 respectively, and are coloured red in the table below. For clarity, Figure 4.33 and Figure 4.34 present the contours of the control group and Group 36M and the control group and Group 60M separately.

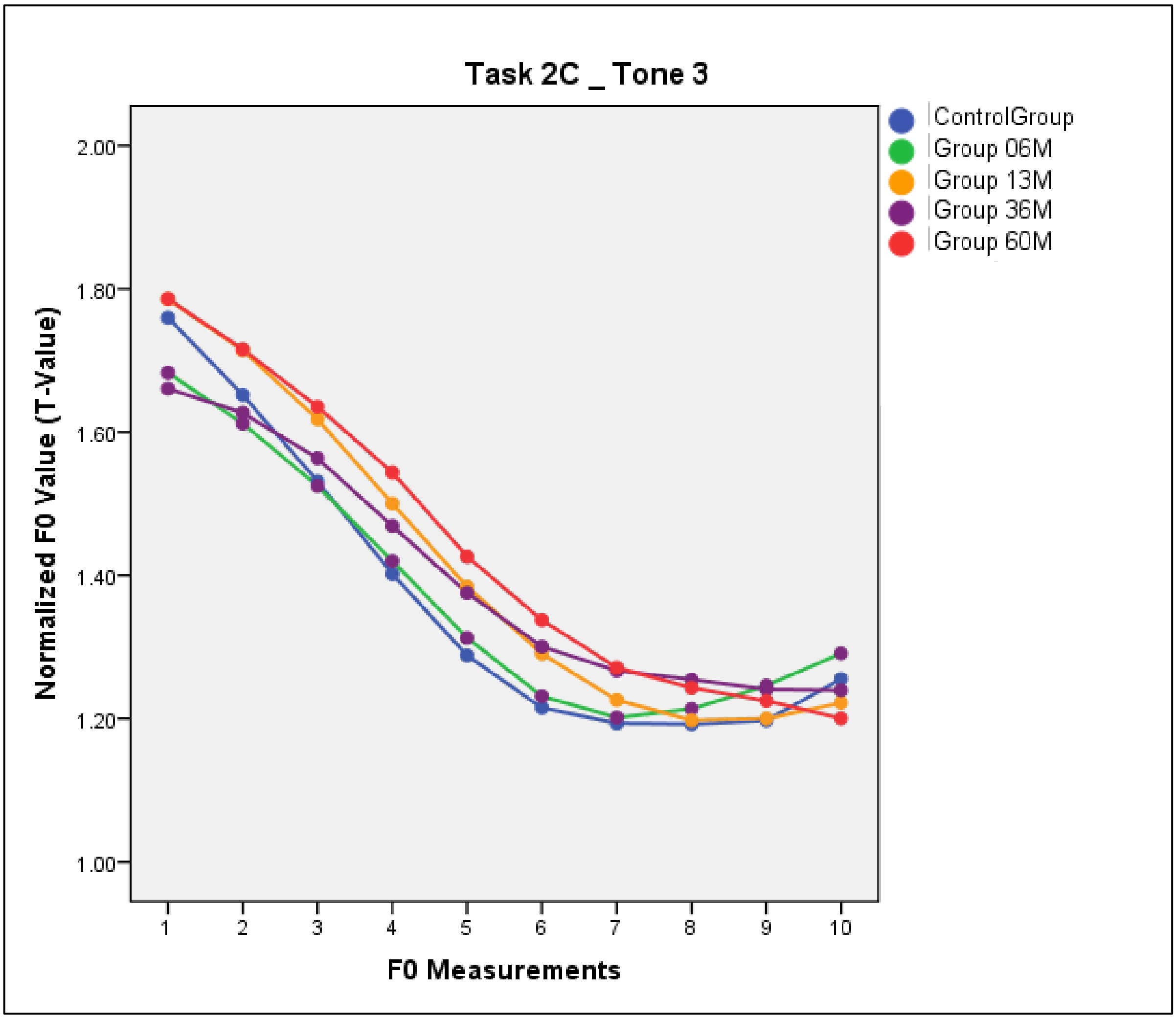


Figure 4.32 Pitch contours for Task 2C Tone 3

Table 4.28 T-values and significant differences for Task 2C Tone 3

Task 2C_Tone 3		$1T_{f_0}$	$2T_{f_0}$	$3T_{f_0}$	$4T_{f_0}$	$5T_{f_0}$	$6T_{f_0}$	$7T_{f_0}$	$8T_{f_0}$	$9T_{f_0}$	$10T_{f_0}$
Chinese Monolinguals	Control Group	1.760	1.652	1.531	1.402	1.288	1.215	1.193	1.192*	1.197	1.255
Chinese-English Bilinguals	Group 06M	1.683	1.612	1.525	1.420	1.313	1.231	1.201*	1.213	1.246	1.291
	Group 13M	1.786	1.714	1.618	1.500	1.384	1.290	1.226	1.198*	1.200	1.222
	Group 36M	1.661	1.627	1.563	1.469	1.375	1.300	1.267	1.254	1.241	1.239*
	Group 60M	1.786	1.716	1.635	1.544	1.426	1.337	1.271	1.243	1.225	1.200*

Clearly, the tone 3 contour for the control group had falling part and rising part, which was smoother and shorter than in Tasks 2A and 2B. Compared to the control group, tone 3 contour for Group 36M in this task had only a falling part. Please see Figure 4.33 below. Meanwhile, the pitch heights for Group 36M were consistently higher than for the control group, which led to a significant difference at measurement $6T_{f_0}$.

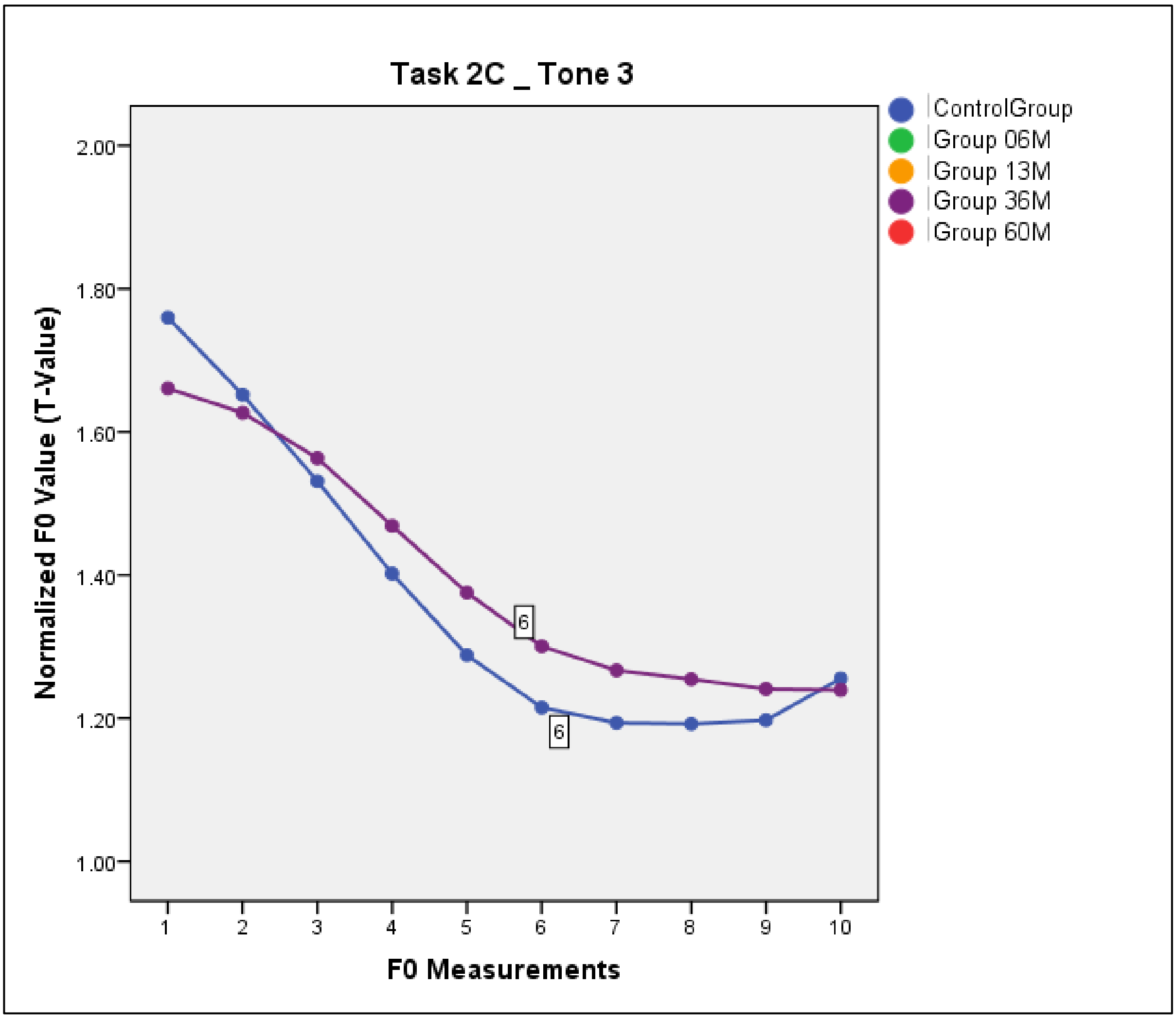


Figure 4.33 Pitch contours for Task 2C Tone 3: Control Group vs. Group 36M

Figure 4.34 illustrates tone 3 contours for the control group and Group 60M. Group 60M, compared to the control group, had a falling contour only and a higher pitch height for the majority of measurements. Thus, significant differences were demonstrated on the three measurements $4T_{f_0}$, $5T_{f_0}$, and $6T_{f_0}$, which were consistent with the results of Tasks 2A and 2B.

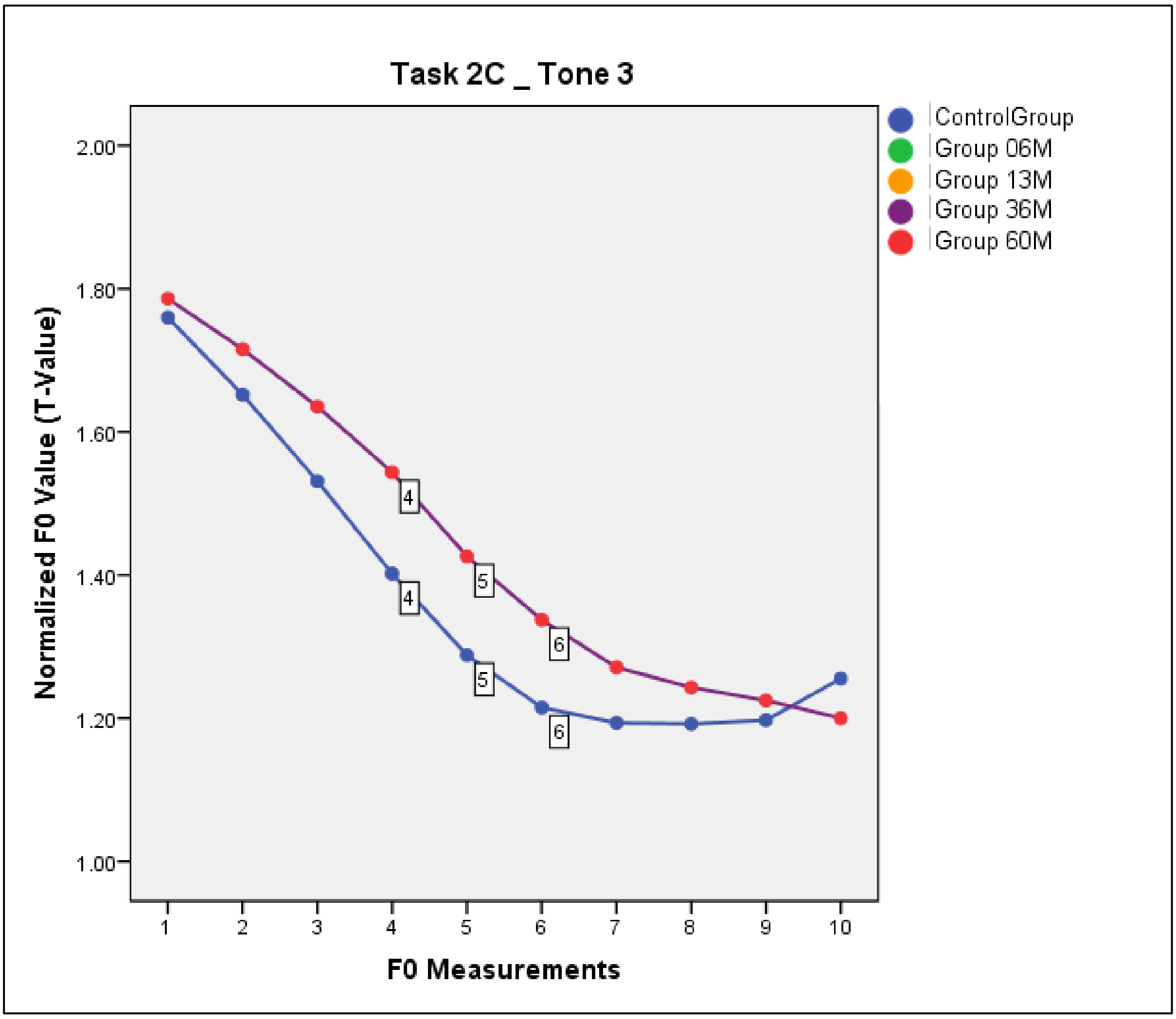


Figure 4.34 Pitch contours for Task 2C Tone 3: Control Group vs. Group 60M

Similar findings are presented in Figure 4.35 below. The control group clearly produced a rising part from the turning point to the end of measurement. Group 06M, unexpectedly, demonstrated a clear rising part. Group 13M had a lowered rising part. Groups 36M and 60M produced no rising parts for tone 3, which is shown in their level lines. Significant differences were found when comparing the control group and the other four groups.

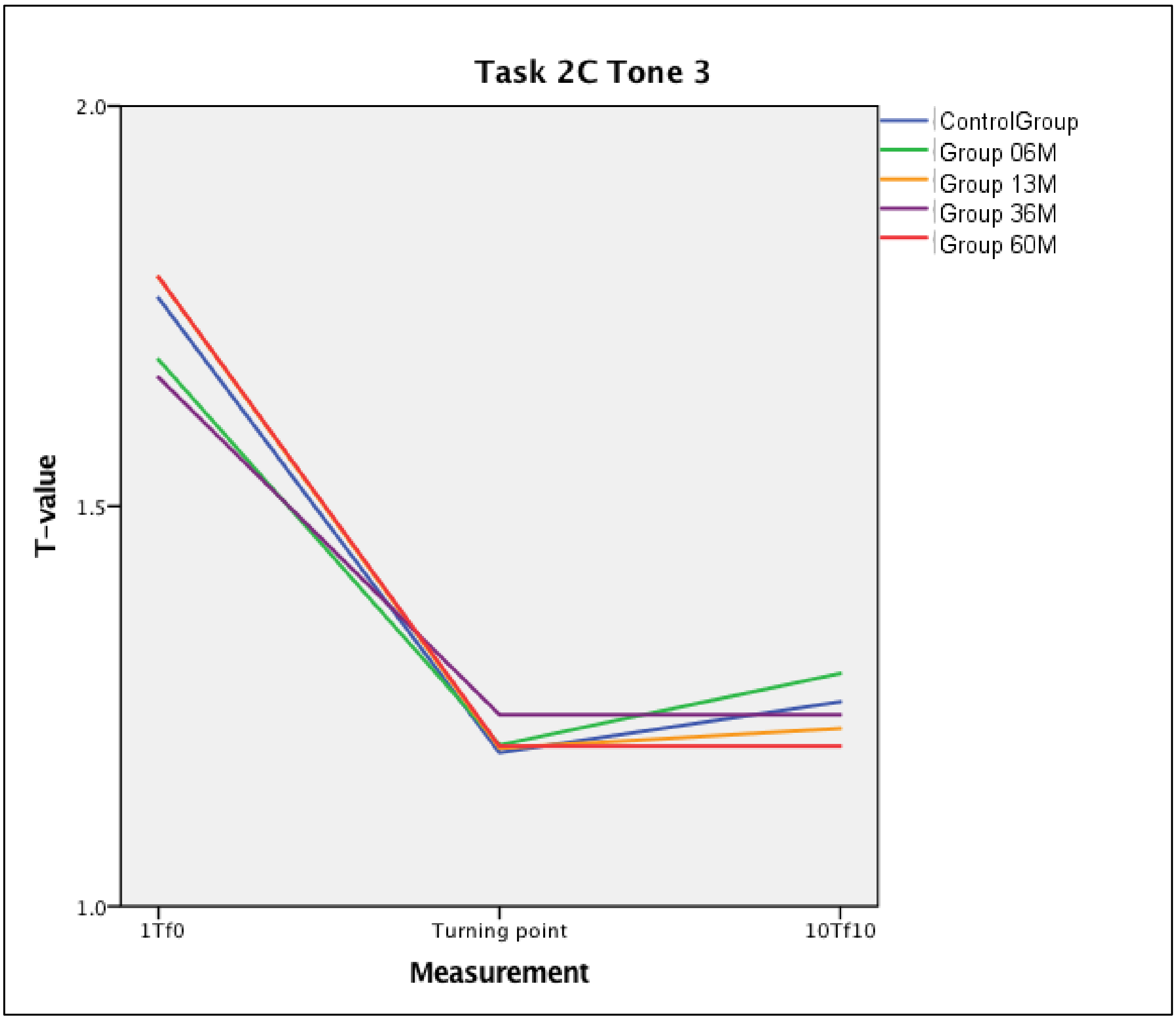


Figure 4.35 Simplified tone 3 contours for five groups for Task 2C

Table 4.29 T-values and significant differences for simplified tone 3 for five groups for Task

	Starting $1T_{f_0}$	Turning Point (Min T_{f_0})	Ending $10T_{f_0}$		
Control Group	1.709	1.134	1.255		
Group 06M	1.683	1.169	1.291		
Group 13M	1.806	1.154	1.222		
Group 36M	1.661	1.228	1.239		
Group 60M	1.692	1.200	1.200		

Tone 4

Figure 4.36 shows the T4 production of all five groups, which in all cases demonstrated a falling pitch contour. T4 as produced by the control group fell from the starting point of T-value 3.973 to the end point of 2.847. Group 06M had a lower T4 contour than the control group. However, its falling contour was very clear. Group 13M had a very similar T4 contour to the control group, with some overlapping measurements. The contour's end point dropped to 2.754. Group 06M had a similar pitch contour, but a lower register than the control group. Group 13M overlapped in the first five measurements with Group 06M, while the remaining five measurements had higher T-values than Group 13M. Groups 36M and 60M had similar pitch contours with most measurements overlapping with each other. Group 36M produced T4s with higher registers than the control group. Group 60M overlapped in the majority of measurements with Group 13M. The four bilingual groups showed no significant differences when compared with the control group.

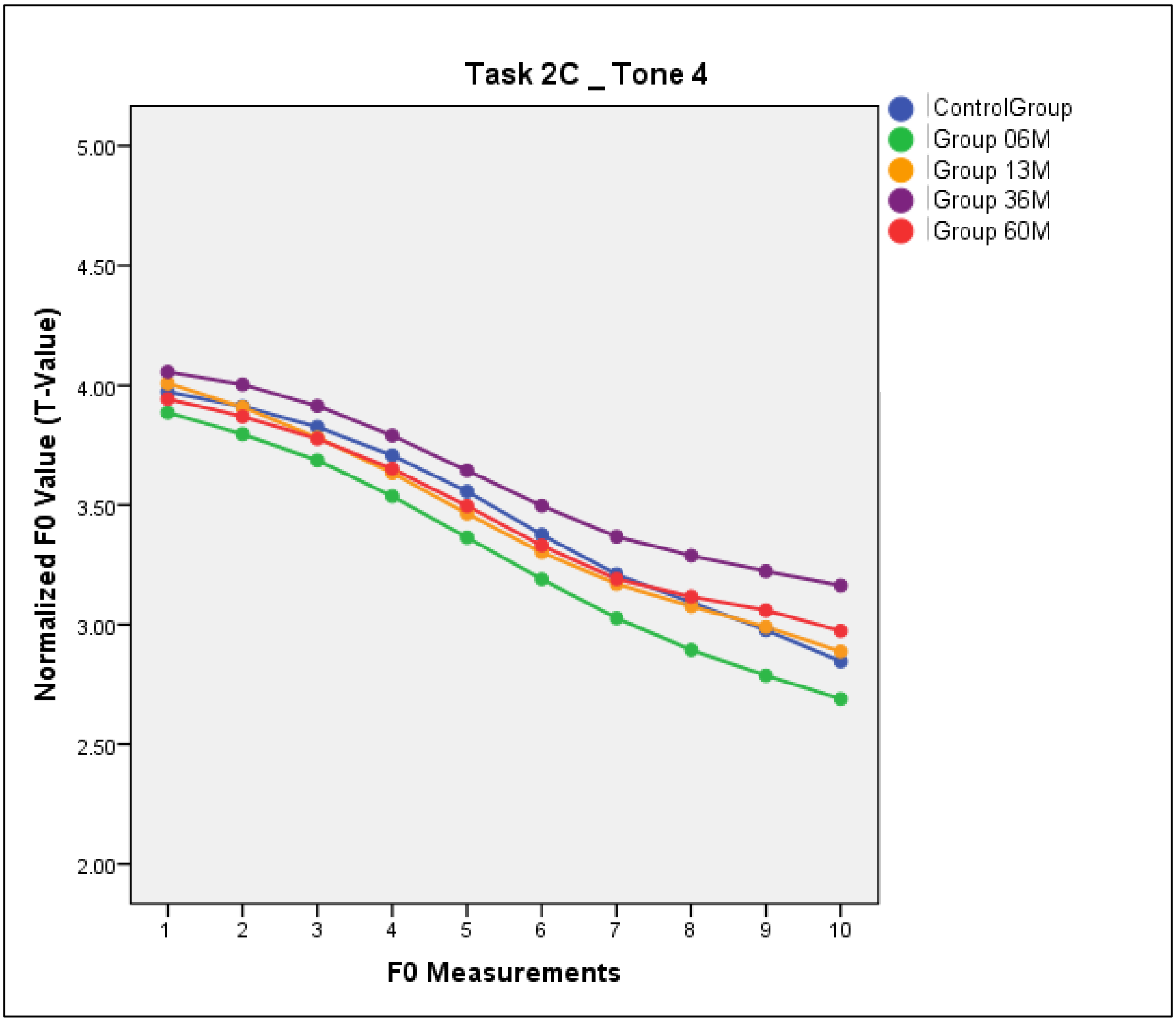


Figure 4.36 Pitch contours for Task 2C Tone 4

Table 4.30 T-values and significant differences for Task 2C Tone 4

Task 2C_Tone 4		$1T_{f_0}$	$2T_{f_0}$	$3T_{f_0}$	$4T_{f_0}$	$5T_{f_0}$	$6T_{f_0}$	$7T_{f_0}$	$8T_{f_0}$	$9T_{f_0}$	$10T_{f_0}$
Chinese Monolinguals	Control Group	3.973	3.912	3.826	3.707	3.556	3.377	3.210	3.094	2.977	2.847
Chinese-English Bilinguals	Group 06M	3.886	3.795	3.687	3.536	3.364	3.190	3.027	2.894	2.787	2.689
	Group 13M	4.009	3.908	3.781	3.634	3.464	3.302	3.170	3.077	2.990	2.887
	Group 36M	4.056	4.003	3.914	3.790	3.644	3.497	3.368	3.288	3.223	3.163
	Group 60M	3.943	3.869	3.777	3.652	3.496	3.331	3.191	3.117	3.060	2.973

Tone 4 Variation

Figure 4.37 below illustrates T44 contours for all five groups, which followed the T4 variation rule. The control group produced the first T4 with a higher ending at T-value 2.969, and the second T4 with a lower starting point at T-value 2.966. The bilingual groups produced T44s with a higher register than the control group did. Group 06M had the highest ending pitch for the first T4 among the five groups. Group 13M overlapped in the first four measurements with the control group, and then sharply fell to the end of the second T4. Group 36M had a similar T44 production to the control group. Group 60M produced a representative T44 in which the starting point of the second T4 was slightly higher than the ending of the first T44, forming a curved contour.

There were no significant differences between the control group and each bilingual group.

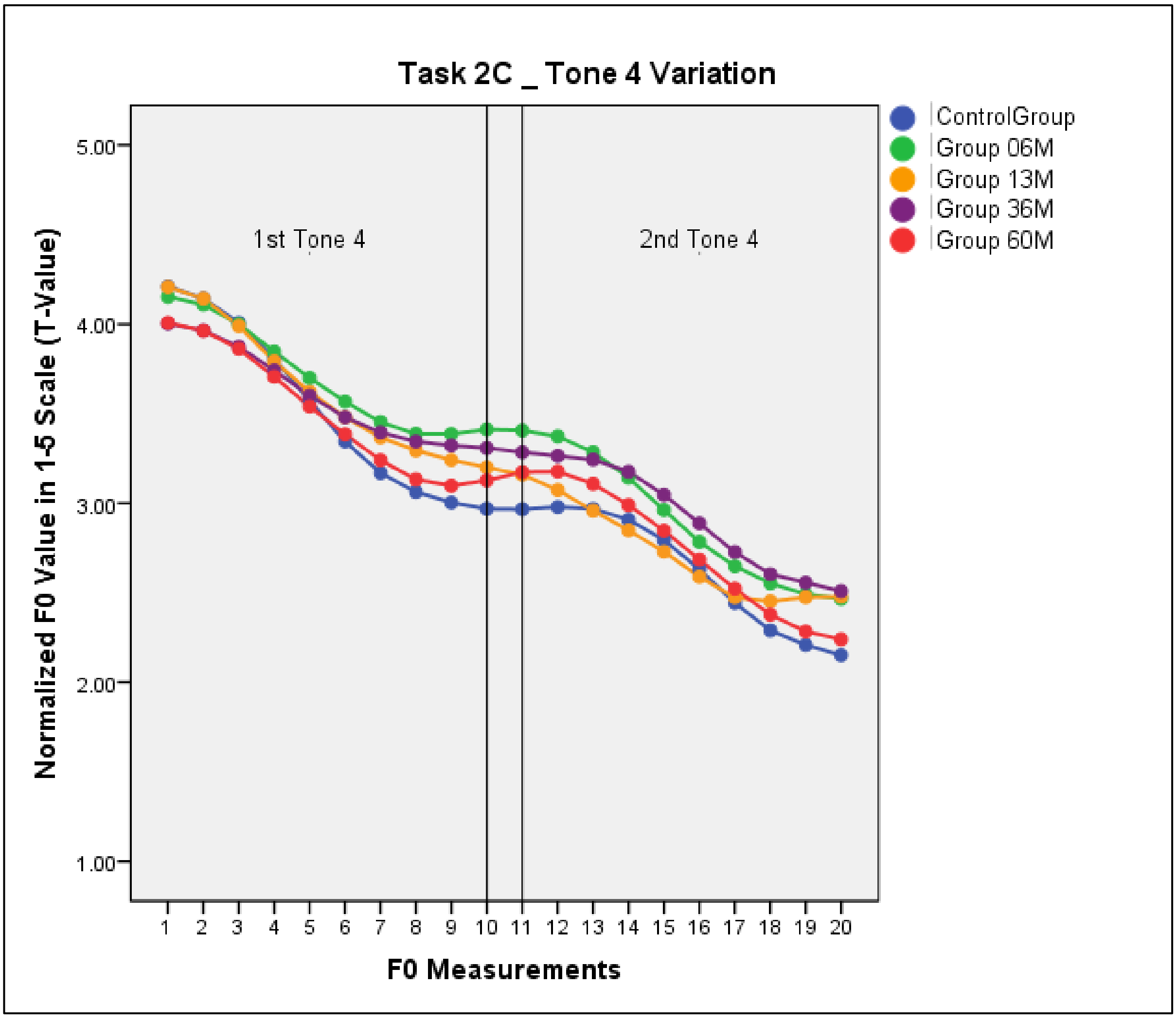


Figure 4.37 Pitch contours for Task 2C Tone 4 variation

Table 4.31 T-values and significant differences for Task 2C Tone 4 variation

Task 2C Tone 4 variation 1st T4		$1T_{f_0}$	$2T_{f_0}$	$3T_{f_0}$	$4T_{f_0}$	$5T_{f_0}$	$6T_{f_0}$	$7T_{f_0}$	$8T_{f_0}$	$9T_{f_0}$	$10T_{f_0}$
Chinese Monolinguals	Control	4.211	4.144	4.008	3.807	3.573	3.345	3.169	3.063	3.003	2.969
Chinese-English Bilinguals	Group 06M	4.153	4.109	4.000	3.848	3.699	3.567	3.454	3.387	3.387	3.413
	Group 13M	4.208	4.144	3.990	3.793	3.622	3.480	3.368	3.295	3.242	3.200
	Group 36M	4.003	3.965	3.873	3.742	3.601	3.480	3.395	3.345	3.323	3.309
	Group 60M	4.008	3.964	3.862	3.706	3.540	3.385	3.241	3.133	3.098	3.128
Task 2C Tone 4 variation 2nd T4		$11T_{f_0}$	$12T_{f_0}$	$13T_{f_0}$	$14T_{f_0}$	$15T_{f_0}$	$6T_{f_0}$	$17T_{f_0}$	$18T_{f_0}$	$19T_{f_0}$	$20T_{f_0}$
Chinese Monolinguals	Control	2.966	2.979	2.969	2.908	2.795	2.630	2.443	2.290	2.208	2.151
Chinese-English Bilinguals	Group 06M	3.407	3.373	3.285	3.142	2.962	2.785	2.648	2.553	2.492	2.466
	Group 13M	3.159	3.073	2.958	2.849	2.730	2.589	2.474	2.452	2.475	2.478
	Group 36M	3.285	3.265	3.244	3.176	3.047	2.888	2.727	2.604	2.557	2.509
	Group 60M	3.174	3.177	3.109	2.990	2.847	2.685	2.522	2.378	2.283	2.240

Tone Sandhi

Figure 4.38 presents the tone sandhi contours for Task 2C. The control group and the bilingual groups 06M, 13M, and 36M followed the tone sandhi rule and produced T3 as a rising tone. The control group and Group 06M produced tone sandhi contours of rising curves. Group 13M produced tone sandhi as a level tone that was different from the other four groups. Group 36M and 60M produced a tone sandhi contour showing a rising tone. Though the majority followed the tone sandhi rule in the task, the contours rose less than the normal T2 since all T-values ranged from 2 to 3. No significant differences between the groups were found for tone sandhi.

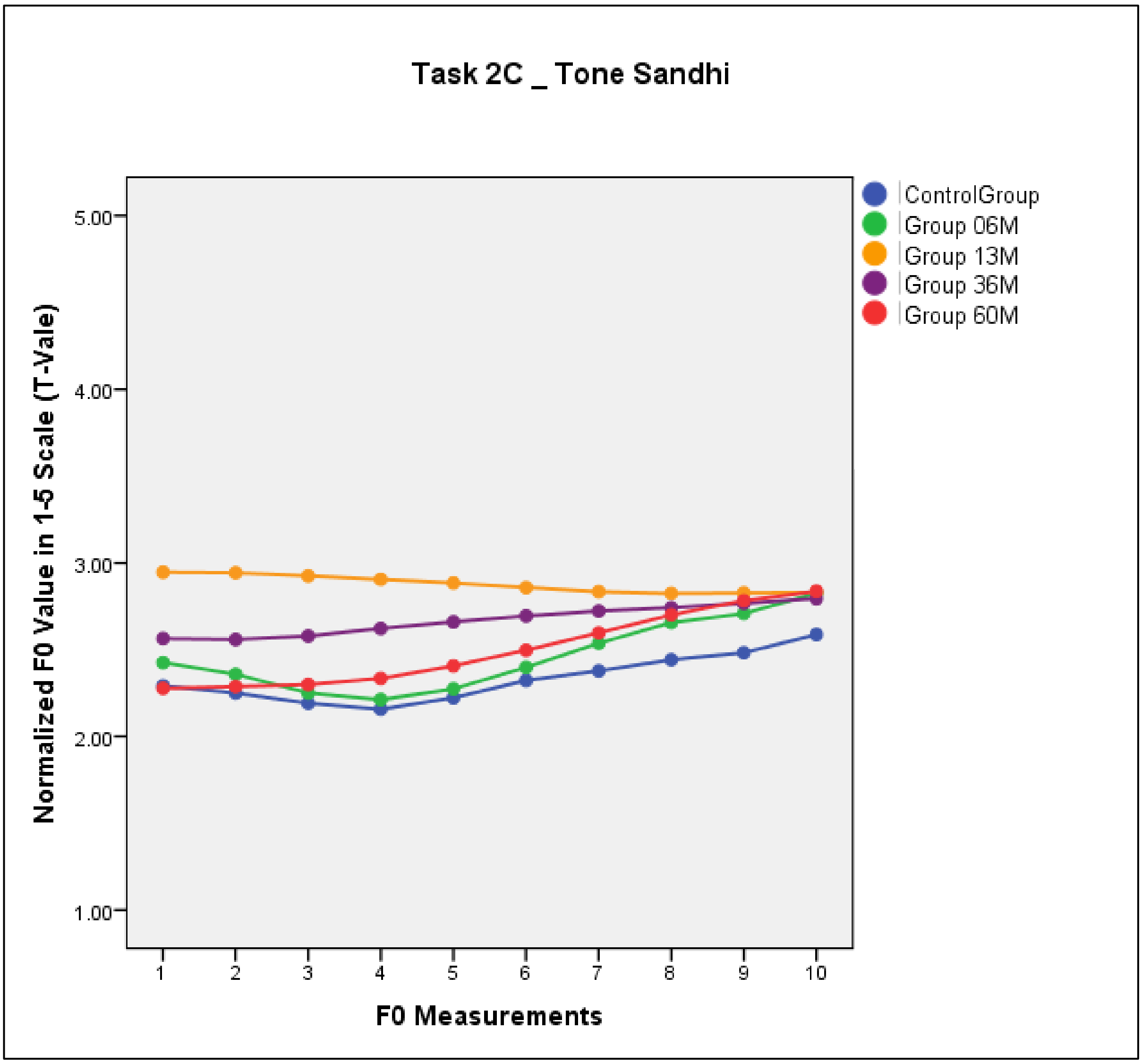


Figure 4.38 Pitch contours for Task 2C tone sandhi

Table 4.32 T-values and significant differences of Task 2C tone sandhi

Task 2C_Tone sandhi		$1T_{f_0}$	$2T_{f_0}$	$3T_{f_0}$	$4T_{f_0}$	$5T_{f_0}$	$6T_{f_0}$	$7T_{f_0}$	$8T_{f_0}$	$9T_{f_0}$	$10T_{f_0}$
Chinese Monolinguals	Control Group	2.291	2.250	2.192	2.157	2.223	2.323	2.377	2.442	2.483	2.588
Chinese-English Bilinguals	Group 06M	2.426	2.358	2.250	2.212	2.274	2.398	2.537	2.656	2.708	2.825
	Group 13M	2.591	2.588	2.567	2.543	2.518	2.486	2.457	2.447	2.456	2.469
	Group 36M	2.565	2.559	2.578	2.622	2.661	2.694	2.723	2.742	2.767	2.794
	Group 60M	2.277	2.287	2.299	2.334	2.406	2.497	2.597	2.700	2.782	2.836

yi variation

It is clear from Figure 4.39 below that all five groups produced *yi* T1→T4 variation with a falling contour when it was followed by T1, T2, or T3. The contour for the control group is a straight falling line. Group 06M produced a relatively sharp falling *yi* tone with a lower register than the control group. Group 13M had a similar *yi* tone contour to Group 06M. The difference is that Group 13M had a higher register. Groups 36M and 60M, similar to the control group, produced straight falling contours with different registers. No significant differences were present.

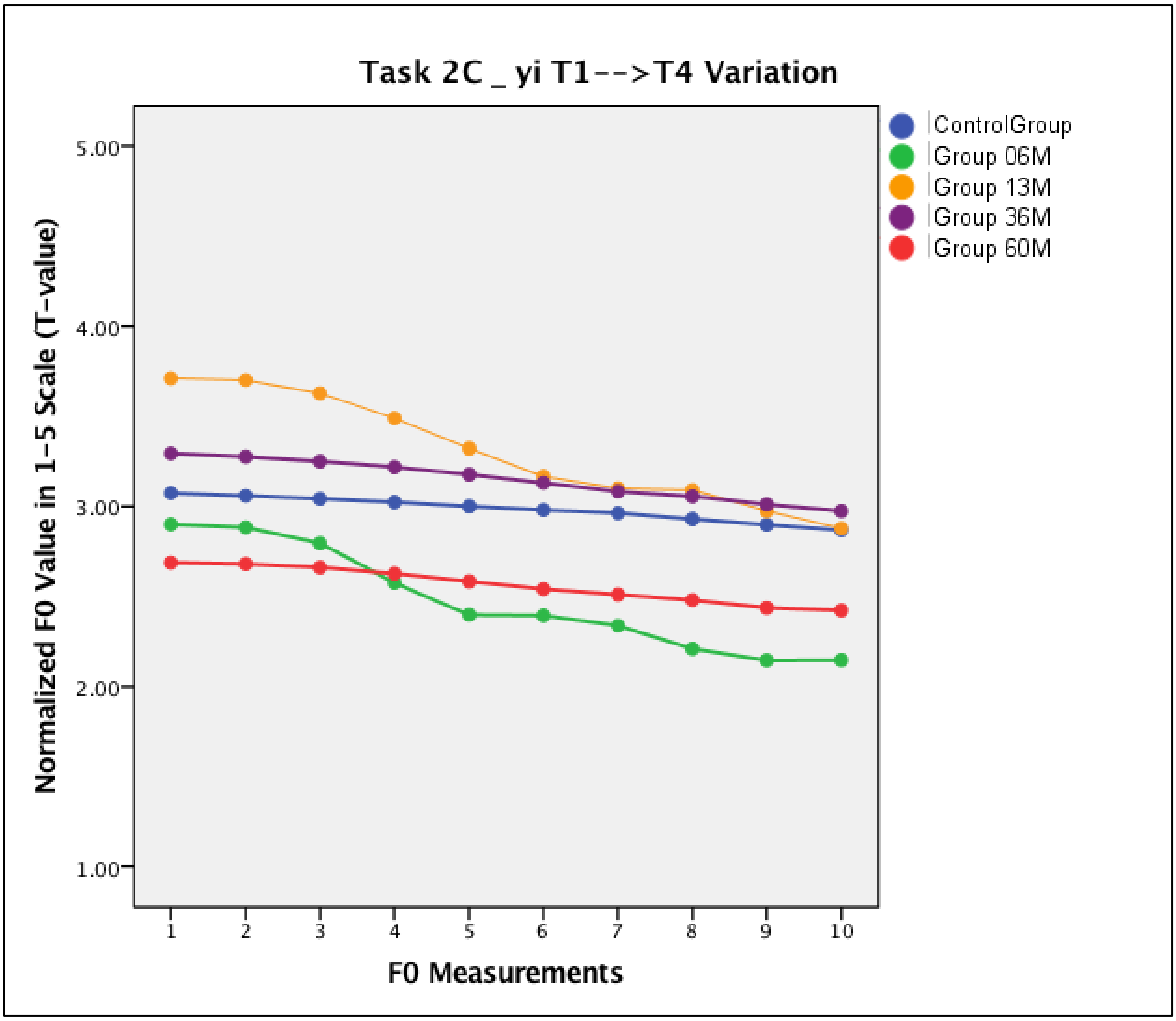


Figure 4.39 Pitch contours of Task 2C yi T1→T4 variation

Table 4.33 T-values and significant differences for Task 2C yi T1→T4 variation

Task 2C_*yi* T1→T4 variation		$1T_{f_0}$	$2T_{f_0}$	$3T_{f_0}$	$4T_{f_0}$	$5T_{f_0}$	$6T_{f_0}$	$7T_{f_0}$	$8T_{f_0}$	$9T_{f_0}$	$10T_{f_0}$
Chinese Monolinguals	Control Group	3.075	3.059	3.043	3.024	3.000	2.980	2.963	2.929	2.897	2.868
Chinese-English Bilinguals	Group 06M	2.900	2.883	2.795	2.577	2.398	2.394	2.338	2.208	2.145	2.146
	Group 13M	3.712	3.702	3.628	3.488	3.321	3.167	3.101	3.092	2.974	2.877
	Group 36M	3.293	3.276	3.250	3.219	3.178	3.132	3.083	3.056	3.011	2.974
	Group 60M	2.687	2.680	2.661	2.627	2.584	2.542	2.512	2.481	2.438	2.423

Figure 4.40 presents *yi* T1→T2 variation when it preceded a T4. The control group had a relatively smooth rising contour with a starting point of T-value 2.602 and an ending point at 2.804. Group 06M had the lowest *yi* tone contour, which rose slightly. Group 13M produced *yi* with an almost level tone, with only 0.052 difference between the starting point and the end point. Group 36M had a similar *yi* tone contour to Group 13M, with a rise of 0.082. Group 60M had a comparatively sharp rising *yi* tone. Its contour was close to that of the control group.

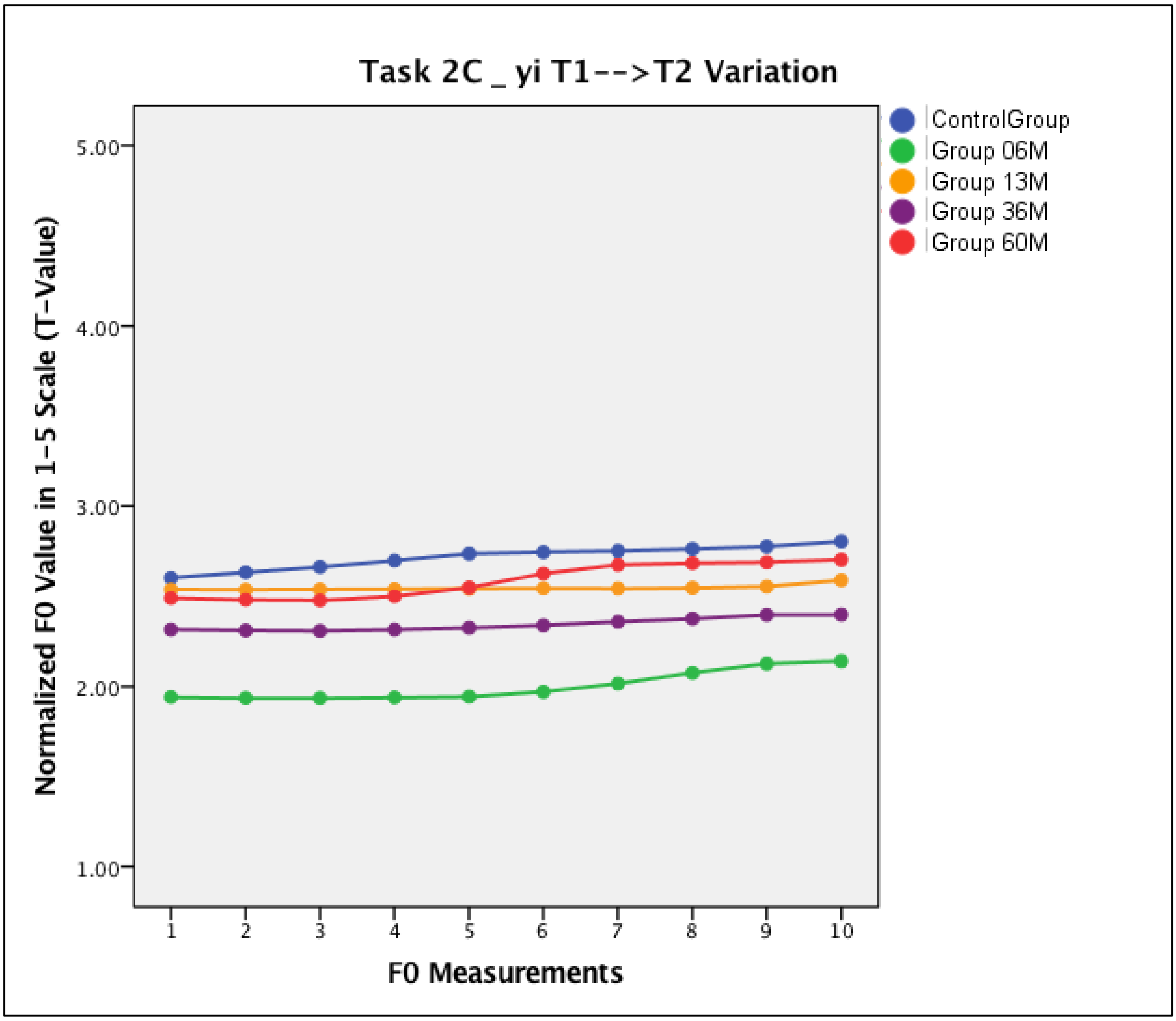


Figure 4.40 Pitch contours for Task 2C yi T1→T4 variation

Table 4.34 T-Values and Significant Differences of yi T1→T2 variation

Task 2C_*yi* T1→T2 variation		$1T_{f_0}$	$2T_{f_0}$	$3T_{f_0}$	$4T_{f_0}$	$5T_{f_0}$	$6T_{f_0}$	$7T_{f_0}$	$8T_{f_0}$	$9T_{f_0}$	$10T_{f_0}$
Chinese Monolinguals	Control Group	2.602	2.633	2.663	2.698	2.736	2.745	2.752	2.763	2.776	2.804
Chinese-English Bilinguals	Group 06M	1.940	1.935	1.935	1.938	1.943	1.971	2.016	2.075	2.126	2.140
	Group 13M	2.537	2.536	2.538	2.539	2.543	2.544	2.543	2.546	2.554	2.589
	Group 36M	2.315	2.310	2.307	2.314	2.325	2.338	2.358	2.375	2.396	2.397
	Group 60M	2.489	2.480	2.476	2.499	2.548	2.626	2.675	2.684	2.689	2.704

4.3.5. Comparison of the three production tasks

Task 2A was designed to simulate speaking in a formal situation and Task 2C was designed to simulate casual speaking circumstances. Task 2B was considered the transition between Tasks 2A and 2C, and was designed to produce semi-formal speaking circumstances. The vertical comparisons across the three tasks for the four tones, tone sandhi, and tone variations are illustrated below. The comparisons aim to test different speaking circumstances that may or may not impact tone productions. A one-way ANOVA was applied for multiple comparisons of the three tasks for each group. Each measurement T_{f_0} in the three tasks was compared as dependent variable, while each group was considered an independent variable.

Figure 4.41 below demonstrates the contours of the four tones for the control group and each bilingual group across three production tasks. The straight line represents Task 2A, the dotted line represents Task 2B, and the dashed line represents Task 2C. The T-values of each measurement for each group have already been presented above. Tables 4.20, 4.29, and 4.37 present details of these measurements.

Generally, tones produced in all three tasks had clearly contrasting contours. Figure 4.41 below demonstrated four tones for five groups of the three production tasks. For each group, there was no significant differences demonstrated of the three tasks. Hence, there are no significant differences for each group speaking in different circumstances. Appendix 7.7 lists p-values.

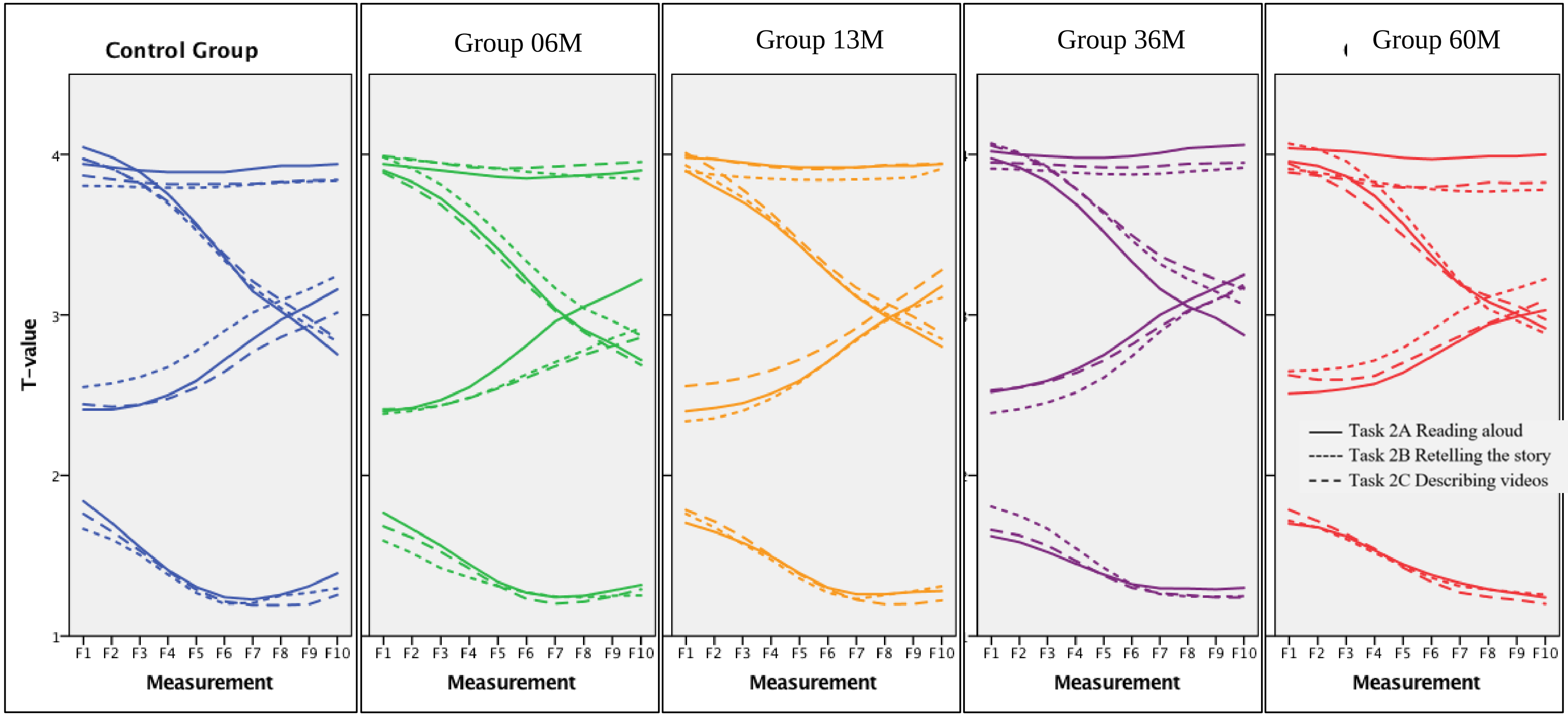


Figure 4.41 Contour for four tones for five groups across three production tasks

Table 4.35 Significant differences for three tasks for each group

Task 2C_Tone 1		$1T_{f_0}$	$2T_{f_0}$	$3T_{f_0}$	$4T_{f_0}$	$5T_{f_0}$	$6T_{f_0}$	$7T_{f_0}$	$8T_{f_0}$	$9T_{f_0}$	$10T_{f_0}$
Chinese Monolinguals	Control Group	3.868	3.845	3.826	3.816	3.816	3.817	3.818	3.829	3.839	3.841
Chinese-English Bilinguals	Group 06M	3.991	3.971	3.945	3.921	3.914	3.916	3.925	3.935	3.944	3.953
	Group 13M	3.994	3.972	3.943	3.923	3.910	3.909	3.919	3.934	3.938	3.943
	Group 36M	3.949	3.945	3.938	3.927	3.919	3.919	3.928	3.942	3.945	3.948
	Group 60M	3.887	3.869	3.843	3.805	3.795	3.797	3.806	3.826	3.821	3.825

Tone 4 variation

Contours for tone 4 variation for each group across the three tasks are illustrated in Figure 4.32 below. The control group and the four bilingual groups produced tone 4 variations in the three tasks in line with the rules, though significant differences were demonstrated. The control group demonstrates significant differences at measurements $9T_{f_0}$(*p-value=0.020),* $10T_{f_0}$(*p-value=0.011)*, $11T_{f_0}$(*p-value=0.04)*, and $12T_{f_0}$(*p-value=0.03*.) in the comparison between Tasks 2A and 2C. Tone 4 variations produced by Groups 06M, 13M, and 60M have closed contours for each task with no significant differences. Group 36M demonstrates the most dynamic results for tone 4 production across the three tasks. Tone 4 variations demonstrate significant differences between Tasks 2A and 2B at each measurement from $11T_{f_0}$ to $18T_{f_0}$ with *p-values* listed in Appendix 7.7. The T-value of measurement $19T_{f_0}$ for Task 2A is significantly different from the corresponding measurement for Task 2C.

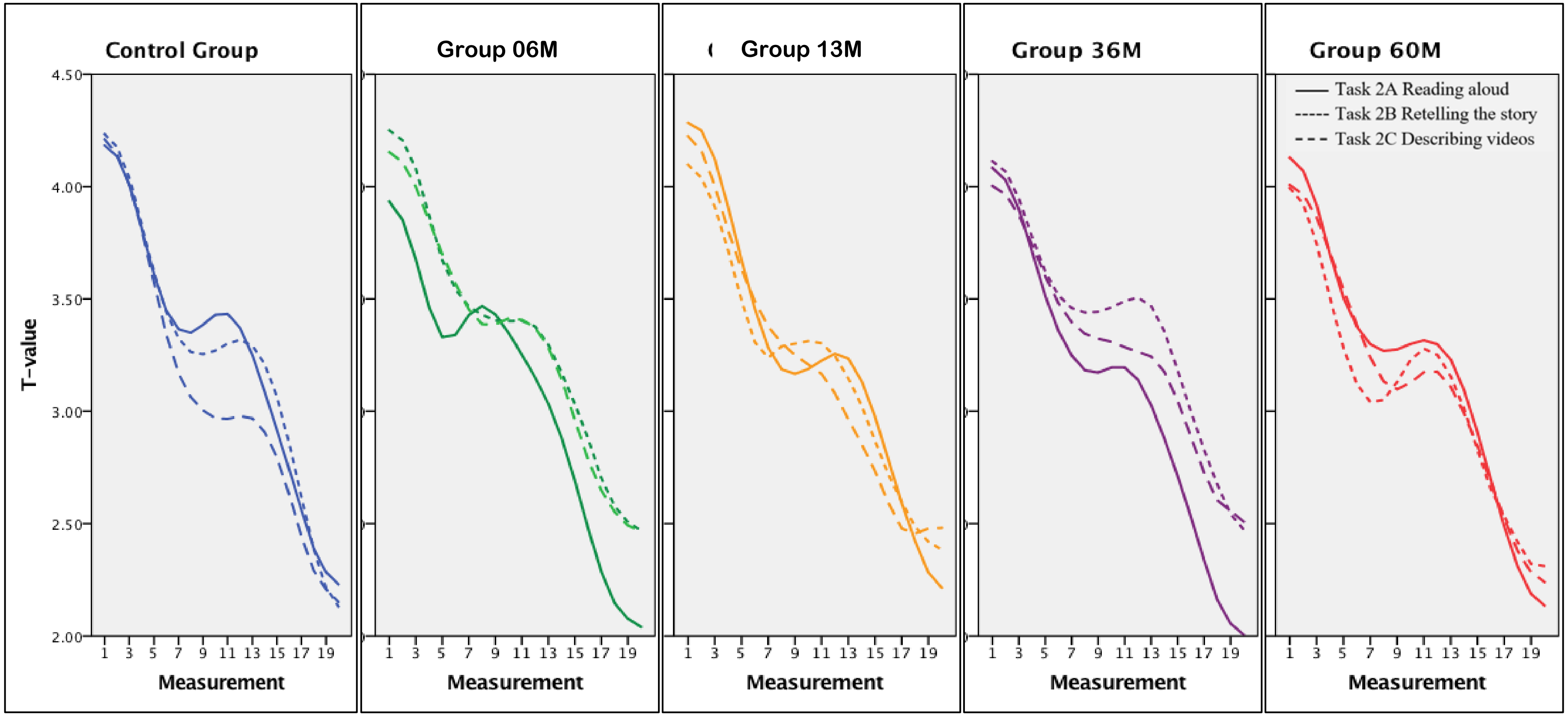


Figure 4.42 Contour for tone 4 variations for five groups across three production tasks

Tone sandhi

The control group and the four bilingual groups produced tone sandhi in Task 2A (simulated formal speaking circumstance) that clearly followed the rule that first tone 3 adjusts itself to the rising tone. By switching the speaking situation, contours for tone sandhi become higher and smoother, which can be seen in Figure 4.43 below. Each group demonstrated significant differences from task to task.

For the control group, t-values for measurement $1T_{f_0}$ collected from Task 2C are significantly different from those of either Task 2A or Task 2B. The *p*-values are 0.03 and 0.044 respectively, comparing Task 2A and 2B with Task 2C. Group 06M demonstrates only one significant difference at measurement $10T_{f_0}$. Task 2B has significantly higher T-value than Task 2C with a *p*-value of 0.047. The first four measurements for Group 13M have much higher contours for Task 2C than for Task 2A. The *p*-values for $1T_{f_0}$, $2T_{f_0}$, $3T_{f_0}$, and $4T_{f_0}$ are 0.042, 0.04, 0.038, and 0.046 respectively. Group 36M also had higher contours for Task 2C than for Task 2B. Significant differences were demonstrated at measurement $1T_{f_0}$(*p*-value=0.049), $2T_{f_0}$(*p*-value=0.032), $3T_{f_0}$ (*p*-value=0.032), and $4T_{f_0}$(*p*-value=0.048). Group 60M, similar to the other four groups, had a higher pitch contour for Task 2C. Measurements $1T_{f_0}$, $2T_{f_0}$, and $3T_{f_0}$ produced in Task 2C are significantly higher than the corresponding measurements in Task 2A, with *p*-values of 0.041, 0.034, and 0.037 respectively.

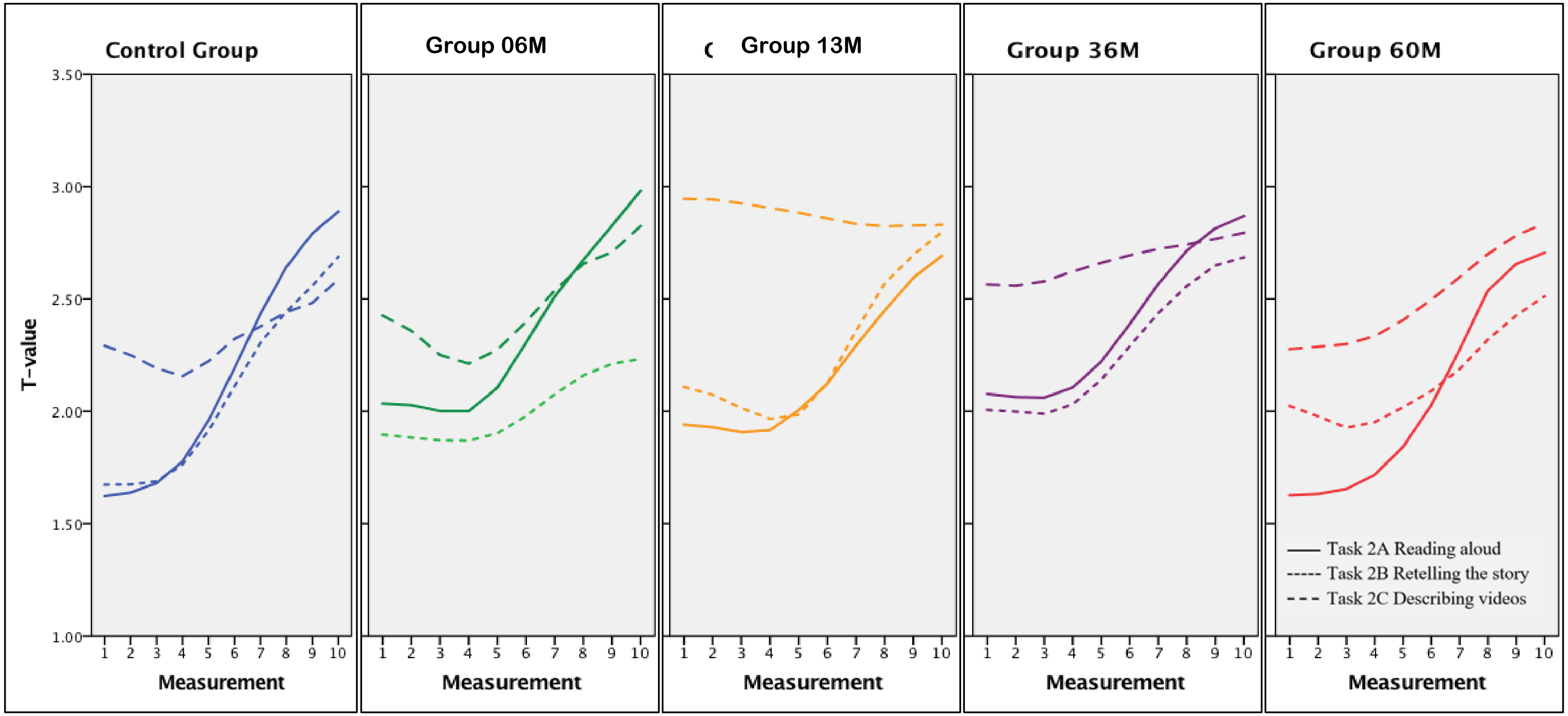


Figure 4.43 Contour for tone sandhi for five groups across three production tasks

yi tone variations

yi T1→T4 variation, regardless of groups and tasks, was produced as a falling tone. The contours listed in Figure 4.44 below demonstrate the falling line clearly. There were no significant differences detected for the control group and the bilingual groups 06M, 13M and 36M, respectively, for the comparison across three tasks. Appendix 7.7 presents p-values in detail. The entire contour for *yi* T1→T4 variation produced by Group 60M had a significantly lower pitch height in Task 2C than in Task 2B, which had the highest pitch contour in all three tasks. The *p*-values of comparisons between Tasks 2B and 2C are all smaller than 0.05.

yi T1→T2 variation produced by the control group and each bilingual group varied throughout the tasks. *yi* T1→T2 variation produced by the control group was significantly different throughout the three tasks. Task 2C had significantly lower contours than Tasks 2A and 2B. Similarly, Group 06M produced the lowest *yi* T1→T2 variation in Task 2C, which is significantly different to the results of Tasks 2A and 2B. Group 13M's *yi* T1→T2 production varied according to the tasks. However, Group 36M demonstrated no significant differences in *yi* T1→T2 variation throughout the tasks. Group 60M only had two measurements – $5T_{f_0}$ and $6T_{f_0}$ – in Task 2A that differed significantly from the corresponding measurements in Task 2C.

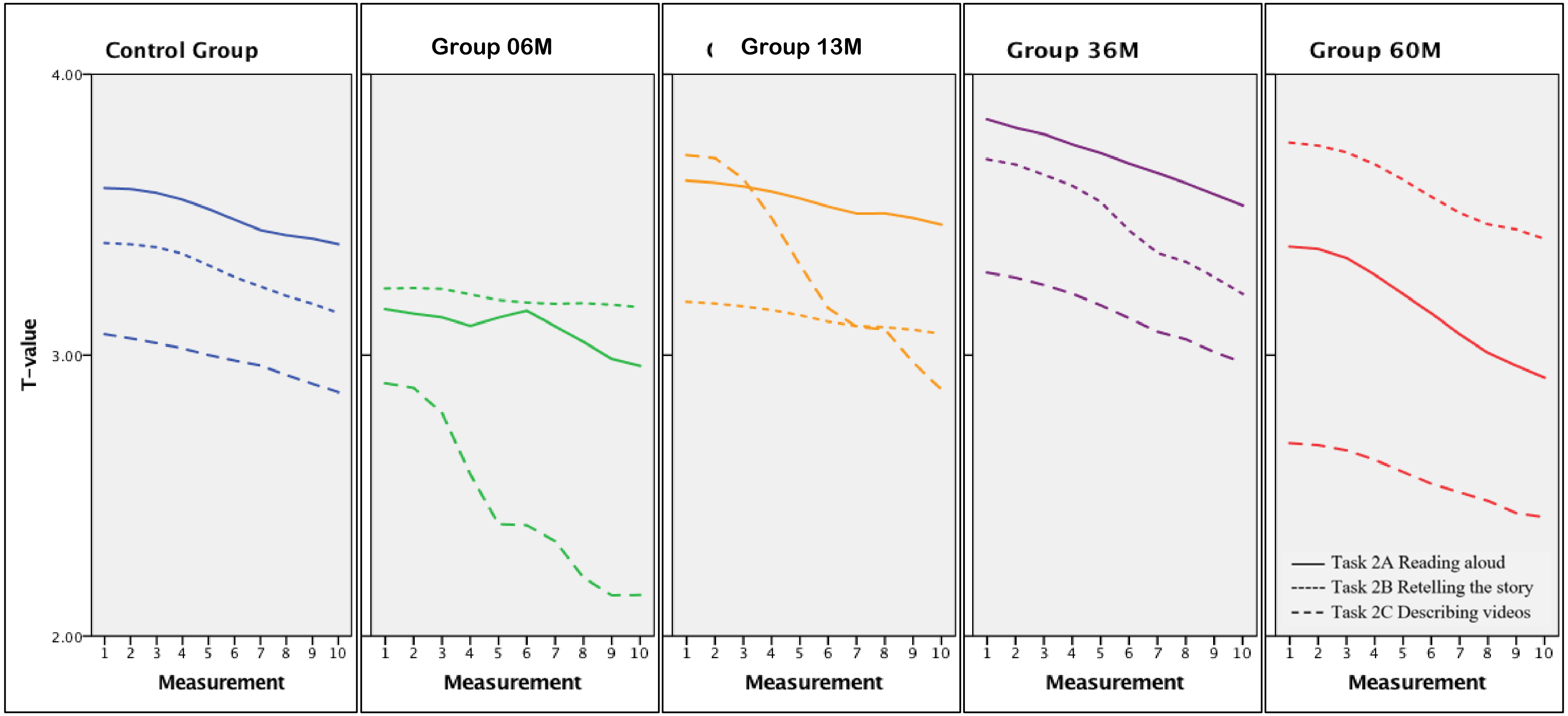


Figure 4.44 Contour for yi T1→T4 variation for five groups across three production tasks

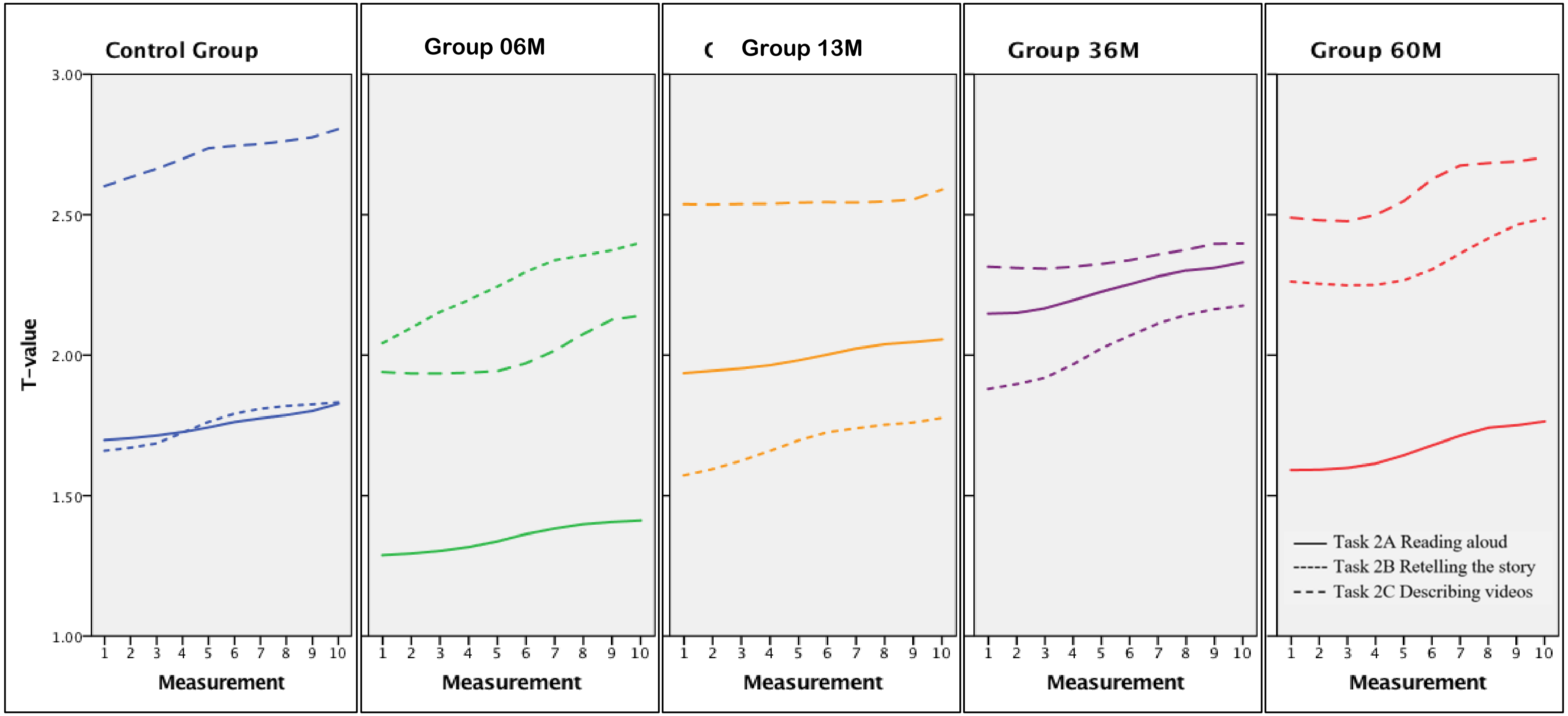


Figure 4.45 Contour for yi T1→T2 variation for five groups across three production tasks

4.3.6. Summary

Data for the production tasks is illustrated above. Normalizations for time and pitch were applied in acoustic analysis in order to eliminate individual differences. Tone 3 is the only tone for which bilinguals demonstrated significant differences in production compared to the control group in all three tasks. The control group produced tone 3 with falling and rising parts. Bilingual groups 06M and 13M had similar contours to the control group. Tone 3 produced by Group 36M had a smoother and shorter rising part that was significantly different from the control group. Group 60M produced tone 3 with no rising part in all three tasks, which was also significantly different from the control group.

On the other hand, data for comparisons across tasks was diverse and hard to summarise. The ANOVA multiple comparison indicated significant differences between the control group and each bilingual group in tone sandhi and tone variations. However, it is impossible to summarise rules for the significant differences between tasks within each group.

Chapter 5. Discussion

The present chapter will analyse the results and discuss the implications according to the purpose of the research. The current study aimed to analyse L1 tone attrition among Mandarin-English late bilinguals in an L2 environment. One control group and four bilingual groups with different L2 residential lengths were studied. ABX discrimination and multiple tone identification tasks were used to examine tone perceptions while reading aloud stories and retelling stories, and video descriptions were used to test tone production in connected speech.

Four hypotheses have been addressed and the discussion follows:

5.1. Hypotheses

1. Mandarin-English bilinguals will demonstrate attrition on three tones in Mandarin, namely T2, T3 and T4.

   1a. The order of attrition by degree expected is T3 > T2 > T4. (That is, tone attrition will mirror the acquisition order for children on L1 attested in the L1 acquisition literature.)

   1b. This will be demonstrated on both production and perception tasks.

Based on the observed data and acoustic analysis for tone attrition, Hypothesis 1 is partially supported. The Mandarin-English bilinguals demonstrated attrition on tone 3 only. Attrition was not demonstrated on tone 2 or tone 4. Hence, further investigation will be needed to determine tone attrition order in order to see whether it will mirror acquisition order (1a). Meanwhile, L1 attrition was only observed in tone production tasks in the present study. The data negatively supported the hypothesis that L1 attrition occurred in bilinguals' perceptions (1b).

2. Attrited T3 will be produced with either half rising part or falling part.

In this study, no rising part was produced in attrited tone 3. In connected speech, due to tone coarticulation, the production of tone 3 tends to reduce or omit the rising part when followed by another tone. Tone 3 is only produced fully in the final position of a sentence. Hence, an attrited tone 3 is difficult to distinguish from a non-attrited tone 3. The attrition signs were captured by Praat.

3. Amount of use of L1 and/or L2 will affect attrition, as measured by years of UK residence and interaction in the dominant language, English.
4. Tone attrition will be in more evidence in casual contexts than in formal situations

The present study tested four Mandarin-English late bilingual groups with different lengths of L2 residence. L1 attrition occurred in Group 60M, whose members had lived in the L2 environment for over 60 months. Meanwhile, the data for language contacts for both L1 and L2 supported that L1 attrition was affected by the increasing use of L2 and decreasing contact with L1. However, there were no differences in tone attrition occurring in formal verses causal circumstances.

A detailed discussion and possible reasons for each finding is presented below.

5.2. Perception

The discussion of tone perception here is separated into two parts: normal tone pairs and tone variations. In each subsection, the results from Task 1A and 1B are discussed together.

5.2.1. Normal tone pairs

In the perception tests, Tasks 1A and 1B, four tones were tested with pairwise combinations. This provided 14 tone pairs for each task. Generally, in Task 1A, both the control group and the four bilingual groups showed incorrect perception in 11 tone pairs out of 14. T23, T31, and T32 were perceived 100% correctly. The incorrect perception exhibited by all five groups was freely distributed. In Task 1B, 10 tone pairs out of 14 were incorrectly perceived across the five groups. T11, T14, T24, and T31 were all perceived accurately. T31 was the only tone pair to be perceived perfectly in both Task 1A and Task 1B. It is clear that there were no significant differences between the two tasks from this point of view, which confirms the objectivity and accuracy of the tone perception experiment. Although nearly all of the tone pairs were incorrectly perceived by the different groups, there was no sign of L1 attrition in tone perception at this stage.

In Task 1A, the control group misperceived three tone pairs in total in each task, which was the minimum number of pairs misperceived across groups. Group 06M incorrectly perceived four tone pairs. Group 13M made an incorrect judgment for eight tone pairs. Group 36M perceived four tone pairs inaccurately, which was the same as Group 60M. In Task 1B, the control group had exactly the same number of incorrectly perceived tone pairs as in Task 1A. Group 06M had an incorrect assumption for five, Group 13M misinterpreted seven, and Groups 36M and 60M only perceived three tone pairs incorrectly. It is very interesting that Group 13M had the most incorrectly perceived tone pairs in both tasks. The potential factors that may have led to this consequence will be discussed in Section 6.3. However, the results are hardly an indication that L1 attrition occurs.

For a single tone pair in Task 1A, the control group had the lowest error rates, with no more than 5%. The four bilingual groups had a maximum error rate of 10%. In Task 1B, the control group's error rate increased to 15% in T13, while the remaining tone pairs had an error rate lower than 10%. The four bilingual groups had a maximum rate of 10% for the different tone pairs, which corresponds with the findings from Task 1A. However, there was no significant difference in each tone pair when comparing the control group to each bilingual group in both Task 1A and 1B. Therefore, bilingual speakers' tone perception had not been attrited in normal tone pairs.

5.2.2. Tone variations and tone sandhi

Tone sandhi in both tasks demonstrated high error rates – much higher than the normal tone pairs – for all five groups. Nearly one third tone sandhi were perceived incorrectly in Task 1A. In Task 1B, the error rates slightly declined, but the average error rate was still around 20%. The differences between the control group and the four bilingual groups were not significant, which indicated that tone sandhi perception is not influenced by the L2 environment for bilinguals.

Tone 4 variations had very low error rates – lower than 10% in both tasks. The differences between the control group and the four bilingual groups were minimal, which does not indicate L1 attrition. *yi* T1→T2 variation was perceived incorrectly by Group 06M only, with a 5% error rate in Task 1A. In Task 1B, this variation was perceived with 100% accuracy. The error rates for *yi* T1→T4 variation were up to 20% across all five groups for Task 1A. In Task 1B, the control group, Group 06M and Group 60M perceived *yi* T1→T4 variation incorrectly, with an error rate of 5%. The error rates of the bilingual groups were similar to those of the control group, which means that no L1 attrition occurred at any tone variation.

5.2.3. Discussion

The data from two perception tasks indicated that bilinguals retained the perception of Mandarin tones at a native level. Though some tone pairs were incorrectly perceived, the error rates were minor and reasonable for native speakers. The error rates for the four tones in Mandarin are in line with those from previous studies in the field (Yeh & Lin, 2015; Quama & Creelb, 2017).

The possible reasons that tone perception was found to have been retained in the study is that attrition for tone perception should follow attrition in production based on the regression model (Kees de Bot & Weltens, 1991; Kuhl, 2004). Attrition order mirrors the language acquisition order, and once tone production attrites, tone perception shoud demonstrate attrition afterwards. Tone production showed signs of attrition, but the attrition was minor (analysis in Section 5.3). Hence, more time would be needed for attrition signs in perception to be demonstrable.

Second, the ability to perceive tone is stabilised among early bilinguals who have resided in an L2 environment for more than five years (Zhou & Broersma, 2014; Piercea, Klein, Chen, Delcenserie, & Genesee, 2014). For adult bilinguals who had already completely acquired L1, five years of residence in an L2 environment is too short to affect L1 perception. This is not only because L2 exposure experiences competition with L1 in perception in line with the dynamic model of multilingualism, but also because the activation threshold for understanding and comprehension is originally lower than that of production (Gürel, 2004) (Paradis, 1993). The increased L2 exposure and decreased L1 contact may raise the activation threshold in language processing for both perception and production, but the activation threshold is not high enough to stop access to perception. Therefore, tone perception was retained for all bilinguals in this study.

5.3. Production

This section discusses tone 1 through tone 4, tone 4 variation, tone sandhi, and *yi* tone. The tones in this research were all naturally produced in simultaneous speech. Hence, pitch contours are different from those of tones produced in isolation, which are all fully produced. In other words, tone contours in this research are not as standard as the tone descriptions presented in Chao's letter. They may be shorter in length or lower in register, but they maintain the model depicted by Xu (1990).

For the purpose of this research, the following discussion will pay particular attention to tones that saw significant differences between the control group and the four bilingual groups.

5.3.1. Tone 1

Tone 1, as produced by all five groups in Task 2A, was standard, which conveyed a high-level tone. Each group produced tone 1 as a high-level tone, and there were no significant differences demonstrated between the control group and each bilingual group. Therefore, in the simulated formal speaking circumstances, no signs of L1 attrition for tone 1 were shown among the four bilingual groups.

In Task 2B, there was a significant difference at $1T_{f_0}$ when comparing the control group and Group 06M. This indicated that Group 06M produced a significantly higher pitch register than the control group at the starting measurement. No major differences were detected between the control group and Groups 06M, 36M, and 60M. In other words, these three bilingual groups maintained their tone 1 production in a semi-formal speaking environment.

The results of Task 2C were similar to those from Task 2A to the extent that there were no significant differences between the control group and each bilingual group. Therefore, the significant difference for Group 06M at $1T_{f_0}$ in Task 2B was excluded from the signs of attrition. All four bilingual groups maintained their native proficiency in tone 1, and there was a lack of evidence to support that tone 1 had been attrited.

5.3.2. Tone 2

In all three tasks, the control group and the four bilingual groups produced tone 2 as a high rising tone. There were very slight differences in the pitch register between groups at a zoomed-in scale. The contours of Tone 2 basically coincided with each other on a normal 1-5 scale. No significant differences were detected between the control group and the bilingual groups in each task. Therefore, the production of tone 2 for all four bilingual groups was not affected under either formal or casual speech circumstances.

5.3.3. Tone 3

Tone 3, being the most complicated tone, demonstrated complicated results. In order to explain the results clearly, the discussion will be outlined task by task.

In Task 2A, the control group produced Tone 3 as standard, with obvious falling and rising parts. Tone 3 as produced by Groups 06M and 13M had contours similar to that of the control group. The turning points were all at measurement $7T_{f_0}$. The pitch registers for these two bilingual groups were also similar to those of the control group. But along with the increasing length of residence in the L2 environment, the pitch contours of tone 3 were higher than those of the control group. Groups 36M and 60M demonstrated significant differences from the control group. Not only were their main body contours higher than those of the control group, but also their rising parts were notably different. From Figures 4.11 and 4.12, it is clear that Group 36M only had a very short and slight rising part, while Group 60M had no rising part. Hence, the significant differences were related to the rising part of tone 3 between the control group and Group 36M and Group 60M, rather than the pitch register.

The rising part, as shown in Figure 4.10, was clearly produced by the control group. But with the growth of residential length in the L2 environment, the degree of rising gradually reduced among bilingual groups. The degree of rising produced by Group 06M was lower than that of the control group. Group 13M produced a low rising contour that was slightly lower than Group 06M. The rising part produced by Group 36M was almost level, which means that the degree of the rising part was very small. The rising part produced by Group 60M was level, which means that it produced tone 3 with no rising part at all. Significant differences in initial rises (∇T_{f_0}) occurred between the control group and Group 60M only, with a p-value of 0.013.

In sum, tone 3 productions changed from group to group. The change was in the rising part, which gradually deteriorated until it was lost completely. The degree of loss of the rising part correlates with the increasing length of residence in the L2 environment. Hence, the loss of the rising part of tone 3 can be seen as a sign of L1 attrition in formal speaking circumstances.

In Task 2B, the control group produced tone 3 fully, with a falling part and a rising part. Tone 3 as produced by Group 06M and Group 13M was similar to that produced by the control group and contained both falling and rising parts. The differences between the control group and these two bilingual groups were not significant. However, similar to Task 2A, Group 36M had a very smooth rising part that can be considered a level contour. Group 60M demonstrated no rising part. Group 36M and Group 60M demonstrated significant differences due to a lack of rising parts. These differences can be seen clearly in Figures 4.22 and 4.23. Group 36M had significant differences on three measurements: 4 T_{f_0}, 5T_{f_0}, and 6T_{f_0}. Group 60M demonstrated significant differences on measurements 5T_{f_0}, 6T_{f_0}, and 7T_{f_0}, which were the same as in Task 2A.

Task 2B simulated a semi-casual speaking environment and was a transition from Task 2A, the formal speaking circumstance, to Task 2C, the casual speaking circumstance. Compared to Task 2A, the rising contour for the control group was lower and smoother than that in Task 2B. Groups 06M and 13M, which had obvious rising contours, also demonstrated smoother rising contours. Hence, the degrees of falling and rising between the control group and each bilingual group, especially for Group 36M and Group 60M, had no significant differences. It is clear in Figure 4.21 that the falling parts of the control group and each bilingual group had similar contours. No significant differences were detected at the staring measurement, turning point, and ending measurement.

Task 2C aimed to stimulate naturally occurring speech in a casual circumstance by having participants describe two videos simultaneously. The control group produced tone 3 – which had both falling and rising parts – fully, though the rising part was smoother than that in Tasks 2A and 2B. Group 06M had falling and rising contours for tone 3 production that were very similar to those of the control group. Group 13M had a shortened rising part in comparison to the control group. However, the differences between the control group and these two bilingual groups were not significant.

Group 36M produced tone 3 with a very slightly rising part, which is hard to detect from Figures 4.33 and 4.34. One significant difference was detected on measurement 6 T_{f_0} compared to the control group. Group 60M demonstrated no rising part for tone 3 production, with three measurements that differed significantly from the control group. Although the control group smoothed its rising part for tone 3 in simulated casual speaking circumstances, Group 36M and Group 60M still demonstrated significant differences in the rising parts.

Looking over the results for the three tasks, Group 36M seemed to play a transitional role among the four bilingual groups. Contours for tone 3 production were in between those of the control group and Group 60M. On the one hand, Group 36M produced rising parts in all three tasks, although they were much shorter and smoother than those of the control group. On the other hand, the number of measurements demonstrating significant differences changed from one to three, and then back to one task by task, which was not as consistent as Group 60M. It can be said that that tone 3 was not yet attrited at the stage of Group 36M but was becoming vulnerable. With two more years' residence in the L2 environment, signs of L1 attrition occurred on tone 3 production, which could be observed from Group 60M.

5.3.4. Tone 4

In the three tasks, tone 4 as produced by the control group and the four bilingual groups had very similar falling pitch contours. In Task 2A, only Group 06M demonstrated significant differences at two measurements when compared to the control group. The pitch registers of these two measurements in Group 06M were lower than those in the control group. However, the entire tone 4 contour for Group 06M was lower than the control group. The differences among these two measurements had no influence on the falling degree, which is to say that tone 4 as produced by Group 06M could still be recognized as a high falling tone. Hence, the significant differences between the control group and Group 06M were an occasionally occurring phenomenon that was not linked to L1 attrition.

In Task 2B and Task 2C, contours for tone 4 were falling with no significant differences detected between the control group and each of the bilingual groups. Hence, tone 4 is not vulnerable to attrition among bilinguals in any speaking circumstances. From the above analysis for four tones, it is clear that only tone 3 demonstrated attrition.

5.3.5. Tone 4 variation

It is clear from Figures 4.15, 4.26 and 4.37, that the control group and the four bilingual groups followed the rules to produce tone 4 variations in three tasks. The first tone 4 had falling contours with higher endings than the normal tone 4. The second tone 4 had a similar falling contour with a lower starting point. T-values of the starting measurement of the first tone 4 and the ending the of second tone 4 were in the range of the normal tone 4. No significant differences were detected for each task. Hence, tone 4 variations are not vulnerable to be attrited.

5.3.6. Tone sandhi

Tone sandhi is when the first tone 3 is produced as a rising tone when followed by another tone 3. The results of the control group and the four bilingual groups followed the tone sandhi rule in Chinese in three tasks. Both in formal and casual circumstances, there were no significant differences between the control group and the bilingual groups in producing the tone sandhi. In other words, the tone sandhi produced by each bilingual group was as stable as the one produced by the control group, and it was not vulnerable to be attrited even for bilinguals who had lived in the L2 environment for more than five years.

5.3.7. *yi* tone variations

The control group followed the rules to produce *yi* tones. *yi* T1→T4 variation was produced as a falling tone and *yi* T1→T2 variation was produced as a rising tone. Each bilingual group followed the rules as well, and produced dynamic *yi* tone variations. In *yi* T1→T4 variation, the last two measurements $9T_{f_0}$ and $10T_{f_0}$ for Group 60M exhibited significant differences verses those of the control group in Task 2A. Meanwhile, also in Task 2A, Group 06M manifested a significant difference in the ending measurement $10T_{f_0}$ for *yi* T1→T2 variation. However, due to no significant differences being detected at the same measurement in the other tasks, it is hard to prove that L1 attrition occurred for *yi* tone variation.

5.3.8. Discussion

The previous analysis for tone production indicated that signs of L1 tone attrition occurred on tone 3 in all three tasks. The possible reasons that tone attrition occurred on tone 3 only are listed below. First, tone acquisition order, from the easiest to the most complicated, is tone 1, tone 4, tone 2, and tone 3. Tone 3 is the last tone to be acquired in language acquisition. Hence, it should be the first tone to be attrited based on the regression model, This is supported by the data. The other three tones did not demonstrate any signs of attrition.

Second, L1 bilinguals living in an L2 environment generally have a high activation threshold according to the activation threshold model. At the same time, bilinguals have a decreased general effort (only maintenance effort) for L1 and an increased general effort (maintenance effort and acquisition effort) for L2 in the long-term. In line with the dynamic model of multilingualism, once the increasing general effort for L2 exceeds the decreased L1 general effort, the activation threshold for L1 will be higher. L2 English is a non-tone language, which means that for bilinguals, it is impossible to practice tones. Thus, L1 tones in the study are vulnerable to be attrited.

Third, the sign of an attrited tone 3 is that it lacks or omits the rising part. In the context, tone 3 is produced with a falling contour [21] only in the initial position instead of the complete contour [214] in the final position (Yip, 2002). Lack of the rising part has almost no impact on tone 3 perception. In other words, the rising part for tone 3 is more vulnerable to be affected than others in L2 environment. Thus, an attrited tone 3 has not changed its basic properties, which is a finding similar to those of previous studies on L1 tone attrition.

One interesting phenomenon in the study is that few of the $f_0$measurements from Group 06M or 13M demonstrated significant differences from the control group in each task. These significant differences can be accounted for by the coarticulation effect from neighbouring tones due to no other groups demonstrating significant differences.

Tone 1 and tone 4 – those acquired first and second in order – were retained among all bilingual groups, as expected. This is not only because they were acquired earlier than tone 3, but also because they do not require extra maintenance effort in production in an L2 environment. At least with 60 months of residence in an L2 environment, it is still impossible to reduce maintenance effort and increase activation thresholds enough to destabilise tone 1 and tone 4. Tone 2, as the third acquisition, was retained as well for the same reasons.

Though two tone 4 in tone 4 variation changed the pitch height respectively, pitch contours for both tone 4s were maintained as falling tones. This is to say that tone 4 variation is hardly involved in L1 attrition, in line with the regression model and the dynamic model of multilingualism. Tone sandhi is where the first tone 3 adjusts to tone 2 if it precedes another tone 3. Therefore, tone sandhi should be considered under the same situation as tone 2 in the study. No attrition in tone 2 was observed, which means that tone sandhi is not vulnerable to be attrited, as confirmed by previous studies (Zhou and Broersma, 2014b). *yi* tone variations saw no attrition signs demonstrated in the study for two possible reasons. First, *yi* tone variations are where the *yi* tone adjusts itself from a level tone 1 to a rising or falling tone. From the results, it is clear that *yi* tone variations produced by the control group and the four bilingual groups had not been replaced by tone 2 or tone 4 entirely. In other words, *yi* tone variations maintained the basic properties of a level tone 1. As it mentioned above, *yi* tone variations should be the last to be attrited due to the acquisition order in line with the regression model.

Three production tasks were designed to simulate different speaking circumstances: formal, semi-formal, and casual situations. The data showed that L1 tone attrition occurred in all three tasks, which means that L1 tone would not be less attrited in formal speaking circumstance. Though Major (1992) stated that bilinguals tended to demonstrate more evidence of attrition in casual speaking environments, the present study does not support this. A possible reason for this consistency is that the attrited tone 3 retained basic properties, as mentioned above. Therefore, the change of speaking circumstances had no influence on the degree of attrition.

5.4. Variables

The discussion in the above two sections indicated that signs of L1 attrition were shown in tone 3 production for Mandarin-English late bilinguals living in an L2 environment for over five years. The following will attempt to determine the relationships between L1 attrition and the variables presented in the results chapter.

5.4.1. Age and gender

For the purpose of the research, the age and gender of all participants was restricted to avoid impacts on the results. From the data, it is clear that in the research, L1 tone attrition was not affected by age, including actual age, AOA, and L2 exposure age, as expected. First, for the purpose of the research, the participants were Mandarin-English late bilinguals between 18 and 30 years old. The age gap between the oldest participant and youngest one was only 10 years, which means that all of the participants were from the same generation. They had similar social and educational backgrounds. Hence, actual age, as an important factor in L1 attrition, has been excluded from the research.

Second, the AOA for each bilingual group was very close to the other groups, with no significant differences. All bilingual participants were late bilinguals who settled in the L2 environment after puberty. The majority of the bilinguals moved to the L2 environment after having turned 18. Therefore, AOA has been removed from the variables for L1 attrition. Third, participants had similar L2 exposure ages both at school and at home. The majority of the participants learned L2 English when they were around 10 years old at school. Hence, L2 exposure age is not likely to have had an effect on L1 tone attrition.

The gender variable is much simpler. Both the control group and each bilingual group had an equal number of male and female participants. The results confirmed that the gender effect on L1 attrition was eliminated from the very beginning.

5.4.2. Length of residence, language contact, and English proficiency

Length of residence, amount of continued exposure to L1 to L2, and English proficiency will be discussed in this subsection. In the four bilingual groups, L1 tone attrition was demonstrated in Group 60M, which had the longest length of residence (over five years) in the L2 environment. Group 36M, which had more than three years of living experience in the L2 environment, demonstrated that L1 tones were vulnerable to attrition. Hence, it is clear that there is a connection between L1 tone attrition and the duration of residence in an L2 environment.

In line with DMM, not only the residential length, but also language contact and L2 English proficiency can be linked to L1 tone attrition in the research. As was discussed in Chapter 2 Section 2.3.2, general efforts (GE) for a language are comprised of maintenance effort (ME) and acquisition effort (AE). Different language proficiencies requires different MEs and AEs.

Bilinguals in the research had upper intermediate L2 proficiency when in the L1 environment. This required normal MEs for the L1 and maximum MEs for the L2. Bilinguals needed to switch the normal ME to the maximum in order to maintain high L1 proficiencies in the L2 domain. It is possible to increase L1 ME to cope with the increased acquisition demands from L2. However, the maximum ME is not supported by the surrounding environment. Participants, meanwhile, were hardly aware of the higher language maintenance effort needed for their native language. The data clearly stated that the four bilingual groups had sharply reduced L1 contacts in comparison to the control group in the L2 environment. In other words, L1 ME is reduced instead of being upgraded to a maximum. It is impossible for bilinguals to maintain L1 proficiency with an inadequate ME in the L2 domain. L1 will be either fossilised or attrited.

However, bilingual groups in the L2 environment preserved maximum L2 GE in order to integrate into local life more quickly and easily. The average L2 contact for the bilingual groups was around 10 hours per day in order to maintain the maximum GE. When the maximum L2 GE lasts for a sufficient amount of time, the L2 will eventually interfere with the vulnerable L1 in the L2 domains. Therefore, Group 60M among the four bilingual groups demonstrated tone 3 attrition.

Furthermore, in line with the activation threshold model, a long-term inadequate simulation would increase the activation threshold for L1. In practice however, the activation threshold for processing L2 is lower due to the high frequency of use. Once a large number of L2 items have had a lower activation threshold than L1 production for some time, it would be difficult for L1 to compete with the interference from L2, and that would lead to a gradual loss of proficiency.

5.5. Summary

In this chapter, the hypotheses proposed have been reviewed and discussed based on the data presented in the results chapter. Some hypotheses have been confirmed, while others need further investigation. Mandarin-English late bilinguals do experience L1 tone attrition. Signs of L1 attrition were shown on tone 3 consistently in each task. No signs of attrition were observed in the other three tones, tone sandhi, and tone variations.

The data also confirmed that tone attrition is hardly noticeable, and that the sign of tone 3 attrition is a loss of the rising part only. However, as mentioned in Chapter 3, tone 3 can still be perceived correctly with only the falling part. In other words, an attrited tone 3 is hardly distinguishable from a normal one by listening. Via the dedicated software Praat, attrited tone 3 was able to be observed. Across the three tasks, it was found that each bilingual group consistently performed each tone and each tone variation in comparison to the control group. The signs of tone 3 attrition were demonstrated in each production task. Therefore, once L1 attrition occurs on a Mandarin tone, it will be consistent across different speaking circumstances.

Chapter 6. Conclusion

This thesis set out to explore L1 Mandarin tone attrition in relation to L2 proficiency, amount of L1 and L2 exposure, and type of exposure to L2 in the L2 environment. The present study observed L1 attrition in terms of Mandarin tones among forty Mandarin-English bilinguals. Stimuli for L1 perception, L1 production, and exposure levels of L1 and L2 were investigated to collect data for an analysis and discussion of L1 attrition in Mandarin tones in the L2 environment.

The findings of the present study confirm that tone, as one of the most identifiable phonological features in L1 Mandarin, may be vulnerable to be attrited. The results indirectly confirmed that L1 attrition on tones is a real but slow process that is intensively connected to and affected by L2 proficiency and the amount of exposure to both languages for bilinguals in the L2 environment.

With guidance from previous studies, three models – activation threshold model, dynamic model of multilingualism (DMM), and regression model – were reviewed in relation to the development of the study of L1 attrition from different linguistic perspectives. Let us look at the present study relates to these.

Based on the activation threshold model, bilingual participants (especially for Groups 36M and 60M) had lower activation thresholds for the L2 linguistic items under scrutiny in the L2 environment. This can be connected to data from the questionnaire that indicates most participants had over 50% L2 exposure daily. On the contrary to high L2 exposure levels, with an average L1 exposure of less than 30% of the day, activation thresholds for tones were certainly higher for the bilingual groups than for participants from the control group. Thus, with higher and higher activation thresholds over a period of more than five years of residence in the L2 environment, production of tones, such as tone T3, will eventually not be native-like. In other words, L1 attrition can be seen to occur over time with high daily levels of L2 exposure.

The findings support the notion that L1 attrition is not only caused by increasing L2 exposure, but also decreasing maintenance of L1. As the DMM states, general language effort is made up of language maintenance effort and language acquisition effort. In the L2 environment, participants needed to increase L1 language maintenance effort by one unit – from two units to three units – in order to maintain a high L1 proficiency. However, analysis of the data on L1 daily exposure data for the control group and the four bilingual groups did not show significant differences. In other words, participants from the four bilingual groups did not increase their L1 exposures, but their L2 exposures increased due to language environment changes. Thus, over time, the L1 would be in a position of disadvantage in competing with L2 in the L2 environment, leading to L1 attrition. It is undeniable that L2 acquisition plays an important role in L1 attrition among late bilinguals. Variables such as language proficiency and language exposure/contact were predicted to have an impact on L1 maintenance and lead to tone attrition and, indirectly, the results of this study supported this idea.

The results not only link potential factors such as language proficiency and exposure amounts to L1 attrition, but also demonstrate the attrition order for tones. This follows the paradigm of the regression model – "last acquired, first lost". The tone acquisition order in L1 acquisition is T1, T4, T2, and finally, T3. Participants from Groups 36M and 60M tended to produce T3 with no rising part, which was significantly different from how it was produced by the control group. The other three tones saw no differences between the control group and the four bilingual groups.

6.1. Contributions

The current research makes contributions to several linguistic subfields. First, it focuses on Mandarin tones in connected speech, which has been barely looked at in the field of L1 attrition research. It presents a comprehensive investigation of bilinguals' tone perceptions and production. Several difficulties, such as capturing dynamic tone contours and removing coarticulation effects from surrounding tones, were overcome in the data collection and analysis. The results confirm that tone is vulnerable to undergoing attrition, similar to other linguistic items.

Second, this study observed language multi-competence among late Mandarin-English bilinguals. Subjects' performance in both L1 and L2 was recorded along with the dimensions of frequency, proficiency, and accuracy (Larsen & Freeman, 2009). The investigation of multi-competence for bilingualism confirmed not only that adult bilinguals are vulnerable to undergo attrition in Mandarin tone, but also that two language systems impact each other bi-directionally (Jessner, 2003). The positive interaction reinforces two languages, while the negative interaction causes language attrition due to interference between two systems.

6.2. Limitations and future research

The applicability of the data in the present study is limited for use in wider contexts by some limitations. These limitations can also be considered directions for future research. First, this was a small-scale and very targeted study, and the generalisability of the results might be low. The subjects were limited to late Mandarin-English bilinguals with high proficiencies in the L2. The data and implications can only be straightforwardly used in comparison to other studies in this very narrow field. Higher generalizability could be achieved by recruiting more bilinguals, perhaps those who speak other Chinese dialects or those with different language proficiencies.

Second, this study examines tone perception by accuracy rate. The process of tone perception, such as reaction or processing time, is not involved in the study. It is hard to tell whether the ability for tone perception retains due to the prolonged reaction time. Therefore, in future research, eye-tracking stimuli or EGG should be involved to test the process of L1 attrition.

Third, for bilinguals, L1 attrition is a slow progress that must be observed longitudinally (Schmid, 2004). Sixty months of residence in an L2 environment is not long enough to study L1 attrition comprehensively. The dynamic interactions between L1 and L2 will be much more intensive and clearer among bilinguals with at least 10 years of residence in the L2 domain. Meanwhile, bilinguals have a higher frequency in switching language domains than monolinguals. Examining their language changes after each time they switch domains would be an efficient method to track dynamic interactions between L1 and L2.

Fourth, in the current research, it was hard to tell whether the ability to produce a full tone 3 had been lost permanently or was just temporarily unaccusable. Investigation of the internal mechanism for L1 attrition is a very promising research direction.

The original purpose of this research has been fulfilled, in that the explanation for the “strange phenomenon” of native language attrition has been discussed. Additionally, this research also hopes to raise more attention on this issue in order to protect and preserve native languages and ensure that bilingualism or multilingualism is no longer the exception in the era of the rapid development of globalization (Harris & McGhee Nelson 1992).

Appendices

7.1. Participant Information Sheet

Title of project: Attrition in Mandarin Tones by Late Bilinguals Living in the UK

Name of Supervisor: Professor Martha Young-Scholten

Email: martha.young-scholten@ncl.ac.uk Telephone: +44 (0) 191 208 7751

Name of Researcher: Xiangjie Cao

Email: xiangjie.cao@ncl.ac.uk Telephone: +44(0) 7462528384

Contact Address: School of English Literature language and Linguistics, Percy Building, Newcastle University, Newcastle upon Tyne, Tyne and Wear, NE1 7RU, United Kingdom.

Brief introduction of the research

The research aims to evaluate Mandarin phonological change among adult Mandarin-English bilinguals in both perception and production.

Participant selection

Before you decide to take part in the project, you need understand some basic information. Please take your time to read the information on this form before deciding to participate in the project.

You are invited to participate in this project as a Mandarin native speaker. Your participation in this project is entirely voluntary. If you decide to participate, you will be asked to sign a consent form to indicate your willingness to participate and complete a questionnaire of personal information. You have the right to withdraw your consent and participation at any time without any consequences. If withdraw, your data will be destroyed or will only be used with your permission.

Participation

If you agree to participate in this project, you will be asked to take a quick English replacement test and attend two tasks, which last 10 to 15 minutes respectively. In the first task, you will be asked to record tones and recognize lexicon in Mandarin while listening a 10 to 15 minutes record. In the second task, you will be asked to read a story and re-tell the story in Mandarin, and then participate in a 5 minute one-to-one interview with the researcher. During the interview, you will be asked some questions related with the story you re-told. The two tasks will be recorded with a digital recorder.

Benefit and risk

Participation does not involve any known or anticipated risks for you. However, participation may cause inconvenience as it will require one hour of your time.

The potential benefits associated with your participation include the fact you will have a sense of how your pronunciation might change in your native language when you learn a second language.

Confidentiality, data storage and usage

In the formal report, your real name will be never be used, which will be replaced by a code. Your confidentiality and that of the data will be protected during and after the research. The recordings and other documents will only be used in this research, and will not be accessed or used by the third party without your permission. The data will be stored in password-secured computer and password-secured server. Hard copies of transcriptions and other information documents will be stored securely by the researcher and will only be accessed by the researcher. When the research is completed, the data will be stored as above and kept in a secured place (in a locked drawer in the researcher’s office).

Dissemination of result

It is anticipated that the results of this research will be shared by the researcher in publications, and presentations.

Further information

If you have any requires or concerns about this research, or would like more information or to hear about the results, please do not hesitate to contact the researcher or the supervisor with the information above.

7.2. Participant Risk Assessment

Physical risk

All equipment will be used in the experiment are a digital voice recorder, headphones and a laptop. There will not any risk or discomfort to the participants.

There is no risk of having participants travel to another location for this research as the research is going to be conducted at the university/the researcher's home.

Psychological risk

There is no known psychological risk associated with the research currently.

Environment risk

The research will be located in Newcastle upon Tyne, UK, and Beijing, China, which are all highly secure cities. Therefore, in the event of any unanticipated environment risk which may cause physical injury, for example earthquake, the safety of the participants and researcher will be considered most important. The research will be suspended and all will follow first aid procedures strictly.

7.3. Consent Form

Name of Supervisor: Professor Martha Young-Scholten

Email: martha.young-scholten@ncl.ac.uk **Telephone**: +44 (0) 191 208 7751

Name of Researcher: Xiangjie Cao

Email: xiangjie.cao@ncl.ac.uk **Telephone**: +44(0) 7462528384

Contact Address: School of English Literature language and Linguistics, Percy Building, Newcastle University, Newcastle upon Tyne, Tyne and Wear, NE1 7RU, United Kingdom.

I, the undersigned participant confirm that (please tick box appropriately):

[ ] I have read and understood the information about the project as provided on the information sheet.

[ ] I have been given the opportunity to ask questions about the project and my participation.

[ ] I agree to voluntarily take part in the project

[ ] I understand that I can withdraw at any time without giving reasons or being penalised nor will I be questioned for withdrawing.

[ ] I understand that a voice recorder will be used to collect data and I agree to my voice being recorded for the purpose of this research project.

[ ] The procedures regarding confidentiality and anonymity have been clearly explained to me.

[ ] I understand that the recording of my voice and other accompanying materials may be stored in password-protected files on a computer.

[ ] I understand that anonymised extracts of my data may be used in research, publication, public presentations, teaching and training purposes.

[ ] Storage and usage of data has been explained to me.

[ ] I understand that I will receive no payment as incentive for my participation in this project.

Name of participant giving consent	---
Signature of participant	---
Date	---
Name of researcher taking consent	---
Signature of researcher	---
Date	---

7.4. Participant Debriefing Sheet

Thank you for taking part in this research. I really appreciate your cooperation. As a final stage of the research, I would like to introduce the research in detail as follows.

The research is titled as Mandarin tones by late bilinguals in the UK. Attrition is very natural changes that can sometimes occur in your native language when you learn a second one. The study examined the four tones in Mandarin and tried to figure out whether bilinguals attrite Mandarin tones and if they do so, how they attrite. The research is important because the findings could unveil tone change when a tone language speaker moves into nontone language environment.

The data are being analysed using professional acoustic analysis software called Praat and SPSS (statistical analysis software). The results will available at the end of the summer in 2015. If you would like to review the research results, give feedback about the research, and need further information about the research, please contact me or my supervisors.

Name of Supervisor: Professor Martha Young-Scholten

Email: martha.young-scholten@ncl.ac.uk Name of Researcher: Xiangjie Cao Email: xiangjie.cao@ncl.ac.uk Researcher's Name:

Signature:

Telephone: +44 (0) 191 208 7751 Telephone: +44(0) 7462528384

Date:

7.5. Participant General Background

Groups	Code	Months	Gender	Native language	2nd language	Age	AOA
Control Group	CG01	0	Female	Chinese	N/A	20	N/A
	CG02	0	Male	Chinese	N/A	22	N/A
	CG03	0	Female	Chinese	N/A	21	N/A
	CG04	0	Male	Chinese	N/A	20	N/A
	CG05	0	Female	Chinese	N/A	22	N/A
	CG06	0	Female	Chinese	N/A	19	N/A
	CG07	0	Female	Chinese	N/A	19	N/A
	CG08	0	Male	Chinese	N/A	26	N/A
	CG09	0	Male	Chinese	N/A	30	N/A
	CG10	0	Male	Chinese	N/A	19	N/A
Group 06M	G06M01	06	Female	Chinese	English	21	21
	G06M02	06	Female	Chinese	English	27	27
	G06M03	06	Male	Chinese	English	21	21
	G06M04	06	Female	Chinese	English	22	21
	G06M05	12	Male	Chinese	English	24	23
	G06M06	06	Male	Chinese	English	22	23
	G06M07	06	Female	Chinese	English	21	20
	G06M08	06	Female	Chinese	English	24	23
	G06M09	07	Male	Chinese	English	25	25
	G06M10	06	Female	Chinese	English	21	20
Group 13M	G13M01	18	Female	Chinese	English	27	25
	G13M02	18	Male	Chinese	English	20	18
	G13M03	15	Female	Chinese	English	28	26
	G13M04	12	Male	Chinese	English	34	33
	G13M05	12	Female	Chinese	English	19	18
	G13M06	24	Male	Chinese	English	25	23
	G13M07	18	Male	Chinese	English	25	23
	G13M08	12	Female	Chinese	English	23	22
	G13M09	24	Female	Chinese	English	20	18
	G13M10	24	Female	Chinese	English	24	20
Group 36M	G36M01	36	Male	Chinese	English	26	23
	G36M02	48	Male	Chinese	English	27	21
	G36M03	36	Female	Chinese	English	28	25
	G36M04	30	Male	Chinese	English	27	24
	G36M05	36	Female	Chinese	English	25	22
	G36M06	48	Female	Chinese	English	25	21
	G36M07	36	Male	Chinese	English	25	22
	G36M08	36	Female	Chinese	English	26	23
	G36M09	48	Female	Chinese	English	27	22
	G3M10	48	Female	Chinese	English	25	21
Group 60M	G60M01	60	Male	Chinese	English	24	19
	G60M02	72	Female	Chinese	English	29	23
	G60M03	60	Female	Chinese	English	29	24
	G60M04	60	Female	Chinese	English	27	22
	G60M05	60	Male	Chinese	English	27	22
	G60M06	72	Male	Chinese	English	27	22
	G60M07	96	Male	Chinese	English	27	19
	G60M08	120	Female	Chinese	English	25	13
	G60M09	72	Male	Chinese	English	28	22
	G60M10	120	Male	Chinese	English	27	17

7.6. Stimuli materials

7.6.1. Perception Task 1A

ANSWER SHEET 1A

Multiple Choice

Please listen to the recording and circus the appropriate pronunciation (A, B or C) for each word. Example:

e.g.	吃饭	A	B	C

1	今天	A	B	C
2	韶华	A	B	C
3	打网球	A	B	C
4	眼睫毛	A	B	C
5	便利店	A	B	C
6	帆布袋	A	B	C
7	拖鞋	A	B	C
8	火箭	A	B	C
9	小蚂蚁	A	B	C
10	大拇指	A	B	C
11	练习	A	B	C
12	蒙古语	A	B	C
13	篮球场	A	B	C
14	实习生	A	B	C
15	繁琐	A	B	C
16	遮阳板	A	B	C
17	奔走	A	B	C
18	潜水艇	A	B	C
19	卡塔尔	A	B	C
20	诋毁	A	B	C
21	信用卡	A	B	C
22	干枯	A	B	C
23	消防员	A	B	C
24	战斗	A	B	C
25	赌场	A	B	C
26	尽管	A	B	C
27	核潜艇	A	B	C
28	刺绣	A	B	C
29	多媒体	A	B	C
30	世界杯	A	B	C
31	儒学	A	B	C
32	遗孀	A	B	C
33	演唱会	A	B	C

34	实验室	A	B	C
35	动物园	A	B	C
36	艺术品	A	B	C
37	血小板	A	B	C
38	品牌	A	B	C
39	摆脱	A	B	C
40	主旨	A	B	C
41	十一月	A	B	C
42	落枕	A	B	C
43	继承人	A	B	C
44	专卖店	A	B	C
45	沙哑	A	B	C
46	颐和园	A	B	C
47	会议	A	B	C
48	温度	A	B	C
49	理睬	A	B	C
50	世界	A	B	C
51	女主角	A	B	C
52	枸杞	A	B	C
53	挣钱	A	B	C
54	峨嵋山	A	B	C
55	决心	A	B	C
56	同义字	A	B	C
57	堡垒	A	B	C
58	水浒传	A	B	C
59	退休	A	B	C
60	樱桃树	A	B	C
61	传统	A	B	C
62	好友	A	B	C
63	早晨	A	B	C
64	领导	A	B	C
65	勾当	A	B	C
66	蝴蝶结	A	B	C

67	奢侈品	A	B	C
68	虚荣心	A	B	C
69	足球队	A	B	C
70	委屈	A	B	C
71	设计师	A	B	C
72	栽培	A	B	C
73	麦芽糖	A	B	C
74	副作用	A	B	C
75	建筑学	A	B	C
76	等候室	A	B	C
77	血浆	A	B	C
78	磨砺	A	B	C
79	晃眼	A	B	C
80	兵马俑	A	B	C
81	语言学	A	B	C
82	时事	A	B	C
83	一年	A	B	C
84	古董	A	B	C
85	准确	A	B	C
86	历史	A	B	C
87	归化	A	B	C
88	一定	A	B	C
89	不要	A	B	C
90	科学家	A	B	C
91	天文学	A	B	C
92	生活费	A	B	C
93	处女座	A	B	C
94	管理	A	B	C
95	做到	A	B	C
96	审美观	A	B	C
97	不对	A	B	C
98	蒙古包	A	B	C
99	一样	A	B	C

7.6.2. Perception task 1B

ANSWER SHEET 1B

ABX Task

Please listen to the recording carefully and choose which pronunciation (A or B) matches X.

Example: if A is the same pronunciation with X, please circus A.

e.g.	A	B	X

1.	A	B	X
2.	A	B	X
3.	A	B	X
4.	A	B	X
5.	A	B	X
6.	A	B	X
7.	A	B	X
8.	A	B	X
9.	A	B	X
10.	A	B	X
11.	A	B	X
12.	A	B	X
13.	A	B	X
14.	A	B	X
15.	A	B	X
16.	A	B	X
17.	A	B	X
18.	A	B	X
19.	A	B	X
20.	A	B	X
21.	A	B	X
22.	A	B	X
23.	A	B	X
24.	A	B	X
25.	A	B	X
26.	A	B	X
27.	A	B	X
28.	A	B	X
29.	A	B	X
30.	A	B	X
31.	A	B	X
32.	A	B	X
33.	A	B	X

34.	A	B	X
35.	A	B	X
36.	A	B	X
37.	A	B	X
38.	A	B	X
39.	A	B	X
40.	A	B	X
41.	A	B	X
42.	A	B	X
43.	A	B	X
44.	A	B	X
45.	A	B	X
46.	A	B	X
47.	A	B	X
48.	A	B	X
49.	A	B	X
50.	A	B	X
51.	A	B	X
52.	A	B	X
53.	A	B	X
54.	A	B	X
55.	A	B	X
56.	A	B	X
57.	A	B	X
58.	A	B	X
59.	A	B	X
60.	A	B	X
61.	A	B	X
62.	A	B	X
63.	A	B	X
64.	A	B	X
65.	A	B	X
66.	A	B	X

67.	A	B	X
68.	A	B	X
69.	A	B	X
70.	A	B	X
71.	A	B	X
72.	A	B	X
73.	A	B	X
74.	A	B	X
75.	A	B	X
76.	A	B	X
77.	A	B	X
78.	A	B	X
79.	A	B	X
80.	A	B	X
81.	A	B	X
82.	A	B	X
83.	A	B	X
84.	A	B	X
85.	A	B	X
86.	A	B	X
87.	A	B	X
88.	A	B	X
89.	A	B	X
90.	A	B	X
91.	A	B	X
92.	A	B	X
93.	A	B	X
94.	A	B	X
95.	A	B	X
96.	A	B	X
97.	A	B	X
98.	A	B	X
99.	A	B	X

7.6.3. Production Task 2A

TASK 2A

Reading the story

Please read the story (including the title) in Mandarin with your normal speaking speed.

莫高窟

在浩瀚无垠的沙漠里，有一片美丽的绿洲，绿洲里藏着一颗闪光的珍珠。这颗珍珠就是敦煌莫高窟。它坐落在我国甘肃省敦煌市三危山和鸣沙山的怀抱中。

鸣沙山东麓是平均高度为十七米的崖壁。在一千六百多米长的崖壁上，凿有大小洞窟七百余个，形成了规模宏伟的石窟群。其中四百九十二个洞窟中，共有彩色塑像两千一百余尊，各种壁画共四万五千多平方米。莫高窟是我国古代无数艺术匠师留给人类的珍贵文化遗产。

莫高窟的彩塑，每一尊都是一件精美的艺术品。最大的有九层楼那么高，最小的还不如一个手掌大。这些彩塑个性鲜明，神态各异。有慈眉善目的菩萨，有威风凛凛的天王，还有强壮勇猛的力士……

莫高窟壁画的内容丰富多彩，有的是描绘古代劳动人民打猎、捕鱼、耕田、收割的情景，有的是描绘人们奏乐、舞蹈、演杂技的场面，还有的是描绘大自然的美丽风光。其中最引人注目的是飞天。壁画上的飞天，有的臂挎花篮，采摘鲜花；有的反弹琵琶，轻拨银弦；有的倒悬身子，自天而降；有的彩带飘拂，漫天遨游；有的舒展着双臂，翩翩起舞。看着这些精美动人的壁画，就像走进了灿烂辉煌的艺术殿堂。

莫高窟里还有一个面积不大的洞窟——藏经洞。洞里曾藏有我国古代的各种经卷、文书、帛画、刺绣、铜像等共六万多件。由于清朝政府腐败无能，大量珍贵的文物被外国强盗掠走。仅存的部分经卷，现在陈列于北京故宫等处。

莫高窟是举世闻名的艺术宝库。这里的每一尊彩塑、每一幅壁画、每一件文物，都是中国古代人民智慧的结晶。

7.6.4. Production Task 2B

TASK 2B

Story Retelling

Please retell the story in task 2A in Mandarin with following keywords with your normal speaking speed.

浩瀚无垠 / 沙漠 / 一片美丽 / 绿洲 / 藏着一颗 / 珍珠 / 敦煌 / 莫高窟 / 坐落 / 甘肃省 / 三危山 / 鸣沙山 / 怀抱中

鸣沙山 / 东麓 / 平均高度 / 十七米 / 崖壁 / 一千六百多米 / 凿有 / 洞窟七百余个 / 形成 / 规模宏伟 / 石窟群 / 四百九十二个 / 彩色塑像 / 两千一百余 / 各种壁画 / 四万五千多平方米 / 我国古代 / 艺术匠师 / 人类 / 文化遗产。

彩塑 / 每一尊 / 精美 / 艺术品 / 最大 / 九层楼 / 高 / 最小 /一个手掌大 / 彩塑个性鲜明 / 神态各异 / 慈眉善目 / 菩萨 / 威风凛凛 / 天王 / 强壮勇猛 / 力士

壁画 / 内容 / 丰富多彩 / 描绘 / 古代 / 劳动人民 / 打猎 / 捕鱼 / 耕田 / 收割 / 情景 / 奏乐 / 舞蹈 / 演杂技 / 场面 / 大自然 / 美丽风光 / 最引人注目 / 飞天 / 有的 / 臂挎花篮 / 采摘鲜花 / 反弹琵琶 / 轻拨银弦 / 倒悬身子 / 自天而降 / 彩带飘拂 / 漫天遨游 / 舒展着双臂 / 翩翩起舞 / 看着 / 精美动人的壁画 / 走进了 / 灿烂辉煌 / 艺术殿堂

一个面积不大 / 洞窟 / 藏经洞 / 曾藏有 / 我国古代 / 各种经卷 / 文书 / 帛画 / 刺绣 / 铜像 / 六万多件 / 清朝政府 / 腐败无能 / 大量珍贵 / 文物 / 外国强盗 / 掠走 / 仅存 / 部分经卷 / 陈列于 / 北京故宫

莫高窟 / 举世闻名 / 艺术宝库 / 每一尊 / 彩塑 / 壁画 / 文物 / 中国 / 古代人民 / 智慧 / 结晶

7.6.5. Questionnaire

Part A

1. Age (in years):
2. Gender (circle one): Male / Female
3. Education (degree obtained or school level attended):
4. Residence:
   i. Country of origin:
   ii. Country of residence:
   iii. If (a) and (b) are different , how long have you been in the country of your current residence (in years):
5. What is your native language?
6. Do you speak a second language?
   i. YES My second language is__________________________________
   ii. NO If you answered NO, you need not to continue this form.
7. If you answered YES to Question 6, please specify the age at which you started to learn your second language in the following situations:
   i. At home:
   ii. In school:
   iii. After arriving in the second language speaking country:
8. How did you learn your second language up to this point? (circle one)
   i. Mainly / Mostly / Occasionally through formal classroom instruction
   ii. Mainly / Mostly / Occasionally through interacting with people
   iii. A mixture of both, but more classroom / more interaction / equally both.
   iv. Other, please specify: ____

9. List ALL foreign languages you know in order of most proficient to lease proficient. Rate your ability on the following aspects in each language. Please rate according to the following case.

Very poor	Poor	Fair	Functional	Good	Very good	Native-like
1	2	3	4	5	6	7

Language	**Reading proficiency**	**Writing proficiency**	**Speaking fluency**	**Listening proficiency**

10. Provide the age at which you were first exposed to each foreign language in terms of speaking, reading, and writing, and the number of years you have spent on learning each language.

Language	**Age first exposed to the language**				**Number of years learning**
	Speaking	**Reading**	**Writing**	**Listening**	

11. Do you have a foreign accent in ALL languages you speak? If so, please rate the strength of your accent according to the following scales (write down the number in the table):

No accent	Very weak	Weak	Intermediate	Strong	Very strong
1	2	3	4	5	6

Language					
Accent (circle one)	Y N	Y N	Y N	Y N	Y N
Strength					

Part B

12. Estimate, in terms of percentages, how often you use your native language and other languages per day (in all daily activities combined, circle one that applied):

A.	B.	C.	D.	E.
<25%	25-50%	50-75%	75-100%	100%

1. Native language:
2. Second language:
3. Other language:

   (Please specify the language: ____)

13. Estimate, in terms of hours per day, how often you engaged in the following activities with your native and second languages, including using social software (e.g. Facebook, Skype, QQ, Renren, Wechat, Line)

Activities	**First language**	**Second language**	**Other language**
Listen to Radio	____________(hrs)	____________(hrs)	____________(hrs)
Watching TV	____________(hrs)	____________(hrs)	____________(hrs)
Reading for fun	____________(hrs)	____________(hrs)	____________(hrs)
Reading for work	____________(hrs)	____________(hrs)	____________(hrs)
Writing SMS	____________(hrs)	____________(hrs)	____________(hrs)
Writing articles/papers	____________(hrs)	____________(hrs)	____________(hrs)
Writing / Typing on social software	____________(hrs)	____________(hrs)	____________(hrs)

14. Estimate, in terms of hours per day, how often you speak (or used to speak) your native and second languages with following people, including using social software (e.g. Facebook, Skype, QQ, Renren, Wechat, Line)

	First Language	**Second Language**
Father:	_______________(hrs)	_______________(hrs)
Mother:	_______________(hrs)	_______________(hrs)
Grandfather:	_______________(hrs)	_______________(hrs)

Grandmother:	________________(hrs)	________________(hrs)
Sibling(s):	________________(hrs)	________________(hrs)
Other family members:	________________(hrs)	________________(hrs)

15. Estimate, in terms of hours per day, how often you now speak your native and second languages with the following people, including using social software (e.g. Facebook, Skype, QQ, Renren, Wechat, Line)

	First Language	**Second Language**
Spouse/Partner:	________________(hrs)	________________(hrs)
Friends:	________________(hrs)	________________(hrs)
Classmates:	________________(hrs)	________________(hrs)
Co-workers/Colleague:	________________(hrs)	________________(hrs)
Others:	________________(hrs)	________________(hrs)

16. Writing down the name of the language in which you received instruction in school, for each schooling level:

i. Primary / Elementary School:

ii. Secondary / Middle School:

iii. High School:

iv. Undergraduate:

v. Postgraduate:

17. Writing down the name of the language in which you received instruction at work:

i. Work 1

ii. Work 2

iii. Work 3

18. In which languages do you usually:

i. Count, add, multiply, and do simple arithmetic?

ii. Dream?

iii. Express anger or affection?

19. When you are speaking, do you ever mix words or sentences from the two or more languages you know?

i. YES, please go to Question 20.

ii. NO, please go to Question 21.

20. List the language that you mix and rate the frequency of mixing in normal conversation with the following people according to the following scales (writing down the number in the table):

Rarely	Occasionally	Sometimes	Frequently	Very frequently
1	2	3	4	5

Relationship	**Language mixed**	**Frequency of mixing**
Spouse / Family members		
Friends		
Co-workers / Colleagues		
Classmates		
Others		

21. In which language (among your best two languages) do you feel you usually do better? Writing the name of the language under each condition.

	At home	**At school / work**
Reading	______________________	______________________
Writing	______________________	______________________
Speaking	______________________	______________________
Listening / Understanding	______________________	______________________

22. Among languages you know, which language is the one that you would prefer to use in these situations?

i. At home:

ii. At work:

iii. At a party:

iv. In general:

23. If you have lived or travelled in other countries for more than three months, please indicate the names of the country or countries, your length of stay, and the language you learned or tried to learn.

24. If you have taken a standardized test of proficiency for languages, including your native language, (e.g., TOEFL or IELTS), please indicate the scores you received for each.

Language	**Name of the test**	**Scores**
__________________	__________________	__________________
__________________	__________________	__________________
__________________	__________________	__________________
__________________	__________________	__________________
__________________	__________________	__________________

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

26. Do you have additional questions that you feel are not included above? If YES, please write down your questions and answers in separate sheet.

27. Do you have some knowledge about tone sandhi in Mandarin?

i. YES. Please specify in which way you know tone sandhi:__________________
ii. NO.

7.7. Statistics for comparison of the three productions tasks

Dependent variables	Tasks		p-values			
			Tone 1	Tone 2	Tone 3	Tone 4
Control Group	Task 2A	Task 2B	0.186	0.368	0.155	0.301
$1T_{f_0}$	Task 2A	Task 2C	0.468	0.828	0.505	0.308
	Task 2B	Task 2C	0.540	0.492	0.437	0.989
$2T_{f_0}$	Task 2A	Task 2B	0.229	0.300	0.241	0.308
	Task 2A	Task 2C	0.427	0.931	0.543	0.305
	Task 2B	Task 2C	0.675	0.341	0.566	0.994
$3T_{f_0}$	Task 2A	Task 2B	0.297	0.253	0.516	0.349
	Task 2A	Task 2C	0.446	0.995	0.768	0.384
	Task 2B	Task 2C	0.774	0.250	0.722	0.945
$4T_{f_0}$	Task 2A	Task 2B	0.338	0.224	0.685	0.486
	Task 2A	Task 2C	0.466	0.903	0.904	0.586
	Task 2B	Task 2C	0.815	0.182	0.776	0.878
$5T_{f_0}$	Task 2A	Task 2B	0.335	0.211	0.904	0.694
	Task 2A	Task 2C	0.466	0.774	0.776	0.914
	Task 2B	Task 2C	0.811	0.128	0.793	0.774
$6T_{f_0}$	Task 2A	Task 2B	0.337	0.252	0.564	0.884
	Task 2A	Task 2C	0.428	0.644	0.752	0.879
	Task 2B	Task 2C	0.864	0.113	0.600	0.765
$7T_{f_0}$	Task 2A	Task 2B	0.360	0.349	0.423	0.869
	Task 2A	Task 2C	0.376	0.646	0.780	0.684
	Task 2B	Task 2C	0.976	0.168	0.406	0.808
$8T_{f_0}$	Task 2A	Task 2B	0.323	0.492	0.606	0.915
	Task 2A	Task 2C	0.338	0.560	0.749	0.708
	Task 2B	Task 2C	0.975	0.209	0.749	0.788
$9T_{f_0}$	Task 2A	Task 2B	0.334	0.607	0.919	0.869
	Task 2A	Task 2C	0.371	0.500	0.153	0.714
	Task 2B	Task 2C	0.941	0.239	0.182	0.840
$10T_{f_0}$	Task 2A	Task 2B	0.318	0.672	0.491	0.723
	Task 2A	Task 2C	0.335	0.480	0.064	0.688
	Task 2B	Task 2C	0.971	0.263	0.228	0.962

Group 06M			Tone 1	Tone 2	Tone 3	Tone 4
	Task 2A	Task 2B	0.532	0.763	0.127	0.482
	Task 2A	Task 2C	0.458	0.948	0.441	0.810
$1T_{f_0}$	Task 2B	Task 2C	0.921	0.811	0.423	0.351
	Task 2A	Task 2B	0.510	0.759	0.104	0.457
	Task 2A	Task 2C	0.455	0.837	0.536	0.663
$2T_{f_0}$	Task 2B	Task 2C	0.944	0.914	0.292	0.247
	Task 2A	Task 2B	0.501	0.641	0.062	0.428
	Task 2A	Task 2C	0.504	0.623	0.587	0.656
$3T_{f_0}$	Task 2B	Task 2C	0.983	0.991	0.170	0.225
	Task 2A	Task 2B	0.492	0.484	0.197	0.388
	Task 2A	Task 2C	0.546	0.464	0.671	0.694
$4T_{f_0}$	Task 2B	Task 2C	0.920	0.990	0.373	0.217
	Task 2A	Task 2B	0.519	0.311	0.624	0.394
	Task 2A	Task 2C	0.497	0.278	0.643	0.714
$5T_{f_0}$	Task 2B	Task 2C	0.986	0.964	0.969	0.231
	Task 2A	Task 2B	0.643	0.202	0.945	0.383
	Task 2A	Task 2C	0.483	0.152	0.355	0.839
$6T_{f_0}$	Task 2B	Task 2C	0.825	0.900	0.333	0.287
	Task 2A	Task 2B	0.838	0.129	0.940	0.355
	Task 2A	Task 2C	0.520	0.094	0.317	0.982
$7T_{f_0}$	Task 2B	Task 2C	0.673	0.900	0.295	0.366
	Task 2A	Task 2B	0.934	0.117	0.847	0.401
	Task 2A	Task 2C	0.599	0.083	0.434	0.977
$8T_{f_0}$	Task 2B	Task 2C	0.552	0.896	0.568	0.417
	Task 2A	Task 2B	0.827	0.134	0.565	0.416
	Task 2A	Task 2C	0.606	0.079	0.504	0.956
$9T_{f_0}$	Task 2B	Task 2C	0.472	0.820	0.939	0.386
	Task 2A	Task 2B	0.680	0.122	0.401	0.398
	Task 2A	Task 2C	0.688	0.068	0.724	0.997
$10T_{f_0}$	Task 2B	Task 2C	0.424	0.803	0.617	0.395

Group 13M			**Tone 1**	**Tone 2**	**Tone 3**	**Tone 4**
	Task 2A	Task 2B	0.419	0.631	0.718	0.786
	Task 2A	Task 2C	0.919	0.274	0.606	0.388
$1T_{f_0}$	Task 2B	Task 2C	0.364	0.121	0.876	0.552
	Task 2A	Task 2B	0.371	0.666	0.839	0.743
	Task 2A	Task 2C	0.995	0.247	0.626	0.370
$2T_{f_0}$	Task 2B	Task 2C	0.374	0.117	0.776	0.566
	Task 2A	Task 2B	0.409	0.719	0.942	0.815
	Task 2A	Task 2C	0.939	0.264	0.732	0.525
$3T_{f_0}$	Task 2B	Task 2C	0.453	0.144	0.678	0.686
	Task 2A	Task 2B	0.450	0.817	0.805	0.879
	Task 2A	Task 2C	0.917	0.307	0.969	0.671
$4T_{f_0}$	Task 2B	Task 2C	0.514	0.214	0.775	0.785
	Task 2A	Task 2B	0.492	0.917	0.552	0.969
	Task 2A	Task 2C	0.926	0.380	0.902	0.796
$5T_{f_0}$	Task 2B	Task 2C	0.552	0.327	0.636	0.826
	Task 2A	Task 2B	0.516	0.990	0.401	0.978
	Task 2A	Task 2C	0.943	0.542	0.799	0.768
$6T_{f_0}$	Task 2B	Task 2C	0.563	0.534	0.556	0.789
	Task 2A	Task 2B	0.518	0.962	0.382	0.962
	Task 2A	Task 2C	0.971	0.697	0.306	0.656
$7T_{f_0}$	Task 2B	Task 2C	0.541	0.662	0.878	0.691
	Task 2A	Task 2B	0.503	0.960	0.902	0.906
	Task 2A	Task 2C	0.986	0.721	0.117	0.539
$8T_{f_0}$	Task 2B	Task 2C	0.491	0.683	0.146	0.619
	Task 2A	Task 2B	0.547	0.951	0.932	0.825
	Task 2A	Task 2C	0.974	0.683	0.135	0.530
$9T_{f_0}$	Task 2B	Task 2C	0.525	0.639	0.115	0.683
	Task 2A	Task 2B	0.836	0.797	0.683	0.716
	Task 2A	Task 2C	0.967	0.707	0.405	0.538
$10T_{f_0}$	Task 2B	Task 2C	0.804	0.528	0.219	0.799

Group 36M			Tone 1	Tone 2	Tone 3	Tone 4
$1T_{f_0}$	Task 2A	Task 2B	0.075	0.436	0.077	0.141
	Task 2A	Task 2C	0.238	0.972	0.595	0.204
	Task 2B	Task 2C	0.527	0.416	0.057	0.831
$2T_{f_0}$	Task 2A	Task 2B	0.105	0.437	0.024	0.149
	Task 2A	Task 2C	0.320	0.998	0.545	0.191
	Task 2B	Task 2C	0.512	0.438	0.086	0.888
$3T_{f_0}$	Task 2A	Task 2B	0.119	0.431	0.083	0.188
	Task 2A	Task 2C	0.368	0.958	0.531	0.237
	Task 2B	Task 2C	0.493	0.462	0.118	0.888
$4T_{f_0}$	Task 2A	Task 2B	0.115	0.409	0.089	0.240
	Task 2A	Task 2C	0.366	0.902	0.739	0.238
	Task 2B	Task 2C	0.484	0.480	0.165	0.996
$5T_{f_0}$	Task 2A	Task 2B	0.099	0.402	0.348	0.238
	Task 2A	Task 2C	0.319	0.826	0.875	0.192
	Task 2B	Task 2C	0.495	0.535	0.275	0.897
$6T_{f_0}$	Task 2A	Task 2B	0.058	0.442	0.939	0.221
	Task 2A	Task 2C	0.231	0.740	0.520	0.133
	Task 2B	Task 2C	0.458	0.660	0.570	0.769
$7T_{f_0}$	Task 2A	Task 2B	0.232	0.548	0.176	0.196
	Task 2A	Task 2C	0.135	0.681	0.255	0.090
	Task 2B	Task 2C	0.393	0.848	0.822	0.669
$8T_{f_0}$	Task 2A	Task 2B	0.140	0.672	0.076	0.203
	Task 2A	Task 2C	0.096	0.700	0.137	0.084
	Task 2B	Task 2C	0.373	0.969	0.759	0.629
$9T_{f_0}$	Task 2A	Task 2B	0.139	0.676	0.204	0.248
	Task 2A	Task 2C	0.071	0.679	0.166	0.095
	Task 2B	Task 2C	0.459	0.997	0.904	0.586
$10T_{f_0}$	Task 2A	Task 2B	0.150	0.764	0.180	0.218
	Task 2A	Task 2C	0.053	0.705	0.641	0.064
	Task 2B	Task 2C	0.568	0.937	0.405	0.510

Group 60M			**Tone 1**	**Tone 2**	**Tone 3**	**Tone 4**
	Task 2A	Task 2B	0.176	0.459	0.882	0.574
	Task 2A	Task 2C	0.127	0.715	0.570	0.962
$1T_{f_0}$	Task 2B	Task 2C	0.855	0.706	0.674	0.607
	Task 2A	Task 2B	0.124	0.477	0.979	0.580
	Task 2A	Task 2C	0.097	0.876	0.828	0.723
$2T_{f_0}$	Task 2B	Task 2C	0.894	0.578	0.807	0.367
	Task 2A	Task 2B	0.101	0.504	0.849	0.618
	Task 2A	Task 2C	0.083	0.949	0.994	0.580
$3T_{f_0}$	Task 2B	Task 2C	0.919	0.545	0.844	0.297
	Task 2A	Task 2B	0.119	0.519	0.815	0.673
	Task 2A	Task 2C	0.088	0.996	0.999	0.609
$4T_{f_0}$	Task 2B	Task 2C	0.873	0.523	0.816	0.354
	Task 2A	Task 2B	0.129	0.525	0.835	0.720
	Task 2A	Task 2C	0.125	0.924	0.572	0.759
$5T_{f_0}$	Task 2B	Task 2C	0.987	0.589	0.721	0.507
	Task 2A	Task 2B	0.117	0.515	0.673	0.803
	Task 2A	Task 2C	0.153	0.964	0.260	0.972
$6T_{f_0}$	Task 2B	Task 2C	0.882	0.545	0.475	0.775
	Task 2A	Task 2B	0.096	0.520	0.644	0.945
	Task 2A	Task 2C	0.169	0.959	0.173	0.847
$7T_{f_0}$	Task 2B	Task 2C	0.761	0.488	0.359	0.901
	Task 2A	Task 2B	0.071	0.527	0.978	0.891
	Task 2A	Task 2C	0.178	0.919	0.296	0.726
$8T_{f_0}$	Task 2B	Task 2C	0.625	0.464	0.308	0.626
	Task 2A	Task 2B	0.070	0.550	0.889	0.904
	Task 2A	Task 2C	0.146	0.985	0.414	0.682
$9T_{f_0}$	Task 2B	Task 2C	0.697	0.537	0.341	0.596
	Task 2A	Task 2B	0.054	0.558	0.724	0.974
	Task 2A	Task 2C	0.122	0.924	0.436	0.697
$10T_{f_0}$	Task 2B	Task 2C	0.683	0.624	0.261	0.673

Tone 4 Variations			Control Group	Group 06M	Group 13M	Group 36M	Group 60M
	Task 2A	Task 2B	0.558	0.185	0.150	0.892	0.609
	Task 2A	Task 2C	0.750	0.369	0.700	0.714	0.646
$1T_{f_0}$	Task 2B	Task 2C	0.788	0.657	0.322	0.616	0.958
	Task 2A	Task 2B	0.612	0.123	0.092	0.853	0.568
	Task 2A	Task 2C	0.905	0.294	0.526	0.763	0.684
$2T_{f_0}$	Task 2B	Task 2C	0.698	0.605	0.323	0.626	0.869
	Task 2A	Task 2B	0.712	0.129	0.101	0.809	0.496
	Task 2A	Task 2C	0.986	0.306	0.412	0.890	0.824
$3T_{f_0}$	Task 2B	Task 2C	0.699	0.608	0.447	0.704	0.645
	Task 2A	Task 2B	0.851	0.243	0.217	0.721	0.433
	Task 2A	Task 2C	0.925	0.556	0.560	0.863	0.975
$4T_{f_0}$	Task 2B	Task 2C	0.778	0.555	0.552	0.853	0.415
	Task 2A	Task 2B	0.923	0.373	0.356	0.545	0.362
	Task 2A	Task 2C	0.748	0.957	0.887	0.623	0.884
$5T_{f_0}$	Task 2B	Task 2C	0.677	0.402	0.465	0.909	0.292
	Task 2A	Task 2B	0.963	0.534	0.526	0.364	0.319
	Task 2A	Task 2C	0.463	0.702	0.796	0.477	0.976
$6T_{f_0}$	Task 2B	Task 2C	0.492	0.318	0.395	0.840	0.305
	Task 2A	Task 2B	0.791	0.954	0.953	0.218	0.356
	Task 2A	Task 2C	0.214	0.477	0.579	0.386	0.834
$7T_{f_0}$	Task 2B	Task 2C	0.324	0.442	0.542	0.706	0.473
	Task 2A	Task 2B	0.571	0.542	0.543	0.124	0.450
	Task 2A	Task 2C	0.066	0.457	0.557	0.325	0.636
$8T_{f_0}$	Task 2B	Task 2C	0.190	0.891	0.989	0.564	0.775
	Task 2A	Task 2B	0.403	0.485	0.487	0.088	0.615
	Task 2A	Task 2C	0.020	0.557	0.664	0.335	0.537
$9T_{f_0}$	Task 2B	Task 2C	0.115	0.911	0.823	0.439	0.908
	Task 2A	Task 2B	0.355	0.536	0.535	0.076	0.802
	Task 2A	Task 2C	0.011	0.738	0.851	0.439	0.548
$10T_{f_0}$	Task 2B	Task 2C	0.084	0.774	0.691	0.300	0.725
	Task 2A	Task 2B	0.463	0.675	0.672	0.045	0.901
	Task 2A	Task 2C	0.014	0.964	0.923	0.527	0.626
$11T_{f_0}$	Task 2B	Task 2C	0.069	0.708	0.620	0.156	0.717
	Task 2A	Task 2B	0.753	0.950	0.949	0.017	0.876
	Task 2A	Task 2C	0.030	0.705	0.587	0.395	0.685
$12T_{f_0}$	Task 2B	Task 2C	0.059	0.660	0.546	0.105	0.803
	Task 2A	Task 2B	0.803	0.781	0.772	0.010	0.805
	Task 2A	Task 2C	0.105	0.477	0.365	0.186	0.689
$13T_{f_0}$	Task 2B	Task 2C	0.064	0.662	0.524	0.171	0.877
	Task 2A	Task 2B	0.494	0.726	0.713	0.014	0.785
	Task 2A	Task 2C	0.312	0.486	0.370	0.111	0.731
$14T_{f_0}$	Task 2B	Task 2C	0.096	0.727	0.579	0.329	0.943
	Task 2A	Task 2B	0.430	0.764	0.753	0.023	0.787

$15T_{f_0}$	Task 2A	Task 2C	0.518	0.633	0.494	0.099	0.837
	Task 2B	Task 2C	0.157	0.859	0.697	0.491	0.949
$16T_{f_0}$	Task 2A	Task 2B	0.551	0.904	0.900	0.032	0.880
	Task 2A	Task 2C	0.562	0.815	0.639	0.095	0.973
	Task 2B	Task 2C	0.244	0.910	0.725	0.596	0.906
$17T_{f_0}$	Task 2A	Task 2B	0.779	0.894	0.889	0.033	0.880
	Task 2A	Task 2C	0.563	0.947	0.850	0.085	0.907
	Task 2B	Task 2C	0.392	0.947	0.748	0.645	0.973
$18T_{f_0}$	Task 2A	Task 2B	0.986	0.738	0.725	0.032	0.743
	Task 2A	Task 2C	0.661	0.577	0.734	0.062	0.836
	Task 2B	Task 2C	0.674	0.823	0.993	0.757	0.904
$19T_{f_0}$	Task 2A	Task 2B	0.779	0.576	0.561	0.055	0.693
	Task 2A	Task 2C	0.757	0.304	0.392	0.049	0.777
	Task 2B	Task 2C	0.977	0.633	0.754	0.954	0.911
$20T_{f_0}$	Task 2A	Task 2B	0.690	0.519	0.506	0.077	0.611
	Task 2A	Task 2C	0.749	0.230	0.299	0.058	0.763
	Task 2B	Task 2C	0.936	0.570	0.675	0.889	0.835

Tone Sandhi			Control Group	Group 06M	Group 13M	Group 36M	Group 60M
$1T_{f_0}$	Task 2A	Task 2B	0.856	0.176	0.846	0.810	0.129
	Task 2A	Task 2C	0.030	0.671	0.042	0.077	0.041
	Task 2B	Task 2C	0.044	0.096	0.058	0.049	0.415
$2T_{f_0}$	Task 2A	Task 2B	0.893	0.202	0.831	0.828	0.169
	Task 2A	Task 2C	0.041	0.731	0.040	0.075	0.034
	Task 2B	Task 2C	0.053	0.129	0.057	0.050	0.304
$3T_{f_0}$	Task 2A	Task 2B	0.976	0.236	0.778	0.807	0.274
	Task 2A	Task 2C	0.077	0.860	0.038	0.058	0.037
	Task 2B	Task 2C	0.081	0.198	0.062	0.036	0.222
$4T_{f_0}$	Task 2A	Task 2B	0.959	0.260	0.775	0.800	0.384
	Task 2A	Task 2C	0.190	0.883	0.046	0.052	0.063
	Task 2B	Task 2C	0.175	0.229	0.074	0.032	0.246
$5T_{f_0}$	Task 2A	Task 2B	0.868	0.239	0.856	0.788	0.551
	Task 2A	Task 2C	0.365	0.876	0.075	0.078	0.117
	Task 2B	Task 2C	0.289	0.208	0.099	0.048	0.282
$6T_{f_0}$	Task 2A	Task 2B	0.766	0.238	0.807	0.742	0.839
	Task 2A	Task 2C	0.653	0.801	0.116	0.152	0.213
	Task 2B	Task 2C	0.466	0.177	0.166	0.087	0.287
$7T_{f_0}$	Task 2A	Task 2B	0.633	0.269	0.692	0.657	0.789
	Task 2A	Task 2C	0.847	0.623	0.214	0.307	0.405
	Task 2B	Task 2C	0.797	0.135	0.352	0.159	0.302
$8T_{f_0}$	Task 2A	Task 2B	0.450	0.262	0.597	0.577	0.536
	Task 2A	Task 2C	0.474	0.512	0.385	0.539	0.696
	Task 2B	Task 2C	0.997	0.098	0.658	0.267	0.374
$9T_{f_0}$	Task 2A	Task 2B	0.361	0.230	0.630	0.557	0.523
	Task 2A	Task 2C	0.258	0.489	0.585	0.709	0.767
	Task 2B	Task 2C	0.781	0.079	0.878	0.367	0.416
$10T_{f_0}$	Task 2A	Task 2B	0.428	0.150	0.608	0.523	0.578
	Task 2A	Task 2C	0.270	0.479	0.728	0.764	0.753
	Task 2B	Task 2C	0.715	0.047	0.943	0.381	0.444

yi tone variations *yi* T1→T4			Control Group	Group 06M	Group 13M	Group 36M	Group 60M
$1T_{f_0}$	Task 2A	Task 2B	0.471	0.879	0.223	0.670	0.327
	Task 2A	Task 2C	0.152	0.669	0.800	0.466	0.115
	Task 2B	Task 2C	0.363	0.608	0.280	0.692	0.023
$2T_{f_0}$	Task 2A	Task 2B	0.464	0.843	0.221	0.699	0.328
	Task 2A	Task 2C	0.139	0.669	0.799	0.490	0.114
	Task 2B	Task 2C	0.342	0.590	0.278	0.699	0.023
$3T_{f_0}$	Task 2A	Task 2B	0.466	0.825	0.217	0.667	0.311
	Task 2A	Task 2C	0.132	0.593	0.876	0.484	0.115
	Task 2B	Task 2C	0.326	0.511	0.318	0.717	0.022
$4T_{f_0}$	Task 2A	Task 2B	0.460	0.811	0.211	0.667	0.277
	Task 2A	Task 2C	0.127	0.431	0.955	0.494	0.119
	Task 2B	Task 2C	0.320	0.359	0.421	0.728	0.019
$5T_{f_0}$	Task 2A	Task 2B	0.428	0.913	0.202	0.607	0.247
	Task 2A	Task 2C	0.123	0.304	0.747	0.468	0.122
	Task 2B	Task 2C	0.331	0.280	0.577	0.746	0.018
$6T_{f_0}$	Task 2A	Task 2B	0.413	0.975	0.195	0.478	0.228
	Task 2A	Task 2C	0.130	0.301	0.565	0.440	0.129
	Task 2B	Task 2C	0.355	0.297	0.748	0.826	0.017
$7T_{f_0}$	Task 2A	Task 2B	0.421	0.879	0.193	0.406	0.207
	Task 2A	Task 2C	0.144	0.284	0.499	0.419	0.155
	Task 2B	Task 2C	0.379	0.251	0.823	0.872	0.019
$8T_{f_0}$	Task 2A	Task 2B	0.391	0.770	0.187	0.430	0.184
	Task 2A	Task 2C	0.135	0.232	0.482	0.448	0.182
	Task 2B	Task 2C	0.382	0.178	0.836	0.885	0.020
$9T_{f_0}$	Task 2A	Task 2B	0.365	0.666	0.189	0.416	0.158
	Task 2A	Task 2C	0.125	0.224	0.359	0.438	0.183
	Task 2B	Task 2C	0.379	0.150	0.987	0.887	0.017
$10T_{f_0}$	Task 2A	Task 2B	0.349	0.636	0.192	0.397	0.153
	Task 2A	Task 2C	0.126	0.235	0.278	0.441	0.208
	Task 2B	Task 2C	0.393	0.151	0.845	0.913	0.020

yi tone variations ***yi* T1→T2**			**Control Group**	**Group 06M**	**Group 13M**	**Group 36M**	**Group 60M**
$1T_{f_0}$	Task 2A	Task 2B	0.917	0.005	0.247	0.410	0.076
	Task 2A	Task 2C	0.016	0.036	0.085	0.546	0.055
	Task 2B	Task 2C	0.022	0.732	0.011	0.161	0.608
$2T_{f_0}$	Task 2A	Task 2B	0.925	0.006	0.272	0.437	0.080
	Task 2A	Task 2C	0.011	0.058	0.094	0.563	0.057
	Task 2B	Task 2C	0.016	0.620	0.014	0.182	0.610
$3T_{f_0}$	Task 2A	Task 2B	0.936	0.007	0.309	0.448	0.084
	Task 2A	Task 2C	0.008	0.084	0.100	0.606	0.059
	Task 2B	Task 2C	0.012	0.543	0.018	0.209	0.606
$4T_{f_0}$	Task 2A	Task 2B	0.995	0.007	0.355	0.486	0.087
	Task 2A	Task 2C	0.005	0.097	0.107	0.661	0.054
	Task 2B	Task 2C	0.010	0.485	0.024	0.261	0.568
$5T_{f_0}$	Task 2A	Task 2B	0.951	0.007	0.402	0.542	0.091
	Task 2A	Task 2C	0.004	0.118	0.115	0.713	0.049
	Task 2B	Task 2C	0.009	0.434	0.030	0.332	0.519
$6T_{f_0}$	Task 2A	Task 2B	0.926	0.009	0.433	0.580	0.095
	Task 2A	Task 2C	0.004	0.140	0.126	0.752	0.043
	Task 2B	Task 2C	0.009	0.428	0.037	0.388	0.469
$7T_{f_0}$	Task 2A	Task 2B	0.915	0.012	0.435	0.621	0.104
	Task 2A	Task 2C	0.004	0.153	0.136	0.784	0.053
	Task 2B	Task 2C	0.010	0.466	0.041	0.445	0.507
$8T_{f_0}$	Task 2A	Task 2B	0.918	0.017	0.441	0.651	0.114
	Task 2A	Task 2C	0.004	0.151	0.143	0.808	0.074
	Task 2B	Task 2C	0.010	0.551	0.044	0.489	0.594
$9T_{f_0}$	Task 2A	Task 2B	0.940	0.017	0.450	0.681	0.112
	Task 2A	Task 2C	0.004	0.132	0.143	0.793	0.089
	Task 2B	Task 2C	0.010	0.602	0.045	0.502	0.670
$10T_{f_0}$	Task 2A	Task 2B	0.988	0.017	0.459	0.672	0.118
	Task 2A	Task 2C	0.004	0.134	0.117	0.839	0.099
	Task 2B	Task 2C	0.008	0.590	0.037	0.532	0.691

One-way ANOVA with multiple comparison			
Dependent variables	**Independent variables**		**p-values**
Gender	Control Group	Group 06M	0.993
		Group 13M	0.993
		Group 36M	0.993
		Group 60M	0.993
	Group 06M	Group 13M	1.000
		Group 36M	1.000
		Group 60M	0.909
	Group 13M	Group 36M	1.000
		Group 60M	0.909
	Group 36M	Group 60M	0.909
Residential length	Control Group	Group 06M	0.047
		Group 13M	0.010
		Group 36M	0.000
		Group 60M	0.000
	Group 06M	Group 13M	0.022
		Group 36M	0.000
		Group 60M	0.000
	Group 13M	Group 36M	0.001
		Group 60M	0.000
	Group 36M	Group 60M	0.000
Actual age	Control Group	Group 06M	0.440
		Group 13M	0.041
		Group 36M	0.002
		Group 60M	0.000
	Group 06M	Group 13M	0.192
		Group 36M	0.014
		Group 60M	0.002
	Group 13M	Group 36M	0.219
		Group 60M	0.058
	Group 36M	Group 60M	0.487
AOA	Control Group	Group 06M	0.000
		Group 13M	0.000
		Group 36M	0.000
		Group 60M	0.000
	Group 06M	Group 13M	1.000
		Group 36M	1.000
		Group 60M	0.419

	Group 13M	Group 36M	1.000
		Group 60M	0.335
L2 exposure age at home	Control Group	Group 06M	0.997
		Group 13M	0.980
		Group 36M	0.998
		Group 60M	1.000
	Group 06M	Group 13M	0.743
		Group 36M	0.969
		Group 60M	0.992
	Group 13M	Group 36M	0.999
		Group 60M	0.950
	Group 36M	Group 60M	0.997
L2 exposure age at school	Control Group	Group 06M	0.999
		Group 13M	0.572
		Group 36M	0.851
		Group 60M	0.882
	Group 06M	Group 13M	0.691
		Group 36M	0.930
		Group 60M	0.948
	Group 13M	Group 36M	0.984
		Group 60M	0.980
	Group 36M	Group 60M	1.000
Daily usage of Mandarin	Control Group	Group 06M	0.032
		Group 13M	0.007
		Group 36M	0.009
		Group 60M	0.234
	Group 06M	Group 13M	0.980
		Group 36M	0.984
		Group 60M	0.797
	Group 13M	Group 36M	1.000
		Group 60M	0.461
	Group 36M	Group 60M	0.480
Daily usage of English	Control Group	Group 06M	0.002
		Group 13M	0.001
		Group 36M	0.000
		Group 60M	0.001
	Group 06M	Group 13M	0.710
		Group 36M	1.000
		Group 60M	0.999

	Group 13M	Group 36M	0.649
		Group 60M	0.808
	Group 36M	Group 60M	0.998
IELTS	Control Group	Group 06M	0.088
		Group 13M	0.602
		Group 36M	0.760
		Group 60M	0.228
	Group 06M	Group 13M	0.169
		Group 36M	0.839
		Group 60M	0.088
	Group 13M	Group 36M	0.602
		Group 60M	0.760
OQPT	Control Group	Group 06M	0.043
		Group 13M	0.013
		Group 36M	0.006
		Group 60M	0.013
	Group 06M	Group 13M	0.991
		Group 36M	0.945
		Group 60M	0.991
	Group 13M	Group 36M	0.998
		Group 60M	1.000

7.8. Common European Framework of Reference for Languages - Self-assessment grid

IELTS and OQPT in CEFR

Participants	Control Group		Group 06M		Group 13M		Group 36M		Group 60M	
	IELTS	OQPT	IELTS	OQPT	IELTS	OQPT	IELTS	OQPT	IELTS	OQPT
P1	N/A	A2	B2	C1	C1	C1	C1	C1	C1	B2
P2	N/A	A2	C1	C1	B2	B1	C1	B2	C1	C2
P3	N/A	B1	C1	B1	C1	B2	C1	B2	C1	C1
P4	N/A	B1	B2	B1	C1	C2	C1	B2	C1	B2
P5	N/A	B1	C1	C1	C1	B2	C1	C1	B2	B2
P6	N/A	B2	B2	B1	B2	B2	C1	C2	C1	B2
P7	N/A	B2	B2	B2	C1	B1	B2	C1	B2	C1
P8	N/A	A2	B2	B1	C1	C3	B2	B2	N/A	C2
P9	N/A	B1	C1	C1	C1	B2	C1	C1	B2	B1
P10	N/A	B2	B2	B2	C1	C1	B2	B1	B2	B2

Common European Framework of Reference for Languages - Self-assessment grid

		A1 Basic User	A2 Basic User	B1 Independent user	B2 Independent user	C1 Proficient user	C2 Proficient user
Understanding	Listening	I can understand familiar words and very basic phrases concerning myself, my family and immediate concrete surroundings when people speak slowly and clearly.	I can understand phrases and the highest frequency vocabulary related to areas of most immediate personal relevance (e.g. very basic personal and family information, shopping, local area, employment). I can catch the main point in short, clear, simple messages and announcements.	I can understand the main points of clear standard speech on familiar matters regularly encountered in work, school, leisure, etc. I can understand the main point of many radio or TV programmes on current affairs or topics of personal or professional interest when the delivery is relatively slow and clear.	I can understand extended speech and lectures and follow even complex lines of argument provided the topic is reasonably familiar. I can understand most TV news and current affairs programmes. I can understand the majority of films in standard dialect.	I can understand extended speech even when it is not clearly structured and when relationships are only implied and not signalled explicitly. I can understand television programmes and films without too much effort.	I have no difficulty in understanding any kind of spoken language, whether live or broadcast, even when delivered at fast native speed, provided I have some time to get familiar with the accent.
	Reading	I can understand familiar names, words and very simple sentences, for example on notices and posters or in catalogues.	I can read very short, simple texts. I can find specific, predictable information in simple everyday material such as advertisements, prospectuses, menus and timetables and I can understand short simple personal letters.	I can understand texts that consist mainly of high frequency everyday or job-related language. I can understand the description of events, feelings and wishes in personal letters.	I can read articles and reports concerned with contemporary problems in which the writers adopt particular attitudes or viewpoints. I can understand contemporary literary prose.	I can understand long and complex factual and literary texts, appreciating distinctions of style. I can understand specialised articles and longer technical instructions, even when they do not relate to my field.	I can read with ease virtually all forms of the written language, including abstract, structurally or linguistically complex texts such as manuals, specialised articles and literary works.
Speaking	Spoken interaction	I can interact in a simple way provided the other person is prepared to repeat or rephrase things at a slower rate of speech and help me formulate what I'm trying to say. I can ask and answer simple questions in areas of immediate need or on very familiar topics.	I can communicate in simple and routine tasks requiring a simple and direct exchange of information on familiar topics and activities. I can handle very short social exchanges, even though I can't usually understand enough to keep the conversation going myself.	I can deal with most situations likely to arise whilst travelling in an area where the language is spoken. I can enter unprepared into conversation on topics that are familiar, of personal interest or pertinent to everyday life (e.g. family, hobbies, work, travel and current events).	I can interact with a degree of fluency and spontaneity that makes regular interaction with native speakers quite possible. I can take an active part in discussion in familiar contexts, accounting for and sustaining my views.	I can express myself fluently and spontaneously without much obvious searching for expressions. I can use language flexibly and effectively for social and professional purposes. I can formulate ideas and opinions with precision and relate my contribution skilfully to those of other speakers.	I can take part effortlessly in any conversation or discussion and have a good familiarity with idiomatic expressions and colloquialisms. I can express myself fluently and convey finer shades of meaning precisely. If I do have a problem I can backtrack and restructure around the difficulty so smoothly that other people are hardly aware of it.
	Spoken production	I can use simple phrases and sentences to describe where I live and people I know.	I can use a series of phrases and sentences to describe in simple terms my family and other people, living conditions, my educational background and my present or most recent job.	I can connect phrases in a simple way in order to describe experiences and events, my dreams, hopes and ambitions. I can briefly give reasons and explanations for opinions and plans. I can narrate a story or relate the plot of a book or film and describe my reactions.	I can present clear, detailed descriptions on a wide range of subjects related to my field of interest. I can explain a viewpoint on a topical issue giving the advantages and disadvantages of various options.	I can present clear, detailed descriptions of complex subjects integrating sub-themes, developing particular points and rounding off with an appropriate conclusion.	I can present a clear, smoothly-flowing description or argument in a style appropriate to the context and with an effective logical structure which helps the recipient to notice and remember significant points.
Writing	Writing	I can write a short, simple postcard, for example sending holiday greetings. I can fill in forms with personal details, for example entering my name, nationality and address on a hotel registration form.	I can write short, simple notes and messages. I can write a very simple personal letter, for example thanking someone for something.	I can write simple connected text on topics which are familiar or of personal interest. I can write personal letters describing experiences and impressions.	I can write clear, detailed text on a wide range of subjects related to my interests. I can write an essay or report, passing on information or giving reasons in support of or against a particular point of view. I can write letters highlighting the personal significance of events and experiences.	I can express myself in clear, well-structured text, expressing points of view at some length. I can write about complex subjects in a letter, an essay or a report, underlining what I consider to be the salient issues. I can select a style appropriate to the reader in mind.	I can write clear, smoothly-flowing text in an appropriate style. I can write complex letters, reports or articles which present a case with an effective logical structure which helps the recipient to notice and remember significant points. I can write summaries and reviews of professional or literary works.

Reference

Baken, R. (1987) *Clinical measurement of speech and voice*. Boston: College-Hill Press.
Baker, C. (2001) *Foundations of bilingual education and bilingualism*. Clevedon: Multilingual Matters.
Bao, Z. (1990) *On the Nature of Tone*. MIT.
Bialystok, E. (2001) *Bilingualism in development*. Cambridge: Cambridge University Press.
Bloomfield, L. (1933) *Language*. New York: The University of Chicago Press.
Boersma, P. and Weenink, D. (2016) *Praat: Doing Phonetics by Computers* (Version 6.0.17) [Computer program]. Available at: http://www.praat.org/.
Briggs, J. and Peat, F.D. (1989) *Turbulent mirror: an illustrated guide to chaos theory and the science of wholeness*. New York: Harper and Row.
Bullock, B. and Gerfen, C. (2004a) 'Frenchville French: a case study in phonological attrition', *International Journal of Bilingualism*, 8(3), pp. 303-320.
Chang, C.B., Yao, Y., Hyaynes, E.F. and Rhodes, R. (2011) 'Production of phonetic and phonological contrast by heritage speakers of Mandarin', *The Journal of the Acoustical Society of America*, 129(6), pp. 3964-3980.
Chang, Y. (2014a) 'First language Taiwanese tonal attrition: revisiting first language attrition hypotheses and their relevance', *University of Pennsylvania Working Papers in Linguistics*, 20(1), pp. 42-50.
Chang, Y. (2014b) 'First language Taiwanese tonal attrition: revisiting first language attrition hypotheses and their relevance.', *37th Annual Penn Linguistics Conference*. Philadelphia, PA.
Chao, Y.-R. (1930) 'A system of tone letters', *Le Maître phonétique*, 45, pp. 24-27.
Chao, Y.-R. (1968) *A grammar of spoken chinese*. Berkeley and Los Angeles: University of California Press.
Chen, M.Y. (2000) *Tone sandhi: patterns across chinese dialects*. Cambridge: Cambridge University Press.
Cheng, C.-c. (1973) *A synchronic phonology of Mandarin Chinese*. The Hague: Mouton & Co. N. V.
Clyne, M. (1981) *Deutsch als Muttersprache in Australien*. Wiesbaden: Steiner.
Cook, V. (1992) 'Evidence for Multi-Competence', *Language Learning*, 42(4), pp. 557-591.
Cook, V. (1995) 'Multi-Competence and Effects of Age', in Singleton, D. and Lengyel, Z. (eds.) *The Age Factor in Second Language Acquisition: A Critical Look at the Critical Period Hypothesis*. Clevedon: Multilingual Matters Ltd.
Cook, V. (2003) 'Introduction: the changing L1 in the L2 user's mind', in Cook, V. (ed.) *Effects of the Second Language on the First*. Sydney: Multilingual Matters.
Cook, V.J. (1991) 'The Poverty of the Stimulus Argument and Multi-Competence', *Second Language Research*, 7(2), pp. 103-117.
Costa, A., Caramazza, A. and Sebastian-Gallés, N. (2000) ' The cognate facilitation effect: implications for models of lexical access. ', *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 26, pp. 1283–1296.
de Bot, K. (1999) 'Introduction', in Hansen, L. (ed.) *Second language attrition in Japanese contexts*. Oxford: Oxford University Press, pp. 1-7.
de Bot, K. (2004) 'Special issue on language attrition', *International Journal of Bilingualism*, 8(3), pp. 233-237.
de Bot, K. and Clyne, M. (1989) 'Language reversion revisited', *Studies in Second Language Acquisition*, 11, pp. 167-177.
de Bot, K., Gommans, P. and Rossing, C. (1991) 'L1 Loss in an L2 environment: Dutch immigrants in France', in Seliger, H.W. and Vago, R.M. (eds.) *First Language Attrition*. Cambridge: Cambridge University Press, p. 87.
de Bot, K. and Hulsen, M. (2002) 'Language attrition: Tests, self-assessments and perceptions.', in Cook, V. (ed.) *Portraits of the L2 User*. Clevedon: Multilingual Matters Ltd, pp. 253-274.

de Bot, K., Lowie, W. and Verspoor, M. (2007) 'A Dynamic Systems Theory approach to second language acquisition', *Bilingualism: Language and Cognition*, 10(1), pp. 7-21.
de Bot, K. and Makoni, S. (2005) *Language and aging in multilingual contexts*. Clevedon: Multilingual Matters.
de Bot, K. and Weltens, B. (1991) 'Racapitulation, regression, and language loss', in Seliger, H.W. and Vago, R.M. (eds.) *First Language Attrition* Avon: Cambridge University Press.
de Bot, K. and Weltens, B. (1995) 'Foreign language attrition', *Annual Review of Applied Linguistics*, 15, pp. 151-164.
de Leeuw, E., Mennen, I. and Scobbie, J. (2011) 'Singing a different tune in your native language: first language attrition of prosody', *International Journal of Bilingualism*, 16(1), pp. 101-116.
Duanmu, S. (1990) *A formal study of syllable, tone, stress and domain in Chinese languages*.
Duanmu, S. (2002) *The phonology of standard Chinese*. Oxford: Oxford University Press.
Ecke, P. (2004) 'Language attrition and theories of forgetting: A cross-disciplinary review', *International Journal of Bilingualism*, 8(3), pp. 321-354.
Fishman, J. (1972) *Language in sociocultural change*. Stanford: Stanford University Press.
Flege, J.E. (1987) 'A critical period for learning to pronounce foreign languages', *Applied Linguistics*, 8, pp. 162-177.
Goral, M. (2004) 'First-Language decline in healthy aging: Implications for attrition in bilingualism', *Journal of Neurolinguistics*, 17(1), pp. 31-52.
Gottfried, T.L. and Suiter, T.L. (1997) 'Effect of linguistic experience on the identification of Mandarin Chinese vowels and tones', *Journal of Phonetics*, 25, pp. 207-231.
Goullier, F. (2007) *The Common European Framework of Reference for Languages (CEFR) and the development of language policies: challenges and responsibilities*. www.coe.int/lang.
Green, D.W. (1986) 'Control, activation, and resource: a framework and a model for the control of speech in bilinguals', *Brain and Language*, 27, pp. 210-223.
Gürel, A. (2004) 'Selectivity in L2-induced L1 attrition: a psycholinguistic account', *Journal of Neurolinguistics*, 17, pp. 53-78.
Hansen, L. (2001) 'Language attrition: The fate of the start', *Annual Review of Applied Linguistics*, 21, pp. 60-73.
Hansen, L. and Chen, Y.L. (2001) 'What counts in the acquisition and attrition of numeral classifiers?', *JALT Journal*, 23(1), pp. 83-100.
Hart, J., Collier, R. and Cohen, A. (1990) *A perceptual study of intonation: an experimental phonetic approach to speech melody*. Cambridge: Cambridge University Press.
Hayes, B. (1989) 'Compensatory lengthening in moraic phonology', *Linguistic Inquiry*, 20(2), pp. 253-306.
Heridina, P. and Jessner, U. (2002) *A Dynamic Model of Multilingualism: perspectives of change in psycholinguistics*. UK: Cromwell Press Ltd.
Hirose, K., Hu, H., Wang, X. and Minematsu, N. (2006) 'Tone recognition of continuous speech of standard Chinese using neural network and Tone Nucleus Model ', *IEICE Transactions on Information and Systems*, 91(6), pp. 1748-1755.
Howie, J.M. (1976) *Acoustical studies of Mandarin vowels and tones.* Cambridge: Cambridge University Press.
Hu, G. (2002) 'English language teaching in the People's Republic of China', in Silver, R.E., Hu, G. and Iino, M. (eds.) *English Language Education in China, Japan, And Singapore*. Singapore: National Institute of Education.
Hu, G. (2005) 'English language education in China: policies, progress, and problems', *Language Policy*, 4(1), pp. 5-24.
Hulsen, M. (2000) *Language loss and language processing: three generations of Dutch Migrants in New Zealand*. Nijmegen: Katholieke Universiteit Nijmegen: 261.
Hyltenstam, K. and Obler, L.K. (1989) 'Bilingualism across the lifespan: an introduction', in *Bilingualism Across the Lifespan*. Cambridge: Cambridge University Press.
Hyman, L. (1985) *A theory of phonological weight*. Dordrecht: Foris.
IELTS (2019) *Understand the IELTS Test Format*. Available at: https://takeielts.britishcouncil.org/prepare-test/understand-test-format/speaking-test.

Jaspaert, K. and Kroon, S. (1992) 'From the typewriter of A.L.: a case study in language loss', in Fase, W., Jaspaert, K. and Kroon, S. (eds.) *Maintenance and Loss of Minority Languages*. Amsterdam: John Benjamins Publishing, pp. 138-147.
Jessner, U. (2003) 'A dynamic approach to language attrition in multilingual systems', in Cook, V. (ed.) *The Effect of the Second Language on the First*. Clevedon: Multilingual Matters, pp. 234-246.
Jia, G. and Aaronson, D. (1999) 'Age differences in second language acquisition: the dominant language switch and maintenance hypothesis', *Proceeding of the 23rd Boston University Conference on Language Development*. Somerville, MA. Cascadilla Press, pp. 301-312.
Jongman, A., Wayland, R. and Wong, S. (2000) 'Acoustic characteristics of English fricatives', *Journal of the Acoustical Society of America*, 108, pp. 1252–1263.
Kaufman, D.H. (1991) *First language attrition as a creative interplay between two languages*. New York: State of University of New York.
Keijzer, M. (2010) 'The regression hypothesis as a framework for first language attrition', *Bilingualism: Language and Cognition*, 13(01), pp. 9-18.
Köpke, B. (2007a) 'Language Attrition at the Crossroads of Brain, Mind, and Society', in Köpke, B., Schmid, M.S., Keijzer, M. and Dostert, S. (eds.) *Language Attrition Theoretical Perspectives*. John Benjamins, pp. 9-37.
Köpke, B. (2007b) *Language attrition: theoretical perspectives*. Amsterdam: John Benjamins Publishing Company.
Köpke, B. and Nespoulous, J.-L. (2001) 'First language attrition in production skills and metalinguistic abilities in German-English and German-French bilinguals', in Ammerlaan, T., Hulsen, M., Strating, H. and Yagmur, K. (eds.) *Sociolinguistic and Psycholinguistic Perspectives on Maintenance and Loss in Minority Languages*. Münster: Waxmann, pp. 221–234.
Köpke, B. and Schimid, M.S. (2004) 'Language attrition: the next phase', in Schimid, M.S., Köpke, B., Keijzer, M. and Weilemar, L. (eds.) *Language Attrition: Interdisciplinary Perspectives on Methodological Issues*. Amsterdam: John Benjamins, pp. 1-43.
Köpke, B., Schmid, M., Keijzer, M. and Dostert, S. (2007) *Language attrition: theoretical perspectives*. Amsterdam: John Benjamins Publishing Company.
Labov, W. and Waletzky, J. (1967) 'Narrative analysis: oral versions of personal experience', *Journal of Narrative and Life History*, 7(1-4), pp. 3-38.
Lambert, R.D. and Freed, B.F. (1982) *The loss of language skills*. Rowley, Massachusetts: Newbury House.
Larsen-Freeman, D. and Cameron, L. (2008) *Complex systems and applied linguistics*. Oxford: Oxford University Press.
Lee, C.-Y., Tao, L. and Bong, Z.S. (2008) 'Identification of acoustically modified Mandarin tones by native listeners', *Journal of Phonetics*, 36, pp. 537-563.
Liang, L. and Meng, X. (2013) 'The Tone Variation of Chongqing Dialect', *Language and Linguistics*, 14(5), pp. 929-959.
Lin, W.C.J. (1985) 'Teaching Mandarin tones to adult English speakers: analysis of difficulties with suggested remedies', *RELC Journal*, 16(2).
Lin, Y.-H. (1989) *Autosegmental treatment of segmental process in Chinese phonology*. University of Texas
Lin, Y.-H. (2007) *The sounds of Chinese*. Cambridge: Cambridge University Press.
Linville, S.E. and Rens, J. (2001) 'Vocal tract resonance analysis of aging voice using long-term average spectra', *Journal of Voice*, 15(3), pp. 323-330.
Liu, F. (1924) *Szu Sheng Shih Yen Lu* Shanghai: Ch'un Yi.
Mackey, W.F. (1962) 'The description of bilingualism', *Canadian Journal of Linguistics* 7, pp. 51-85.
MacWhinney, B. and Pléh, C. (1997) 'Double agreement: role identification in Hungarian', *Language and Cognitive Processes*, 12, pp. 67-102.
Mägiste, E. (1979) 'The Competing Language Systems of the Multilingual: A Developmental Study of Decoding and Encoding Processes.', *Journal of Verbal Learning and Verbal Behavior*, 18, pp. 79-89.
Major, R.C. (1992) 'Losing English as a first language', *The Modern Language Journal*, 76(2), pp. 190-208.
Major, R.C. (2002) 'The phonology of the L2 user', in Cook, V. (ed.) *Portraits of the L2 User*. Clevedon: Multilingual Matters, pp. 67-92.

Marian, V. and Spivey, M. (2003) 'Competing activation in bilingual language processing: within- and between-language competition.', *Biling. Lang. Cogn.*, 6, pp. 97-115.
Marino, B.J. (1983) 'Language loss in bilingual Chicano children', *Journal of Applied Developmental Psychology*, 4(3), pp. 277-294.
Mayr, R., Price, S. and Mennen, I. (2012) 'First language attrition in the speech of Dutch-English bilinguals: The case of monozygotic twin sisters', *Bilingualism: Language and Cognition*, 15(4), pp. 687-700.
Menn, L. and Boyce, S. (1982) 'Fundamental frequency and discourse structure', *Language and Speech*, 25, pp. 341-383.
Mennen, I. (2004) 'Bi-directional interference in the intonation of Dutch speakers of Greek', *Journal of Phonetics*, 32, pp. 543-563.
Neisser, U. (1984) 'Interpreting Harry Bahrick's discovery: what confers immunity against forgetting?', *Journal of Experimental Psychology: General*, 113, pp. 32-35.
Ng, B.C. and Wigglesworh, G. (2007) *Bilingualism: an advanced resource book*. London: Routledge.
Opitz, C. (2011) *First Language Attrition and Second Language Acquisition in a Second Language Environment*. University of Dublin.
Oxford Dictionary of English (2010) Oxford: Oxford University Press.
Paradis, M. (1993) 'Linguistic, psycholinguistic, and neurolinguistic aspects of interference in bilinguals speakers: the activation threshold hypothesis', *International Journal of Psycholinguistics*, 9(2), pp. 133-145.
Paradis, M. (2004) *A neuralinguistic theory of bilingualism*. Amsterdam: John Benjamins Publishing Company.
Paradis, M. (2007) 'L1 attrition features by a neurolinguistic theory of bilingualism', in Köpke, B., Schimid, M.S., Keijzer, M. and Dostert, S. (eds.) *Language Attrition: Theoretical Perspectives*. Amsterdam: John Benjamins Publishing Company, pp. 121-133.
Piercea, L.J., Klein, D., Chen, J.-K., Delcenserie, A. and Genesee, F. (2014a) 'Mapping the unconscious maintenance of a lost first language', *Psychological and Cognitive Sciences*, 8(112), pp. 17314–17319.
Piercea, L.J., Klein, D., Chen, J.-K., Delcenserie, A. and Genesee, F. (2014b) 'Mapping the unconscious maintenance of a lost first language', *National Academy of Sciences of the United States of America*.
Qin, Z. and Mok, P. (2014) 'Discrimination of Cantonese tones by speakers of tone and non-tone languages', *Kansas Working Papers in Linguistics* 34.
Quam, C. and Creel, S.C. (2017) 'Tone attrition in Mandarin speakers of varying English proficiency', *Journal of Speech, Language, and Hearing Research*, 60, pp. 293-305.
Rose, P. (1989) 'Phonetics and phonology of Yang tone phonation types in Zhen-hai', *CLAO* pp. 229-245.
Rose, P.J. (1988) 'On the non-equivalence of fundamental frequency and pitch in tonal description', in Bradley, D., Henderson, E.J.A. and Mazaudon, M. (eds.) *Prosodic Analysis and Asian Linguistics: To Honour R. K. Sprigg*. Canberra: Pacific Linguistics.
Samata, S. (2014) *Cultural Memory of Language: Contemporary Applied Linguistics*. Bloomsbury Publishing.
Schmid, M.S. (2002) *First language attrition, use and maintenance: the case of German Jews in Anglophone countries.* . Amsterdam: John Benjamin.
Schmid, M.S. (2013) 'First language attrition', *Wiley Interdisciplinary Reviews: Cognitive Science*, 4.2, pp. 117-123.
Schmid, M.S. and Köpke, B. (2013) *First language attrition*. Amsterdam: John Benhamins Publishing Company.
Schmid, M.S., Köpke, B., Keijzer, M. and Weilemar, L. (2004) *First language attrition: interdisciplinary perspectives on methodological issues*. Amsterdam: John Benjamins Publishing.
Schumann, J. (1976) 'Second language acquisition: the pidginization hypothesis.', *Language Learning*, 26(391-408).
Sebastián-Gallé , N. and Soto-Faraco, S. (1999) 'Online processing of native and non-native phonemic contrasts in early bilinguals', *Cognition*, 72, pp. 111-123.

Seliger, H.W. and Vago, R.M. (1991) *First language attrition*. Cambridge: Cambridge University Press.
Shi, F. (1986) 'Tianjin Fangyan Shuangzizu Shengdiao Fenxi', *Yuyan Yanjiu*, 1, pp. 67-83.
Shi, F. and Wang, P. (2006a) 'Beijinghua Danzi Shengdiao de Fenzu Tongji Fenxi', *Comtemporary Linguistics*, 8(4), pp. 324-333.
Shi, F. and Wang, P. (2006b) 'Beijinghua Danziyin Shengdiaode Fenzu Tongji Fenxi (Statistical Analysis of Grouping of Monosyllable Tones in Beijing Dialect)', *Dangdai Yuyanxue (Contemporary Linguistics)*, 8(4), pp. 324-333.
Shibles, W.A. (1994) 'Chinese romanization systems: IPA transliteration', *Sino-Platonic Papers*, (52).
Shih, C.-L. (2000) 'A Declination Model of Mandarin Chinese', in Botinis, A. (ed.) *Intonation: Analysis, Modelling and Technology*. Dordrecht: Kluwer Academic Publishers, pp. 234-268.
Shittu , S. and Tessier, A.-M. (2015) *Boston University Conference on Language Developmentn 39*. Boston. Boston University.
Shittu, S. and Tessier, A.-M. (2015) 'Perceptual attrition of lexical tone among L1 Yoruba-speaking children in Canada', *Boston University Conference on Language Development*.
Slobin, D.I., Dasinger, L., Küntay, A. and Toupin, C. (1993) 'Native language reacquisition in early childhood', *Twenty-fourth Annual Child Language Research Forum*. Stanford, CA: Center for the Study of Language and Information. pp. 176-196.
Smith, M.S. (1983) 'On first language loss in the second language acquirer: Problems of transfer', *Language Transfer in Language Learning*, pp. 222-231.
Smith, M.S. and van Buren, P. (1991) 'First language attrition and the Parameter setting model', in Seliger, H.W. and Vago, R.M. (eds.) *First Language Attrition*. Cambridge: Cambridge University Press, pp. 17-30.
Sorace, A. (2000) 'Differential effects of attrition in the L1 syntax of near-native L2 speakers', in Howell, C.S., Fish, S.A. and Keit-Lucas, T. (eds.) *Proceedings of the 24th Annual Boston University Conference on Language Development*. Somerville, MA: Cascadilla Press, pp. 719-725.
Spolsky, B. and Sigurd, B. (1968) 'Preliminary studies for the development of techniques for testing overall second language proficiency', *Language Learning*, 18(3), pp. 79-101.
UCLES (2001) 'Oxford Quick Placement Test'. University of Cambridge Local Examination Syndicate. Available at: file:///H:/Downloads/oxford-test%20(1).pdf.
Valdés, G. and Figueroa, R.A. (1994) *Bilingualism and testing: a special case of bias*. Norwood: NJ, Ablex.
Valdman, A. (1982) 'Language attrition and te administration of secondary school and college foreign languae instruction', in Lambert, R. and Freed, B. (eds.) *The loss of language skills*. Rowley, MA: Newbury House, pp. 155-175.
van Els, T. (1986) 'An overview of european research on language attrition', in Weltens, B., de Bot, K. and van Els, T. (eds.) *Language Attrition in Process*. Dordrecht: Foris Publications, pp. 3-18.
van Els, T. (1989) 'Errors and foreign language loss', in Freudenstein, R. (ed.) *Erros in foreign languages: Analysis and treatment*. Oxford: Pergamon, pp. 104-112.
Waas, M. (1996) *Language attrition downunder*. Frankfurt: Peter Lang.
Wang, H. and Miao, L. (2016) 'Annual Report on the Development of Chinese Students Studying Abroad 2016', *Center for China & Globalization*, [Online]. Available at: http://www.ccg.org.cn/Research/Book.aspx?ClassId=27 (Accessed: 12 14).
Wang, Q. (2007) 'The national curriculum changes and their effects on English language teaching in the People's Republic of China', in Cummins, J. and Davison, C. (eds.) *International Handbook of English Language Teaching*. Dordrecht: Springer, pp. 87-105.
Wang, W.S.-Y. (1967) 'Phonological features of tone', *International Journal of American Linguistics*, 33(2), pp. 93-105.
Wang, Y., Jongman, A. and Sereno, J.A. (2003) 'Acoustic and perceptual evaluation of Mandarin tone productions before and after perceptual training.', *Acoustical Society of America*, (113), pp. 1033-1043.
Weinreich, U. (1953) *Language in contact: findings and problems*. The Hague, The Netherlands: Mouton de Gruyter.
Weltens, B., de Bot, K. and van Els, T. (1986) *Language attrition in progress*. Dordrecht: Foris Publications.

Wen, R. (ed.) (2015) *Liunianji Yuwen* 12 edn. Beijing: People's Education Press.
White, N. (2013) *Migration Statistics Quarterly Report* Office for National Statistics. [Online]. Available at: http://webarchive.nationalarchives.gov.uk/20160129120704/http://www.ons.gov.uk/ons/rel/migration1/migration-statistics-quarterly-report/august-2013/index.html.
Woo, N.H. (1969) *Prosody and phonology*. MIT.
Wray, A. and Trott, K. (1998) *Projects in Linguistics: A Practical Guide to Researching Language*. London: Arnold.
Wu, Z. (1997) *Cong Shengdiao yu Yueli de Guanxi Tichu Putonghua Yudiao Chuli de Xinfangfa*. Shangwu Yinshuguan.
Xiao, H. (2012) 'Xiandai Hanyu Changyong Zibiao' 1988. Beijing: Yuwen Press. Available at: http://corpus.zhonghuayuwen.org/resources.aspx.
Xu, H. (2006) 'Zailun Hanyu de Shengdiao yu Zhongyin', *language and Linguistics*, 7(1), pp. 109-137.
Xu, Y. (1997) 'Contextual tonal variations in Mandarin', *Journal of Phonetics*, 25, pp. 61-83.
Xu, Y. (1999) *F0 peak delay: when, where and why it occurs. In: Proceedings of the 14th International Congress - Phonetic Science*. San Francisco.
Xu, Y. and Xu, C.X. (2005) 'Phonetic Realization of Focus in English Declarative Intonation', *journal of Phonetics*, 33, pp. 159-197.
Yang, B. (2015) *Perception and production of Mandarin tones by native speakers and L2 learners*. New York: Springer.
Yeh, C. (2011) 'Language attrition and tonal change in Hakka', *Psycholinguistic Representation of Tone Conference*. pp. 111-114.
Yeni-Komshian, G.H., Flege, J.E. and Liu, S. (2000) 'Pronunciation proficiency in the first and second languages of Korean-English bilinguals', *Bilingualism: Language and Cognition*, 3(2), pp. 131-149.
Yi, M. (2016) 'Mo Gao Ku', in Ma, L. (ed.) *Youer Jiaoshi Yuyan Xunlianyuceshi Zhidao*. Tianjing: Nankai University Press.
Yilmaz, G. and Schmid, M.S. (2018) 'First language attrition and bilingualism ', in Miller, D., Bayram, F., Rothman, J. and Serratrice, L. (eds.) *BIlingual cognition and language: the state of science across its subfields*. Amsterdam: John Benjamins.
Yip, M. (1980) *Tonal phonology of Chinese* MIT.
Yip, M. (2002) *Tone*. Cambridge: Cambridge University Press.
Young, N., Johnson, K. and Hinton, L. (2007) 'A case study of phonological attrition of Taiwanese Mandarin in California', *Linguistics*.
Yukawa, E. (1997) *Language attrition from the psycholinguistic perspective: a literature review*. Stockholm University.
Zhang, J. (2018) *Hanyu Pinyin for Mandarin speakers*. Available at: http://web.mit.edu/jinzhang/www/pinyin/.
Zhang, J. and Hirose, K. (2004) 'Tone Nucleus Modeling for Chinese lexical tone recognition', *Speech Communication*, 42, pp. 447-466.
Zhou, W. and Broersma, M. (2014a) 'Perception of birth language tone contrasts by adopted Chinese children', *4th International Symposium on Tonal Aspects of Language*. pp. 63-66.
Zhou, W. and Broersma, M. (2014b) *4th International Symposium on Tonal Aspects of Languages (TAL-2014) Nijmegen, The Netherlands May 13-16 2014*.
Zhu, X. (2008) *Yuyinxue [Phonetics]*. Beijing: Commerical Press.