NANYANG TECHNOLOGICAL UNIVERSITY

SCHOOL OF HUMANITIES AND SOCIAL SCIENCES

Effects of L1 Lexical Tone Awareness on Linguistic and Musical Pitch Processing

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Declaration of Authorship

I declare that this assignment is my own original work, unless otherwise referenced, as defined by the NTU policy on plagiarism. I have read the NTU Honour Code and Pledge.

No part of this Final Year Project has been or is being concurrently submitted for any other qualification at any other university.

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   Even though my FYP is not an extension of my supervisor's project, some materials have been borrowed for use from the lab.

   i) Most aspects of the study from the conceptualization of the research questions and hypotheses to the methodology to the analysis and discussion was from my own intellectual contributions.

   ii) Faced with a methodology that involves several different tasks and a tight schedule to work with, it was a huge challenge to construct all the tasks required from scratch. To ease my burden, I have used Thai sound files created by another FYP student who was previously under my supervisor. However, I have made extensive changes to the stimuli such as determining how the pairs of Thai words were to be matched, the number of trials to use and further normalizing the sound files to better control for extraneous variables and to meet the needs of my study. The NTU music test (hosted on http://ntumusictest.com/) also served as one of the task required for my FYP. After reading studies that used the music test and even trying it out myself, this music task was specifically chosen because it matched exactly what I was looking for: to determine individuals' performance to discriminate musical pitch.

ACKNOWLEDGEMENTS

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Most importantly, I would like to thank my loved ones for the support they have showed me through this FYP journey. To my friends, thank you for taking your time and effort to travel all the way down to NTU to participate in my study and for actively helping me out with the recruitment of participants within such a short frame of time. Special mention goes to Iris Lee for readily helping me out with the recording of my Mandarin stimuli, even after a second request to have them re-done when the first recording did not turn out satisfactorily. Last but not least, to my family, thank you for being my pillar of support; cheering me on whenever I was troubled over FYP and struggling to meet deadlines.

This seemingly endless FYP journey has now finally reached its destination.

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Abstract

To resolve the long-standing debate of the extent of the perceptual processes that is shared between music and language, one highly studied aspect is pitch processing within the linguistic and across the non-linguistic domains. However, past studies mainly compared pitch processing performance of individuals from different linguistic or musical background. This study thus sought to understand pitch processing of individuals with similar linguistic and musical background. The main identified factor of interest is the differing ability in their first language (L1) lexical tone awareness as a predictor of pitch processing within and across domains. 43 English-Mandarin bilinguals and non-musicians underwent a series of tasks. There is a language perception task where participants had to identify the lexical tones of auditorily-presented words from their L1 Mandarin and to discriminate the lexical tones of auditorily-presented pairs of Thai words, a language foreign to them. To capture how participants produced the tones of their L1 Mandarin and the non-native Thai, recordings were made of them reading Mandarin sentences and mimicking Thai words heard through the headphones. Furthermore, they listened and discriminated pairs of melodies that differ either in pitch or rhythm. Results showed that L1 lexical tone awareness served as a predictor of pitch processing within but not across domains. Individuals with high L1 Mandarin tone awareness were better at perceiving and producing the non-native Thai tones than individuals with low L1 Mandarin tone awareness. Overall, the findings reflect the importance of phonetic continuity for enduring transfer benefits within the linguistic domain.

1. Introduction

Language and music are domains unique and specific to human. Both share many similar properties such as the prominent role of pitch. As evident from Krumhansl (2004) and London (2012), pitch can convey information about music such as tonality and rhythm respectively. Correspondingly for speech, pitch expresses information about word stress and serves as pragmatic cues (Vaissiere, 2008). Within the large class of tone languages, pitch changes, otherwise known as F0 variations, can even serve to distinguish lexical meaning (Yip, 2002). One highly cited example comes from the Mandarin /ma/ syllable, where different meanings can arise depending on which tone was being used (Yip, 2002):

Table 1.

Example of different meanings arising from tonal contrasts in Mandarin.

Mandarin Chinese Character	Pinyin	Pitch Pattern	Meaning
妈	*Ma*^{1}	Level	"Mother"
麻	*Ma*^{2}	Rising	"Hemp"
马	*Ma*^{3}	Dipping	"Horse"
骂	*Ma*^{4}	Falling	"Scold"

With similarities apparent between both domains, a question slowly emerged: To what extent are pitch processing components shared between speech and music? Traditionally, the linguistic and non-linguistic domains were viewed as separate psychological faculties. For instance, in older theories and studies such as Bever and Chiarello's study (1974), linguistic abilities were believed to be localized in the left brain hemisphere whereas musicianship was considered a right-brain skill. However, counter-arguments began to arise with the advancement of brain research methodologies. Recent findings have revealed many features that were shared between the two areas of interest (Fedorenko, Patel, Casasanto, Winawer, & Gibson, 2009; Patel, 2003).

Additionally, behavioural evidence are emerging to show how L1 speech functions can result in positive transfer during second language (L2) learning. This positive transfer is even observable from music to language. On the contrary, less is known from the opposite direction of language to music. Furthermore, most studies examining the domain-specificity or generality of pitch processing based their results on the comparison of groups of individuals from different backgrounds.

This present study thus examines the extent of the perceptual mechanisms shared between linguistic and musical pitch processing for individuals with similar language and

music experiences. Particular interest and focus would be placed on gaining insights into how one's L1 lexical tone awareness ability influences performance within (a) the linguistic domain: L1-to-L2 and across (b) the non-linguistic domain: language-to-music.

2. Literature Review

2.1 Linguistic Domain: Transfer effects between L1 and L2

There are many second language acquisition (SLA) studies that have examined the influence of first language on second language learning. Within the phonology subfield of SLA, some theoretical frameworks include the Speech Learning Model (SLM) and the Perceptual Assimilation Model (PAM). The SLM attempts to explain how speech perception would affect phonological acquisition. The more similar the L1 and L2 sound are, the more hindrance one would experience in establishing a new phonetic category for it. The PAM then looks at how these similar L2 sounds are assimilated into the L1 sound categories (Brown, 2000). Even though these models are mainly applied at the segmental level, research has shown that these models are applicable for suprasegmental mapping such as tone and pitch.

For instance, Wayland and Guion (2004) carried out a Thai tone discriminative perception task among L1 Mandarin and English speakers respectively. They found that L1 Mandarin speakers outperformed the L1 English speakers pre- and post-training. Additionally, Mandarin speakers were better at identifying foreign Cantonese lexical tones than English speakers (Lee, Vakoch & Wurm,1996). Even among languages with different tonal inventories such as Cantonese and Mandarin, categorical perception of pitch contours may differ. In a study that looked at non-speech and speech tones, it was found that L1 Mandarin speakers were able to differentiate speech better than non-speech. On the other hand, the L1 Cantonese speakers display equal boundary for both speech and non-speech continuum. The researchers attributed it to the fact that the Cantonese language have a richer tone inventory which may have further strengthened the speakers' pitch perception in the non-speech domain as compared to L1 Mandarin speakers (Peng et al., 2010). Together, these studies demonstrated the advantages and differences of transfer effects brought about by one's linguistic experience with tone languages.

Another widely discussed topic within the field of SLA is studying how language perception is related to production. For example, Flege, Bohn and Jang (1997) looked at the

English vowels production from non-native speakers who differ in their years of exposure to English. They found a positive correlation between speech perception and production. Individuals with more years of exposure to English had better perception and production than individuals who were relatively inexperienced with the language. Similarly for one's native language, a link was found to exist between perception and production. A study tested university students on their accent changes in English over the course of two years. They found that students with a distinct accent had higher accuracy in the identification of that same accent (Evans & Iverson, 2007). Be it an individual's L1 acquisition or L2 learning, it is evident from previous studies that both speech perception and production are closely associated with each other.

2.2 Non-Linguistic Domain: Transfer effects between Language and Music

The transfer benefits of musicianship on language learning is extensively studied and well-documented. For one, musical ability is shown to be a predictor of how well an individual is able to acquire the phonological structure of a language. According to Eastlund Gromko (2005), kindergarten children who had music training showed a significant improvement in their reading ability, especially in the area of phonemic awareness. This extends to L2 learning. Native Japanese speakers who display higher musical aptitude perform better in receptive and productive phonology tasks of their L2 English than those with lower musical aptitude (Robert Slevc & Miyake, 2006). Additionally, learning music enhances lexical tone perception of tonal languages by non-tonal speakers. Despite the lack of prior exposure to Mandarin, musicians who are L1 English speakers were able to discriminate the Mandarin tones better than English-speaking non-musicians (Alexander, Wong & Bradlow, 2005; Lee & Hung, 2008). Some other areas of benefits that musicianship brings about is evident in memory and intelligence involving language and to perceive speech-in-noise (Franklin et al., 2008; Moreno et al., 2011; Parbery-Clark, Skoe, Lam & Kraus, 2009).

With many studies showing the positive transfer from music-to-language, Patel (2008) believed that speech and music have a possible shared sound category across the two domains. In 2011, Patel came up with a theory known as the OPERA hypothesis to account for the neurocognitive aspect. According to the OPERA hypothesis, the transfer benefits to language that was often seen in musicians could be attributed to the widespread overlapping neurological network that is activated during speech and music-related activities (Patel,

2011). This is further supported from research that examined how musicians and non-musicians process language differently in their subcortical and cortical regions. A positive correlation was found concerning the neural representation of speech and the amount of training relating to music that one receives. This is an indication of how music instruction impacts the neural mechanism beyond music domain-specific regions (Musacchia, Sams, Skoe & Kraus, 2007). When listening to speech, musicians was also found to have higher activations in both the left and right middle temporal gyri as compared to non-musicians. Moreover, as individuals continue to receive more musical training, lower activation was required in their primary auditory cortex areas (Oechslin, Meyer & Jäncke, 2010).

However, musical training is not the only factor that could enhance the auditory encoding of speech. An individual's language experiences is found to impact the neural mechanism of speech similarly. According to a study that looked at brainstem responses, both Mandarin speaking non-musicians and English speaking musicians were found to have more activation in their brainstems and displayed higher accuracy at detecting pitch changes in both the musical and linguistic domains than English speaking non-musicians (Bidelman, Gandour & Krishnan, 2011). Also, being a bilingual can bring about physiological changes to the brain. A study that compared Spanish-English bilinguals and monolinguals showed subcortical enhancement during F0 encoding (Krizman, Marian, Shook, Skoe & Kraus, 2012).

Yet, behavioural evidence for transfer benefits from language-to-music has been limited and conflicting. Peretz, Nguyen and Cummings (2011) were unable to find any evidence of heightened musical pitch perception among tone language speakers. Nevertheless, some research were able to suggest that tone language speakers display superior pitch-processing ability within the non-linguistic domains. For instance, L1 Chinese speakers were able to better differentiate between non-speech tone as compared to L1 English speakers (Xu, Gandour, & Francis, 2006). Moreover, there are higher occurrences of music conservatory students with absolute pitch in China than in America (Deutsch, Henthorn, Marvin, & Xu, 2006). Interestingly, the prevalence of absolute pitch was found to be associated with one's level of fluency in a tone language. According to a study conducted in another American music conservatory, it was found that students who rated themselves as very proficient or fluent in a tone language outperformed students who rated themselves as less proficient in a tone language in an absolute pitch naming task (Deutsch, Dooley, Henthorn & Head, 2009).

This thus reflects the importance of the continuous use of a tone language for cross-domain benefits to be lasting.

3. The Present Study

3.1 Motivation & Research Questions

After reviewing past literature that explored the pitch perceptual mechanisms shared within the linguistic and across the non-linguistic domains, it is evident that several research gaps exist.

Within the linguistic domain, most studies examining tonal language mapping only focused on how L1 could aid in L2 learning from either the perception or production perspective. Even for studies that considered both language perception and production data, most were focused on studying the relationship within native speech perception and production or between non-native speech perception and production. Not much is known of how L1 can influence L2 perception and production.

As for the non-linguistic domain, research on the transfer effects of language-to-music has been scarce and inconclusive. Additionally, most of the studies were dedicated to examine how tonal languages are possibly related to absolute pitch ability . Absolute pitch, according to Deutsch et al.(2009), is defined as "the ability to name a musical note in the absence of a reference note" (p.2398). As a result, most studies could only recruit musicians who could read music. Consequently, even less information is available about the transfer benefits that non-musicians with tone language background may reap in the non-linguistic domain.

On the whole, it was common to note that results were often solely based on comparing individuals with different linguistic and musical experiences (e.g. between tonal- and non-tonal language speakers, between musicians and non-musicians). Furthermore, this form of categorization tend to be over-simplified. All languages that use tones were classified as tonal languages despite the differences in the tonal inventories. Similarly, for non-tonal languages, the use of pitch may differ.

The current study thus aim at investigating the positive transfer of pitch processing within the linguistic and across the non-linguistic domain among individuals with similar

language and music background (i.e. English-Mandarin Bilinguals that are non-musicians). With Deutsch et al.'s (2009) study that examined how lexical tone awareness or proficiency is a predictor of absolute pitch ability serving as the main inspiration, this study primarily sought to further investigate the role of L1 lexical tone awareness as a predictor for performance in the domain of language and music.

With the above objectives in mind, the following research questions were generated:

(1) Would one's ability in L1 lexical tone awareness serve as a predictor for the perception and production of the lexical tones of a non-native tonal language?

(2) Would one's ability in L1 lexical tone awareness transfer towards discriminating musical pitch?

3.2 Predictions

The hypothesis generated from each of the research question would be discussed in relation to the literature review:

(1) Would one's ability in L1 lexical tone awareness serve as a predictor for the perception and production of the lexical tones of a non-native tonal language?

According to past studies (Lee et al.,1996; Wayland & Guion ,2004), individuals were able to better discriminate the lexical tones of a non-native language if their linguistic repertoire involves a tonal language. Anchoring on the SLM and PAM theoretical framework of phonological acquisition and coupled with the evidence showing the linkage between speech perception and production (Evans & Iverson, 2007; Flege et al.,1997), it would be hypothesized that an individual's ability in L1 lexical tone awareness would serve as a predictor for discriminating and producing non-native lexical tones.

(2) Would one's ability in L1 lexical tone awareness transfer towards discriminating musical pitch?

Since the current study is inspired from Deutsch et al.'s (2009) study, it would be anticipated that this study would yield similar results. Even though Deutsch et al. (2009) only observed musicians, a similar trend should be observed even among non-musicians. This is supported from other past studies that were able to identify how non-musicians with tone language background displayed better performance in a non-speech task as compared to non-musicians with no tone language background (Xu et al., 2006). Hence, it would be

hypothesized that one's ability in L1 lexical tone awareness would serve as a predictor for performance in discriminating musical pitch.

4. Methodology

4.1 Participants

45 English-Mandarin bilinguals who were born and brought up in Singapore participated in the study. They were recruited with the use of a screening questionnaire hosted online that was adapted from Birdsong, Gertken and Amengual's (2012) Bilingual Language Profile tool (see Appendix A).

Selection of participants was based upon two main criteria. They were required to have minimal prior exposure to the Thai language as it was chosen to be the stimuli representative of a foreign tonal language in this study. Further elaboration as to why Thai was chosen as the non-native tonal language would be mentioned under the stimuli section. Moreover, all participants were non-musicians; defined as individuals with less than three years of music instruction or participation in music-related interest groups. This is in accord with past literature that considered non-musicians as participants in their investigation of the transfer effects between language and music (Alexander et al., 2005; Bidelman et al., 2011).

During the data analysis process, responses from two participants were eventually excluded. One was found to have provided incomplete responses while another was later found to be ineligible for the study. As a result, the final group of participants consisted of 43 individuals (19 males and 24 females), with ages ranging from 19 to 28 years (M=22.86, SD=2.27 years).

With Singapore being a multilingual society, it was foreseeable that most participants noted down in their questionnaire as being proficient in other languages with the exception of the Thai language. During a pre-experiment audiometric testing, all participants displayed normal hearing. A short screening test for absolute pitch was also carried out to rule out individuals who may have an aptitude for it that could potentially affect the outcome of the study. Upon completing the experiment that lasted for approximately one hour, all participants were paid accordingly.

4.2 Stimuli

As this study explored the role of L1 lexical tone awareness on pitch processing performance in the non-linguistic and linguistic domain, the materials used as a measure of each domain would be described accordingly.

4.2.1 Linguistic Domain.

To determine the performance of L1 lexical tone awareness, 25 monosyllabic mandarin characters were used (see appendix B). The list of words were adapted from Ji et al. (2011) because they had been phonemically balanced and took into consideration of how frequently each lexical tone occurs in everyday use.

Each of the 25 words was embedded within the carrier sentence:

这个 X 字.	[Mandarin Chinese]
Zhe^4 ge^4 X zi^4.	[Pinyin]
"This character X."	[English]

A native female speaker of Singapore Mandarin assisted with the recording of the words. Each sentence was read thrice at a normal speaking rate within a sound proof room, where each audio file was digitised with the Audacity software. Following that, Praat was used to extract the best exemplar of the words and to normalise the amplitude and duration of each sound file.

To be able to study the natural production of Mandarin lexical tones from participants, the following sentences were adapted from Yang (2015):

Table 2.

Mandarin carrier sentences for use in the production task.

Carrier 1:	他要掏钱. ta^{1} yao^{4} tao^{1} qian^{2}. "He wants to pay the money."	[Mandarin Chinese] [Pinyin] [English]
Carrier 2:	他要逃钱. ta^{1} yao^{4} tao^{2} qian^{2}. "He wants to avoid paying the money."	[Mandarin Chinese] [Pinyin] [English]
Carrier 3:	他要讨钱. ta^{1} yao^{4} tao^{3} qian^{2}. "He wants to ask for money."	[Mandarin Chinese] [Pinyin] [English]
Carrier 4:	他要套钱. ta^{1} yao^{4} tao^{4} qian^{2}. "He wants to get the money back."	[Mandarin Chinese] [Pinyin] [English]

Note. The word of interest is the Mandarin character underlined in each sentence that differs only in their tonality but is able to cause a resulting change in the meaning of each sentence .

As for the foreign tonal language, Thai was specifically chosen because of its difference in the tone inventory from Mandarin. Thai has five lexical tones, of which three differ by pitch height (as low, mid and high) and two differ by pitch direction (rising and falling). As for Mandarin, there is four lexical tones of which only one is level and the remaining three are contour tones: rising, dipping and falling (Tillman et al., 2011). Please refer to figure 1 for a schematic representation of the lexical tones in the two languages.

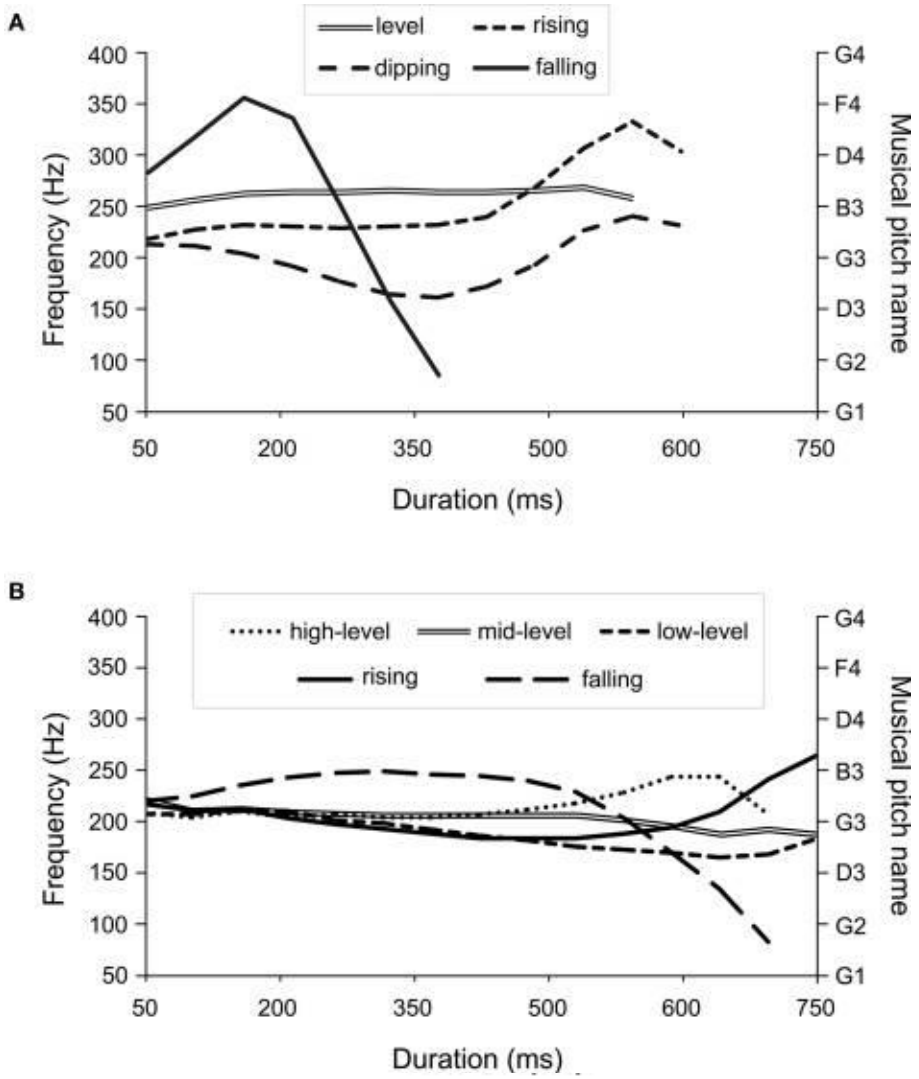

Figure 1. Lexical tones of A. Mandarin and B. Thai (Tillman et al., 2011, p.110).

As evident from figure 1, the tone categories in Mandarin are more distinctly differentiated as compared to Thai. Additionally, Thai tones have generally longer duration than Mandarin tones. Even though similarities exist between Mandarin and Thai such as the presence of rising and falling tones, their realisation of the tone may differ. This can be observed from the falling tone where the slope for the Mandarin tone is steeper than that of the Thai tone. Hence, with the presence of many differences between the two languages, this serves as a good measure to understand the transfer benefits of pitch processing between tonal languages.

To determine the performance of foreign lexical tone awareness, Thai words were used. The Thai stimuli was borrowed from a previous student, Tan (2013), who completed her undergraduate thesis relating to Thai lexical tones (see appendix C for the list of words used). Noting the limitation that Tan (2013) mentioned about her lack of duration

normalization that could have unintentionally became a cue which participants rely on to discriminate lexical tones, further measures were taken to normalize the duration.

4.2.2 Non-Linguistic Domain.

To test pitch processing performance in the domain of music, Wong's (n.d.) On-line Identification Test of Congenital Amusia was used. Even though the test is a tool to identify amusia, this test was still employed in studies to observe non- amusics' ability to discriminate musical pitch in melodies (Wong et al., 2012). Furthermore, the melodies used in the test involved different tune systems (western musical and atonal). This prevents performance to be affected by one's familiarity with the western scale.

4.3 Procedure

Prior to the experiment, written consent was sought from the participants to ensure that they were well aware of their rights.

For the experiment, participants were required to complete three different tasks: A language perception task, a language production task and a music perception task,. Aside from the music perception task, the remaining tasks were administered with the E-Prime 2.0 software. As most of the stimuli were presented aurally and the collection of speech production data were required, a quiet environment was crucial. Hence, the experiment was conducted in a sound proof lab and involved the use of headphones and microphone. During the recording of the speech production, the microphone was placed at an appropriate distance to obtain a clean sound.

Within each task, there was two practice trials to allow participants to familiarize with the experiment. To control for order effects, the appearance of each stimuli was randomized while the presentation of tasks were counterbalanced. To prevent fatigue, participants were given a five minutes break after the completion of each task.

4.3.1 Language Perception Task.

For this task, there were two separate blocks. In the first block, participants listened to monosyllabic Mandarin words. They were required to identify the lexical tones of the aurally presented words. To prevent ceiling effects from occurring, participants were only given a time limit of 1500ms to make a response. For the second block, it was an AX

discrimination task. Participants heard 40 pairs of Thai words that differ only in their tonality. As it was found that a 1500ms interval between words allow individuals to sufficiently process them at a phonological level, the words in each pair were separated by this similar interval (Werker & Tees, 1984).

4.3.2 Language Production Task.

Similar to the language perception task, there were two blocks in this task. In the first block, participants heard a Thai word that is realized in the five different tones of the language. They were required to mimic the words. In the second part, four mandarin sentences, differing only in tone for one of the characters, were presented on the computer screen. Participants had to read aloud each sentence thrice. For participants that experienced difficulty with the identification of the Mandarin Characters, the experimenter would then proceed to read aloud the words once to allow them to mimic accordingly.

4.3.3 Music Perception Task.

This was another AX discrimination task where participants listened to 36 pairs of melodies that differed either in pitch or rhythm. They had to identify whether each pair of melodies were the same or different and made their responses accordingly.

5. Results

5.1 Linguistic Domain

5.1.1 Perception Task.

A Pearson product-moment correlation coefficient was carried out to determine whether a relationship exists between their performance in the L1 Mandarin perception task and the non-native Thai perception task.

The data suggest that a significant correlation exists between the L1 Mandarin tone identification scores and the non-native Thai tone discrimination scores (r= 0.341, N=43, p<0.05). The better an individual is at identifying the L1 Mandarin tones, the better he or she is at discriminating the non-native Thai tones.

However, running a correlation test alone does not reveal much information about the transfer effects between the two languages. After observing how well-distributed the spread of L1 Mandarin tone identification scores were, the participants were then allocated into

two groups: the low L1 tone awareness and the high L1 tone awareness group (see figure 2). As there were no external criteria to validate a cut-off score for the grouping, the conventional median score was used.

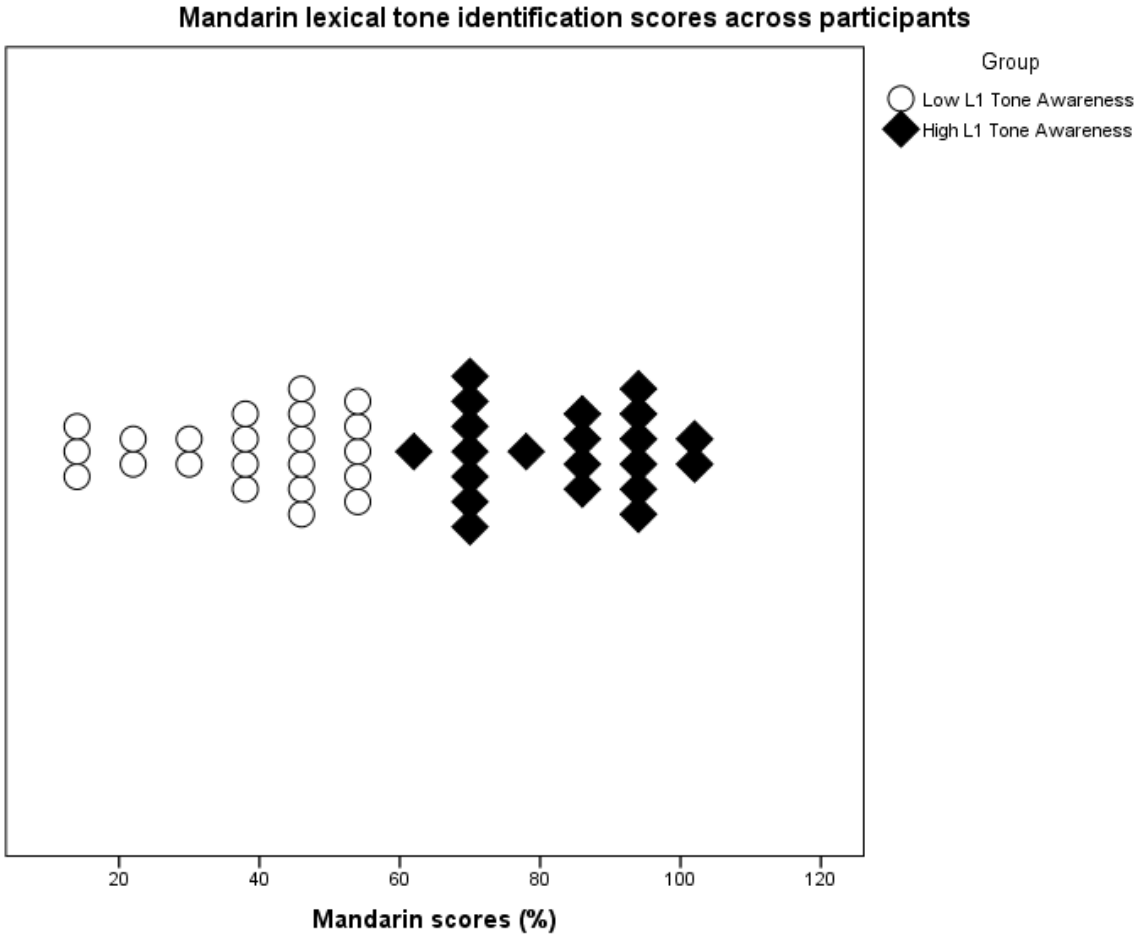

Figure 2. Distribution of participants' scores in the Mandarin tone identification task according to their respective grouping.

To ensure that a comparison could be made between the two groups, an independent-sample t-test was conducted. The mean Mandarin score for the low L1 tone awareness was 38.36 out of 100 (*SD* = 14.06) and that for the high L1 tone awareness was 82.67 out of 100 (*SD* =13.23). Participants from the high L1 tone awareness group performed significantly better than the low L1 tone awareness participants; $t(41) = 10.63$, $p < 0.01$.

A 2 (group: Low L1 tone awareness, High L1 tone awareness) X 2 (language perception task: Mandarin Identification, Thai Discrimination) mixed ANOVA with repeated measures on the language perception task was conducted. There was a significant main effect of language perception task, $F(1, 41) = 277.03$, $p<0.01$. Participants were doing

better in the Thai discrimination task (*M*=95.35,*SD*=5.05) than in the Mandarin Identification task (*M*=60.00, *SD*=26.16) There was a significant main effect of group, *F*(1, 41) = 103.90, *p*<0.01. Participants in the high L1 Tone awareness group scored better for both tasks (Mandarin: *M*=82.67, *SD*=13.24, Thai: *M* = 96.9, *SD* =3.53) than participants in the low L1 tone awareness (Mandarin: *M*=38.36, *SD*=14.06, Thai: *M* =93.86, *SD* = 5.86). There was a significant interaction effect between the group and language perception task, *F* (1, 41) = 96.98, *p*<0.01. Further analysis revealed that despite the difference in the performance for the L1 Mandarin tone identification task between the groups, both groups were performing very well for the Thai task. This is an indication of a ceiling effect in the Thai discrimination with high performance being evident even in the low L1 tone awareness group (see figure 3) .

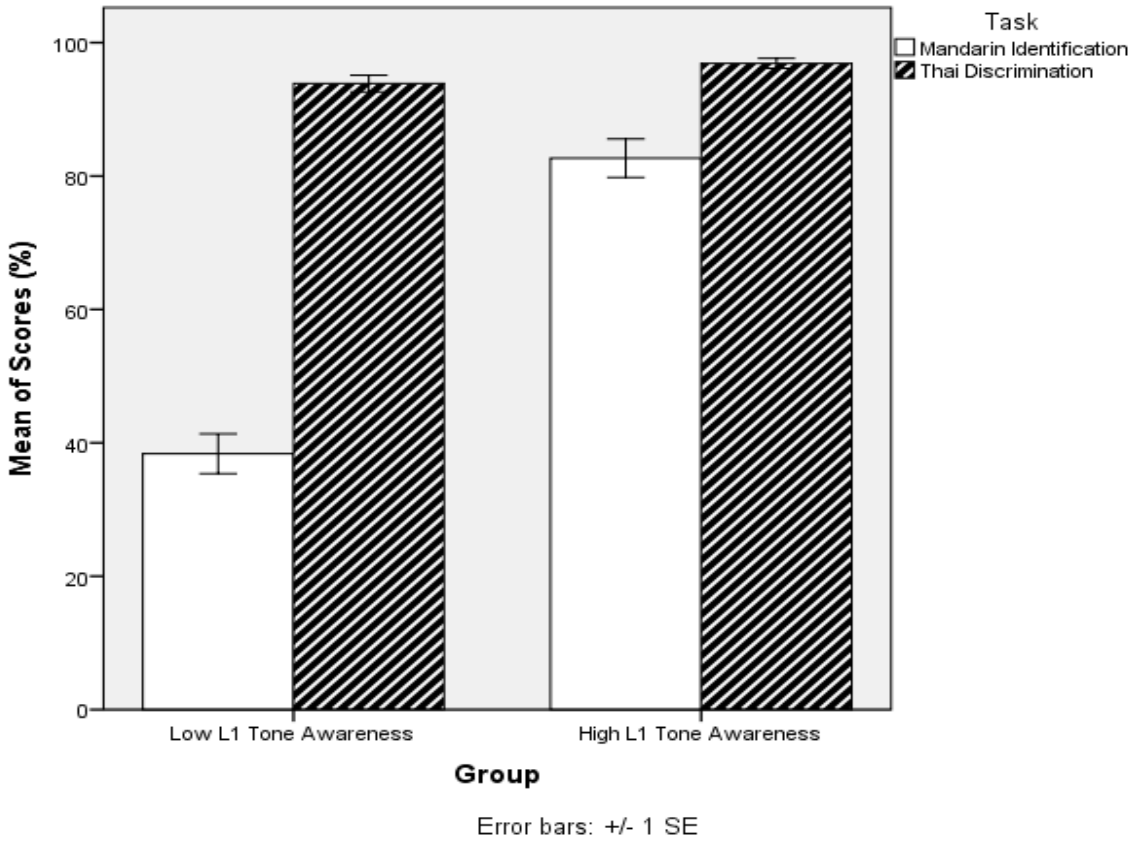

Figure 3. Bar graph of the mixed model ANOVA with the language perception task as the within subject factor.

Despite the ceiling effect observed in the Thai tone discrimination task, analysis was still conducted on the error rates. The errors for the Thai tone pairs were first categorized according to tonal features: pitch direction (tones involving only contour pairs), pitch height (tones involving level pairs) and mixed (tones involving a mixture of contour and

level pairs) This categorisation follows closely to a study that analysed how speakers of language groups that differs in pitch usage perceive Thai tones (Schaefer & Darcy, 2014).

To analyse the types of errors participants were making, a repeated measures ANOVA was carried out with the group (Low L1 tone awareness, High L1 tone awareness) as the between-subject factor and the types of errors (Direction, Height, Mixed) as the within-subject factor (see figure 4). There was a significant main effect of error type, $F(2, 82) = 6.05$, $p<0.05$. Further analysis revealed that errors relating to pitch direction ($M = 1.16$, $SD=7.62$) was significantly lower than pitch height ($M = 6.59$, $SD=11.00$); $t(42) = 2.55$, $p<0.05$. Similarly, errors relating to pitch direction was significantly lower than pairs involving mixed pitch ($M = 7.56$, $SD = 9.42$); $t(42) =3.27$, $p<0.01$. However, the types of error were not significantly different between pitch height and mixed pitch; $t(42) = 0.057$, $p=0.58$. As for the main effect of group, marginal significance was reached, $F(1,41) = 4.03$, $p=0.051$. However, there was no interaction effect between the group and error types, $F(2, 82) = 2.46$, $p =0.092$).

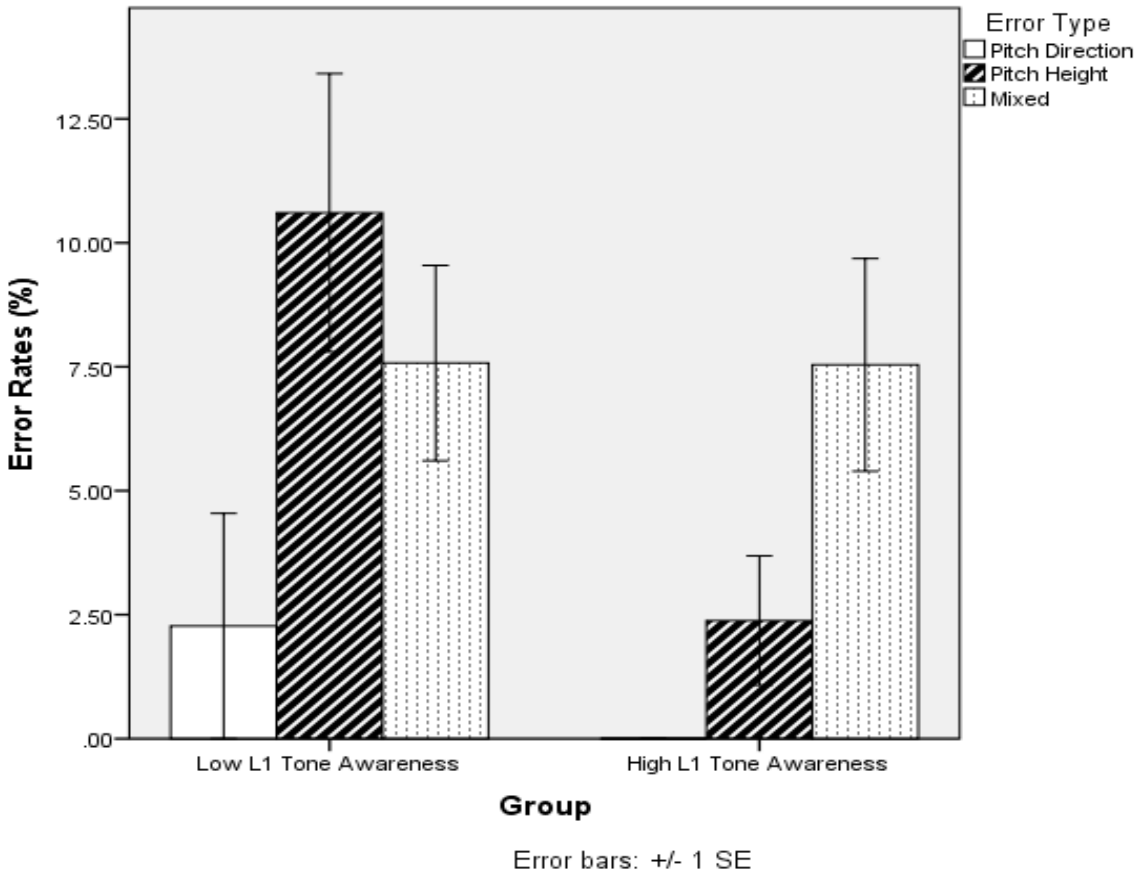

Figure 4. Bar graph of the 2X3 mixed ANOVA with group as the between subject factor and the error type as the within subject factor.

5.1.2 Production Task.

Pitch contours of the four Mandarin tones and the five Thai tones produced by participants were extracted using Praat. As the native Thai speaker used as the standard for comparison against the participants' non-native Thai tones production was a female, only the production data of female participants were considered. A total of 24 female participants (12 in each group) thus were evaluated. The F0 value were taken from ten regular intervals for each lexical tone, averaged and plotted on line graphs. As Rose (1993) have shown in his study how important retaining tonal duration for linguistic tonetic comparison was, the duration of each lexical tone was not equalised. Instead, it is normalised against the lexical tone that required the longest duration for each language.

5.1.2.1 Mandarin Lexical Tone Production.

The following figure depicts the pitch contour of the four Mandarin lexical tones as produced by participants from the two groups.

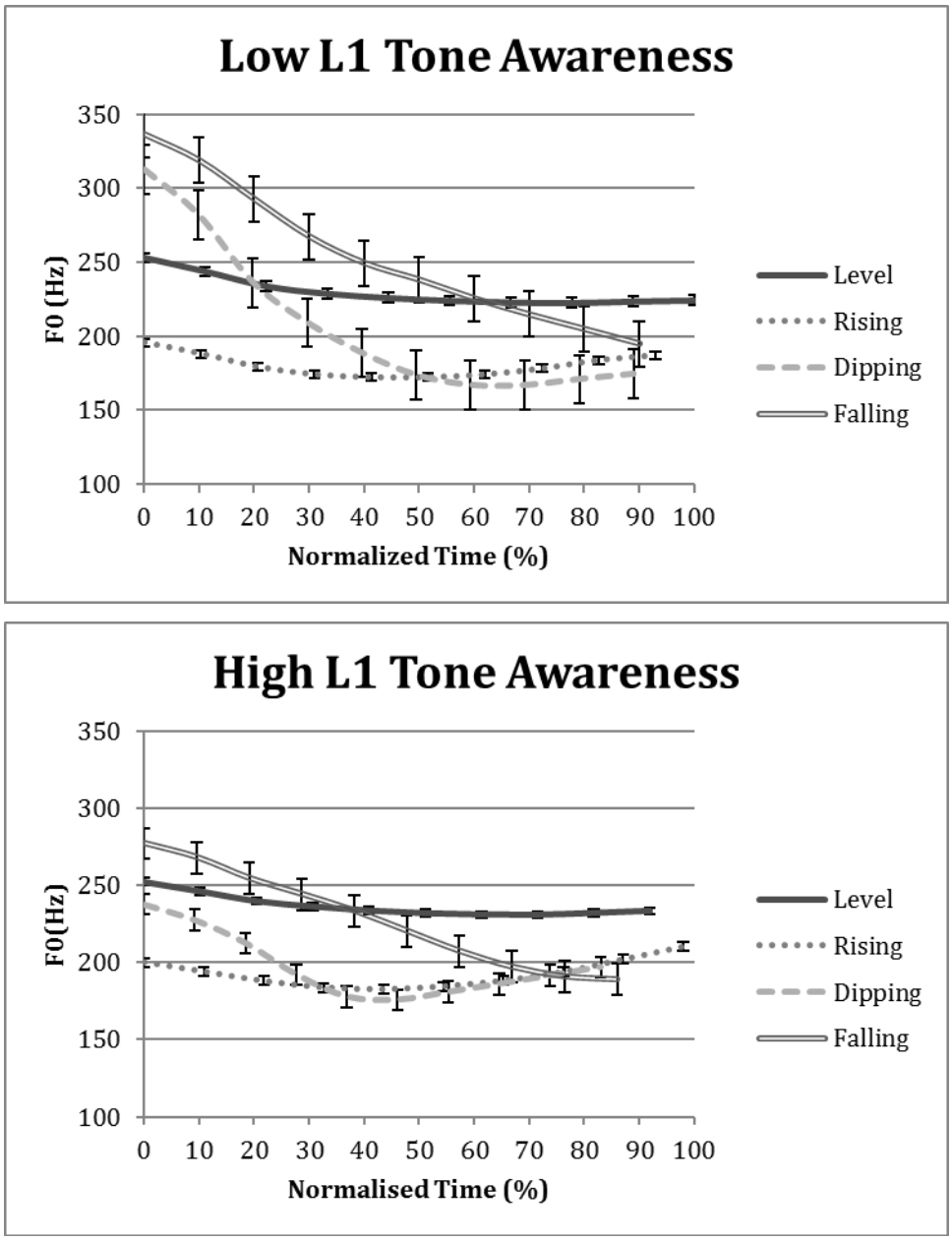

Figure 5. Pitch contours of the four Mandarin lexical tones according to groups. In the low L1 tone awareness group, the pitch contours were more distinctly different and used a wider range of relative frequency in the onset (min: 195.8Hz, max: 336.5Hz). As for the duration, there is lesser distinction between the tones, with level tones having the longest duration (Level: 354.3ms, Rising: 328.8ms, Dipping, 316.2ms, Falling: 320.1ms). As for the high L1 tone awareness group, the pitch contours were not as distinct and used a narrower range of relative frequency in the onset (min: 200.1Hz, max: 277.0Hz). More distinction were made with regards to duration of each tones, with dipping tones having the longest duration (Level: 324.6ms, Rising: 346.2ms, Dipping: 293.9ms,Falling: 305.4ms).

5.1.2.2 Thai Lexical Tone Production.

The following figure depicts the pitch contour of the two contour tones in Thai as produced by a native Thai speaker and participants from the two groups.

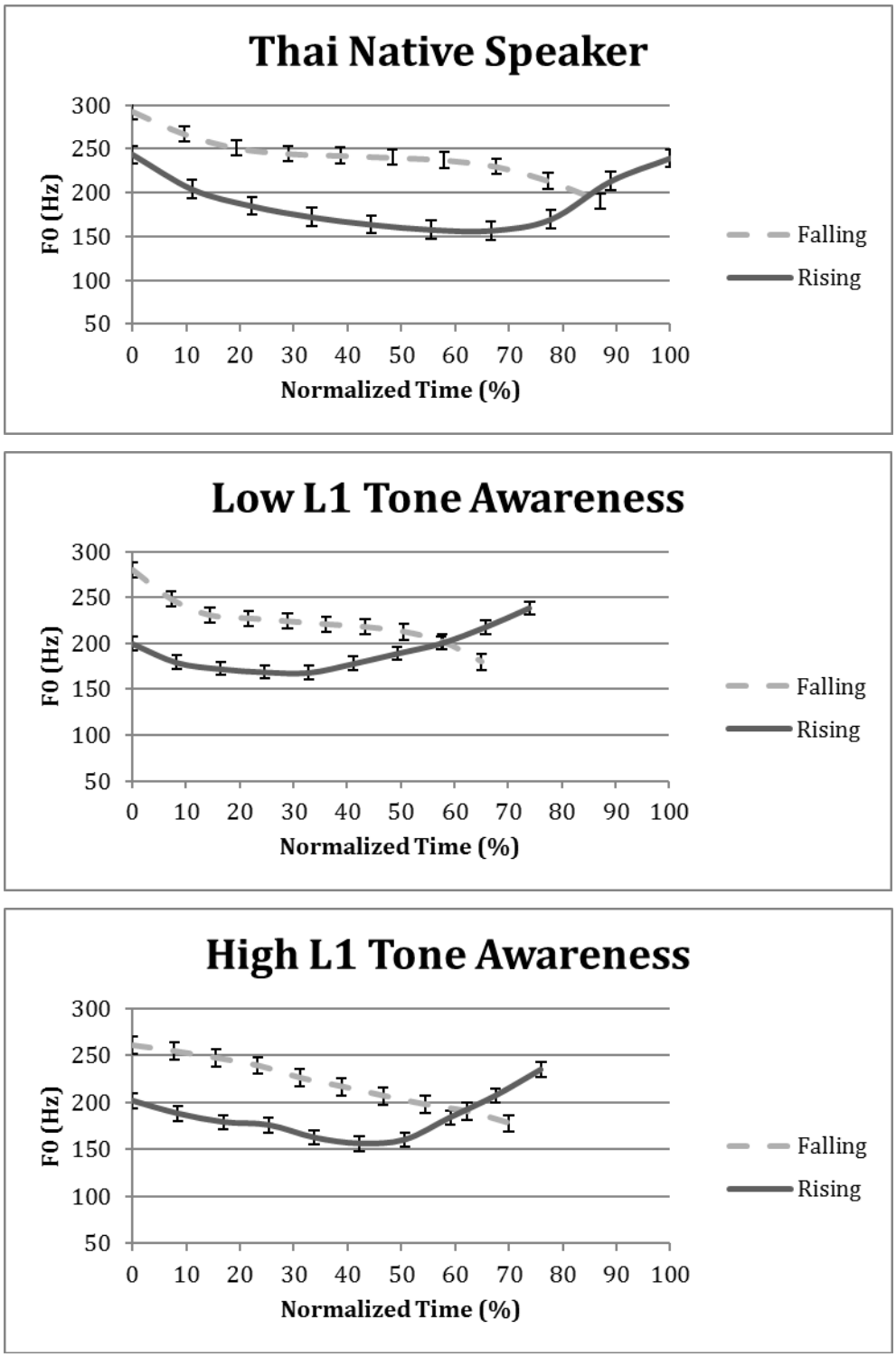

Figure 6. Pitch contours of the two Thai contour tones (falling, rising) according to a native speaker and the two groups. Generally, there is high similarity in the pitch contour across the three groups. Even though both groups have shorter duration for both contour tones as compared to the Thai native speaker, it is still observable that the relative duration is comparable. Both groups had shorter duration for the falling tone than for the rising tone.

The following figure depicts the pitch contour of the three level tones in Thai as produced by the native speaker and participants from the two groups.

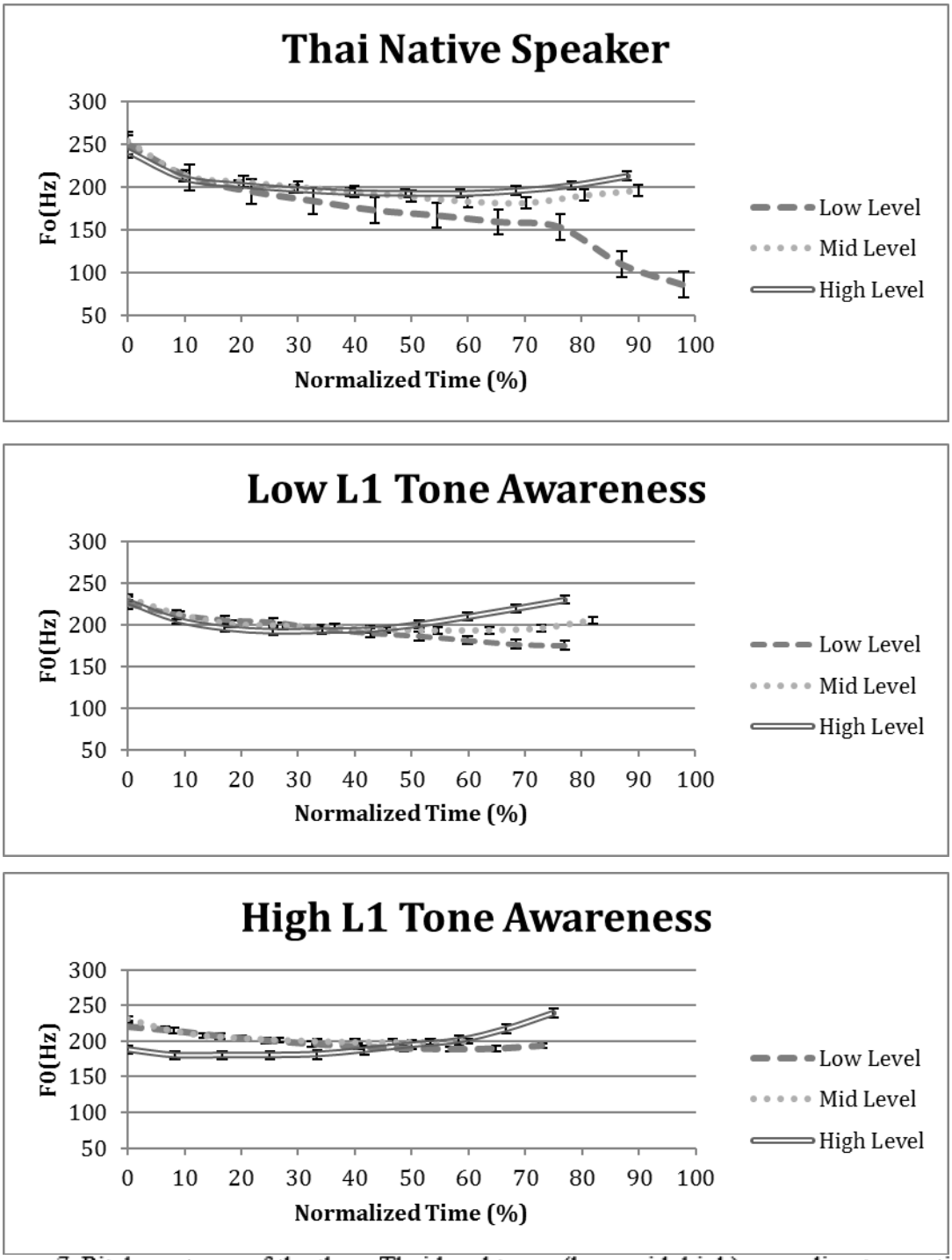

Figure 7. Pitch contours of the three Thai level tones (low, mid, high) according to a native speaker and the two groups. For the level tones produced by the Thai native speaker, the difference between each level tone was not as distinctly differentiated. A slight dip seen in the frequency for the low level tone at the end could have occurred as a result of individual variation in tone production. This dip may not be evident at the perceptual level as no similar dip in production was observed in participants from both groups. Comparing the production from both groups, the low L1 tone awareness group showed little variability in the frequency and duration as compared to the high L1 tone awareness group.

5.2 Non-Linguistic Domain

A Pearson product-moment correlation coefficient was computed to determine if any relationship exist between their performance in the language perception tasks and the music perception task (scores analysed according to two factors: musical-pitch and rhythm).

No relationship was found between their performance in the Mandarin perception task and in their performance in the musical-pitch related task ($r = 0.251$, $N = 43$, $p = 0.105$) and rhythm-related task ($r = 0.194$, $N = 43$, $p = 0.213$). Similarly, no relationship was found between their performance in the Thai perception task and their performance in the musical-pitch ($r = 0.114$, $N = 43$, $p = 0.469$) and rhythm related task($r = 0.020$, $N = 43$, $p = 0.899$).

As the test for musical pitch involves the use of melodies in familiar tune systems (western musical), participants may be basing their responses due to their daily life exposure to melodies in such scales. Hence, another correlation test was conducted for responses to the atonal melodies that is not tied to any particular system. However, no relationship was found between performance in the Mandarin perception task and their performance to discriminate musical pitch in atonal melodies ($r = 0.157$, $N=43$, $p=0.314$).

6. Discussion

6.1 Linguistic Domain

Overall, results support the first hypothesis that an individual's ability in L1 lexical tone awareness would serve as a predictor for discriminating and producing non-native lexical tones. Participants in the high L1 tone awareness group performed significantly better in the Thai discrimination task as compared to participants in the low L1 tone awareness group.

In addition, it extends past findings that looked at speakers from diverse language backgrounds (Lee et al., 1996; Peng et al., 2010; Wayland & Guion., 2004). Even for individuals speaking the same language, individual differences such as L1 lexical tone awareness have a crucial role to cause variability in the perceptive ability of a non-native language.

However, the errors made in the Thai AX discrimination task did not corroborate with the SLM and PAM model. Participants did not make the most errors in discriminating pairs of Thai tones that differ in pitch height. However, this could be attributed to the lack of control on ensuring an equal number of trials between the different tone features as error rates was not an area of consideration during the conceptualization of this study. Hence, the number of trials differ considerably among the tone features (n. of pitch direction trials = 2, n. of pitch height trials = 6, n. of mixed trials =12). This could serve to explain why the error rates did not differ significantly between pitch height and mixed trials. Although significantly lesser errors were found for pitch direction trials, no conclusive statement could be made as the results may have occurred due to the lower number of trials involved.

On the other hand, the production data were able to support the applicability of the SLM and PAM model for suprasegmental features. With the difference in the inventory of level tones between Mandarin (one level tone)and Thai (three level tone), the Thai level tones ought to sound similar to a Mandarin speaker. As predicted in SLM and PAM, participants experienced more hindrance mimicking and assimilating the Thai level tones into the L1 sound categories. In contrast, no difficulty was found when mimicking and assimilating the Thai contour tones due to the existence of similar falling and rising lexical tone categories in Mandarin.

With the differences in the production data evident between the groups, it also revealed deeper insights into the relationship between speech perception and production. L1 lexical tone awareness not only serve as a predictor of L1 production, but appear to extend to non-native language production.

The low L1 lexical tone awareness group made greater differentiation between the Mandarin lexical tones and showed greater variability among participants. Comparatively, participants in the high L1 lexical tone awareness group had lesser variability and produced less differentiated Mandarin tones. One possible explanation for the greater differentiation seen in the low L1 lexical tone awareness group could be attributed to the experimenter. As some of the participants in the group had difficulty pronouncing the Chinese characters, assistance was sought from the experimenter which may consequentially brought about more careful articulation of the Mandarin tones.

Even though the production data from both groups bared little resemblance to figure 1 which was taken from Tillman et al.'s (2011) study, this could be attributed to the context. For Tillman et al.'s (2011) study, the schematic representation of the lexical tones were based upon production data from isolated words. However, in this study, the words investigated for their tone quality were extracted from within a carrier sentence. According to Yang (2015), lexical tone boundary of words are affected by the tone boundary of preceding and following words, which provide an explanation as to the divergence between figure 1 and figure 6.

As for the Thai tones mimicry, both groups had similar performance in their imitation of the contour tones. However, the high L1 tone awareness group was able to produce more distinctive articulation of the three different Thai level tones by displaying a greater variability in the duration. According to Rose (1993),the use of duration information is a reflection of the individuals' ability to perceive differences between the tones. Hence, this lend support to a possible relationship between L1 lexical tone awareness and non-native tone production.

6.2 Non-Linguistic Domain

For the second hypothesis, the results do not support that one's ability in L1 lexical tone awareness would serve as a predictor for performance in discriminating musical pitch. Despite further narrowing the focus only to participants' musical pitch discrimination performance for the atonal condition, no significant relationship was found.

One probable explanation could be that the transfer of one's L1 lexical tone awareness ability is only applicable for individuals with music background or absolute pitch aptitude, which is in accord with past studies looking at the transfer benefits from language to music (Deutsch et al., 2006; Deutsch et al., 2009). Another likely explanation could be that having experience in a tonal language offers similar advantage to all non-musicians in spite of one's L1 lexical tone awarenes, which is consistent with findings from Xu et al. (2006). Alternatively, it could have been the existence of other tonal languages in their linguistic repertoire that affected their performance in the music perception task. After reviewing some responses from the screening questionnaire, this becomes a possibility as some participants rated their proficiency in another tone language such as Hokkien and Cantonese to be as good as Mandarin.

However, it would be premature to dismiss one's ability in L1 lexical tone awareness as a possible predictor. It could be that the difference between the participants' L1 lexical tone awareness ability was not drastic enough to observe any considerable difference in performance for discriminating musical pitch. When groups' ability differ drastically (i.e. comparing between normal individuals and amusics), possible differences may be yielded. This can be observed in a study conducted on Mandarin amusics. Jiang, Hamm, Lim, Kirk, and Yang (2012) found that the amusics have impaired categorical perception of the Mandarin lexical tones as compared to Mandarin controls, providing evidence for a transfer effect between language and music.

6.3 General Discussion

The findings from the present study illustrate the complexity involved in the influences of L1 experience on non-native language and musical pitch processing. Having experience with tone languages is insufficient to bring about a lasting positive transfer between linguistic and across non-linguistic domains. Having a clear categorical boundaries of L1 lexical tones is equally crucial for ensuring a successful transfer effects from L1 to L2. However, without any significant transfer effects observed from language to music, it is difficult to further insights into understanding the extent of pitch perceptual mechanism shared between the domains of language and music.

Nevertheless, the present study bring further insights into existing SLA research by showing the importance of individual variation in L1 lexical pitch awareness for speakers within the same language community on the perception and production of non-native tones. These findings may even be useful knowledge for L2 adult educators to better help students learning tonal languages.

In addition, one main limitation was identified in this study. Despite enforcing more control measures over the Thai stimuli, it was insufficient to prevent a ceiling effect from occurring for the Thai AX discrimination task. According to Wayland and Guion (2004), careful selection of words are required. Hence, for future replication of similar task or this study, only minimal pairs that are difficult even for Thai native speakers to discriminate should be used.

Future studies could also consider placing more emphasis on studying how individuals with differing L1 tone awareness ability would perform in discriminating tone pairs according to tone features (i.e. pitch height, pitch direction and mixture of pitch). This may provide more in-depth insights into how individuals with differing L1 tone awareness ability are performing in discriminating different tone pairs that are similar or different to their native language. Similarly, more areas of non-linguistic domain such as melody memory and production of non-speech tones could be explored.

7. Conclusion

The current study focused on the effects of L1 lexical tone awareness on foreign lexical tone and musical pitch processing. The relationship between speech perception and production was also examined. Results of the study revealed L1 lexical tone awareness as a possible factor having an influence on the extent of positive transfer from L1 to L2. However, little is still known about the influence of having a tone language background on the ability to discriminate musical pitch for non-musicians.

In short, the findings reveal that transfer benefits of lexical pitch processing from L1 to L2 is not just dependent on the existence of a tone language in one's linguistic repertoire. Continuity in the awareness of the category boundaries of one's L1 is important. With these new findings, it can have far-reaching implications within the SLA field and the L2 learning process.

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Appendix A: Screening questionnaire on musical and linguistic background

Name:_____ Age:_____ Gender: M / F Email:_____

Section A: Language Experience

1. Can you speak or understand the THAI language?
   - Yes.
   - No.

2. For each of the language you know, please rate how proficient you are on a scale from 1 to 5 (not proficient - very proficient) in the following aspects:

Language	Speaking	Listening	Writing	Reading
1.				
2.				
3.				

3. Please list the percentage of the time you use each language you know WITH FAMILY. (Your percentages should add up to 100%):

List language here:	1	2	3		
List percentage here:					

4. Please list the percentage of the time you use each language you know WITH FRIENDS. (Your percentages should add up to 100%):

List language here:	1	2	3		
List percentage here:					

5. Please list the percentage of the time you use each language you know AT SCHOOL/WORK. (Your percentages should add up to 100%):

List language here:	1	2	3		
List percentage here:					

6. Please list the percentage of the time you use each language you know TO TALK TO YOURSELF. (Your percentages should add up to 100%):

List language here:	1	2	3		
List percentage here:					

7. Please list the percentage of the time you use each language you know TO COUNT. (Your percentages should add up to 100%):

List language here:	1	2	3		
List percentage here:					

Section B: Musical Experience

1. Have you ever had music lessons outside of those compulsory in school?
   - Yes. Please state the number of years of music lessons received:
   - No.

2. In an average week, how frequently do you listen to music? (*e.g. on your computer/phone/ Spotify etc.)*
   - Never
   - About once per week
   - A few times per week
   - Everyday

Appendix B: Mandarin and Thai Stimuli Word List

Mandarin Stimuli

No.	Mandarin Chinese Character	Pinyin
1	冰	bing^{1}
2	东	dong^{1}
3	黑	hei^{1}
4	交	jiao^{1}
5	突	tu^{1}
6	宣	xuan^{1}
7	池	chi^{2}
8	鹅	e^{2}
9	魔	mo^{2}
10	峡	xia^{2}
11	移	yi^{2}
12	油	you^{2}
13	感	gan^{3}
14	管	guan^{3}
15	脑	nao^{3}
16	沈	shen^{3}
17	以	yi^{3}
18	主	zhu^{3}
19	罢	ba^{4}
20	错	cuo^{4}
21	力	li^{4}
22	倩	qian^{4}
23	瑞	rui^{4}
24	上	shang^{4}
25	在	zai^{4}

Legend (Pinyin):

1 - level tone

2 - rising tone

3 - dipping tone

4 - falling tone

Thai Stimuli

No. of Set	Thai Words	Meaning
1	faa	"a note"
	fàa	"palm (of the hand), sole (of the foot)"
	fâa	"scum"
	fáa	"sky"
	fǎa	"pot cover"
2	khaa	"to be stuck"
	khàa	"galangal"
	khâa	"value"
	kháa	"to trade"
	khǎa	"leg"
	khaa	"to be stuck"
3	naa	"rice field"
	nàa	"custard apple"
	nâa	"face"
	náa	"mother's younger sibling"
	nǎa	"thick"
4	khaj	'dried sweat'
	khàj	'egg'
	khâj	'fever'
	kháj	'to scoop out'
	khǎj	'to unlock'

Legend:

a - mid tone

à - low tone

â - falling tone

á - high tone

ǎ - rising tone