Relationship Between Language and Music Processing: Evidence from Cross Linguistic Influence on Rhythmic and Melodic Perception

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Previous studies on the relationship between language and music have looked at the influence of music on language and vice versa. The current study consisted of two experiments that observed the transfer of learning effect from language to music, specifically the influence on rhythmic and melodic perception. Both experiments used the Musical Ear Test (MET) to assess the rhythmic and melodic aptitude. Working memory and phonological memory tasks were administered to control for individual differences. The first experiment investigated the differences in rhythmic perception among English monolinguals and Finnish multilinguals and revealed that there was no significant difference in their rhythmic aptitude. This could be attributed to the monolingual nature of the English participants and the rhythmic properties of English and Finnish since they do not differ in metric preference. In the second experiment, Dutch speakers learning Chinese were recruited to compare their performances on the melodic aptitude test with Chinese-English bilinguals and Dutch-English bilinguals. Only Chinese-English bilinguals showed a significantly higher score on melodic aptitude task than the Chinese learners and Dutch-English bilinguals. This finding suggests that learning a tonal language does not provide sufficient sensitivity in pitch processing as seen among native tonal language speakers to yield a significant transfer effect from language to music. Results also showed that Chinese learners had no correlation between the language task and musical task similar to the Chinese-English bilinguals, indicating that they tend to split the processing of lexical tones from the musical pitch variations unlike the Dutch-English bilinguals who show correlation as they perceive the pitch input from both language and music tasks as general psychoacoustic information. This study adds supporting evidence to the existing literature on the transfer of learning effect and cross domain relationship between language and music.

Keywords: Language, music, transfer effect, rhythm, pitch.

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"Two sides of the same coin" is a phrase that aptly fits the description of the relationship between language and music. Language and music are two defining features present in our daily life that are universal and present across all cultures and societies (Nettl, 2000; Williamson, 2009). On putting more thought into what constitutes language and music, we can see how both may seem different, especially in terms of their functionality, and yet they have various commonalities. This invites an interesting topic of research involving the study of two systems – language and music - that are also specific and relatable to human beings. It also brings views from an interdisciplinary standpoint ranging from linguistics, musicology, cognitive neuroscience, philosophy, and even evolution. Exploring the relationship between language and music opens doors to understanding how they are represented in the brain, whether they function in parallel or share overlapping brain regions, and whether expertise can be transferable between the two sound systems. This thesis aims to explore the transfer of learning effect between language and music, and especially focuses on the transfer of enhanced sensitivity of rhythm and pitch differences from language to music.

Both language and music are similar auditory inputs constituting of features like pitch, timbre, and rhythm that span across both (Williamson, 2009). The two sound systems contain patterns of sound which are put together to form meaningful phrases (Arbib, 2011). Auditory processing enables us to make sense of these different sounds that we hear and to associate them with meaningful relevant information (Kraus & Banai, 2007). Irrespective of whether the input is language or music, the first step in the processing of both language and music is the same, that involves combining the smaller units (musical notes or syllables) into meaningful larger units (like melodies or sentences) based on certain rules or syntax relevant for each system (Patel, 2008).

Auditory processing is dynamic and malleable and can change based on the exposure or experience gained, in particular sound systems (Kraus & Banai, 2007). With respect to language, one can see the impact of language experience on processing of sounds as early as infancy. Newborns show the ability to distinguish different phonemes across all languages but as months go by, their processing is tuned towards sounds from their native language (Kuhl et al., 2006). Studies performed among adults, for instance Mandarin speakers, show changes in neural circuitry in the cortical and subcortical areas indicating strong encoding of pitch content that arose due to their experience with tones (Krishnan, Xu, Gandaour & Cariani, 2005).

Similar to language, musical experience can also shape auditory processing as evidended by studies comparing musicians with non-musicians. Musicians show better sensitivity to incoming pitch information (Schön, Magne & Besson, 2004) and better responses towards artificial tones than non-musicians (Peretz & Zatorre, 2005). On a neural level, musicians show more robust encoding of pitch related information in the subcortical areas of the auditory pathway as shown by Wong, Skoe, Russo, Dees & Kraus (2007). Mussachia, Strait & Kraus (2008) also found that musical training enhanced the auditory memory in addition to shaping the pitch-specific encoding. There is also evidence showing that the N400 effect is seen both in music and language. Similar to language, tones and chords can elicit N400 effects similar to that seen in words (Koelsch, 2011).

All in all, it is evident that the language or musical experience can modify auditory processing which also shapes the brain and neural circuitry. Influence of experience is not only specific to auditory processing but can also be seen in cognitive domains like intelligence and executive control. Studies have shown that being a bilingual improves overall executive functioning (e.g., Bialystok, 2006) and similarly, being a musician also enhances executive control (Schellenberg, 2006). Looking at how language and music influence auditory processing and lead to cognitive benefits in their respective ways, brings the spotlight back to realizing the commonalities that exist between the two domains. Rhythm and pitch are two acoustic properties that exist in both language and music and by focusing on common features such as these, it is possible to study the relationship between language and music. To delve into this deeper, it is important to have a clear understanding about what constitutes rhythm and pitch in language and music.

Rhythm in language and music

Linguistic rhythm

In order to understand speech, segmentation of the speech input is necessary, which is done using the basis of linguistic rhythm (Cutler, 1994). Linguistic rhythm refers to the way language units are arranged periodically in time (Patel & Daniele, 2003) and can also rely on the position of lexical stress on the syllables in a word (Liberman, 1975). The two forms of linguistic rhythm are explained as follows.

Unit level classification

Pike (1945) proposed a classification of languages based on rhythm that depended on their stress and syllable patterns. This led to categorising languages as stress-timed and syllable-timed languages. Stress-timed languages are those that have roughly equal time intervals between stresses. English, German, and Dutch are few examples of stress-timed languages. In case of syllable-timed languages, syllables occur in a periodic fashion which are seen in languages like Turkish, Finnish, and French. There is also a third category that represents the periodic interval of morae in a language. Mora is a unit which is smaller than a syllable consisting of a consonant and a vowel or just a consonant or a vowel (Patel, 2008). Japanese is an example of languages that are mora-timed. Overall, the rhythmic classification of languages is based on the isochrony in speech, in this case, recurrence of a particular type of speech unit: stress, syllable, or mora (Low, 2006). Although studies have opposed the idea of isochrony (e.g., Roach 1982), the core principle behind this classification lies in how the rhythm is structured in the language which tends to be similar among certain languages leading to this categorisation (Dauer, 1983).

Metric foot preference

Another rhythmic aspect in a language is the metric foot that represents the rhythmic structure of a word based on stress patterns. The rhythmic pattern of stressed and unstressed syllables enables better comprehension (Jusczyk, Cutler & Redanz, 1993). The stress pattern of a word indicates the strength and dominance of the word. The stress could be placed either in the beginning of the word for the first syllable or at the end of the word. This leads to the classification of metric preference based on the position of stressed syllables: word-initial stress (Trochaic) and word-final stress (Iambic; Hayes, 1985). English, German and Finnish follow the trochaic metric preference whereas Turkish is an example of a language with iambic stress patterns.

Musical rhythm

Rhythm is also an important trait in music. Upon listening to certain songs, our instinct is to tap our feet or move in line with the rhythm of the song. Rhythm provides a temporal reference for the musical piece and characterizes the periodicity that is seen in music (Patel, 2008). Rythm is not only present by mean of beats, but also by means of grouping of various tones in particular patterns of phrases (Patel, 2003).

Although rhythm in language and music have distinct purposes, features like statistical patterning and rhythming grouping present in both language and music emphasize their commonality (Patel, 2003). This common property of rhythm opens doors to explore the possibilities of transfer of learning effect that can occur from language to music since rhythm is featured in both.

Pitch in language and music

Pitch is an important feature that is prevalent in language and music. In language, pitch plays a key role in pragmatics through prosody. Differences in pitch, in the form of intonation, convey different emotions or intentions that the speaker wishes to express. Apart from being a common feature in intonations, pitch also takes a lexical role in tonal languages. Pitch variations indicate difference in word meaning which are the traits of a tonal language. Mandarin Chinese is an example of one such language that has four distinct lexical tones (Duanmu, 2000). If a tonal speaker uses a different tone in place of a right tone, it can lead to a different semantic context and change the course of the conversation. Such tonal variations that indicate different word meanings are not present in non-tonal languages. Therefore, it is crucial for tonal speakers to understand and enunciate the pitch differences (in tones) correctly, as it has a major impact on communication.

As commonly seen in music, pitch takes a major role in defining a musical piece. The universality of how every music across cultures relies on pitch differences in notes from an octave makes pitch a defining feature of music (McDermott & Hauser, 2005). The scales, which are a set of pitches, encompass a musical melody (Bidelman, Gandour & Krishnan, 2011).

Similar to how rhythm is represented in language and music, pitch also tends to serve different functions for each domain but remains a shared feature between language and music. This makes it interesting to look at the possible effects of pitch exposure in one domain onto the other domain that may lead to a transfer of learning effect across the two domains of language and music.

Language & music – two sides of the same coin?

Going back to the claim that the relationship between language and music is like two sides of the same coin, the above information regarding rhythm and pitch in language and music provides support for this claim by showing that language and music share features like rhythm and pitch even though they serve different purposes. Neuroimaging studies have also shown support for shared processing between language and music. Certain areas in the brain like the Heschl's gyrus show activation for both words and musical tones (Binder et al.,1996). Primary auditory regions have also shown to respond in similar manner for both speech and music (Zatorre, Evans & Meyer, 1992). While reading musical notes and understanding symbols in a language, the supramarginal gyrus is involved (Falk, 2000). It is also interesting to note that similar to how Broca's region is responsible language production, it is also active during a music performance (Falk, 2000). In addition to this, there are numerous studies (e.g. Brown, Martinez & Parsons, 2006) showing overlapping brain regions for language and music processing. Koelsch (2000) stated music and language are two poles in the language-music continuum and experiences in music or language can have an impact on both.

Transfer effect

As it is evident that language and music share features both acoustically and cortically, there is a chance that expertise or experience in one domain can transfer to the other domain. This can happen due to the fact that the two domains share overlapping physical properties and neural features that can lead to enhancement in one domain due to the effect of the other. This can either occur from music to language, wherein musical abilities can improve language processing, or from language to music, in which language skills may help in performing musical tasks better. For this project, the transfer effect was studied based on the physical properties shared between language and music behaviourally without focusing on the neural and cortical properties.

Music to language transfer

Many studies showing the transfer of training effects from music to language have been reported. These include evidence that show an enhancement in second language learning especially of the phonetic structure, as well as an enhancement in phonological processing due to musical abilities (Anvari, Trainor, Woodside & Levy, 2002; Slevc & Miyake, 2006). Musicians also tend to have higher sensitivity to prosodic cues in language (Thompson et al. 2004) and better perception of metric structure of words (Marie, Magne & Besson, 2011).

These results show that there are benefits in language-related skills due to the expertise in music. While comparing the influence of musicality on lexical tone identification, musicians showed superior performance in identifying lexical tones accurately (Chua & Brunt, 2015). In fact, musicians with no experience of a tonal language performed as good as those who were experts in a tonal language, like Mandarin Chinese speakers (Delogu, Lampi & Belardinelli, 2010). These transfer effects could possibly stem from musical training providing an overall enhancement in sensory perception and cognitive mechanism that operate on different levels enriching the auditory processing that is seen in language-related skills (Bidelman, Hutka & Moreno, 2013).

Language to music transfer

As both language and music operate similarly, even with shared networks on the cortical level (Patel, 2011), the transfer effect could also occur in the other direction: from language to music. Tonal language speakers provide an interesting group to study with respect to transfer of learning effect as they are exposed to pitch differences in the form of lexical tones. Bidelman, Hutka & Moreno (2013) studied this bidirectionality by comparing musicians with Cantonese speakers and English speakers on their performance on auditory acuity, music perception, and general cognitive abilities. Apart from musicians, who performed better in all tasks, Cantonese speakers also showed better performance in music perception than English speakers indicating the effect of their tonal background on musical perception. Bilinguals have also be shown to have benefits in the musical domain as bilinguals, specifically second language learners of English outperformed monolinguals in the melodic and rhythmic aptitude task (Roncaglia-Denissen, Roor, Chen & Sadakata, 2016). By comparing bilingual speakers of languages that have different rhythmic classification, such as syllable-timed and stress-timed languages, Roncaglia-Denissen, Schmidt-Kassow, Heine, Vuust & Kotz (2013) found that speaking two languages with distinct rhythmic features helped in perceiving musical rhythms more than speaking languages that shared similar rhythmic features. This was argued to be due to the auditory enhancement that the rhythmic variation provides which is transferred to the musical domain where rhythm plays a role.

Present Study

Although there is evidence showing language to music transfer, the literature is still scarce compared to the numerous studies done on music to language transfer. This study focusses on the transfer of learning effect from language to music, specifically in the ability to distinguish rhythmic and pitch differences. As mentioned earlier, speaking languages that are rhythmically diverse or speaking a tonal language can have an influence on the musical pitch and musical rhythmic perception (Chen, Lui, & Kager, 2016; Roncaglia-Denissen et al., 2013; 2016). However, groups with various types of language background differing in rhythmic or tonal exposure need to be studied and compared to explore the transfer effect further. For example, studying languages that are different in unit level rhythmic classification but share rhythmic feature of metric preference might show us whether enhanced musical rhythmic perception is present similar to the effects seen by studying languages that are rhythmically different in metric preference and unit level classification in Roncaglia Denissen et al. (2013). With respect to enhanced pitch perception, studies so far have shown the effects of being a native tonal speaker on increased melodic skills (Chen, Lui, & Kager, 2016). But it is yet to be investigated whether adult learners of a tonal language can also contribute to enhanced melodic pitch perception like native tonal speakers. In this study, two independent experiments were conducted to analyse the influence of linguistic background on rhythmic and melodic perception. Experiment 1 aimed to determine whether there is a difference in rhythmic perception between English monolinguals and Finnish multilinguals that have different rhythmic properties at the unit level but share metric preference, whereas Experiment 2 aimed to find if learners of a tonal language, namely Mandarin Chinese, show enhanced melodic perception like Chinese-English bilinguals. Further details on the background, motivation, along with the methods and results will be discussed individually for each experiment in the following sections.

EXPERIMENT 1 – RHYTHMIC PERCEPTION

Background

The aim of this experiment is to observe whether there is an enhanced rhythmic perception among multilinguals speaking languages with varied characteristics compared to monolinguals. This is done by comparing the rhythmic aptitude of the two language groups: English monolinguals and Finnish multilinguals by controlling for factors such as musical experience, working memory, and phonological ability. Previous studies have found that mastering languages with different rhythmic features leads to enhancement in musical rhythmic perception which supports the transfer of learning effect (Roncaglia-Denissen et al., 2013; 2016). The diversity in rhythmic features of the languages that were studied corresponds to rhythmic classification based on unit level and metric preference. In the past, the language groups that were compared were either both stress-timed languages with same metric preference (Dutch-English, German-English), or different in unit level, one being syllable-timed language and one being a stress-timed language with different metric preference (Turkish-English, Turkish-German). On comparing the rhythmic perception of Turkish–German learners and German-English learners, the former had better rhythmic aptitude than the latter. The authors attributed this to the factor that Turkish-German learners were more varied in their rhythmic background than German-English learners as Turkish and German have different rhythmic properties in both unit level and metric preference compared to German and English which are both stress-timed languages having the same metric preference. Hence being sensitive to varied rhythmic cues from the language learnt can help perceiving musical rhythms better. The same trend was also seen while comparing Turkish-English participants with Dutch-English participants owing to the expansive rhythmic exposure of Turkish-English that was lacking in Dutch-English group. In contrast to previous studies, this experiment studies the influence of rhythmic variation by comparing languages that are syllable-timed (Finnish) and stress-timed (English) but share the metric preference of trochee which is word-initial stress. As previous studies focused on a more general view on rhythmic variability in terms of differences in both unit level classification and metric preference, studying English and Finnish enables us to disentangle the factor of metric preference in order to check whether that is crucial for rhythmic transfer to take place. English was chosen as the monolingual group since previous studies only looked at Dutch monolinguals and Turkish monolinguals. Finnish was chosen due to the feasibility of approaching participants and it also fit with the target language that needed to be studied. In addition to studying rhythmically diverse languages, Roncaglia-Denissen et al. (2016) also found that Dutch, Turkish, and Chinese learners of English performed better than Turkish monolinguals in both melodic and rhythmic perception indicating that bilingual exposure might improve overall musical perception. As Turkish monolinguals constituted the only monolingual group that was investigated in previous studies, adding the English monolingual dataset from this experiment will prove useful to further substantiate the bilingual advantage. Hence comparing English monolinguals with Finnish native speakers who were multilinguals provided a platform to explore whether speaking more than one language enhances overall musical perception as shown in Roncaglia-Denissen et al. (2016). Since previous studies have shown enhancement caused by bilingualism, we expected that Finnish multilinguals will have higher rhythmic aptitude than the English monolinguals. Also, due to the fact that English and Finnish share the same trochaic metric preference (Jusczyk et al., 1993; Livonen & Harnud, 2005) but differ in terms of being stress-timed and syllable-timed languages, the Finnish multilingual group having more exposure is expected to show better performances in musical rhythmic aptitude than English monolinguals. In case they show no differences then it would provide a newer insight about the influence of having the same metric preference on rhythmic perception as that was not covered in previous studies.

Method

Participants

The study comprised of 15 English monolinguals (N = 15, female = 11, Mean Age = 22.81 years) and 15 Finnish multilinguals (N = 15, female = 12, Mean Age =24.6 years). They were recruited from Nijmegen, Amsterdam, Ghent, and Brussels. Most of them were university students. English monolingual participants were from English-speaking countries, namely the United Kingdom (N = 8), the United States of America (N = 4), the Caribbean (N = 2) and Indonesia (N = 1) who were studying at the Radboud University in Nijmegen or the University of Amsterdam. Finnish multilingual participants were native Finnish speakers whose second language was English and additionally learnt mostly Swedish, German, or Dutch. This sample size was chosen due to the challenging nature of finding English monolinguals in a non-English-speaking country.

Participants from the English and Finnish groups had an average of 2.7 years and 4.1 years of musical experience respectively. All the participants had normal or corrected-to-normal vision and did not have any neurological impairment, epilepsy, hearing or visual impairments. Upon giving detailed instructions about the experiment, written consent was obtained from the participants for the purpose of data collection and publication use. They were provided with a monetary compensation of 10 Euros.

This study was approved by the Ethics Committee of the Faculty of Humanities of the University of Amsterdam and Faculty of Social Sciences of the Radboud University in Nijmegen.

Materials

The following tests were administered to the participants.

Musical Ear Test

The musical ear test (MET) by Wallentin Nielson, Fris-Olivarius, Vuust & Vuust (2010) was designed to measure the musical abilities of musicians and non-musicians in a relatively shorter duration. This test was used in our study in order to assess the participants' musical aptitude. The test consists of two parts: Melody and Rhythm, and the participants had to judge whether the two melodic or rhythmic phrases were similar or different. Each part comprised of 52 trials, making it a total of 104 trials with 2 practice questions for each part. The melodic part was represented by short piano phrases that ranged from 3 to 8 tones. They were presented in pairs, where the melodies had a duration of one measure played at the speed of 100 bpm. Half of the 52 trials were "same" and the other half comprised of "different" trials, but the order in which they were presented, was randomized. The 26 trials that were different were characterized by a pitch violation among which, 13 of them had a pitch violation along with a contour violation.

The rhythmic part was characterised by rhythmical phrases or beats that were played with a wood block. This subtest also consisted of 52 trials where 26 of them were "same" and 26 were "different" with respect to one rhythmic change. Thirty-seven of the 52 trials began on the downbeat and rest of the trials started later. They also varied in rhythmic complexity, however the order of the trials was randomized.

The entire test took about 18 minutes to complete and didF not provide feedback at the end of the test. Participants were advised to wear headphones during the test and asked to answer as quick as possible and intuitively in case of any difficult trials. The participants listened to the trials (melody and rhythm) and were asked to judge whether the pair comprised of same melodies/rhythms or different melodies/rhythms by clicking the "same" or "different" option.

Chinese Tone discrimination task

The Chinese Tone discrimination task was administered to all the groups of participants irrespective of their language background. This task was used by Chen, Lui, & Kager (2016) to study the differences between the processing of lexical tone by asking the participants to discriminate between monosyllabic and bisyllabic pairs of Chinese tones. This test consisted of two parts: Monosyllabic (MT) and Bisyllabic (BT) discrimination. The stimuli consisted of monosyllables such as: /ba/, /bwɔ/, /bi/, /da/, /dwɔ/, /di/, /la/, /lwɔ/, /li/, /ma/, /mwɔ/, /mi/, /na/, /nwɔ/, /ni/, which were recorded separately by a female native speaker. Every syllable was recorded with all the possible tones: high level (T1), rising (T2), low-dipping (T3), and high-falling (T4). For MT, the participants had to distinguish between the tonal pairs of T1 and T4 and between T2 and T3. For each tonal pair all possible combinations were presented, for example, T1-T1, T1-T4, T4-T1, T4-T4. This part consisted of 120 trials. For BT, the stimuli consisted of two syllables followed by another set of two syllables which would either be the same as the first set or different. The possible combinations included T3T3–T2T3, T3T3–T3T2, T3T3–T2T2, T4T4–T1T4, T4T4–T4T1, and T4T4–T1T1. This part had 180 trials and the participants had to click "same" or "different" based on what they heard. The experiment was designed in such a way that the trials progress quickly, leaving only a second for the participant to answer, after which the next trial is presented automatically.

Phonological and Working memory measures

Phonological memory has been shown to be important for the processing of novel sounds and word learning (Baddeley, Gathercole, & Papagno, 1998). This is relevant to our study as it involves the ability to retain words and working memory efficiency which tends to vary between monolinguals and multilinguals (e.g., Bialystok et.al., 2004). In order to study the phonological memory capacity of an individual, the Mottier test (Mottier, 1951) was conducted. The Mottier test consists of pseudowords (words that have no meaning) which were recorded by a native English and a native Finnish speaker and was administered to the participant groups accordingly. The pseudowords began with two syllables and after each set, which contained 6 words, another syllable was added, thus increasing the length of the pseudowords. Maximum of six sets were used which meant that the maximum length of the pseudowords presented was 7 syllables. After listening to each word, the participants were asked to repeat the word.

To assess the participants' working memory, the Backward Digit Span (BDS) task was used. In this experiment, the test consisted of 14 sets of two trials that begin with a series of two numbers. There is an increase of one number after every set. Similar to the Mottier test, the stimuli for BDS were recorded by a native speaker of each group (English and Finnish) which were then administered to the respective group.

Self-Reported Language Questionnaire

Before the experiment, a language background questionnaire was given to the participants. This extensive language questionnaire contained information that tapped into their proficiency level and experience for the languages they know (Marian, Blumenfeld, & Kaushanskaya, 2007). This was done in order to assess their language skills, giving us a better picture of their language background. It was especially important to administer this test to verify the monolingual nature of English participants. The questionnaire included questions about their age of acquisition, how long they have been learning, along with rating scales about their reading, speaking, writing, and listening skills in each language. The questionnaires for the participants were administered through an online link that was created using Qualtrics.

Musical Background Questionnaire

It was important to assess the participants' musical background as it could be a potential factor that can contribute to their performance in the MET (Wallentin, et al., 2010). This was done with the help of Goldsmith Musical Sophistication Index (Müllensiefen, Gingras, Stewart & Musil, 2014), specifically using the subsets Perceptual Ability & Musical training. It included questions such as their ability to perceive an out of tune/beat of a song, how long they have been learning, etc. This test was also administered online through Qualtrics.

Procedure

The Chinese Tone Discrimination task, MET, Mottier test, and BDS were conducted using a laptop, inside a quiet room on the day of experiment. The Self-reported language questionnaires and musical background questionnaires were sent to the participants through an online link prior to the day of experiment and they were advised to complete it before participating. The entire experiment lasted for an hour. For the listening tasks, i.e., MET and Chinese tone discrimination, the participants used over-the-ear headphones while for the repetition tasks, i.e., Mottier test and BDS, they listened to the stimuli from the laptop speaker and repeated aloud while the experimenter scored their responses.

Mottier Test

The audio files with the pseudo-words were played one by one from the laptop following which the participant repeated them. It was scored simultaneously on the respective Answer Sheet. The test was terminated if the participant failed to recall more than four pseudo words from a set. The scores were calculated based on the number of correctly repeated pseudowords with a maximum score of 36.

Backward Digit Span

This follows a similar set up as the Mottier test, in which the audio is played from the laptop and the participant repeats the series of numbers that were heard, in the reverse order. The test was terminated when two consecutive errors were made while repeating backwards, irrespective of the length of the series. The total number of correct trials was counted as the score obtained by the participant, with the maximum of 14 as the total score.

Musical Ear Test

The melodies and rhythms for the MET were presented on the laptop through an online link using Qualtrics. The participants played each of the trials and clicked "same" or "different" based on their response. The accuracy percentage of each part was calculated by dividing the correct number of trials by 52 for both melody and rhythm.

Chinese tone Discrimination task

This task was programmed using ZEP (Veenker, 2017) and was opened on the laptop, separately for monosyllabic and bisyllabic discrimination. BT always preceded the MT. The reason to follow this particular order is due to the fact that non-tonal speakers were more accurate in the MT than the BT. Hence, in situations where MT preceded BT, a possible learning effect could occur that might influence the performance in discrimination disyllables (Chen et. al, 2016). However, it is unlikely that BT could lead to this effect as accuracy in MT was already quite high and hence BT is administered first following which MT is administered. During both these tasks the participants were asked to click the "same" or "different" option that appeared on the screen after the presentation of the stimuli. The experiment proceeded quickly and the participant had only a second to answer the question after which it automatically proceeded to the next question. For every correct answer, incorrect answer and a skipped question the scores were coded as 1, 0, and -1 respectively. The accuracy percentage was calculated based on the number of correct trials divided by the total number of trials.

Statistical Analysis

The musical background of the participants was compared between the groups to identify group differences using Mann-Whitney U tests. This was done to avoid any confounding factor of musical experience which could interfere with their performance in the MET (Wallentin et al., 2010). The scores from the language background questionnaires were used to check whether monolingual participants learnt any other languages and the scores revealed that none of the participants showed no formal learning of any other language. However, the limitation here is the fact that an exposure to other languages cannot be controlled since they were living in the Netherlands.

Additionally, we also checked for group differences in the working memory and phonological memory measures by comparing the groups' scores on BDS and Mottier test using a Mann-Whitney U test. Analysis of Covariances (ANCOVA) was used to compute the group differences in rhythmic perception. Their mean scores percentage in the MET-Rhythm subtest was entered as the dependent variable and the language groups were the between-subjects factor. The covariates that were considered for this analysis were the participants' scores of BDS and Mottier test as well as their performance in the MET-Melody subtest. These were the covariates that were used in previous studies as well (Roncaglia-Denissen et al., 2013; 2016) as it is known that working memory and the other subtest of MET have an influence in the MET performance (Wallentin et al., 2010).

The participants' performances in the Chinese Tone discrimination tasks, specifically the number of missed trials, were also assessed using independent *t*-tests in order to see differences in terms of how quickly the participants responded that might relate to the executive control advantage seen in multilinguals. The language groups were entered as between-subjects factor and the number of missed trials of MT and BT tasks and their accuracy percentage in both the tasks as dependent variables.

Experiment 1 Results

Musical Background

Mann-Whitney U test was performed to compare differences in the musical background of the English and Finnish groups. Their perceptual abilities, musical training, and number of years of formal training were entered as dependent variables keeping the language groups as the between-subject factor. With respect to the musical background, no significant differences were present between the groups' musical perceptual abilities (U = 90.5, p = .367), training (U = 107.5, p = .838), and years of formal training (U = 143, p = .217). Their mean scores in the perceptual ability and musical training questionnaires from the MSI along with the mean of number of years of training are shown in Table 1.

Phonological and working memory measures

The results exhibited a significant difference between the groups in their Mottier Test performances, U = 179, p <.05, indicating that the Finnish Multilingual group (M = 28.8, SD = 3.1) outperformed the English Monolingual group (M = 24.8, SD = 3.6). However, there was no significant difference in the BDS scores, U = 87.5, p = .305 between the Finnish multilinguals (M = 7.4, SD = 2.2) and English monolinguals (M = 8.4, SD = 2.5).

Rhythmic Aptitude

To compare the rhythmic aptitude between the two groups, ANCOVA was used, and the scores on BDS, Mottier Test and other subset of MET (MET-Melody) were entered as covariates. No significant group difference in their MET-Rhythm scores, $F(1,28)$ = 3.415, p = .076 (r^2 = .229) was found. This shows that the Finnish multilinguals did not significantly differ in their rhythmic perception from English monolinguals. However, as seen in Figure 1, Finnish multilinguals showed a higher percentage in their accuracy of MET-Rhythm test than the English monolinguals but this was not significant.

Chinese Tone Discrimination Task

On comparing the participants' discrimination accuracy in the Chinese Tone discrimination task, no group differences were found, for both MT and BT. Since the task was designed in such a way that the participants had only one second to answer, their ability to respond on time was assessed by comparing the number of missed trials between the groups. For MT, the missed trial count between groups did not differ significantly, $t(28)$ = 0.440, *n.s.* and for BT, similar results were seen, showing no significant difference, $t(28)$ = 0.090, *n.s.* The mean values of the number of missed trials per group are shown in Table 2.

Table 1.
Mean of the number of years of training and Musical Sophistication Index (MSI) subscales: Perceptual Ability, Musical training.

	English Monolinguals		Finnish Multilinguals	
Variables	Mean	SD	Mean	SD
Number of years of musical training	2.2	2.5	4.1	3.8
MSI-Perceptual Abilities	46.8	6.5	44.06	8.11
MSI-Musical Training	21.7	7.7	21.8	9.1

Table 2.
Mean and Standard Deviation of Number of missed trials in Chinese Tone Discrimination tasks.

	English Monolinguals		Finnish Multilinguals	
	Mean	SD	Mean	SD
Missed Trials in MT[1]	16.16	19.45	10.33	8.3
Missed Trials in BT[2]	16.28	12.63	15.90	11.09

[1]Monosyllabic Discrimination
[2]Bisyllabic Discrimination

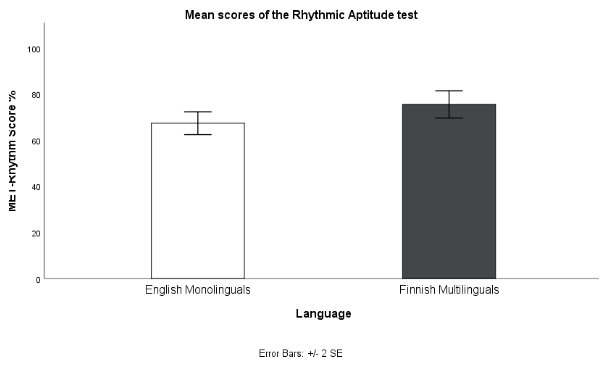

Fig.1. Mean scores in MET-Rhythm subtest among English Monolinguals and Finnish Multilinguals showing the error bars that indicate standard error.

Discussion

This experiment aimed to explore the enhancing effects of being a multilingual on musical rhythmic perception. Additionally, we also looked at whether speaking languages that are different on unit level but share the same metric preference can contribute to this effect. English monolinguals and Finnish multilinguals represented a language grouping that enabled us to observe the effects of multilingualism. With respect to rhythmic diversity, English is a stress-timed language and Finnish is a syllable-timed language and both share the metric preference for trochee, which was in contrast to the languages grouped in previous studies that differed in both unit level classification and metric preference (e.g., Roncaglia-Denissen et al., 2013; 2016). The groups were administered with a musical aptitude test using MET, cognitive tests on working memory and phonological memory and a Chinese tone discrimination task. To answer our research question whether Finnish multilinguals are better in musical rhythmic perception than English monolinguals, we compared MET-Rhythm scores of the two groups, controlling for the cognitive measures and MET-Melody score.

The results showed that Finnish multilinguals did not show a significantly higher performance in the rhythmic perception task compared to the English monolinguals. Although the average of the rhythmic aptitude score was higher in Finnish multilinguals the difference was not significant. This is contrary to the work done earlier (Roncaglia-Denissen et al., 2016) which showed that second language learners performed better than monolinguals. In terms of rhythmic variability, the differences in Finnish, and English, being syllable-timed and stress-timed languages respectively, did not account for an enhancement in musical rhythmic perception. This result also does not conform with the findings from Roncaglia-Denissen et al. (2013) which showed that Turkish-German learners performed better than German-English learners in the rhythmic aptitude test. However, it is to be noted that the Turkish and German have differences in rhythmic properties both at the unit level and metric preference as they are syllable-timed and stress-timed languages respectively, with preference for the iambic foot for Turkish and trochaic foot for German. This is not the case for Finnish, and English that were studied in this experiment as they are syllable-timed and stress-timed languages respectively but shared the metric preference of trochee. This could mean that, it is important for the languages to differ not only in unit level classification (syllable-timed or stress-timed), but also in word level (metric preference of trochaic or iambic) to be able to see a significant enhancement in musical rhythmic perception. As the Finnish multilinguals were not exposed to rhythmic diversity in terms of the metric preference, their sensitivity to rhythmic differences might not have been as high as individuals who are exposed to languages having more variations in their rhythmic properties of unit level classification and metric preference, as seen in Turkish-German learners. This could possibly explain why the transfer of learning effect from language to music was not evident. However, Arvaniti & Ross (2011) have mentioned that this type of rhythmic classification cannot be reliable or translated based on listeners' perception so it is questionable to use this mode of classification. Being the first study looking at rhythmic transfer from the perspective of sharing a metric preference, no strong claim regarding the effects can be made without a replication or a follow-up study. It would be useful to analyse the language properties further to see what features could be teased apart in order to see a significant transfer effect. For example, as this experiment looked at languages that differed in unit level rhythmic classification having shared metrical preference, a next step could probably move in the direction of comparing languages that have same unit level rhythmic classification but differ in metric preference. For instance, participants who speak both Turkish and Spanish could be recruited and compared with Turkish-German speakers. Since both Spanish and Turkish are syllable-timed languages they differ in metrical preference as Turkish is iambic, preferring word final stress (Inkelas & Orgun, 2003) while Spanish is trochaic (Schmidt-Kassow et al., 2011). By comparing these two language pairs, more insight on the influence of rhythmic variation could be established.

In addition to rhythmic perception, the groups were also compared with their performance on the Chinese tone discrimination task. We expected to see similar trends of bilingual advantage in discrimination accuracy as shown in Chen et al., (in prep) but found that the results of English monolinguals were on par with Finnish multilinguals in discrimination accuracy and number of missed trials. This failed to show a multilingual advantage which made us rethink about the true monolingual nature of the English participants. The English monolinguals that participated in this experiment were exchange or graduate students studying in the Netherlands who also differed in origin of English-speaking countries. Recruiting English monolinguals from the same country living in an English speaking environment like England might prove to be a better group for comparison with multilinguals. However, in studies by Roncaglia-Denissen et al. (2016) and Chen et al. (in prep), only Turkish monolinguals were used to compare the rhythmic perception and Chinese tone discrimination accuracy with second language learners, and the monolingual group had lower scores in all the tasks. Future studies can broaden the dataset by studying other monolinguals to further validate the presence of a bilingual advantage in musical rhythmic perception.

EXPERIMENT 2 – PITCH PERCEPTION

Background

While looking at effects of music on language perception, it has been found that musical training enhances mandarin tone perception among non-tonal speakers (e.g., Hung & Lee, 2008; Mok & Zuo, 2012). The auditory brainstem response is said to be domain general since the brainstem shows activation for pitch processing in both music and language (Bidelman, Hutka & Moreno, 2013). This could mean that possible effects can be seen while observing effects of language skills on musical perception. Studies based on the transfer of learning from language to music have found that tonal language speakers show better perceptual discrimination of musical pitch (e.g., Pfordresher & Brown, 2009). Roncaglia-Denissen et al. (2016) also studied the transfer effect focusing on pitch perception, and found that Chinese-English bilinguals show better performance in melodic aptitude compared to Dutch-English bilinguals and Turkish Monolinguals. Chen et al. (2016) also found that Chinese native listeners outperformed the Dutch native listeners in musical tasks. They also looked at the correlation of the performances of both the musical aptitude test and the lexical tone discrimination task for the Dutch learners and Chinese listeners in order to explore the relationship in pitch processing in language and music. No correlation between language and music tasks existed among Chinese-English bilinguals, but Dutch-English bilinguals showed correlation between the musical task and the lexical tone discrimination task. This difference led the authors to propose the "split hypothesis": Native tone language listeners tend to split the input of lexical tones from other types of pitch variation, in this case, musical pitch. Although cross domain benefits, like better melodic pitch perception among tonal language speakers, are evident between the domains of language and music, it is important to note the acoustic pitch input that tonal language speakers receive, is contextually different from nontonal language speakers as the former has tonal exposure with pitch playing a lexical role. This could explain why a correlation between musical and language tasks existed only for nontonal speakers and not Mandarin Chinese speakers as nontonal speakers perceive the input from a general psychoacoustic perspective without any contextual differences.

Experiment 2 aimed to look at the effect of learning a tonal language on the melodic perception by comparing the performance of adult tonal language learners in melodic aptitude tasks with that of tonal and nontonal speakers. For this purpose, native Dutch speakers who are learning Mandarin Chinese were recruited and their performance in melodic aptitude tests were compared with those of Chinese-English bilinguals and Dutch-English bilinguals, representing a native tonal group and nontonal group respectively. The learners of Chinese were further divided into two categories: Beginners and Advanced, based on the number of weeks of learning. The performance of both groups of Chinese learners in melodic aptitude test were compared with Chinese-English bilinguals and Dutch-English bilinguals to check whether the enhanced musical pitch perception is prominent among learners of Mandarin Chinese.

Furthermore, this experiment also aimed to explore the relationship between the melodic tasks and the lexical tone discrimination tasks to see whether the split hypothesis holds for learners of a tonal language. Since the split hypothesis proposes that individuals with tonal exposure tend to split the perception of lexical tones from musical pitch variations, it would be interesting to see whether Chinese learners show similar trend like the Chinese-English participants from Chen et al. (2016). Therefore, we hypothesized that advanced learners especially, will not show any correlation between the performance of lexical task and musical task due to their exposure to tone language that enables them to split the perception of lexical tones from musical pitch variation.

Methods

Participants

The participants in Experiment 2 consisted of 27 Dutch learners of Mandarin Chinese, who were categorised into Beginner Learners (N=14, Mean Age = 22.07 years) and Advanced learners (N = 13, Mean Age = 23.31 years) based on the number of weeks spent in learning Mandarin Chinese. They were students who were enrolled in Chinese language learning courses from Radboud in'to Languages, Lischerijn college in Utrecht and the programme "China studies" from Universiteit Leiden. Only those who had less than 3 years or no musical experience were recruited.

This experiment also consisted of data of 15 Dutch-English Bilinguals (N = 15, 8 females, Mean Age = 25.53 years) from the study by Roncaglia-Denissen et al. (2016) and 15 Chinese-English bilinguals (N = 15, Mean age = 25.13 years) from Chen et al. (2016) that were studied along with second language learners of Mandarin Chinese.

All the participants had normal or corrected-to-normal vision and did not have any neurological impairment, epilepsy, hearing and visual impairments. Upon giving detailed instructions about the experiment, written consent was obtained from the participants for the purpose of data collection and publication use. They were provided with a monetary compensation of 10 Euros.

This experiment was approved by the Ethics Committee of the Faculty of Humanities of the University of Amsterdam, Faculty of Social Sciences of the Radboud University in Nijmegen and by the Ethics Committee Psychology (CEP) of Leiden University.

Materials

The same tasks: MET, Chinese Tone discrimination task, Mottier test and BDS that were used in Experiment 1 (see Materials under Experiment 1) were used for this Experiment. The differences between the materials used in Experiment 1 and Experiment 2 were in the recorded Stimuli for Mottier test and BDS as they were recorded by a Native Dutch speaker since the participants in this Experiment were native Dutch speakers.

For this experiment, the language and musical background questionnaires were combined into a single questionnaire that focused more on the participants' Chinese learning history unlike the extensive language and musical background questionnaires that were used for Experiment 1. It included questions related to their proficiency in reading, speaking, writing and listening skills in Chinese as well as their first and second language and number of years of musical training.

Procedure

The procedure of administration and scoring of BDS, Mottier Test and Chinese Tone discrimination was identical to Experiment 1. With respect to MET, the test was administered through PsychoPy in place of Qualtrics. In this case, the stimuli automatically played following a fixation cross after which "Same" or "Different" appeared on the screen. Depending on their response the participants pressed the left-arrow key for "Same" and right-arrow key for "Different".

Statistical Analysis

The Mandarin Chinese proficiency among Beginners and Advanced Learners was analysed by observing the participants' competency in Mandarin Chinese skills such as understanding, reading, writing and speaking. This is useful to show a clear distinction between the beginners and advanced learners. To compare their skills, Mann-Whitney U tests were performed by using each of the skills as dependent variables and the Chinese Learner groups (Beginners, Advanced Learners) as between-subjects factor.

The scores of phonological and working memory measures were also compared between all the four groups: Dutch-English, Chinese-English, Beginners and Advanced learners of Mandarin Chinese. This was done with the help of two Analyses of Variance (ANOVAs), one having Mottier scores as a dependent variable and the language groups as a between-subjects factor, and the other used BDS score as a dependent variable with the language groups as between-subjects factor. It is important to note that for this part of the analysis the Dutch-English bilingual data were obtained from an existing data set (from Roncaglia-Denissen et al., 2016).

Moving towards the aim of study we focused on the group differences in the performances in the melodic aptitude test. For this, ANCOVA was used, having the MET-Melody score percentage as the dependent variable while the scores on Mottier test, BDS and their accuracy percentage in the MET-Rhythm subtest were entered as covariates. The language groups were the between-subjects factor. This was also followed from previous studies since working memory measures and MET subtests influence the MET performance (Wallentin et al., 2010)

To analyse the cross-domain correlation between melodic perception and Chinese tone discrimination, Pearson's product moment correlation was used. This was done across groups for both MT and BT tasks. In this section of analysis, the Dutch-English data were from a different study by Chen, Liu & Kager (2016) as the data of Chinese tone discrimination task of Dutch-English group (from Roncaglia-Denissen et al., 2016) were not available[1].

Experiment 2 Results

Mandarin Chinese proficiency

The Mandarin Language skills – understanding, speaking, reading and writing were compared among the beginners and advanced learners of Chinese. For "understanding" skills the two groups differed significantly, $U = 166, p < .001$.

Significant differences were also found in speaking skills, $U = 143, p < .05$. Reading ($U = 157.5, p < .001$) and Writing skills ($U = 132.5, p < .05$) also showed significant differences between the beginners and advanced learners of Chinese.

The mean value of the total number of weeks for which the beginners and advanced learners spent time in learning Mandarin Chinese were also computed. Beginners spent an average of 33 weeks in learning Chinese whereas the advanced learners spent an average of 220.77 weeks in learning Chinese. The categorisation of the Chinese learners were based on the number of weeks spent in learning and seeing significant differences in Mandarin Chinese skills assessing the proficiency validates the usage of criteria of weeks as method of splitting the group.

Phonological & working memory measures

The ANOVA that was carried out to assess differences in working memory performance using BDS scores, revealed significant group differences, $F(3,44) = 3.222, p < .05$. On performing post-hoc analysis using Bonferroni corrections, significant differences were present between Dutch-English Bilinguals ($M = 8, SD = 2.2$) and Chinese-English Bilinguals ($M = 11.11, SD = 3.3$). Other between-group differences including Beginners and Advanced learners of Chinese were not significant. While comparing the Mottier Test scores, no significant differences were found between groups.

Melodic Aptitude

On performing ANCOVA with MET-melody score as dependent variable, the results showed that there was no significant difference between the groups regarding their melodic perception. However,

[1] The data of MET scores for both the sets of Dutch-English data were compared in order to check for group differences. No significant differences were found for MET Melody ($U = 104.5, p = .744$) and MET-Rhythm ($U = 126, p = .595$). As the groups do not differ in their performances in MET, using the different data set would not have influenced the outcome of analysis.

while performing a planned comparisons of the means of the MET Melody scores, the Chinese-English participants had significantly higher mean score (M = 76.66, SD = 6.24) compared to Dutch-English bilinguals (M = 68.06, SD =12.5), Beginners (M = 67.5, SD=13.8) and Advanced learners of Chinese (M = 68.04, SD = 9.30) as seen in Figure 2.

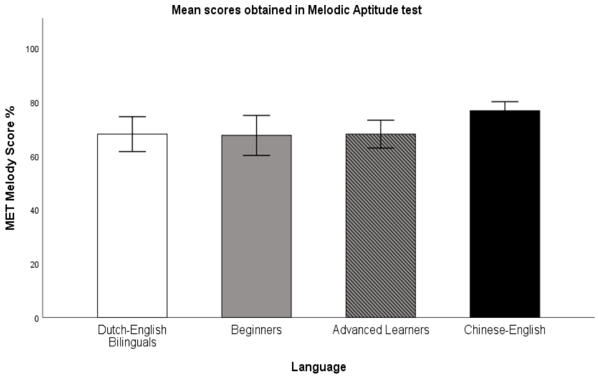

Fig. 2. This figure shows the mean scores obtained by all the four groups in the MET-Melody subtest. Chinese English group had the highest mean which differs significantly while comparing it with other groups.

Chinese Tone vs Melodic Pitch Discrimination

Pearson's product moment correlation was used to observe the relationship between the MT and BT performance and the MET-Melody scores for each

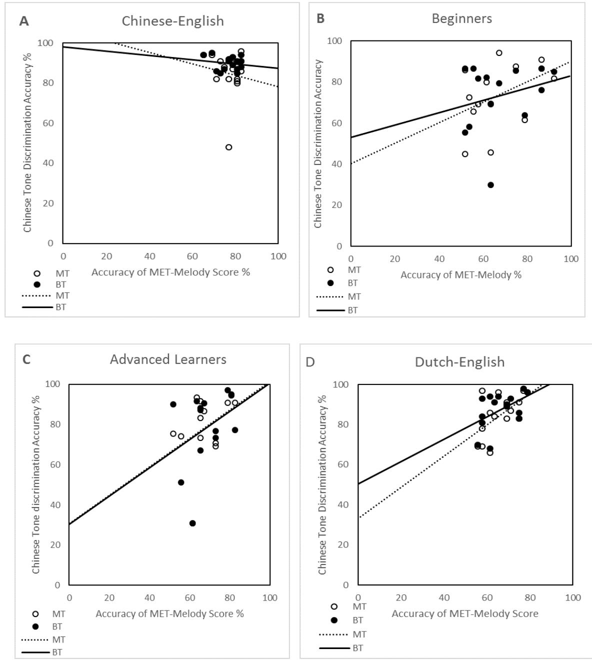

Fig. 3. The correlation plot between Chinese tone Discrimination Accuracy % and MET- Melody Scores % for the four groups. A. Denotes the correlation analysis in Dutch-English Bilinguals in which MT and MET-Melody scores are significantly correlated (r = .581) and there is also a positive correlation for BT and MET-Melody but they are not significantly correlated (r = .488). B. Correlation plot for Beginner learners of Mandarin Chinese which show a less positively correlated trend which is not significant. C. Advanced Learners also show no significant correlation for both BT and MT (Table 3. Illustrates more details on the relationship between the variables). D. Chinese English participants also show no significant correlation between Chinese tone discrimination task and MET-Melody Scores.

Table 3.
Correlation between MET-Melody scores and discrimination accuracy for Monosyllabic Discrimination (MT) and Bisyllabic Discrimination (BT)

		Dutch-English		Beginner Learners		Advanced Learners		Chinese-English	
		MT	BT	MT	BT	MT	BT	MT	BT
MET-Melody	Correlation Coefficient	.581*	.488(*)	.441	.252	.384[a]	.340[a]	-.133	-.166
	p-value	.023	.065	.115	.385	.195	.256	.637	.554

*Significant at p < .05.
[a]Among the advanced learners there was one participant as an outlier with the mean Accuracy of approximately 30% for both MT and BT, by removing this outlier the correlation coefficient for advanced learners is r = .182 (for MT) and r = .090 (for BT).

group. For the Dutch-English bilingual group, there was a significant correlation between the MET-Melody score and the MT discrimination

accuracy, $r = .581$, $p < .05$. Although there was a similar type of correlation for BT, it was not statistically significant, $r = .488$, $p = .065$ (Fig. 3A). There was no significant correlation between MET-Melody and BT and MT tasks for the other three groups – Chinese-English Bilinguals, Beginners and Advanced Learners of Chinese. There was also a trend in the degree of correlation between MET and MT, BT discrimination accuracy between the four groups as the correlation coefficients decreased from Dutch-English bilinguals to beginners and advanced learners and this showing no correlation among Chinese-English bilinguals (see Table 3. For correlational plot, see Fig. 3).

Discussion

The aim of this experiment was to look at effects of learning a tonal language on melodic perception. To observe possible transfer of pitch perception skills from language to music, we compared the melodic aptitude of learners of a tonal language, in this case Mandarin Chinese, with that of Dutch-English and Chinese-English Bilinguals. As previous studies have shown that native Chinese speakers show better melodic perception than non- tonal speakers (e.g., Roncaglia-Denissen et al., 2016; Wong et al., 2012) we expected tonal learners, especially advanced learners, to show better melodic perception than nontonal speakers. The results indicated that Chinese-English bilinguals performed significantly higher than the other three groups: Dutch-English bilinguals, beginners and advanced learners of Mandarin Chinese. This result showing enhanced melodic perception of Chinese-English bilinguals replicated the findings of previous studies (e.g., Chen et al., 2016). This enhancement in melodic perception could be attributed to the exposure and proficiency in discriminating lexical tones that enable the Chinese-English bilinguals to perform better in perception of musical melodies. Although beginners and advanced learners of Chinese were exposed to the Chinese tones for roughly 33 weeks and 220 weeks respectively, no significant enhancement in melodic perception was seen while being compared with the nontonal group of Dutch-English bilinguals. Tonal language learners and native speakers differ in terms of amount of exposure which could possibly be a reason as to why tonal language learners did not perform as well as the native speakers. This is supported by the findings of Bidelman, Gandour & Krishnan (2010) who pointed out that length of exposure is positively associated with the tonal speakers' melodic discrimination abilities and that the neural representation of cross-domain transfer relied on the experience and amount of training an individual has in one of the domains. This could mean that learning a tonal language may not be sufficient to reap the benefits of enhanced melodic perception that is evident among native tonal speakers.

We also aimed to explore the relationship between language and music by observing the cross-domain correlation following up on the "split hypothesis" proposed by Chen et al. (2016). The correlation analysis between the melodic aptitude test (Musical domain) and Chinese tone discrimination task (Language domain) was done for each of the four groups: Chinese-English bilinguals, Dutch-English bilinguals, beginners and advanced learners of Chinese. The Chinese tone discrimination task included both monosyllabic discrimination (comparison between two monosyllabic tones) and bisyllabic discrimination (comparison between two pairs of bisyllabic tones). The results showed that Chinese-English bilinguals had no correlation between the lexical tone discrimination task (both monosyllabic and bisyllabic discriminations) and their melodic aptitude performance, which was similar to the results seen in Chen et al. (2016). The beginners and advanced learners of Chinese also did not show any correlation between the melodic aptitude task and monosyllabic and bisyllabic tone discrimination present in the Chinese tone discrimination task. As portrayed in Chen et al. (2016), the reason behind why there is no correlation among native tonal speakers could be due to the fact that the pitch information that they receive from both the tasks (MET and Chinese tone discrimination) contextually differ. Being tonal speakers, the Chinese-English bilinguals have an intact representation of Chinese tones that carry a lexical role due to which they may split the processing of lexical tones from the processing of other pitch variation from other domains, in this case, music (Chen et al., 2016). Likewise, the same reasoning is valid to explain the absence of correlation between the melodic task and Chinese the tone discrimination task among beginners and advanced learners of Chinese. Both groups have been exposed to lexical tones through learning Chinese, which enabled them to perceive the incoming pitch variations of Chinese tone discrimination task differently from the melodic aptitude task leading to split processing. There has been evidence from Nan, Sun & Peretz, (2010) supporting the independent nature of pitch processing as seen in native tonal speakers who have congenital amusia (inability to discriminate or reproduce different melodic tones). This shows that there may not unified processing of pitch input from both language and music for speakers of tonal language who learn them in different contexts. However, for non-tonal speakers, there is no difference in context in terms of the pitch information they receive from both the tasks. From our results, we noticed that the Dutch-English bilinguals showed significant correlation between the monosyllabic discrimination and melodic task similar to the results of Chen et al. (2016). There was also a similar trend seen between bisyllabic discrimination and melodic task performances among Dutch-English bilinguals. The significant correlation between language task and music task among Dutch-English speakers can be attributed to the fact that they did not undergo any training in learning Chinese tones or music and therefore processed the incoming pitch input as a general psychoacoustic level that led to their correlation. Studies in the past have shown how lexical tones are processed differently among tonal language speakers and nontonal language speakers. For example, Halle, Change & Best (2004) found that French listeners processed lexical tone differently from Cantonese listeners but were still sensitive to the variations. Another study by Francis, Ciocca, Ma & Fenn (2008) found differences in perceptual spaces for tonal speakers and nontonal speakers while processing lexical tone. These findings are in line with the reasoning indicating that nontonal speakers do not split the incoming pitch input as lexical tone from melodic pitch variations.

There is also visible trend of decrease in amount of correlation between melodic task and Chinese tone task: Higher correlation between language and music was evident among Dutch-English bilinguals and this degree of correlation decreased from beginners to advanced learners of Chinese, further leading to no correlation seen among Chinese-English bilinguals. This trend gives us an idea on how the amount of exposure to tone variations in a language can possibly have an influence on nature of relationship between the performances in the language and music tasks.

Exploring the relationship between language and music by observing the "split processing" can give us more details regarding the factors responsible for transfer from language to music to take place. Although the Chinese-English group shows no correlation between the musical task and Chinese tone discrimination task, they still show higher accuracy in melodic aptitude than Dutch-English bilinguals, beginners and advanced learners. This indicates that even though performance in language and music tasks may not be directly related as seen in Chinese-English bilinguals and learners of Chinese, the exposure in tonal variations in Chinese leads to perceptual enhancement of factors like pitch acuity that is shared both by music and language. This enhancement of the common factor like pitch acuity, in turn, helps in perceiving musical tones better. It has been found that expertise in language and music show neural enhancement in auditory brain stem that may lead to better pitch acuity (Bidelman, Gandour & Krishnan, 2011). Hence, looking beyond the direct influence of lexical tone performance on musical task, and knowing that they are not directly correlated shows us the possibility of underlying factors like pitch acuity that could lead to the transfer of learning effect. Future studies can explore this further, by implementing neuroimaging methods in addition to the behavioural evidence.

GENERAL DISCUSSION & CONCLUSION

Both experiments carried out in this study aimed at investigating the influence of experience from speaking certain languages on musical rhythmic and melodic perception. Experiment 1 focused on the transfer of rhythmic perception skills from language to music, while Experiment 2 looked at the transfer of pitch perception skills obtained from learning a tonal language to perceiving melodic differences. Carrying forward from the past studies, the first experiment compared the rhythmic aptitude among two language groups that differed in unit level classification but shared metric preference of trochee. The results did not show a significant enhancement in rhythmic aptitude, possibly because the languages that were studied shared the metric preference. Another important factor to take into account is that the monolingual group may not have been representative of a general monolingual population, because they performed better than another monolingual group tested in the previous study (Roncaglia-Denissen et al., 2016). Therefore, further research needs to be conducted to include other monolingual samples in order to validate the bilingual advantage observed in rhythmic perception skills.

In the second experiment, the native tonal speakers who were Chinese-English bilinguals outperformed all the groups including the Chinese learners, in the melodic aptitude test. This indicates that although the learners of Chinese were exposed to the lexical tone variations, learning a tonal language was not sufficient to exhibit cross-domain transfer that was seen among native tonal language speakers. Instead, interesting patterns of correlations between their lexical tone discrimination accuracy and melodic perception were found. Only the Dutch-English bilinguals group showed significant correlation between their performances in the lexical task and melodic task. The rest of the groups that had been exposed to lexical tones, although varying in amount of exposure, showed no correlation between the two tasks. This may suggest that the participants with no exposure to lexical tones (Dutch-English) and participants with exposure to lexical tones (Chinese-English bilinguals, Beginners and Advanced learners of Chinese), process the incoming tonal information in different ways: As the pitch input from the Chinese tone discrimination task and MET are contextually different for the Chinese learners and Chinese Native speakers, their processing of the lexical tone input is split from the musical pitch variations, implying differences in the way they perceive the pitch input. This ability to split the pitch information is absent among non-tonal speakers as they perceive the input as general acoustic information in the psychophysical form.

Knowing that tonal experience influences the way tonal input is perceived, we understand that the cross-domain transfer between language and music might rely on a deeper underlying shared factor since the two domains do not show any direct correlation in terms of their performance in the language and musical tasks. However, this needs to be further supported by neuroimaging evidence that might give a better picture on the split processing of lexical and musical tones that differ contextually for tonal and non-tonal speakers.

Hence, findings from both the experiments expand the literature on transfer of learning effect from language with respect to the influence of linguistic experience, in terms of speaking languages with rhythmic variability and learning a tonal language on musical rhythmic and melodic perception. Future research can take the findings of both experiments forward, by expanding the study of transfer effect through investigating the mechanisms and cortical areas responsible for music and language and how they rely on each other. This will in turn provide more insight on the relationship between language and music and establish the fact that they are indeed two sides of the same coin.

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