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The Influence of Music Training and Bilingualism on Speech and Music Perception

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The Influence of Music Training and Bilingualism on Speech and Music Perception

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Abstract

This case study investigates the role that bilingualism and/or music training plays on the pitch perception of non-native speech and musical pitch contrasts in 6- to 7-year-old children. This study aimed to investigate two research questions. First, does the infant bilingual advantage in pitch perception persist through childhood? Second, does music training lead to an advantage in pitch perception? There were 4 participants with the following criteria: a monolingual non-musician, monolingual musician, bilingual non-musician, and a bilingual musician. The participants performed a series of perception tasks, including English minimal pairs, Mandarin pitch contrasts, and violin pitch contrasts. It was found that the musician participants outperformed the non-musician participants. In addition, the bilingual musician participant outperformed the bilingual non musician participant. The results of this study serve as preliminary evidence that there is an advantage in pitch perception abilities in children with the presence of music training. While bilingualism alone did not point to an advantage, there was a notable advantage with the presence of bilingualism and music training.

Background

Infants develop the ability to perceive speech and music pitch contrasts as early as six months old. As infants continue to develop, their ability to perceive speech contrasts begins to focus in on their native language, and they lose the ability to perceive non-native speech contrasts (De Groot, 2011). Factors like the presence of bilingualism can influence the way that infants perceive pitch contrasts, however. A study by Liu and Kager (2017) suggests that bilingual infants have an increased ability to perceive musical and speech contrasts as compared to same-aged monolinguals. Research studies have revealed that musicians outperform non-musicians on the perception of non-native pitch contrasts, as well (Krishnan, Gandour & Bidelman, 2012). It remains uncertain if these patterns continue in child and adulthood, however. Additionally, the potential influence and interconnections of bilingualism and music training on pitch perception in school-age children is unknown. The current study investigates the influence that music training and bilingualism have on the pitch processing of non-native speech contrasts and music pitch contrasts in 6- to 7-year-old children who vary in language and music experience.

There are multiple studies investigating similar areas that sparked interest for this study. Liu and Kager (2017) conducted a study to test bilingual and monolingual 9-month-old infants on their perception of pitch changes in both music and non-native sounds. The researchers first presented the infants with four tonal differences in the Mandarin language, a language that was non-native to all participants. The stimuli were recorded by a native Mandarin speaker, and were then manipulated through PRAAT software to make sure that the frequency changes were regulated. After each pitch change was presented, the looking time of the infants was recorded. Infants who were able to perceive the pitch contrasts in the non-native language had a longer looking time than infants that could not. This experiment was then repeated with violin pitch changes. The results of this study concluded that the bilingual infants were able to perceive the music tonal changes, while monolingual infants were not. A later study conducted by Liu, Peter, and Weidemann (2019) confirmed that 11-month-old bilingual infants perceived the non-native pitch contrasts in addition to music pitch contrasts. The researchers concluded that the increase in pitch perception may be due to bilingual infants' increased flexibility in language learning and a potential increase in brain neural plasticity. At 12 months of age, however, bilingual infants lose the ability to perceive non-native speech contrasts, as they begin attuning to their native languages (De Groot, 2011). These studies led to the inquiry of whether the bilingual advantage in perception, specifically musical pitch, will persist into child and adulthood.

A study by Stepanov et al. (2018) aimed to determine whether music training has an effect on non-native speech perception in children. One hundred and eight five- and six-year-olds were presented with tonal differences in French, a language none of the participants had been previously exposed to. Half of the participants had previously been exposed to music training, while the other half had not. After being presented two sentences, the participants were asked to identify whether the sentence was different or the same. The authors concluded that the participants who had music training were able to perceive the non-native pitch contrasts, while the participants who did not have music training could not. While this study did not test participants on the ability to perceive musical pitch contrasts, it is reasonable to infer that music-trained children could perceive musical pitch contrasts better than those who are not music-trained. This inference led to the research question of whether the presence of music training will increase non-native speech and music perception of bilingual children.

A number of connections between the domains of language and music have been proposed in literature. Learning music and a second language both require high cognitive functioning, including increased sustained attention, working memory, and auditory control (Chobert & Besson, 2013). In addition, the effects of learning music and a second language have been found to have great cognitive advantages such as increasing neuroplasticity, flexibility, and preserving memory (Moreno et al., 2015). It has also been suggested that musicians outperform non-musicians in learning language, pointing again towards advantages within these populations (Slevc & Miyake, 2006). There has not been much research done, however, to compare the bilingual and musically-trained populations, especially in the area of pitch perception. Studying the bilingual and musically-trained populations together will help researchers draw connections between the domains of language and music and their impact on pitch perception in children.

The current experiment is a case study investigating the influence that music training and bilingualism have on the pitch processing of non-native speech contrasts and music pitch contrasts in 6- to 7-year-old children. The participants in this study performed a variety of pitch perception tasks, including discriminating between Mandarin speech sound contrasts and violin pitch contrasts. The tasks are based on the study conducted by Liu and Kager (2019) on infants' ability to perceive speech and music contrasts. Based on the previous findings, it was expected that children with the presence of bilingualism and/or music training would perceive speech and music pitch contrasts better than monolinguals without music training. Further, it was expected that the participant with bilingualism and music training present would perform tasks of pitch perception with the highest accuracy.

Methods

Participants

The participants included a monolingual non-musician, a monolingual musician, a bilingual non musician, and a bilingual musician. All of the participants were either 6 or 7 years old, and there was 1 female participant and 3 male participants. To be considered a bilingual participant, the individual had to use their second language at least 20% of the time, according to a parent report. Both of the bilingual participants in this study speak Spanish at home and English at school. To be considered a musically-trained participant, the individual had to have at least one year of music training. Both of the musicians in this study had more than one year of piano lessons. To recruit the participants, an email and flier were sent out to families in the Indianapolis area. In addition, recruitment occurred via Facebook research pages.

After demonstrating interest in participating in the study, the participants' guardians filled out a consent form that outlined the details of the study. Each participant consented to the recording of audio and/or video via Zoom. Then, the participants and their guardians set up a time for preliminary testing. In order to make sure that all participants were typically developing in speech and language, the participants were administered standardized tests. The Goldman Fristoe Test of Articulation, Second Edition (GFTA-2) was administered to make sure all participants were typical in speech development. The Structured Photographic Expressive Language Test, Third Edition (SPELT- 3) was administered to confirm that all participants were typical in language development.

Finally, the Primary Measures of Music Audiation (PMMA) was administered to assess the participants' musical ability in the areas of tone and rhythm. The tasks in this test include listening to pairs of musical tones or rhythms and determining if they were the same or different. This standardized test was administered so that the participant's scores could be compared to their perceptual abilities. It was expected that the order of performance from lowest to highest on the PMMA would be as follows: monolingual non-musician, bilingual non-musician, monolingual musician, bilingual musician. The scores of each participant are shown in Table 1. Preliminary testing confirmed that each participant was typically developing in speech and language, all scoring within normal limits for their chronological age.

Table 1. Performance on Primary measures of music audiation test

Group	Tonal Score	Rhythm Score	Composite Score
Monolingual Non-musician	30	23	53
Bilingual Non-musician	26	28	54
Monolingual Musician	34	28	62
Bilingual Musician	38	34	72

Note: The maximum score possible for the tonal and rhythm sections was 40. The maximum composite score possible was 80.

Stimuli

Stimuli were created for three perception tasks: English minimal pairs (as a control task), non-native speech sound contrasts, and musical pitch contrasts. For the English minimal pair perception task, the words used were *bet* and *vet*. This set of minimal pairs was chosen because the /b/ and /v/ contrast is present in the English and Spanish language. This ensured that there was no potential advantage in the participants who primarily spoke English. After choosing the set of minimal pairs, the audio for each word was downloaded from English Club, an online resource with downloadable audio files of English words. The audio files with each word were uploaded to Audacity. Then, the words were combined into four different arrangements: *bet* and *bet* (same), *bet* and *vet* (different), *vet* and *bet* (different), and *vet* and *vet* (same). Between each word, there was a 2 second pause inserted. Then, each series of words was assigned to a number 1-4. A random number generator was used to pick the order that the audio files would be presented to each participant. Each set of words was presented to each participant three times. After determining the order, the audio files were combined to create one audio file for each participant (4 in total). A random audio file was assigned to each participant using a number generator.

The same procedure was used to create the stimuli for the non-native speech sound contrasts and the musical pitch contrasts. The original audio for these tasks was used in the Liu and Kager (2017) study investigating infants' ability to perceive non-native speech and music pitch contrasts. The audio used for the non-native speech perception task were tonal pitch contrasts in the Mandarin language. The description of the Mandarin pitch contrast stimuli from the Liu and Kager (2017) study is as follows:

> The Mandarin Chinese high level-high falling (T1-T4) tone contrast was selected to create the stimuli with /ta/ as the tone-bearing syllable. /taT1/ 'build' and /taT4/ 'big' are both legal words. Tone-bearing syllable stimuli were recorded using the open source program Audacity® in a sound-proof booth in Utrecht University Phonetics Lab by a Chinese female speaker...Five native speakers of Mandarin Chinese listened to the stimuli in the environmental settings and judged that the stimuli sounded natural (p. 57).

The audio used for the musical pitch perception task were violin pitch contrasts. The description of the violin pitch contrast stimuli from the Liu and Kager (2017) study is as follows:

> To ensure the cross-domain comparison, the musical (violin) tonal stimuli were generated from the same contrast used in Experiment 1. The F0 tiers of the contrasted tonal contrast in Experiment 1 were extracted and replaced the F0 tiers of a violin tone via PRAAT,

> creating novel violin stimuli. In other words, the violin contrast shared the exact same pitch contour as the tonal contrast in Experiment 1, but differed in timbre. Four violin pairs were generated, matching the stimuli design in the first experiment. Five musicians listened to the stimuli and judged that they sounded natural (p. 60).

The audio files were imported to Audacity and manipulated to get the stimuli pairs described above. We followed the same procedures for creating the stimuli for these tasks as described for the minimal pair perception task described above.

Procedure

The data collection process was conducted remotely via Zoom due to COVID-19. The first experimental task administered was the English minimal pairs perception task. This perception task served as a control test of the participants' ability to perceive contrasts in their native/primary language of English. The participants were told that they would be listening to two English words in a row, separated by a two second pause. The participants were directed to decide if the words presented were the same or different. The audio was shared from the administrator's computer through the "share audio" feature on Zoom. After listening to both words, the participant would verbally tell the administrator if the words were the same or different. The administrator recorded the response of the participant on a spreadsheet. The audio was recorded for future reference, as well. The participants listened to 12 pairs of words, 6 of which were the same and 6 of which were different.

After the English minimal pairs perception task, the participants were tested on the non-native Mandarin pitch contrasts. The participants were told to follow the same directions as the previous task. After each pitch pair was presented, the participants were asked if they sounded the same or different. Like the English minimal pairs task, 12 pairs of pitch contrasts were presented to the participants, with half of the pitch pairs being the same, and the other half were different. The pitch contrasts presented that were the same served as the control variable for this task. Regardless of perceptual ability, all of the participants should be able to determine that the identical pitch contrasts are the same. The pitch contrasts presented that were different tested the participants' ability to perceive pitch contrasts in a non-native language. Therefore, if the participants demonstrate the ability to perceive the pitch contrasts, they would respond by saying "different" after the pitch contrasts are presented. If the participant does not demonstrate the ability to perceive the contrasts, they will respond by saying "same" to all of the contrasts presented. The same directions and methods were used to administer the violin musical pitch perception task. This task tested the participants' ability to perceive pitch contrasts in music.

The last portion of the data collection process was a rhythm production task. Each participant was instructed to sing the ABC song using only one word: cat. The administrator made sure that each participant knew the ABC song prior to data collection. The participants were told to follow the rhythm of the ABCs song. The administrator demonstrated the task by singing the word *dog* to the rhythm of the ABC's song. Then, the participants were asked to perform the task on their own using the word *cat*. This task tested the participants' ability to produce rhythm. All participants were able to follow the rhythm of the song.

Results

To determine if the bilingual and musically-trained participants performed higher on the perception tasks, the number of correct discriminations for each task were compared amongst the participants. For the perception task testing the participants' ability to perceive minimal pair contrasts in English, each participant got 6/6 of the contrasts correct. In addition, each participant got 6/6 of the identical pairs correct. This means that all of the participants demonstrated the ability to perceive speech sound contrasts in their native language (specifically the /b/ vs. /v/ contrast in "bet" and "vet"), as well as the ability to recognize when the speech sounds presented were the same. This task served as a control experiment to test the participants' ability to perceive contrasts in their native language, a task that all native English speakers should be able to do with ease. The results of the English minimal pairs perception task are summarized in Table 2.

Table 2. Performance on English minimal pair perception task

Group	Same	Different	Total
Monolingual Non-musician	6	6	12
Bilingual Non-musician	6	6	12
Monolingual Musician	6	6	12
Bilingual Musician	6	6	12

Note: The numbers for the "same" section describe the number of identical words that the participant detected correctly out of 6. The numbers for the "different" section describe the number of minimal pair differences that the participant detected correctly out of 6. The total displays the total number of contrasts that the participant detected correctly.

Next, the results for the non-native tonal perception task were compared amongst the participants. It was hypothesized that the bilingual participants would outperform the monolingual participants in perception of the Mandarin contrasts. In addition, it was hypothesized that the musician participants would outperform the non-musician participants. Finally, it was hypothesized that the bilingual musician would perform the highest out of the group. The results revealed that the bilingual non-musician participant and the monolingual non-musician participant did not distinguish between the Mandarin tonal contrasts. They both identified 0/6 of the tonal contrasts. The monolingual musician participant demonstrated the highest ability to perceive the Mandarin tonal contrasts by correctly discriminating 4/6 of the contrasts. The bilingual musician demonstrated the second highest ability to perceive the Mandarin contrasts (2/6 contrasts correct). All four participants demonstrated the ability to determine when the pitches were identical, as hypothesized. The results of the non-native perception task are summarized in Table 3.

Table 3. Performance on Mandarin tonal non-native perception task

Group	Same	Different	Total
Monolingual Non-musician	5	0	5
Bilingual Non-musician	6	0	6
Monolingual Musician	6	4	10
Bilingual Musician	6	2	8

Note: The numbers for the “same” section describe the number of identical tones that the participant detected correctly out of 6. The numbers for the “different” section describe the number of tonal differences that the participant detected correctly out of 6. The total displays the total number of contrasts that the participant detected correctly.

Finally, the results from the musical pitch perception task were compared amongst the participants. The hypotheses for this task were the same as the non-native pitch perception task. The bilingual non-musician did not demonstrate the ability to perceive the pitch contrasts (0/6 contrasts correct). The monolingual non-musician demonstrated slight ability to perceive the pitch contrasts, as they got 2/6 of the contrasts correct. It should be noted that this participant did not get all of the identical pitches correct (4/6 correct). This was not in line with the hypothesis that all participants would be able to determine when the pitches were identical. The data for this participant will be further analyzed in the discussion section of this paper. Similar to the non-native pitch perception task, the monolingual musician participant demonstrated the highest ability to perceive the musical pitch contrasts (6/6 correct). The bilingual musician participant demonstrated the second highest ability to perceive the musical pitch contrasts, at 3/6 contrasts correct. The results from the musical pitch perception task are summarized in Table 4.

Table 4. Performance on violin pitch perception task

Group	Same	Different	Total
Monolingual Non-musician	4	2	6
Bilingual Non-musician	6	0	6
Monolingual Musician	6	6	12
Bilingual Musician	6	3	9

Note: The numbers for the "same" section describes the number of identical pitches that the participant detected correctly out of 6. The number for the "different" section describes the number of pitch differences that the participant detected correctly out of 6. The total displays the total number of contrasts that the participant detected correctly.

In this case study, the presence of music training led to a higher ability to perceive both non-native tonal speech and musical pitch contrasts. The presence of bilingualism alone did not lead to a higher ability to perceive the contrasts. In combination with music training, however, the presence of bilingualism did lead to the ability to perceive the contrasts. Finally, there was not sufficient evidence to support our hypothesis that the bilingual musician participant would demonstrate the highest ability to perceive the contrasts. In both tasks, the monolingual musician outperformed the bilingual musician. Potential reasoning behind this will be addressed in the discussion section. Overall, the data here suggest that the presence of bilingualism and music training are associated with greater ability to perceive non-native and musical pitch contrasts.

Discussion

The present study aimed to examine the role of bilingualism and/or music training on the perception of non-native speech and musical pitch contrasts. Previous research pointed to a potential bilingual advantage in pitch perception abilities (Liu & Kager, 2017). In addition, background research pointed to a potential advantage in music-trained children in perceiving non-native pitch contrasts (Stepanov, Pavlic, Stateva, & Reboul, 2018). There had not been research done connecting and comparing the two populations and their influence on perceptual skills, however. This study examined two research questions. First, does the bilingual advantage in pitch perception persist throughout childhood? Second, does the presence of music training lead to an advantage in pitch perception? In addition, this study aimed to draw connections between the domains of language and music in relation to pitch perception. It was hypothesized that the participants with the presence of bilingualism and/or music training would be able to perceive speech and music pitch contrasts better than monolingual and non-musician participants. Further, it was expected that the bilingual musician participant would perform the highest on both perception tasks.

Performance on the various tasks supports the hypothesis that the presence of music training could point to a higher ability to perceive non-native and musical pitch contrasts. The presence of bilingualism alone was not sufficient in increasing the perceptual abilities, however. This could be explained by various reasons. It is not surprising that the bilingual participant was not able to perceive the non-native speech contrasts, as previous research suggests that bilingual infants lose the ability to perceive non-native contrasts at 12 months (De Groot, 2011). The inability to perceive the musical pitch contrasts can be explained by other factors. First, the age gap of the participants could have led to a discrepancy in the perceptual ability of the bilingual participant. The bilingual non-musician participant was 6 years 2 months, while the other participants were at least 6 months older. The language development that occurs within 6 months at this age range is rapid and formative. The bilingual non-musician could have not demonstrated the ability to perceive the musical contrasts solely based on the age gap between the participants. The bilingual non-musician's inability to perceive the contrasts could also be explained by the intricacy between the domains of language and music. It could be possible that bilingualism alone is not enough to lead to perceptual advantages; music training may be necessary in addition.

The monolingual musician outperforming the bilingual musician could be explained by multiple variables as well. In addition to extensive piano and singing lessons, the monolingual musician participant received one hour of Hebrew language training a week. This amount of training is not sufficient to classify the participant as bilingual, as one hour a week is less than 1% language use during the week. In order to be considered bilingual, the participant had to have at least 20% usage of the second language a week. Although this participant is not considered bilingual, the Hebrew language exposure could have given the child an advantage in the perception tasks. Hebrew is a tonal language like Mandarin; therefore, it is possible that even <1% of exposure to Hebrew a week led to advantages in the tonal perception task.

The monolingual non-musician not getting all of the identical pitches correct during the musical pitch perception task could point to unreliable data on this task. During the Mandarin tonal perception task, the monolingual non-musician got all of the identical tones correct. In addition, the participant was not able to discriminate between any of the contrasts for this task. During the musical pitch perception task, however, this participant only identified 4/6 of the identical pitches correctly. In addition, the participant correctly discriminated 2/6 of the musical contrasts. Because the participant did not identify the identical pitches correctly, it is possible that the participant resorted to guessing during this task.

Finally, the unexpected patterns of performance could be explained by limitations in the study itself. First and most prominent, the study was intended to be conducted face-to-face in a uniform, controlled environment. Typically, the audio would have been presented to the participants in a sound booth to avoid sound interference and distractions. Because of COVID-19 limitations, the study had to be conducted via Zoom with the participants in their respective homes. Because the data was collected on Zoom, there was a slight delay in the audio being presented. In addition, we did not have control over the participants' internet connection strength and stability at home. These variables may have led to discrepancies in the ability to hear the audio clearly and ultimately perceive the pitch contrasts. In addition, we did not have control over the participants' testing environments. The participants' caregivers were asked to designate a quiet, private space for data collection, but each participant had different testing environments. For example, one participant was in his kitchen during testing, while another participant was in a closed bedroom. The differences in testing environments, along with the unfavorable testing circumstances, could have led to the unexpected results in this study.

This case study provides preliminary data pointing to advantages amongst the bilingual and/or musically trained populations in the perception of non-native speech and musical pitch contrasts. Future research in this domain should be conducted face-to-face in a sound booth to eliminate potential mismatches in testing environments and quality of data collection. In addition, future research should increase the number of participants to improve the reliability of the results, considering even minimal exposure to tonal languages.

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