# Being a tone-language speaker and a musician: the superpower to discriminate melodies?

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# Abstract

It has been shown that musicianship has a positive effect on musical perception. Perhaps a lesser known phenomenon, is that tone-language speakers also have been shown to have improved musical perception. Since both musicians and tone-language speakers have these musical perception benefits, it is interesting to think about what the effect of a combination of the two might mean for musical perception. Therefore, the goal of the current study was to find out whether the combination of being a musician and speaking a tone-language gives you an extra boost when it comes to musical perception. To see whether this hypothesis was true, a melody discrimination task was used. Four groups consisting of non-tone language speaking non-musicians, tone-language speaking non-musicians, non-tone language speaking musicians and tone-language speaking musicians were tested. Results showed that the non-tone language musician group outperformed all the other groups, especially the non-tone language non-musician group and the non-tone language musician group. In conclusion, the hypothesized synergistic effect of the musicianship and tone-language speaker combination was not found. An interesting finding, however, was that among non-tone language speakers the effect of being a musician on musical perception was substantial.

# Content

# 1 Introduction

## 1.1 The role of pitch within music and language

Pitch is an important component in music. It is one of the two main elements musicians use to create melodies, the other being duration (MasterClass Staff: 2022). Musical pitch, as well as timbre – which is *"the sound quality, or tone quality, of a note played on a particular musical instrument"* (MasterClass Staff: 2022) – defines how a note sounds. It is also essential for the existence of different keys and scales and thus a foothold for playing a musical instrument. The meaning of pitch in physics differs in terms of it being described as a specific frequency of a sound wave, which is measured in Hertz (Hz). High pitches have higher frequency vibrations and low pitches have lower frequency vibrations (MasterClass Staff: 2022).

Another domain where pitch is an important component is within language. It is used at word level but also within longer sentences to convey underlying pragmatic information: accentuation, prominence and intonation distinction (Best: 2019). In addition to this prosodic information, it conveys paralinguistic indexical information about the speaker, e.g. the emotions of the speaker, the gender or age etc. (Best: 2019).

Pitch can be extra important for languages that use it to distinguish words, also known as *tone-languages*. These languages make use of *lexical tones*, contrastive sub-syllabic fundamental frequency (pitch) variations referred to as *tonemes* (Jones: 1944). Next to consonants and vowels, tonemes are considered a third class of phonemic elements. Tone languages thus use pitch to make contrast at the segmental level which is non-existent within non-tone languages (Best: 2019). Lexical tones exist in 60 -70% of existing languages. Many of these languages are Asian, African and indigenous American languages, but also a few European and South Pacific (Yip: 2002).

Tones differ in form and usage within different tone-languages. There are languages with two contrastive tones while others have six or seven (Yiu: 2014; Best: 2019). Tones can be assigned to multiple syllables in a word. Furthermore, tone languages differ in how much they rely on lexical tone distinctions. Some rely on them extensively and the tones thus have a high functional load while others rely on them quite restrictively (Best: 2019). Another distinction that has been made is between the definition of a tonal language and a pitch accent language. Pitch accents are only assigned to one syllable in a word. These *lexical pitch accents* are applied to accented syllables of specific words, e.g. this occurs in Japanese and Norwegian.

### 1.2 Non-tone languages vs. tone-languages

It has been argued that tone-language speakers have certain cognitive advantages with regards to pitch perception compared to non-tone language speakers (Bidelman, Hutka & Moreno: 2013; Bradley: 2016). Children who grew up learning a tone-language have been trained to discriminate pitch heights in words in order to understand the semantics, their whole lives. The contrastive pitch in their language is used at every level of the phonological hierarchy (Best: 2019). On the contrary, children who grew up with a non-tone language as their native language have not acquired this explicit skill. Several electrophysiological studies have shown that listeners fluent in Mandarin Chinese have better sensory encoding of simple musical pitch compared to English-speaking controls. These conclusions were drawn because smoother, more robust pitch tracking in their scalp-recorded brainstem responses as well as their overall cortical response magnitudes were found (Bidelman, Gandour, Krishnan: 2011; Giuliano, Pfordresher, Stanley, Narayana, Wicha: 2011).

Bidelman, Hutka & Moreno (2013) compared two groups – differing in whether they were musicians or not – of non-tone language speakers to one group of tone-language speakers (speakers of Cantonese). Participants were asked to conduct two cognitive tasks testing general fluid intelligence and nonverbal working memory and four pitch perception tasks. Results revealed that there was no significant difference in fluid intelligence between the three groups. However, Cantonese speakers showed superior working memory capacity relative to the non-tone language (non-musician) group. Also, the tone-language speakers performed better on the auditory measures compared to the (non-musician) non-tone language participants. They did a melody discrimination task where participants had to judge whether melody pairs – consisting of 6 tones each – were the same or different. The melodies that were different, only had one tone within one of the melodies that was ½ semitone higher or lower, which is smaller than one step on the piano. They repeated this test with a ¼ semitone difference. It turned out that tone-language speakers performed significantly better than the non-tone language speakers on the ½ semitones test but not on the ¼ semitones test.

Bradley (2016) found that speakers of the tone-languages Mandarin and Yoruba outperformed English non-tone language speakers on dynamic aspects of melody (contour and interval). These aspects are argued to resemble important cues to lexical tone perception (direction and slope) in these languages.

## 1.3 Non-musicians vs. musicians

It has been shown that musicians have some cognitive advantages over non-musicians. Bidelman, Hutka & Moreno (2013) compared one musician group to two non-musician groups (which differed in their native language). They found that although there was no difference in fluid intelligence between the groups, musicians showed superior working memory capacity relative to the non-musician controls. Furthermore, musicians demonstrated superior performance on all auditory measures. Lastly, musicians outperformed non-musicians on the ½ and ¼ semitones melody discrimination task, suggesting that – based on the previous analysis – musicianship gives a higher advantage for discriminating melodies than speaking a tone-language.

Skoe & Kraus (2012) found that adults who underwent musical training as a child have more robust brainstem responses to sound than peers who never participated in music lessons. They also found that the magnitude of the response correlates with how recently training ceased. They demonstrated that having had musical training as a child has a positive effect on the auditory perceptual system.

## 1.4 Bidirectionality music and language

Past research has revealed that music and language are closely related to each other. Most research so far has focussed on the influence of music on language (Bradley: 2016), but Bidelman, Hutka & Moreno (2013) were one of the first to centre their paper around the influence of language on music perception. They showed that there are bidirectional influences between the domains of music and language (Bidelman, Hutka & Moreno: 2013;

Bradley: 2016). Musicians have perceptual advantages when it comes to language-specific abilities. They have these benefits because there's an extensive overlap in brain networks engaged during speech and music listening (Bidelman, Hutka & Moreno: 2013).

Furthermore, there is evidence for an interaction regarding pitch processing for lexical tone and music. This interaction exists through an overlap of the way the brain encodes basic sensory properties, especially frequency (Bradley: 2016).

## 1.5 The current study

Since there is an overlap in brain networks involved in music and language perception and both speaking a tone-language and being a musician appears to be beneficial when it comes to pitch perception, it seems like a combination of the two could potentially result in a perceptual boost when it comes to auditory perception measurements.

Past research on the potential synergistic effect of the tone-language musician combination has been done. Cooper & Wang (2012) tested the influence of linguistic and musical experience on Cantonese word learning. They tested native tone-language (Thai) and non-tone language speakers (English) – each subdivided into musician and non-musician groups – on non-native word identification and lexical tone perception. The findings suggest that people with either musical experience or speakers of a tone-language have better non-native word learning proficiency compared to non-tone language non-musicians. However, being a musician was found to be more advantageous than having a tone language background for tone identification. Lastly, no additional advantage was found for Thai musicians, suggesting that the combination of speaking a tone-language and being a musician does not create an extra boost compared to either experience alone with regard to non-native word learning proficiency.

Cooper & Wang (2012) tested the effect of the combination of musicianship and speaking a tone-language on a linguistic aspect. The goal of the current paper is to see whether there is an effect on a musical aspect. Based on earlier findings that showed perceptual auditory benefits for both tone-language speakers and musicians, it would be interesting to see if a boost could be found in this domain.

Interestingly, Bidelman, Hutka & Moreno (2013) – who found advantages for the tone language non-musician group and the non-tone language musician group compared to the non-tone language non-musician group – decided to not sample from a group of participants consisting of tone-language speakers that are also musicians. They did not include this group because they claimed it would not be clear whether the behavioural enhancements would be due to the language or rather the music background.

However, testing this particular group can reveal more information about the strength of the musical perceptual advantage with respect to the musicianship tone-language combination. Therefore, the current paper will test the tone-language musician group in addition to the groups used by Bidelman, Hutka & Moreno (2013) in order to fill this gap in the literature. This resulted in the following main question: is there a synergistic effect to being a tone-language speaking musician with regard to melody discrimination?

To answer this question an adjusted version of the ½ semitone melody discrimination task adopted from Bidelman, Hutka & Moreno (2013) will be used. These researchers did extensive pilot testing to avoid ceiling/floor effects. They also tested a ¼ semitone difference, but they stated that even for musicians, the ½ semitone difference was sufficiently challenging.

# 2 Method

## 2.1 Design

The independent variables were linguistic background and musical background. These two categories were both binary. Within linguistic background there were non-tone language speakers and tone-language speakers. Similarly, within musical background there were non-musicians and musicians. The percentage of correct responses in a melody discrimination task was the dependent variable of this research. A correct response in this research meant any time participants clicked on the “same” button when the two melodies were actually the same or when they clicked on the “different” button when the two melodies were actually different.

## 2.2 Participants

Participants were recruited through the Conservatory of Amsterdam Facebook page, Instagram and WhatsApp. Before the start of the experiment, participants were informed about the goal of the experiment and gave their written consent.

There were 21 participants who took part in this research (four male, 17 female). This gender division was random. They were divided into four groups based on self-reported information about their linguistic background and their music background. A questionnaire regarding musical background and linguistic history had to be filled in by each participant in order to classify them as “musician” or “non-musician” and as speaker of a “tone-language” or a “non-tone language”. Five were speakers of a non-tone language and non-musicians (NT NM). Five were speakers of a tone language – in this study Mandarin Chinese, Cantonese or Vietnamese – and non-musicians (T NM). Six were speakers of a non-tone language and musicians (NT M) and five were speakers of a tone-language and musicians (T M).

The age range of participants was 18 to 35 and participants were asked for their age in the questionnaire. This age range was chosen to avoid getting participants with age-related hearing loss (ARHL). ARHL or Presbycusis is a common chronic health problem affecting individuals above 65 years old (WHO: 2012). However, it can also begin as early as a person's thirties or forties and subsequently worsen gradually over time.

In this paper, the definition of musician was adopted from Bidelman, Hutka & Moreno (2013). Musicians in that study were defined as amateur instrumentalists with at least 10 years of continuous training in Western classical music on their principal instrument. They had to begin at or before the age of 13. Starting before the age of 13 is important since neural changes accompanying musical training during childhood are retained in adulthood (Skoe & Kraus: 2012). Lastly, all musician participants had to have had formal private or group lessons within the past 5 years and they still played their instrument at the time of testing. The definition of a non-musician by Bidelman, Hutka & Moreno (2013) was adopted as well. They defined non-musicians as people who had no more than 3 years of continuous music training on any combination of instruments throughout their lifetime. They also had not received formal music instruction within the past 5 years. Another criteria for the current experiment is that the non-musicians have not played an instrument informally either within the past 5 years.

The tone-language speakers in this study were self-reported speakers of Vietnamese, Mandarin Chinese and/or Cantonese. Whether they spoke a 2nd language was asked, but not relevant for their classification as *tone-language speaker*. The non-tone language speakers were self-reported native speakers of Dutch, English, Spanish, Italian, Japanese, Greek and Polish and if they spoke 2nd languages those languages could not be tone-languages.

Participant 13 from the NT M group was excluded from this study, because this participant claimed to have done the experiment in a noisy room. Therefore, the audio stimuli could not be heard properly. This resulted in 20 participants in total who were included in the data analysis, so five per group.

There were three musician participants who did not meet all the criteria to fall into the *musician* category, but they were decided to be kept in. Participant 14 – who fell in the NT M category – had only eight years of continuous training on this person's principal instrument, but since this is close to ten and the participant met all the other criteria for being a musician, this participant was included. Participant 18 – who was considered a musician – did not specify the amount of years of continuous training. However, this person started at age 12 and met all the other criteria so we kept this participant in. Participant 20 – who was 37 years old – fell outside of the age range, but since ARHL mostly affects people above 65 years old it was decided to include this participant. Participant 21 met all the criteria for being a musician apart from having had private or group lessons within the past five years. It was decided to include this participant in the study because this person started at age 5 – which is very young – and had well over 10 years of continuous musical training.

## 2.3 Stimuli

All the auditory stimuli were made through *Praat* and based on Bidelman, Hutka & Moreno (2013). The melodies – with note names as they are written in Western Music based on the 12-note scale (MasterClass Staff: 2022) – were previously written down by me (Appendix, Table 1). This was done with the help of GarageBand and the melodies were original, so not identical to those created by Bidelman, Hutka and Moreno (2013). There were 40 melody pairs in total. Each melody consisted of six notes each. All notes were in the octave range of C3 to C4 and the melodies were not in particular scales. 20 pairs consisted of the same two melodies (stimuli noted as Melody_same in the appendix). In the other 20 pairs there was one note that differed a ½ semitone (stimuli noted as Melody_different in the appendix). The adjusted – sharpened – note was either note 1, 2, 3, 4, 5 or 6 (this was random) and the adjustment appeared ten times in the first melody and ten times in the second melody.

Like in the experiment of Bidelman, Hutka and Moreno (2013) each note lasted about 433 ms and there were no pauses in between notes. Each melody lasted 2600 ms with a pause of 400 ms in between each melody pair (see Figure 1). Sequences were restricted in duration to minimize working memory effects on melody recognition. There were 40 pairs in total, resulting in 40 responses in total per participant.

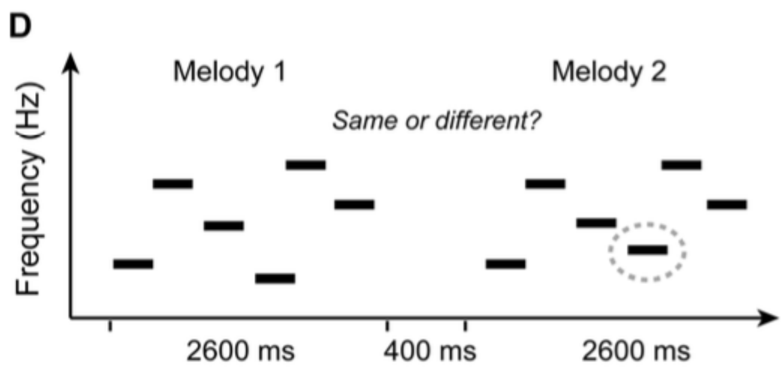


**Figure 1**. *Visualisation of the Auditory* Stimuli. Taken from Bidelman, Hutka & Moreno (2013), p. 4. The fourth note in Melody 2 is a ½ semitone higher.

## 2.4 Procedure

This was an online experiment created through Experiment Designer (ED), a program to create experiments for desktop environments (Vet, D.J., 2022).

After participants signed the consent form, they were asked to fill out a questionnaire (Appendix, Table 2). Questions were asked about their linguistic and musical background. After filling in the questionnaire, the test began.

The task used in this research was online and auditory. Participants were asked to conduct the experiment in a quiet room or with headphones on. They listened to 40 melody pairs in total. These pairs were played in a random order. After each pair, participants had to decide whether the two melodies were the “same” or “different” by clicking on buttons. They could only click on these buttons after the melodies were played in order to avoid clicking before having heard everything. If the response they gave matched the condition of the stimuli – so if they were actually the same or different – the answer was considered correct, but this was not visible to the participants.

# 3 Results

The data were analysed with the help of Rstudio (Urbanek & Bibiko: 2014). For the full data set see Appendix Table 3. There were two between-subject (independent) categorical variables: language background and musical background and one (dependent) numeric variable: percentage of correct responses. Therefore, a two-way ANOVA was performed to analyse the effect of language background and musical background on percentage of correct responses (Table 1).

**Table 1**

*Anova Data Summary*

| | Df | Sum sq | Mean | F value | Pr(>F) |
|---|---|---|---|---|---|
| Language background | 1 | 1.3 | 1.3 | 0.019 | 0.891567 |
| Musical background | 1 | 1361.2 | 1361.2 | 20.892 | 0.000314 *** |
| Interaction | 1 | 320.0 | 320.0 | 4.911 | 0.041525 * |
| Residuals | 16 | 65.2 | 65.2 | | |

The two-way ANOVA revealed that there was a statistically significant interaction between the effects of language background and musical background (F(1, 16) = [4,91], p = [0.042]).

Since there was a significant interaction, a post-hoc analysis was performed by means of four paired *t*-tests (Table 2).

**Table 2**

*Mean and SD of Percentage of Correct Responses per Group*

| *Group* | *Mean* | *SD* |
|---|---|---|
| *NT NM (non-tone, musician)* | 58 | 5.42 |
| *T NM (tone, non-musician)* | 65.5 | 13.16 |
| *NT M (non-tone, musician)* | 82.5 | 5.86 |
| *T M (tone, musician)* | 74 | 4.87 |

The first paired *t*-test, comparing the NT NM group with the NT M group on percentage of correct responses, showed that there was a significant difference between the NT NM group (M = [58], SD = [5.42]) and the NT M group (M = [82.5], SD = [5.86]); t(7.74) = [2.49], p=[0.00].

The second paired *t*-test, comparing the T NM group with the T M group on percentage of correct responses, showed that there was no significant difference between the T NM group (M = [65.5], SD = [13.16]) and the T M group (M = [74], SD = [4.87]); t(5.08) = [-1.35], p=[0.23].

The third paired *t*-test, comparing the NT NM group with the T NM group on percentage of correct responses, showed that there was no significant difference between the NT NM group (M = [58], SD = [5.42]) and the T NM group (M = [65.5], SD = [13.16]); t(5.32) = [-1.18], p=[0.29].

The fourth paired *t*-test, comparing the NT M group with the T M group on percentage of correct responses, showed that there was a significant difference between the NT M group (M = [82.5], SD = [5.86]) and the T M group (M = [74], SD = [4.87]); t(7.74) = [2.49], p=[0.038].

Simple main effects analysis showed that musical background had a statistically significant effect on percentage of correct responses (p = [0.00]). The *t*-tests revealed that being a musician had a significant positive effect on percentage of correct responses within the non-tone language group. This indicates that the relationship between musical background and percentage of correct responses depends on language background: musicianship has a significant positive effect on percentage of correct responses if you do not speak a tone language.

Simple main effects analysis showed that language background did not have a statistically significant effect on percentage of correct responses (p = [0.89]). However, the *t*-test results showed that tone-language speakers performed significantly worse than non-tone language speakers within the musician groups.

Lastly, a notable observation is the difference in range of correct responses within the participant groups. The NT M group and NT NM group seemed to be rather consistent in their amount of correct responses, contrary to – especially – the T NM group whose participants gave more varied responses. In the boxplot this high within-group variance is especially visible.

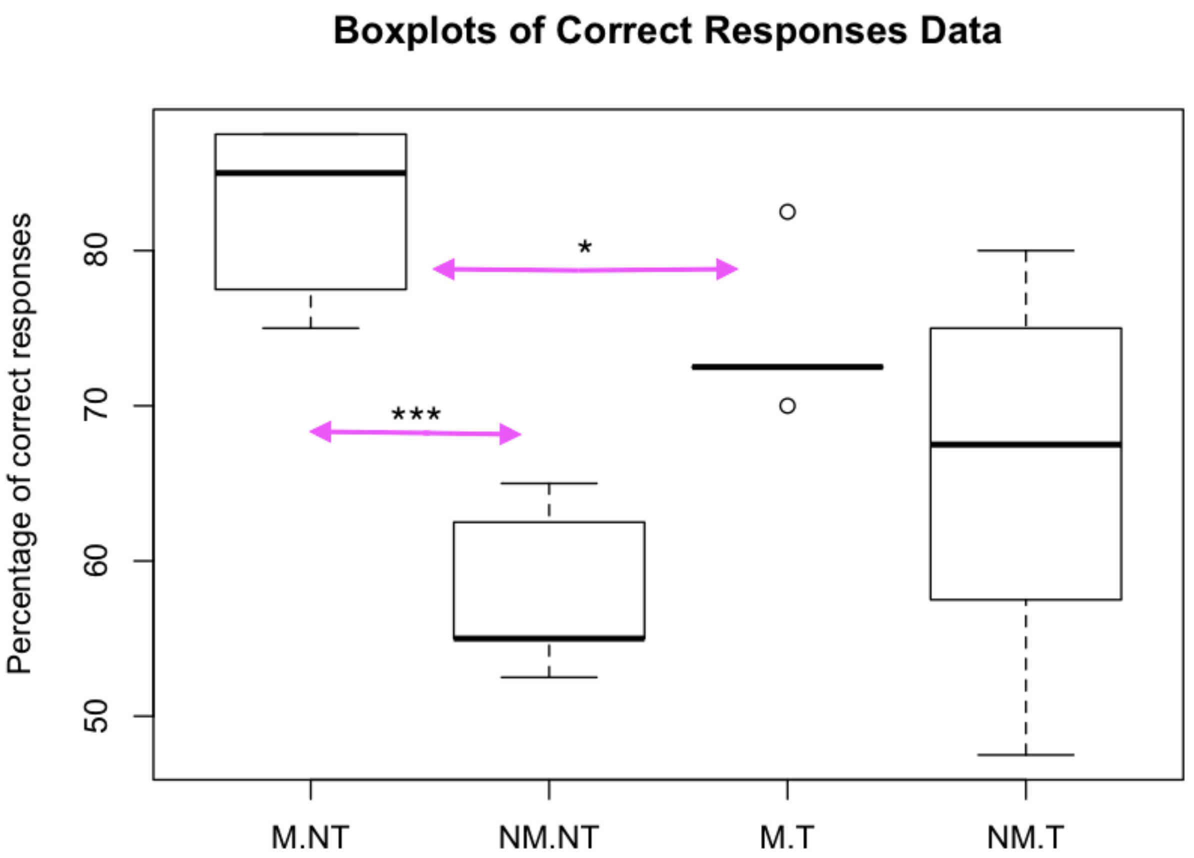


**Figure 2**. *Boxplot*

# 4 Discussion

Results showed that musicians perform better than non-musicians when it comes to discriminating melodies, especially for non-tone language speakers. These findings are in line with earlier research that conclude that the perceptual advantage is the biggest among musicians (Bidelman, Hutka & Moreno: 2013; Skoe & Kraus: 2012; Cooper & Wang: 2012).

Contrary to what I hypothesized, this study showed that tone-language speaking musicians seem to have worse musical perception than non-tone language speaking musicians. Earlier findings by Cooper & Wang (2012) did show that the musician tone-language combination did not lead to enhanced  foreign (Cantonese) word learning skills. This study thus contributes to the idea that a synergistic effect of the tone-language musician combination does not exist in melody discrimination either.

The results of this study, however, even seem to suggest that speaking a tone-language – compared to a non-tone language – among musicians leads to worse musical perception. An explanation for this unexpected finding could perhaps lie in one of the criteria for being a musician: participants had to have started playing their instrument before the age of 13. It turned out that the non-tone language musicians all started before the age of nine, while there were two tone language musicians starting at age 12 and 13, the latter being the cut off. Perhaps this might have contributed to the enhanced musical perception within the non-tone language musician group. A suggestion for future research would be to lower the age limit with regard to when musicians started playing their instrument. This could show whether the age limit might have led to a greater positive contribution of musicianship on musical perception within the non-tone language musician group.

An alternative explanation for the poorer performance – compared to the expectations – of the tone musician group might be due to the fact that the criteria for being categorized as a "musician" were sometimes taken loosely. Two participants in the tone language musician group did not meet all of the criteria. These two participants also had the lowest percentage of correct responses within their group. There was one participant in the non-tone language musician group who also did not meet one of the criteria and this person also had the lowest score of his/her group. However, an important note is that most musician participants were recruited at the conservatorium, which is a good indication of their musicianship too. Nevertheless, an idea for future research could be to strictly stick to the criteria for being a musician set beforehand. There was not enough time and resources in this study to do that unfortunately.

A final explanation could be related to the fact that one participant in the non-tone musician group was Japanese. This language actually does have some tone. It is considered a pitch accent language. This means that tones are used in the language but only in one syllable (Best: 2019). It is important for pitch accent speakers to pay attention to tones in their language as it might make the difference in understanding the semantics of a word. This might have given this participant an unforeseen language background advantage. However, tone language speakers deal with multiple tones in multiple syllables which is more similar to discriminating melodies than within pitch accent languages. Nevertheless, if this experiment were to be repeated, it might be a good idea to not include pitch accent languages in the non-tone language category.

Another suggestion for future research is that the researchers should be present when participants take part in the experiment. Whether the participants in this study did not have any distractions during the experiment cannot be confirmed and this might have affected their performance negatively and in turn could have clouded the results.

It could be argued that two participants within the tone language non-musician group should also be considered musicians since they have had some musical training. They started at age 12 and 15 within the past five years and had four and three years of continuous training, respectively. Skoe & Kraus (2012) found that adults who received formal music instruction as children have more robust brainstem responses to sound than peers who never participated in music lessons and that the magnitude of the response correlates with how recently training ceased. However, two other participants in the tone non-musician group actually had zero musical experience and performed better than these two tone-language speaking semi-musicians. It is thus unlikely that the inclusion of these participants in the non-musician group might have contributed to the slight advantage the tone language non-musician group had over the non-tone language non-musician group. However, in order to get a more clear idea about the individual contribution of language background and music background it might be useful for future research to set the criterium that the non-musician group should have no experience at all in playing an instrument or receiving formal music instruction. It would be perfect if they did not listen to music either, but this seems hard to control for since music is all around us.

In conclusion, future research needs to explore how the degree of music experience – starting age and years of continuous practice on the instrument – influences musical perception. This would contribute, in addition to this study, to helping us better understand the human perceptual system.

# 5 Conclusion

The findings in this study contradicted the hypothesis that the combination of musicianship and speaking a tone-language gives you a boost in musical perception. There is no evidence that the combination of musicianship and speaking a tone-language leads to an extra strong musical perception. However, this study does show that people who have had continuous musical training and professional music classes as a child have better musical perception than people who have not had this. This is advantage is greatest among non-tone language speakers. Lastly, another conclusion that can be drawn from this study is that people who speak a tone-language and are musicians have worse musical perception than people who do not speak a tone-language and are musicians.

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# 7 Appendix

**Table 1**

*Stimuli with note names*

| Stimuli | Sequence_1 | Sequence_2 |
|---|---|---|
| Practice_same | F, F, G#, G, F, G | F, F, G#, G, F, G |
| Melody 1_same | C3, D, F, D, G#, E | C3, D, F, D, G#, E |
| Melody 1_different | !C3, D, F, D, G#, E | C3, D, F, D, G#, E |
| Melody 2_same | B, A, G, A, F, D | B, A, G, A, F, D |
| Melody 2_different | B, A, G, A, F, D | B, A, !G, A, F, D |
| Melody 3_same | C4, F#, A, D, D#, F | C4, F#, A, D, D#, F |
| Meldoy 3_different | C4, !F#, A, D, D#, F | C4, F#, A, D, D#, F |
| Melody 4_same | A, F#, G, D, A#, A | A, F#, G, D, A#, A |
| Melody 4_different | A, F#, G, D, A#, A | A, F#, G, !D, A#, A |
| Melody 5_same | E, G, E, A, G, E | E, G, E, A, G, E |
| Melody 5_different | E, !G, E, A, G, E | E, G, E, A, G, E |
| Melody 6_same | F#, C4#, G#, C3#, D#, E | F#, C4#, G#, C3#, D#, E |
| Melody 6_different | F#, C4#, G#, C3#, D#, E | F#, C4#, G#, C3#, D#, !E |
| Melody 7_same | G#, B, A, F#, E, G# | G#, B, A, F#, E, G# |
| Melody 7_different | !G#, B, A, F#, E, G# | G#, B, A, F#, E, G# |
| Melody 8_same | B, G, A, C4, B, E | B, G, A, C4, B, E |
| Melody 8_different | B, G, A, C4, B, E | B, !G, A, C4, B, E |
| Melody 9_same | A#, B, F#, F, E, G# | A#, B, F#, F, E, G# |
| Melody 9_different | A#, B, !F#, F, E, G# | A#, B, F#, F, E, G# |
| Melody 10_same | C4, B, A, G, G#, E | C4, B, A, G, G#, E |

| | | |
|---|---|---|
| Melody 10_different | C4, B, A, G, G#, E | C4, B, A, !G, G#, E |
| Melody 11_same | A, F#, E, F#, D, E | A, F#, E, F#, D, E |
| Melody 11_different | A, F#, E, F#, !D, E | A, F#, E, F#, D, E |
| Melody 12_same | G#, E, A#, D#, C#, F# | G#, E, A#, D#, C#, F# |
| Melody 12_different | G#, E, A#, D#, C#, F# | G#, E, A#, D#, C#, !F# |
| Melody 13_same | C#, E, C#, F#, E, G# | C#, E, C#, F#, E, G# |
| Melody 13_different | !C#, E, C#, F#, E, G# | C#, E, C#, F#, E, G# |
| Melody 14_same | F#, A#, C4, C3, D#, G# | F#, A#, C4, C3, D#, G# |
| Melody 14_different | F#, A#, C4, C3, D#, G# | F#, !A#, C4, C3, D#, G# |
| Melody 15_same | C#, F#, D#, C3, G#, E | C#, F#, D#, C3, G#, E |
| Melody 15_different | C#, F#, !D#, C3, G#, E | C#, F#, D#, C3, G#, E |
| Melody 16_same | A, G, G, D#, F, C4 | A, G, G, D#, F, C4 |
| Melody 16_different | A, G, G, D#, F, C4 | A, G, G, !D#, F, C4 |
| Melody 17_same | F, G, A, E, D, E | F, G, A, E, D, E |
| Melody 17_different | F, G, A, E, !D, E | F, G, A, E, D, E |
| Melody 18_same | E, A#, B, E, F#, G | E, A#, B, E, F#, G |
| Melody 18_different | E, A#, B, E, F#, G | E, A#, B, E, F#, !G |
| Melody 19_same | G, C3, E, G#, B, A | G, C3, E, G#, B, A |
| Melody 19_different | !G, C3, E, G#, B, A | G, C3, E, G#, B, A |
| Melody 20_same | D#, A#, G#, G, D#, A# | D#, A#, G#, G, D#, A# |
| Melody 20_different | D#, A#, G#, G, D#, A# | D#, !A#, G#, G, D#, A# |

*Note. The "!" before a note name means it was sharpened a ½ semitone*

**Table 2**

*Questionnaire*

| |
|---|
| What is your age? |
| What is your gender? |
| What is/are your native language(s)? |
| Do you speak second language(s), and if so which? |
| Do you play a musical instrument and if so, when did you start? |
| How many years of continuous training have you had on your principal instrument? |
| Do you currently play your instrument? |

**Table 3**

*Results per participant*

| Participant | Correct responses | Incorrect responses | Percentage of correct responses | Language background | Musical background |
|---|---|---|---|---|---|
| *1* | 21 | 19 | 52,5 | NT | NM |
| *2* | 22 | 18 | 55 | NT | NM |
| *3* | 22 | 18 | 55 | NT | NM |
| *4* | 25 | 15 | 62,5 | NT | NM |
| *5* | 26 | 14 | 65 | NT | NM |
| *6* | 32 | 8 | 80 | T | NM |
| *7* | 30 | 10 | 75 | T | NM |
| *8* | 27 | 13 | 67,5 | T | NM |
| *9* | 23 | 17 | 57,5 | T | NM |
| *10* | 19 | 21 | 47,5 | T | NM |
| *11* | 31 | 9 | 77,5 | NT | M |
| *12* | 35 | 5 | 87,5 | NT | M |
| *13* | 22 | 18 | 55 | NT | M |
| *14* | 30 | 10 | 75 | NT | M |
| *15* | 34 | 6 | 85 | NT | M |
| *16* | 35 | 5 | 87,5 | NT | M |
| *17* | 29 | 11 | 72,5 | T | M |
| *18* | 29 | 11 | 72,5 | T | M |
| *19* | 29 | 11 | 72,5 | T | M |
| *20* | 33 | 7 | 82,5 | T | M |
| *21* | 28 | 12 | 70 | T | M |