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Published in:
Proc. Speech Prosody 2022

DOI:
10.21437/SpeechProsody.2022-145

Speech Prosody 2022
23-26 May 2022, Lisbon, Portugal

The relation between musical ability and sentence-level intonation perception: A meta-analysis comparing L1 and non-native listening

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Abstract

Studies investigating the relationship between musical abilities and speech prosody report that musicians show an altered—often enhanced—perception of prosody, or report positive correlations between music perception and prosody perception. However, some studies on L1 perception find no such benefits, but show good prosody perception across listeners. In contrast, even advanced L2 users may show difficulties in processing sentence intonation. We hypothesised that musicality might especially be beneficial in challenging circumstances of non-native intonation perception. To test this, we conducted a meta-analysis of previous research investigating the effect of musical abilities on the perception of sentence-level intonation in L1, L2, and unfamiliar languages. Studies were systematically collected, and included various measures of musicality and intonation perception. The meta-analysis combining these outcomes showed a robust positive correlation between musical ability and intonation perception. This effect did not differ between studies on L1 and unfamiliar languages. We suggest intonation perception in unfamiliar languages might be relatively easy due to the absence of semantic interference. Data on L2 users was lacking. Because semantic processing plays a role in L2 perception, we suggest further research is needed to investigate the influence of musical ability on intonation perception in L2 listening.

Index Terms: intonation, perception, musical ability, meta-analysis, L1, L2

1. Introduction

Research into a connection between music and speech prosody has received increasing attention over the past two decades. Experimental studies investigating the relationship between musical ability and speech prosody report that musicians show alterations or enhancements in the perception of speech prosody [1], [2], or report positive correlations between music perception and prosody perception in populations overall [3], [4], with a majority of studies focusing on the perception of pitch-related phenomena (tone and intonation). Cross-domain transfer of learning has been explained on the basis of neural plasticity in overlapping neural networks for speech and music [5]. However, the potential connection between speech and music in the brain has been disputed recently [6], [7], and not all studies find transfer effects or correlations. Studies reporting small effects or a lack of effects appear to be particularly studies on L1 perception, [8]-[11]. Some report ceiling performance in the intonation perception of L1 participants [10]. Considering that improved speech perception with increasing musical expertise has been shown for difficult listening conditions such as low intelligibility [12], but not always in easy listening conditions, intonation perception in the L1 might be too easy to show an effect of individual differences in musical ability. In contrast, the perception of intonation in an L2 or unfamiliar foreign language may be more difficult, leaving room for musicality-related enhancements. We therefore hypothesised that enhancements in intonation perception related to musical ability would be more pronounced in an L2 or unfamiliar language compared to L1 perception. To quantify the relation between musical ability and intonation perception across studies and to test our hypothesis, we conducted a meta-analysis of previous findings. Henceforth, we use the term 'non-native' to group together L2 and unfamiliar languages (i.e., a language the listener does not understand). We use 'L2' or 'unfamiliar language' when we want to distinguish between the two.

1.1. Non-native intonation perception and musical ability

Even advanced L2 users may demonstrate difficulties in the perception of a range of intonation phenomena, including lexical tones [13], signalling of sentence types (e.g., questions vs statements) or sarcasm [14], and the marking of information structure [15]. It has been proposed that difficulties originate from listeners assimilating foreign intonation patterns to patterns in their L1 (e.g., the Perceptual Assimilation Model for suprasegmentals [16]). As increased musical ability has been related to improved fine-grained pitch perception [1]-[4], individual differences in musical ability may play an important role in the non-native perception of pitch-related linguistic phenomena like lexical tones, the intonation of different sentence types, and cues to information structure. Musical ability has indeed been widely reported to benefit perception of lexical tones in a non-native language [17], [18].

Intonation perception at the sentence level, including intonation in non-tonal languages, has received less attention in relation to musical ability. However, the few existing studies reported similar advantages to those found for lexical tone perception, for instance in the perception of sentence-final pitch deviations [2] and emotional prosody [19].

Previous cross-linguistic studies that investigate the role of musical ability in sentence-level intonation perception in both L1 and non-native perception have varying outcomes. For instance, findings by Zheng and Samuel [8] suggested musicianship had an effect on pitch perception in an unfamiliar

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language, but not in L1. On the other hand, Deguchi *et al.* [20] report a musician advantage in the perception of pitch changes in both an unfamiliar language and the L1.

The aim of the current study was twofold: (1) to evaluate the robustness of the relation between musical ability and intonation perception at the sentence level, and (2) to compare the effect of musical ability in L1 perception and non-native perception. To address these aims, we conducted a meta-analysis of previous research investigating the effect of musical abilities on the L1 and non-native perception of sentence-level intonation. By taking a meta-analytical approach, we were able to assess the state of the art of research on the link between musicality and intonation perception, and establish a foundation for further research on the role of musical ability in L2 listening.

2. Method

2.1. Literature search

For the current study, we compiled a subset of papers that were collected in a large meta-study on musical ability and prosody perception. We identified relevant studies by searching the electronic databases Scopus, Web of Science, APA PsycINFO, PubMed, and ProQuest (March 2021). We searched the titles, abstracts, and keywords using the following search term:

> *(musician* OR musicality OR (music* AND (training OR lessons OR experience OR expertise OR abilit* OR skill* OR aptitude))) AND (speech OR language OR linguistic) AND (prosod* OR intonation OR pitch OR timing) AND (percept* OR recogni* OR discriminat* OR process*)*

An overview of the screening process is given in Figure 1. After combining the outcomes of the database searches, abstracts and titles were screened using the tool Rayyan [21]. For the remaining records, full texts were screened for eligibility.

2.1.1. Inclusion criteria

We used the following inclusion/exclusion criteria:

- The study quantitatively measures intonation perception in speech. Intonation can be linguistic or emotional. We excluded studies measuring speech-to-song illusion.
- Stimuli are stretches of speech longer than one word (phrases or sentences). We included measures with single-word stimuli if the intonation type measured can be considered sentence-level intonation (for example, question/statement intonation).
- The study includes a measure of musical training or (innate) musical aptitude/abilities.
- Participants are normal-hearing.
- Participants are neuro-typical, with one exception: data from participants with amusia (tone-deafness) was included, as we aimed to investigate the relation between musical ability and intonation perception for participants with a wide range of musical abilities.
- We excluded studies that combine measures on the perception of speech with non-speech perception (such as song or vocalisations like laughter) without separating them.

Finally, to facilitate a straightforward interpretation of findings across studies, we excluded ERP measures, as the interpretation of positive or negative relationships with musical ability can differ per component.

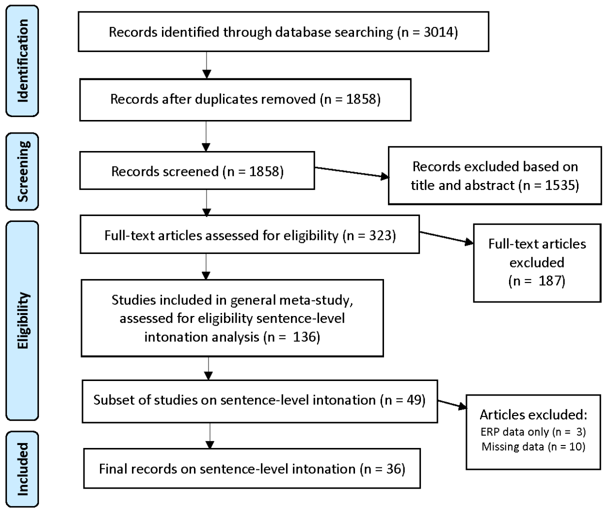

Figure 1: *The record screening process.*

2.1.2. Included studies

A total of 36 records were included in the current analysis [2], [3], [4], [8-11], [19], [20], [22-48]. Many studies reported multiple outcomes. For each outcome, we identified the language tested as the participants' L1, L2, an unfamiliar language, or mixed data (when the data for L1, L2, or unfamiliar language perception was not available separately). Most outcomes came from studies on L1 perception; others involved an unfamiliar language or mixed data. The search provided no data for L2 sentence-level intonation perception. Included studies used a variety of measures of musical ability and intonation perception. Many studies made a categorical distinction between 'musicians' and 'non-musicians' on the basis of various criteria, or used years of musical training as a continuous measure; some compared listeners with amusia to controls; others used tests of music perception skills; and a few studies had a music training intervention. Studies used behavioural measures of intonation perception including discrimination and identification tasks, involving perception of basic acoustic features (such as height or shape of a contour), and intonation signalling phenomena such as sentence type (question/statement), focus, or emotion.

2.2. Effect size calculations

Correlations between musical ability and prosody perception measures were extracted from each paper. For papers comparing groups, we first calculated standardized mean differences (d), which were then converted to a correlation coefficient r, using an effect size calculator [49]. For some effect sizes, the signs were reversed to ensure that a positive correlation indicated a positive relationship between musical ability and prosody perception (for instance, in studies where the prosody perception measure was a discrimination threshold, a negative correlation with musical ability originally indicated that listeners with higher musical ability demonstrated better prosodic discrimination). All correlation coefficients were transformed to Fisher's z for the analysis using the function *escalc* from the *metafor* package [50] in R [51]. The transformed values were converted back to correlations for the presentation of the combined results.

2.3. Statistical analysis

Effect sizes were analysed with a multi-level random-effects (MLRE) model. We used a random-effects model, based on the assumption that there are differences in the true effect sizes of studies due to differences in design, and that included studies provide a random sample from a larger population of studies [52]. Several records reported multiple outcomes, sometimes from different samples. Because effect sizes obtained from the same study or sample cannot be considered independent [52], a multi-level model was required with effects clustered by study and by within-study sample. The MLRE model was fitted in R using the function *rma.mv* from the *metafor* package [50]. Heterogeneity was assessed by calculating the I^2 statistic.

To evaluate the risk of bias (e.g., due to publication bias [52]) we created a funnel plot. This is a scatter plot of effect sizes (x-axis) against standard errors (y-axis), with the mean effect given by a vertical line. Studies with larger standard errors usually show a broader range of effects, giving the funnel shape. An asymmetrical distribution of effects around the mean indicates bias. Bias towards positive effects gives a plot with missing studies on the left side. Bias was assessed formally using Egger's regression test, by adding the variance of the effect sizes as a moderator to the model. A significant coefficient for the moderator indicates funnel plot asymmetry.

Next, we extended the original MLRE model to a mixed-effects model (MLME) to investigate the role of the moderator LANGUAGE TYPE. This factor had three levels: L1, unfamiliar, or mixed data (when a measure included data from both L1 and unfamiliar language perception). There was no 'L2' level, because no data for L2 intonation perception was available.

3. Results

The combined effect sizes of musical ability on sentence-level intonation perception are shown in Figure 2.

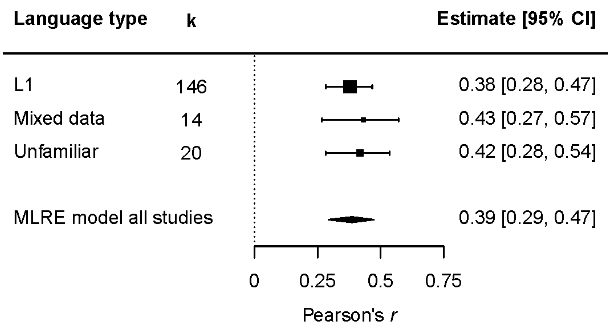

Figure 2: *Correlations between musical ability and sentence-level intonation perception. Summary estimates are given for each category of* LANGUAGE TYPE *in the MLME model (k = number of effect sizes) and for all studies combined in the MLRE model.*

The MLRE model including all study outcomes (k = 180) showed a combined estimate of r = 0.39 (95% CI = 0.29, 0.47), which was significant ($p < .001$). This summary estimate can be considered a medium effect indicating a positive correlation between musical abilities and intonation perception. However, we observed substantial heterogeneity between outcome measures with I^2 = 80.75%, which gives the proportion of variation in effect sizes that cannot be attributed to sampling error. This result is not unexpected, due to the wide range of measures included in the analysis.

Visual inspection of the funnel plot (Figure 3) indicated asymmetry, with missing effect sizes on the left side of the mean. This suggests a slight bias towards larger positive effects. Egger's regression test confirmed this bias (p = .029).

The MLME model showed no effect of LANGUAGE TYPE, indicating there was no significant difference between the correlation estimates of L1 perception and perception in unfamiliar languages (p = 0.471), or between L1 perception and mixed data (p = 0.455). This finding indicates that the musicality effect did not differ depending on whether the participants were tested in their L1 or an unfamiliar language.

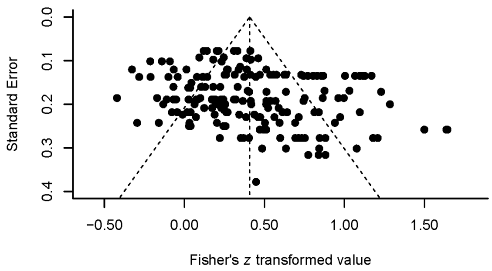

Figure 3: *Funnel plot for correlations between musical ability and sentence-level intonation perception.*

4. Discussion

In this study, we have taken a meta-analytic approach to assess the robustness of the relationship between musical ability and the perception of sentence-level intonation, and to compare the effect of musical ability in L1 perception and non-native perception. The meta-analysis of behavioural findings from 36 studies has shown a medium-sized positive effect in studies overall, indicating that higher musical abilities are related to a better perception of sentence-level intonation. This finding supports the notion of shared cognitive resources for music and speech, with theories proposing that transfer can take place from the domain of music to speech processing due to neural plasticity in overlapping networks [5].

We hypothesised that the effect of musical ability would be larger in non-native perception compared to L1 perception. Contrary to our expectation, we found no significant difference between L1 intonation perception and perception in an unfamiliar language. On the one hand, the lack of differences in the effect of musical ability could be due to a reversed ceiling effect in unfamiliar languages, with intonation perception being too difficult. However, studies indicate listeners were able to perform perception tasks well [2], [19], [42], albeit not as well as in L1 perception [19]. On the other hand, it may be that intonation perception tasks are not especially challenging in an unfamiliar language compared to an L1. A possible explanation is that familiarity can interfere in perception, while in an unfamiliar language the listener can focus on intonation without being hindered by semantic processing [2]. This interference of meaning could also make the perception of L2 intonation more difficult compared to a language the listener does not understand [53]. The extent to which familiarity can interfere possibly depends on the task. Objective acoustic characteristics may be observed better without the distraction of semantic processing, while familiarity with the language may actually be helpful in tasks involving for instance sentence type identification. A final possible explanation for a lack of differences in effects between an L1 and an unfamiliar language is the fact that we included studies on emotional prosody, which may be similar across languages [54]. The role of musicality in the perception of emotional prosody compared to linguistic prosody will be further addressed in a larger meta-study.

It is important to note that studies grouped under the term 'unfamiliar language' report perception in a range of languages, which can be considered to differ in degree of 'familiarity'. In some studies, participants may have had some exposure to the 'unfamiliar language' (e.g., English participants listening to Spanish [43]), while in other studies participants are unlikely to have ever heard the language before (e.g., English participants listening to Tagalog [19]). Typological similarity in language prosody also differs across studies. For instance, in a study by Marques *et al.* [2], the language of the stimuli (Portuguese) is closely related to the L1 of the participants (French), while in a study by Thompson *et al.* [19], the Tagalog stimuli are from an entirely different language family than the participants' L1 English. Both studies showed an effect of musical expertise. It has previously been proposed that the acquisition of prosodic cues is easier in languages that differ more from the L1 compared to languages that have a prosodic system which is similar to the L1 but differs in more subtle ways [55], possibly because listeners assimilate prosodic cues in a foreign language to their L1 prosodic system if these cues resemble L1 cues. Correspondingly, individual differences related to musical ability might be more pronounced when listening to a language that is more similar to the L1. Further research could test this using languages that are typologically similar or different.

The literature search provided no data on the relationship between musical ability and the perception of sentence intonation in L2 listening, with participants listening to a familiar language that is not their L1. An important distinction between listening to an L2 compared to an unfamiliar language is that rather than simply discriminating or identifying intonation cues, L2 listening involves the interpretation of these cues, such as focus accents or cues to sarcasm. Previous research has shown that adding a meaning component to prosodic tasks increases the difficulty of L2 perception in comparison to tasks involving meaningless prosody perception [53], and that L2 users have difficulty with integrating prosodic cues in semantic and pragmatic processing, e.g., [15]. These problematic areas are precisely where musical ability could make a difference, for two reasons: firstly, the enhanced perception of prosody may make listeners more sensitive to differences between L1 and L2 prosodic systems, and secondly, the strengthening of overlapping neural networks for music and speech might facilitate the integration of prosodic cues during speech processing. Most studies included in the current meta-analysis test the perception of acoustic features, but not the processing of the linguistic function of these cues. We will therefore take the next step in our research by investigating whether the positive effect of musical ability in intonation perception extends to the integration of sentence-level intonation cues in the processing of meaning in an L2. The robust positive effect of musical ability on sentence-level intonation perception we found in this meta-analysis provides a solid foundation for this new line of research.

A limitation of this meta-analysis is that the available studies demonstrated a slight bias towards larger positive findings. The correlation that was calculated with this dataset may thus be somewhat overestimated. Bias may have several causes. A common issue is publication bias, which we addressed as far as possible in our search by including conference proceedings and unpublished dissertations. We also found that some records only reported the data or effect sizes for significant effects.

Finally, we note that correlational research cannot infer causality. The causality of musical training can be addressed by longitudinal study designs with randomly-assigned music training interventions. Only a few of the studies on intonation perception we found in our search used such a design, with findings supporting the notion of transfer from music training to intonation perception [19], [37]. More research is needed to tease apart the effects of innate ability and music training.

5. Conclusion

This meta-analysis of previous studies showed a positive correlation between musical ability and sentence-level intonation perception, supporting the notion that speech and music share cognitive resources. We expected that the effect of musical ability would be stronger in non-native perception (i.e., perception of an L2 or an unfamiliar language) compared to L1 perception, but the results showed no difference between studies on L1 and unfamiliar languages. We suggest that intonation perception in unfamiliar languages might be facilitated by the absence of interference of linguistic meaning. Semantic interference plays a role in L2 perception, but research on the relation between musical ability and sentence-level intonation perception in L2 users is lacking. These outcomes fuel the next step in our research, in which we further investigate the role of musical ability in L2 listening, where musical abilities may not only benefit the perception of foreign intonation patterns, but also the interpretation of these cues.

6. Acknowledgements

We thank Marita Everhardt and Jelle Brouwer for advice on meta-analytic methods. This research was financially supported by the Faculty of Arts of the University of Groningen.

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