Studies in Second Language Learning and Teaching
Department of English Studies, Faculty of Pedagogy and Fine Arts, Adam Mickiewicz University, Kalisz
SSLLT 13 (1). 2023. 151-178
https://doi.org/10.14746/ssllt.23166
http://pressto.amu.edu.pl/index.php/ssllt

Musical hearing and the acquisition of foreign-language intonation

Mateusz Jekiel ✉
Adam Mickiewicz University, Poznań, Poland
https://orcid.org/0000-0002-3906-7793
mjekiel@amu.edu.pl

Kamil Malarski
Adam Mickiewicz University, Poznań, Poland
https://orcid.org/0000-0001-7826-7213
kamil.malarski@amu.edu.pl

Abstract

The present study seeks to determine whether superior musical hearing is correlated with successful production of second language (L2) intonation patterns. Fifty Polish speakers of English at the university level were recorded before and after an extensive two-semester accent training course in English. Participants were asked to read aloud a series of short dialogues containing different intonation patterns, complete two musical hearing tests measuring tone deafness and melody discrimination, and a survey regarding musical experience. We visually analyzed and assessed participants' intonation by comparing their F_0 contours with the model provided by their accent training teachers following ToBI (Tones and Break Indices) guidelines and compared the results with the musical hearing test scores and the survey responses. The results suggest that more accurate pitch perception can be related to more correct production of L2 intonation patterns as participants with superior musical ear produced more native-like speech contours after training, similar to those of their teachers. After dividing participants into four categories based on their musical hearing test scores and musical experience, we also observed that some students with better musical hearing test scores were able to produce more correct L2 intonation patterns. However, students with poor musical hearing test scores and no musical background also improved, suggesting that the acquisition of L2 intonation in a formal classroom setting can be successful regardless of one's musical hearing skills.

Keywords: language and music; intonation; pitch perception; pronunciation learning

1. Introduction

The link between the abilities to produce and perceive speech and music, both unique to humans and universal across cultures, has been extensively studied over the years (see Ott & Jäncke, 2013; Patel, 2008). Superficially, spoken language and instrumental music appear to share a range of characteristic features: both have tone, melody and rhythm, both are organized temporally in syntactically-structured sequences of sounds, and both have a limited number of elements that can be used to form an unlimited number of hierarchically-structured signals (Fenk-Oczlon & Fenk, 2009). The prevalent explanation for these similarities is that the processing of speech and music share common neural networks (Schön et al., 2010). These developments have led to a series of studies attempting to assess possible transfers between these two domains, primarily focused on the relationship between musical skills and language skills. Moreover, various research findings imply that musical hearing and musical experience can improve speech processing, including prosody, segments and syntax (Jentschke & Koelsch, 2009; Schön et al., 2004). Studies on musical skills and second language (L2) learning also suggest that the perception and production of foreign language sounds can be improved by musical ability (Slevc & Miyake, 2006) as well as musical expertise (Chobert & Besson, 2013). Overall, these studies suggest that musical skills and language skills are strongly related and can potentially be employed in the process of second language learning and teaching. What some of the previous studies lack, however, is that learners' musicality was not evaluated empirically, but rather self-reported through questionnaires. Another major limitation has been testing the level of accent proficiency through imitation and shadowing tasks, which too often are not a reliable tool for eliciting the actual second-language accent output. In order to address such limitations, the present study explores the relationship between musical hearing and the acquisition of L2 intonation by Polish advanced learners of English in a longitudinal context. The research aim is to determine whether superior musical hearing skills and musical experience are correlated with more successful production of L2 intonation patterns.

2. Literature review

2.1. Prosody in music and language

While various associations between language and music have been researched through the years, prosody in speech and melody in music are arguably the two most similar aspects, as they both rely on the same acoustic parameters, such as fundamental frequency, amplitude, duration, and spectral characteristics (Schön et al., 2004). One particular part of prosody to be investigated in this study is intonation, that is, the melody of speech resulting from pitch variation used to convey linguistic and pragmatic meaning (Wells, 2014). A widely-discussed process suggesting the existence of shared mechanisms between speech and music is pitch perception. Zatorre and Baum (2012) argue that there are two different pitch processing systems functioning in the brain. The first type is "fine-grained" and it is responsible for the accurate encoding of musical intervals, while the second one is "coarse-grained," and allows for discriminating between different contours in both speech and music. Contour information is also more perceptually salient and can be detected at an early stage by infants, suggesting that it is a more basic and innate process (Chen et al., 2017). Therefore, it is possible to assume that pitch perception in speech and music is related and can have an influence on the language learning process.

Superior perception of contours in music can affect the encoding of contours in speech as a result of common brain functions responsible for processing both of these auditory phenomena (Bidelman & Krishnan, 2009; Wong et al., 2007). Ott and Jäncke (2013) showed that musically trained individuals outperform non-musicians in reaction time for auditory processing of different tonal signals. Behroozmand et al. (2014) found that musicians with absolute pitch (i.e., the ability to label the pitch of a single musical note without the help of a reference sound) develop specialized left-hemisphere mechanisms for pitch processing, unlike musicians with relative pitch (i.e., the ability to discriminate the pitch of a sound after hearing a reference sound) or non-musicians. A series of studies on formal musical practice and tonal language speakers have revealed that musicians learning L2 Mandarin are better at discriminating tone contours in L2 speech than non-musicians (Marie et al., 2010; Wong et al., 2007). This can be related to the fact that first language (L1) Mandarin speakers develop absolute pitch recognition skills in the course of their early language acquisition more often than speakers of non-tone languages (Deutsch, 2002). Zatorre and Baum (2012) argue that not only can musicians be better at encoding tones in speech, but also that tone-language speakers are more accurate in identifying musical tones, suggesting the existence of overlapping cognitive and neural mechanisms.

2.2. Musical hearing and second language intonation

Although a number of articles in popular science discuss the idea of a "musical ear" as an asset in L2 learning, there is no single concept that would encompass an individual's musicality as a whole. Indeed, there are a number of aspects of music that can be related to language learning. First, musical aptitude can be regarded as a talent based on innate motoric and cognitive predispositions and is strongly linked to musical hearing skills, including melodic memory and pitch perception, combined with skills in performing instrumental music or singing (Schön et al., 2004). Secondly, musical experience is related to the perception and production of music through musical training and practice and is independent of musical aptitude (Pastuszek-Lipińska, 2008). In other words, one might have exceptional musical aptitude without performing music, or be a practicing musician in spite of their lack of talent. In this light, musical ability can be regarded as a combination of musical aptitude and musical experience and is expressed in how well an individual can perform music due to their aptitude and/or experience. Musical expertise, in turn, is a broad concept that can be used to characterize an expert in music performance and/or music theory. Both concepts may prove to be an asset for learners acquiring L2 English intonation; therefore, both will be taken into account in the present study.

There are a number of studies confirming the relationship between the processing of pitch in language and music, and its potential impact on listening skills in language learning. Schön et al. (2004) showed that adult professional musicians are more accurate in processing small changes in F_0 in both music and language than non-musicians, with shorter onset latency of the brain waves associated with F_0 manipulations. Based on these results, they argued that extensive musical training can affect the perception of pitch contour in both domains. Follow-up studies by Magne et al. (2006), and Moreno and Besson (2006) corroborated these results, revealing that young musicians outperform non-musicians in detecting pitch violations in speech. For adult listeners, Dankovicová et al. (2007) also found a relationship between musical hearing skills and intonation discrimination among university students of English. Finally, a related study by Patel et al. (2005) confirmed that tone-deaf listeners (i.e., not being able to label the difference between two tones in terms of pitch) have difficulties in discriminating intonation contours in speech. The above-mentioned studies prove that finer musical pitch perception can relate to more accurate identification of intonation patterns in speech.

If pitch perception in music is indeed related to the perception of speech in one's L1, a similar relationship should be found for the perception of L2 speech. Wong et al. (2007) set out to determine this link and observed that musical experience can shape human brainstem encoding of pitch patterns in speech. This was confirmed in a subsequent study by Wong and Perrachione (2007), revealing the relationship between former musical experience and adult learners' identification of non-native pitch patterns. A similar study by Alexander et al. (2005) investigated the discrimination of lexical tones in Mandarin Chinese by adult English-speaking musicians and non-musicians, providing more evidence for greater accuracy in L2 pitch perception and musical experience. On the other hand, Kurt et al. (2014) investigated the effects of explicit instruction and musical experience on the perception of L2 English intonation patterns among international students of English with different L1s (Mandarin, Japanese, Spanish, and Arabic). While the effect of explicit training was found, there was no apparent effect of musical familiarity on the correct identification of L2 intonation patterns. Finally, Intartaglia et al. (2017) compared the listening skills of adult native speakers of English with non-native musicians and non-musicians by recording their subcortical electrophysiological responses. The results of native speakers and non-native musicians were comparable, while non-native non-musicians scored lower, suggesting that musical experience can lead to enhanced neural encoding of acoustic information and compensate for the lack of language experience. Although these studies show that musicians can have an advantage when performing analytic listening tasks in L2, they do not explain whether musical experience can help in the acquisition of L2 pronunciation.

While most former studies have focused on the relationship between pitch perception in music and L2 listening skills, there is still a scarcity of research examining the function of pitch perception in L2 speech production. Slevc and Miyake (2006) found that musical hearing skills are correlated with L2 production skills among Japanese adult learners of English. In Milovanov et al. (2010), Finnish adult students of English with higher scores in *Seashore Measures of Musical Talents* (Seashore et al., 1960) produced fewer errors in a speech shadowing task pronouncing challenging English phonemes (e.g., /ʒ/, /ɜː/, /ð/). Pastuszek-Lipińska (2008) reported that Polish learners of English with formal music education produced fewer errors than non-musicians in a speech shadowing task, although both groups performed at a similar level in terms of intonation. In a related study by Zybert and Stępień (2009), Polish adult learners of English who scored better in Edwin Gordon's *Intermediate Measure of Music Audiation* test also received higher scores from a native speaker in a speech shadowing task focused on intonation, word stress, and overall pronunciation.

One limitation of the above studies stems from the use of speech shadowing tasks, in which participants listen to and repeat isolated words or phrases and, consequently, are restricted to speech imitation and may not necessarily represent learners' actual pronunciation skills (Dufour & Nguyen, 2013; Mitterer

& Müsseler, 2013). Another limitation is related to pronunciation assessment. Instead of using speech analysis software to conduct a more objective assessment, most empirical investigations rely on impressionistic judgements of speech. Finally, as most previous studies have compared pronunciation skills of professional musicians to non-musicians, language learners without formal music education but with good musical hearing are potentially overlooked in such studies (Zarate et al., 2012).

2.3. Intonation in the English as a foreign language (EFL) classroom

Mastering discourse intonation (i.e., the segmenting and topic-structuring function of pitch) in the EFL classroom is one of the most difficult linguistic skills to teach and learn effectively (Roach, 2000) and EFL learners have been frequently reported to produce errors in the realization of various intonation patterns (Willems, 1982). However, it is now agreed that intonation is both teachable and learnable, and that it plays an important role in communication, especially in international settings (Aronsson, 2014).

It is well known (e.g., Pijper, 1983; Willems, 1982) that General British (GB) uses considerably large pitch movements (octave up or down), and most GB intonation patterns start at the mid-level (Nooteboom, 1997), rather than at the bottom level, posing considerable difficulties for non-native speakers whose L1 does not incorporate pitch movements to such an extent. Moreover, learners' intonation is frequently influenced by prosodic patterns in their L1 (Mennen, 2004). Studies have shown that L2 learners have problems with selecting appropriate intonation contours (He et al., 2012), often relying on their native tones instead (Gut, 2009). Grabe and Karpinski (2003) was the first study to provide a prosodically annotated and phonetically descriptive corpus of Polish and English speech data. The analysis confirmed the existence of language-specific properties in intonation as English and Polish speakers produced different nuclear accent types and distributed them differently.

Despite many languages sharing a lot of commonalities in their use of intonation, or prosodic universals, the target classroom L2 pronunciation competences, especially at the proficient level, go beyond these universals. Those language-specific modes of intonation are usually perceived as difficult to teach and learn and, consequently, are often avoided by teachers in the EFL classroom (Demirezen, 2009). While researchers agree that prosody should be formally taught in the EFL classroom (Chapman, 2007), teachers find many aspects of intonation difficult, due to a lack of appropriate materials (Derwing, 2008). Nevertheless, practicing intonation and other suprasegmental features can have a significant effect on spoken proficiency and comprehensibility (Kang, 2013). In our study, we investigate the acquisition of English L2 intonation in a longitudinal context, with a specific focus on how musical hearing and musical experience may influence this process.

3. The present study

While the majority of similar studies have focused on imitation tasks in testing pronunciation and treated self-reports as a measure of the level of musical abilities to determine the link between pitch perception in music and speech, the primary goal of this study is to investigate the relationship between music perception and the production of intonation patterns by Polish advanced learners of English before and after an accent training course. In our study, we try to assess whether musical hearing, as measured by three different tests, translates into better production of L2 intonation patterns after training. Indirectly, we also attempt to measure the extent to which intonation is learnable and teachable by comparing the recorded patterns before and after accent training. Our research questions are as follows:

1) Are participants able to produce more correct intonation patterns after training?
2) Do participants who scored better on the musical hearing tests also produce more correct intonation patterns after training?
3) Do participants with musical experience produce more correct intonation patterns after training, regardless of their musical hearing test results?

4. Method

4.1. Participants

Our participants were 50 Polish university students (42 females, 8 males)[1] of English between the ages of 19 and 21 (*M* = 20.14, *SD* = .40) who spoke with standard Polish intonation in their L1. They were learning English at the advanced level of proficiency, between B2 and C1 within the Common European Framework of Reference (Council of Europe, 2001), and had overall good results in their secondary school exit exams in English (*M* = 87.75, *SD* = 6.56). In order to confirm their language proficiency, we conducted the Lexical Test for Advanced Learners of English (LexTALE) by Lemhöfer and Broersma (2012), which aims to assess general L2 English proficiency. The test results also confirmed their EFL proficiency between B2 and C1 (*M* = 74.48%, *SD* = 8.93). None of the

[1] Language majors in Poland are commonly more popular among female than male applicants.

participants had reported having formal accent training in their English classes at previous stages of their education, nor did any of them have medically documented speech or hearing impairments.

4.2. English accent training course and English phonetics and phonology course

As part of their curriculum, all participants took an obligatory English accent training course, which comprised segmental phonetics (i.e., vowels and consonants of English) and suprasegmental phonetics (i.e., intonation, rhythm, syllable stress and sentence stress). All students attended the course twice a week during the first two semesters (90 hours of class work). The primary objective of the accent training course is to teach the students to speak English with an accent that is as native-like as possible. All participants aimed for a General British pronunciation, that is, the accent spoken in the South of England and the English pronunciation model which is most commonly used in the Polish primary and secondary education system (Weckwerth et al., 2006).[2] The course focused on the pronunciation of GB vowels and consonants, word stress, weak forms, connected speech processes, and intonation.

For the purpose of the study, the participants were divided into four different groups and were taught by four different accent training teachers; that is, academic instructors specializing in teaching English pronunciation to Polish learners of English. All teachers were female Polish speakers of English with near-native GB accent and over 20 years of experience in accent training and L2 research. The primary reason for relying on Polish instructors instead of native speakers of English is that the former have the necessary first-hand experience and insight allowing them to identify the differences between Polish and English pronunciation, which in turn can be used to help the learners avoid potential errors.

Phonetic instruction during both academic semesters was holistic; the focal areas were taught not in isolation, but within the framework of connected speech phenomena of coarticulation, connected speech processes, stress and intonation. Teaching methods included in-class drills and repetitions. Student assessment was performed via weekly in-class drama performance or news-reading and monthly recordings based on authentic materials. During the accent training course, all participants were familiarized with English intonation patterns and practiced their usage in different contexts, usually through dialogue reading and drama performance.

All participants also attended a two-semester practical course in English phonetics and phonology, which supplemented the accent training course by raising

[2] Students are offered a choice between the General American and the General British accent training course.

phonological awareness and making students aware of how English speech sounds are produced and transcribed. All students attended the course once a week during their first two semesters (45 hours of class work). Course topics included articulatory and acoustic phonetics, phonetic transcription, English phonemes and allophones, word stress, connected speech processes, and intonation. Assessment relied on regular weekly quizzes, as well as two mid-semester and two end-semester tests.

4.3. Data collection

4.3.1. Speech production

All participants took part in two recording sessions. The first one took place in the first week of their studies, before they received formal instruction in English phonetics and phonology and accent training, both of which were included in their course of study. The second recording session took place at the end of the second semester, allowing insight into participants' progress. Both recording sessions consisted of a spontaneous conversation in English, followed by reading aloud a set of four short dialogues. The dialogues were adapted from Wells (2014) and were meant to elicit as many different intonation contours as possible (see Appendix for more details). The English part of the interview was preceded by a short spontaneous conversation in Polish to verify any possible speech impediments or dialectal variation in their L1, as Polish intonation can differ in certain regions and could influence the results of our study (Gussmann, 2007). Table 1 summarizes the sentences from the adapted dialogues included in the analyses. It also presents the target intonation contours associated with the sentences, written down in the ToBI convention for transcribing intonation; then it provides the target intonation contour in the nucleus; and in the last column, it includes the function of that intonational phrase (statement, command, tag question etc.).

The intonation patterns were verified on the basis of recordings of the four accent training teachers who had taught the participants, as well as a recording of a native speaker representing the target accent. All teachers were consistent in their production. If two out of four teachers produced a different intonation pattern, we considered it as an acceptable alternative answer (hence two options for *yes/no* questions). A total of 1600 tokens were collected (800 before training and 800 after training). Dialogues were displayed in large black font against white background on a computer screen, one dialogue at a time. A short instruction explaining the task preceded the actual dialogues. The participants were asked to read each dialogue silently and then read each one aloud, trying to sound as natural as possible for the given context. The recordings were obtained in a sound-treated booth using a studio microphone and SpeechRecorder software (Draxler & Jänsch, 2019). The tokens were recorded in mono 44.1 kHz and 16-bit resolution.

Table 1 Sentences used in data analysis

Sentence	ToBI	Nucleus	Function
You will have to CHECK that. I'm going for a jog in the PARK.	H*L-L%	high fall	statement
Let me HAVE some. Hands off my DRINK!	H*L-L%	high fall	command
You're broke again, AREN'T you? So the match is on Sunday, ISn't it?	H*L-L%	high fall	tag question (certainty)
What are you DRINKing? How did you like the football match YESterday?	H*L-L%	high fall	wh-question
Shall I pay for the CLEANing? Did you finish the ESSay?	L*H-H% H*H-H%	low rise high rise	yes/no question
ACtually, I don't really like football. ACtually, let's talk about your homework.	H*L-H%	fall-rise	attitude word
I only want to TASTE it... I've finished the introDUCtion...	H*L-H%	fall-rise	non-finality
NEAT! You'd BETTer!	L+H*L-L%	rise-fall	strong approval

4.3.2. Musical hearing and musical experience

At the end of the first recording session, participants were asked to complete two online musical hearing tests (Mandell, 2009) focusing on tone deafness and melody discrimination. The tests measure important indicators of musical hearing skills and rely on similar rules to other musical hearing tests (see Wallentin et al., 2010). Both tests were conducted in a separate room, using a laptop connected to a pair of closed-back headphones AKG K240 MkII with audio frequency bandwidth 15-25000 Hz. Each participant completed the tests in isolation.

The first test was the *Adaptive Pitch Test*, measuring tone deafness and pitch perception, in which participants listened to a series of two tones (300 ms each, with a 100 ms silence between the first and the second tone) and were asked to determine whether the second tone in each pair was higher or lower than the first one by pressing the UP or DOWN arrow on the keyboard, respectively. Participants could use the spacebar to replay the tones. The next pair was played immediately after providing the answer for the previous pair. The test duration was circa one minute. The test was adaptive, so the number of played tokens varied and relied on the correct answers. The pitch difference between the first two sounds was 96 Hz. After providing three correct responses in a row, the pitch difference was halved from the previous trial to 48 Hz, progressing to the next, more difficult level. After providing an incorrect response, the pitch difference would regress to the previous, easier level. The tones in the test oscillated within the range of 50-500 Hz. The test results, expressed in Hertz (Hz), indicate the accuracy of differentiating between two tones. The data from 11.761 subjects available on the test's website show the normal distribution of data, with the mean result of 3.98 Hz. Table 2 provides the interpretation of the test scores.

Table 2 Interpretation of the *Adaptive Pitch Test* results

Result	Performance
< .75 Hz	Exceptional
< 1.5 Hz	Very good
< 6 Hz	Normal
< 12 Hz	Low-normal
> 16 Hz	Below normal

The second test was the *Tonedeaf Test*, measuring melody discrimination and melodic memory. Its utility in investigating pitch discrimination and musical ability has been verified by Palomar-García et al. (2020) and Ning (2020). Each participant listened to 36 pairs of short (2-8 seconds each, with a 2-second interstimulus interval) instrumental melodies representing various musical styles and had to decide whether the melodies were the same or different by clicking on the corresponding button on the screen. No repetition was possible in this test. Each pair of melodies used different sonorities (e.g., piano, keyboard, string instruments, wind instruments) in order to reduce potential bias due to specific instrument training. Each pair also varied from one another in terms of natural or synthesized sounds, duration, intensity, timbre, and number of tones. 18 pairs were identical, while the other 18 pairs differed in the pitch of one note, which occurred in one of the last ten tones of the melody and was modified by up to 11 semitones. Out of the 18 pairs that were different, half had the different note within the scale of the melody, while the other half had the different note outside of the scale of the melody. The test was designed to assess melodic memory and locate neuroanatomical correlates of tone-deafness (congenital amusia). The test takes five minutes to complete and the results are expressed in percentages, indicating the percent of correctly identified pairs. The data from 61.036 subjects available on the test's website follow a normal distribution, with the mean result of 73.8% (SD = 9.99). Table 3 provides the interpretation of the test scores.

Table 3 Interpretation of the *Tonedeaf Test* results

Result	Performance
> 90%	Exceptional
> 80%	Very good
> 70%	Normal
> 60%	Low-normal
< 55%	Below normal

After the musical hearing tests, we also asked our participants to complete a survey (in Polish) to assess their musical experience. The questionnaire comprised the following questions: Did you go to music school? If yes, when and for how long? Can you play a musical instrument? If yes, what kind of instrument(s) can you play and how long have you been playing? Can you sing? If yes, how often do you sing?

4.4. Data analysis

Intonational phrases (IPs) summarized in Table 1 were extracted from the recordings and analyzed by both authors who are trained phoneticians and active accent training teachers. IPs were transcribed, labeled and analyzed acoustically in Praat (Boersma & Weenink, 2022). We labeled the pitch accents and boundary tones using the ToBI convention (Beckman & Elam, 1997; Brugos et al., 2006); pitch measurements were inspected in Praat using the program's algorithm for fundamental frequency (F_0) tracking with pitch floor set to 75 Hz and pitch ceiling set at 600 Hz. Manual corrections were performed for signal failures, such as octave jumps or pitch halvings. To determine the correct intonation contour, we observed the difference in F_0 between the pitch accent and the boundary tone. Following the established model answers by the teachers and the native speaker, we marked H*L-L% (high fall) as correct patterns for statements, commands, tag questions, and wh-questions; L*H-H% (low rise) or H*H-H% (high rise) for yes/no questions; H*L-H% (fall rise) for attitude words and expressions of non-finality; L+H*L-L% (rise-fall) for strong approval. Each participant could score a point for each correct intonation pattern (two points per function), up to a total of 16 points from one recording session. Figure 1 presents a model IP produced by the teacher, an incorrect IP produced by one participant before training, and a correct IP produced by the same participant after training.

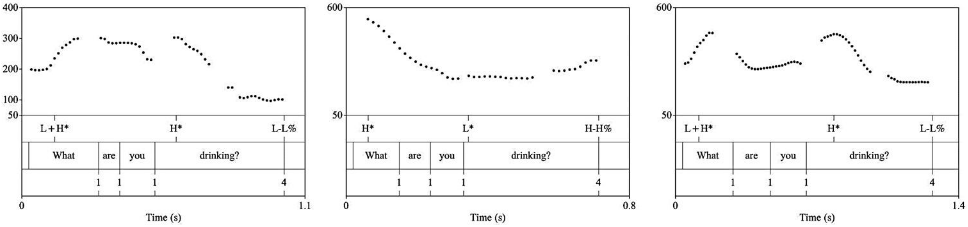

Figure 1 Example wh-question produced by the three speakers: model pattern produced by the teacher (left); incorrect pattern produced by one student before training (mid); correct pattern produced by the same student after training (right)

A one-tailed *t*-test for two dependent means was conducted to investigate participants' progress in acquiring intonation scores before and after training, followed by a linear multiple regression to predict the percentage of correct intonation patterns produced by the participants before and after training, with gender, LexTALE result, *Adaptive Pitch Test* score, *Tonedeaf Test* score, and musical experience as independent variables. Finally, a two-way ANOVA was conducted to examine the effect of musical hearing test scores and musical experience on the production of correct intonation scores before and after training.

5. Results

This section begins with the presentation of intonation scores before and after training, followed by musical hearing test results and participants' musical experience survey responses. Next, we present the effects of phonetic training, musical hearing, and musical experience on intonation scores.

5.1. Intonation scores before and after training

Figure 2 shows an observable improvement in intonation scores for 50 participants after the two-semester accent training course. A one-tailed *t*-test for two dependent means showed a statistically significant difference, $t(49) = 10.02$, $p < .001$ with 95% CI [-Inf, .15]. The mean result was 49.0% before training ($SD = .13$) and 66.8% after training ($SD = .15$).

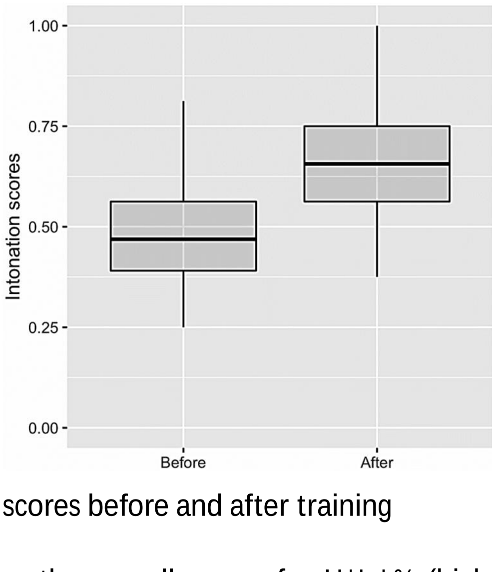

Figure 2 Intonation scores before and after training

Figure 3 shows the overall scores for H*L-L% (high fall) in commands, statements, tag questions, and wh-questions. While statements and commands were both relatively easy to produce for the participants both before (94% and 87%, respectively) and after the training (99% and 95%, respectively), the gains were more pronounced across tag questions (41% before and 66% after) and wh-questions (55% before and 76% after). The most frequent incorrect pattern for these two functions was L*H-H% (low rise) or H*H-H% (high rise).

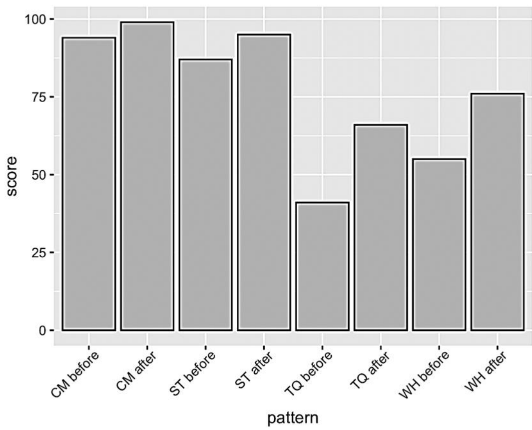

Figure 3 Intonation scores before and after training for H*L-L% (high fall) in commands (CM), statements (ST), tag questions (TQ), and wh-questions (WH)

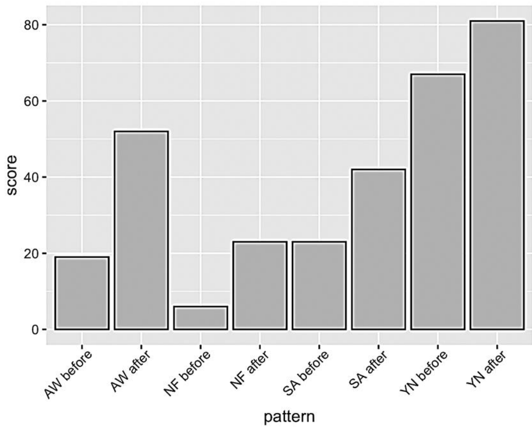

Figure 4 Intonation scores before and after training for the H*L-H% (fall-rise) in attitude words (AW) and non-finality (NF), L+H*L-L% (rise-fall) in strong approval (SA), and L*H-H% (low rise) or H*H-H% (high rise) in yes/no questions (YN)

Figure 4 shows the overall scores for H*L-H% (fall rise) in attitude words and expressions of non-finality; L+H*L-L% (rise-fall) for strong approval; and L*H-H% (low rise) or H*H-H% (high rise) in yes/no questions. The most difficult pattern for participants before training was H*L-H% in non-finality and attitude words (6% and 19%, respectively), although they managed to make a noticeable progress across both functions (23% and 52%, respectively). The second most difficult pattern was L+H*L-L% for strong approval (23% before and 42% after). Out of the following patterns, the use of L*H-H% or H*H-H% for yes/no questions was the least difficult for students, even less difficult than the use of H*L-L% for tag questions or wh-questions (67% before and 81% after). The most frequent incorrect pattern for these functions was H*L-L% (high fall) or L*L-L% (low fall).

5.2. Musical hearing tests

Figure 5 shows the *Adaptive Pitch Test* results, which reveal how precisely participants could differentiate two tones in Hertz values. The mean result was 16.05 Hz (*SE* = 2.24). Participants with musical experience had an average score of 11.08 Hz, while participants without any musical experience had an average score of 18.84 Hz. The two highest results were scored by participants with formal music education and 12 years of musical experience (1 Hz), while the two weakest results were scored by participants without any musical experience (60 Hz).

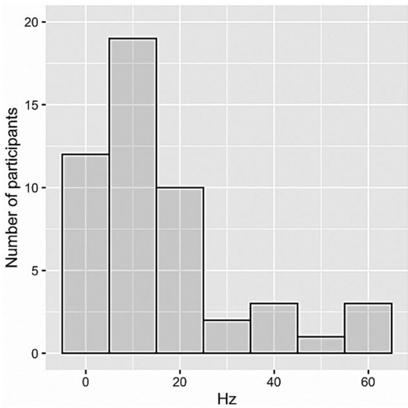

Figure 5 *Adaptive Pitch Test* results

Figure 6 displays the *Tonedeaf Test* results, which express the percentage of correctly identified melodic tokens. The mean result was 68% (*SE* = 1.35). The mean score is similar to the mean score found on the test's website (73.9%) and is comparable to the mean scores found in Ning (2020) for beginner and advanced L2 speakers of Mandarin (63.88% and 74.21%, respectively). Participants with musical experience had an average score of 72%, while participants without any musical experience had an average score of 65.7%. The highest result was scored by a participant with formal music education and 12 years of musical experience (83%), while the weakest result was scored by a participant without any musical experience (44%).

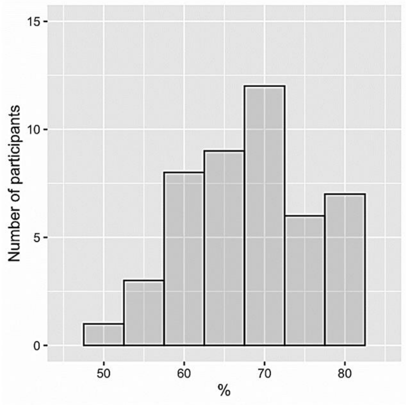

Figure 6 *Tonedeaf Test* results

5.3. Musical experience

Table 4 summarizes the musical experience of our participants that we included as a fixed effect in the linear multiple regression analysis. According to the musical experience survey completed by the participants, 18 out of 50 had some musical experience. Four participants had graduated from music school (first degree); two of them had played a musical instrument for six years, the other two for twelve years. Three participants had played a musical instrument for seven to nine years without any formal music education. Six participants had practiced singing for ten to twelve years without any formal music training. Finally, three participants had played a musical instrument and had practiced singing for four to six years, and two participants had done the same for ten to twelve years. Participants who admitted that they had played a musical instrument or had sung only for a brief episode in their former years (i.e., less than a year) were treated in the analysis as participants with no musical experience.

Table 4 Number of participants with formal music education and musical experience

Years	Music education	Playing a musical instrument (no music education)	Singing (no music education)	Playing a musical instrument and singing (no music education)
10-12	2	-	6	2
7-9	–	3	-	
4-6	2	-	-	3

5.4. Fixed effects on intonation scores before and after training

A linear multiple regression was performed to predict the percentage of correct intonation patterns produced by the participants before the training, based on the following independent variables: gender, LexTALE result, *Adaptive Pitch Test* score, *Tonedeaf Test* score, and musical experience. The regression equation was significant ($F(5,44) = 2.765$, $p < .029$) with an R^2 of .15). The results for individual independent variables are summarized in Table 5 and show that the only significant estimate was found across LexTALE results ($p = .035$), suggesting that a general L2 proficiency might be an indicator in the production of correct intonation patterns. We found no significant results for musical hearing or musical experience at this stage. No multicollinearity between the independent variables in the VIF-scores was uncovered.

Table 5 Summary of fixed effects on intonation scores before training

	Estimate	SE	*z*	*p*	*VIF*
Intercept	.317	.191	-1.656	.105	–
Gender (M)	.098	.051	1.923	.061	1.218
LexTALE	.004	.002	2.172	.035	1.018
Adaptive Pitch Test	-*.002*	.001	-1.317	.195	1.318
Tonedeaf Test	-.002	.002	-.878	.385	1.234
Musical Experience	-.003	.000	-.805	.425	1.337

Note. $N = 50$, $F(5,44) = 2.765$, $p < .029$, $R^2 = .15$, *SE* = Standard Error, *VIF* = Variance Inflation Factor

Table 6 Summary of fixed effects on intonation scores after training

	Estimate	SE	*z*	*p*	*VIF*
Intercept	.655	.235	2.793	.008	–
Gender (M)	.099	.062	1.587	.119	1.219
LexTALE	.002	.002	1.149	.256	1.018
Adaptive Pitch Test	-.003	.001	-1.827	.074	1.318
Tonedeaf Test	-.002	.002	-.999	.323	1.234
Musical Experience	.000	.005	.166	.869	1.337

Note. $N = 50$, $F(5,44) = 1.794$, $p = .134$, $R^2 = .07$, *SE* = Standard Error, *VIF* = Variance Inflation Factor

Another linear multiple regression statistics was run to predict the increase in correct intonation patterns produced by the participants after the training, based on the same independent variables as in the previous analysis. The results for individual independent variables are summarized in Table 6 and show *Adaptive Pitch Test* results ($p = .074$) as significant predictors of intonation score after training. It is important to note that in the case of the *Adaptive Pitch* Test scores, the estimate is negative as higher scores on the test indicate weaker discrimination of pitch in music. Therefore, participants who could discriminate between two tones which were more similar to each other in their pitch in the test also produced more correct intonation contours, similar to their teachers. There were no significant results for other factors, suggesting that learners' gender, lexical proficiency or musical experience are not related to the acquisition of L2 intonation in an advanced EFL classroom setting. We also reported no multicollinearity between the independent variables in the VIF-scores.

Since a traditional multiple linear regression model may not have uncovered all the underlying relations between the acquisition of near-native L2 English intonation and musical hearing or musical experience, we investigated systematically for chances of naturally good musical hearing skills or musical experience to contribute to the production of L2 intonation. Based on the results of the musical hearing tests and the musical experience survey, we categorized our participants into four types of L2 learners in a two-by-two matrix: 1) participants with good musical hearing test scores (i.e., having a result below 6 Hz in the *Adaptive Pitch Test* and/or above 70% in the *Tonedeaf Test*) and musical experience (i.e., singing and/or playing a musical instrument); 2) participants with good musical hearing test scores without musical experience; 3) participants with poor musical hearing test scores but with musical experience; and 4) participants with poor musical hearing test scores and without musical experience. The number of participants and their average results before and after training are provided in Table 7.

Table 7 Division of participants into musicians and non-musicians with good or poor musical hearing test scores (average intonation scores before (BT) and after training (AT) provided in brackets)

		Musical experience		Total
		Musicians	Non-musicians	
Musical hearing	Good	12 (.43 BT, .66 AT)	13 (.53 BT, .71 AT)	25 (.48 BT, .68 AT)
test scores	Poor	6 (.48 BT, .65 AT)	19 (.50 BT, .64 AT)	25 (.49 BT, .64 AT)
Total		18 (.44 BT, .66 AT)	32 (.51 BT, .67 AT)	50 (.49 BT, .66 AT)

A two-way ANOVA was run on the sample of 50 participants to examine the effect of musical hearing test scores and musical experience on the production of correct intonation scores before training. Residuals followed a normal distribution (α = .05, p = .07) without outliers (k = 1.5). Although we found no significant interaction between the effects (F(1, 46) = .33, p = .74), we observed that participants without musical experience were able to achieve higher results than active musicians before training (F(1, 46) = 3.04, p = .08). There was no significant difference between the 25 participants who scored higher and lower on the musical hearing tests (F(1, 46) = .10, p = .74). When observing the distribution of the results in Figure 7, we can see that non-musicians with good musical hearing test scores were able to achieve the highest scores before training. Interestingly, some participants with musical experience and good musical hearing test results scored lower than participants with poor musical hearing test scores or no musical experience.

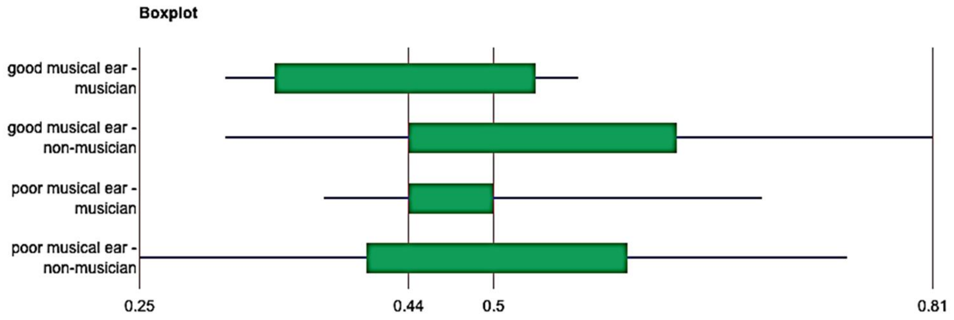

Figure 7 Intonation scores before training by learner type

We conducted a similar analysis on the same sample of 50 participants to examine the effect of musical hearing test scores and musical experience on the production of correct intonation scores after the training. Residuals followed a normal distribution (α = .05, p = .02) without outliers (k = 1.5). We found no significant interaction between the effects ($F(1, 46) = .62$, $p = .43$) and there was no significant difference in the intonation scores between participants with good and poor musical hearing test scores ($F(1, 46) = .06$, $p = .79$) or between participants with and without musical experience ($F(1, 46) = .86$, $p = .35$). By observing the distribution of the results in Figure 8, we were able to determine that some non-musicians with good musical hearing test results were able to achieve higher intonation scores after training. By comparing these results with the intonation scores before training by learner type, we can see that the mean results for all learner types improved, but most of the participants with good musical hearing test scores produced more correct intonation patterns after training. These results suggest that participants with a good musical ear but no musical experience could have been positively stimulated during the accent training course and used their natural talent to their advantage in the acquisition of L2 intonation patterns.

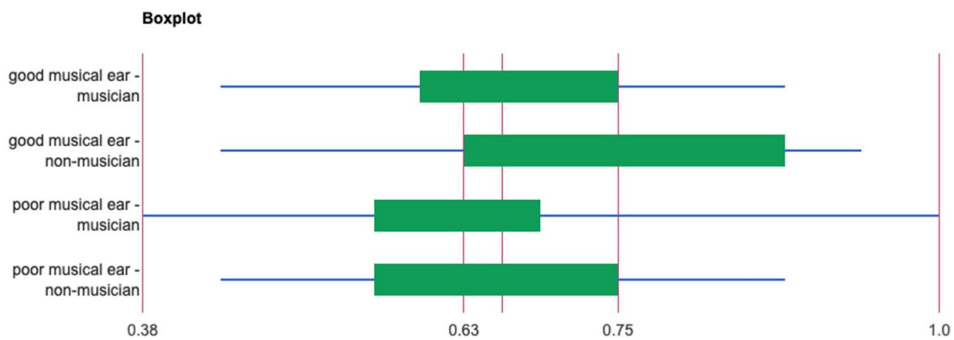

Figure 8 Intonation scores after training by learner type

6. Discussion

The results of the study are threefold. Our first research question asked whether Polish advanced learners of English were able to produce more native-like intonation patterns after training. We found a noticeable improvement in the production of correct GB intonational phrases after two academic semesters of an accent training course, combined with an English phonetics and phonology course. The courses provided the participants with practical pronunciation skills and phonetic awareness in order to acquire the specific features of the GB accent, and, consequently, produce similar intonational phrases to those of their accent training teachers. This finding shows that L2 intonation is both learnable (participants significantly improved their scores over time) and teachable (participants replicated their teachers' pronunciation) to a high level of proficiency in a formal learning environment. Interestingly, we also observed that not all intonational phrases were acquired with the same rate of success. The most difficult intonation patterns were the fall-rise, expressing non-finality, and the rise-fall, used for strong approvals. As these intonation patterns are relatively complex for L2 learners of English and not typically found in Polish speech, they are rarely used by Polish learners of English without formal accent training. At the same time, participants made a noticeable progress in *wh*-questions and tag questions. These results show that a change from a rising tone, used commonly in Polish questions (Mikoś, 1976), to the more typical falling pattern found in GB can be achieved by advanced learners of English after two semesters of formal accent training.

Our second research question considered participants who scored better in the musical hearing tests and whether they produced more correct intonation patterns after training. We found that participants who scored better in the *Adaptive Pitch Test* also produced more correct intonation patterns after training. That said, we found no significant relationship between participants' intonation scores and the *Tonedeaf Test* results. It should be noted that the results of both tests may differ from other musical hearing tests conducted on a wider population (see e.g., Barbaroux et al., 2020 for French non-musicians) as they usually differ across cultures and sample sizes. The tests used in this study were also recently used in other studies (Ning, 2020; Palomar-García et al., 2020), where Vietnamese learners of Mandarin scored comparably to the Polish speakers comprising our sample. Both of these studies have confirmed the validity of the tests and their relevance for studying the relationship between musical hearing and L2 language processing. The tests were used because their design aligned with the aims of this study, that is, researching the perception of tones and contrasting these cognitive skills with the ability of producing prosodic features in a second language. While the results of this study show that it is still possible for a learner with poor musical hearing test scores to produce native-like intonation contours after training, participants who scored higher in the *Adaptive Pitch Test* were able to correctly produce more of them. This finding reveals that being a good listener can be an asset in the production of more native-like L2 intonation patterns. Alternatively, it is possible to interpret these results as an indication that recognizing pitch change in the *Adaptive Pitch Test* is important for students practicing English intonation in the classroom, where rises and falls will be frequently used terms (see Zybert & Stępień, 2009).

Our final research question inquired whether participants with musical experience produced more correct intonation patterns after training, regardless of their musical hearing test results. We did not find any significant relationship between participants' musical experience and more accurate production of L2 intonation. Unlike former studies suggesting a strong link between musical practice and language skills (e.g., Chobert & Besson, 2013; Pastuszek-Lipińska, 2008), this result implies that musical background might not play a key role during a formal accent training course. Alternatively, it might suggest that the accent training course combined with a practical phonetics and phonology course could help all learners acquire L2 intonation and compensate for the lack of former musical practice. However, this does not negate the fact that superior pitch perception, even without formal music education, can be related to more accurate production of L2 intonation patterns.

In regard to long-term language acquisition – especially nowadays, when students are exposed to a great deal of audio and video material in native-spoken English – it is difficult to discern a single, overriding factor responsible for facilitating the acquisition of certain phonetic skills in learners. The results of our study suggest that formal phonetic instruction and practice, combined with finer pitch perception, can raise the success rate for learning foreign language intonation contours. In this study, we mentioned only the contours (i.e., falling tones, rising tones, etc.), but we realize that the acoustic signal in suprasegmental phonology involves not just F_0, but also pitch register, pitch span, rhythm, etc. Thus, it would be interesting to examine these parameters in future research. This study provides tentative evidence for how musical hearing can correlate to the acquisition of L2 intonation, using similar methodology to previous works by the authors investigating L2 vowel production (Jekiel & Malarski, 2021) and L2 rhythm (Jekiel, 2022). The current results refer to a rather narrow context of learning intonation in L2 English by Polish learners – whether they are applicable to other language pairs requires further research.

Despite the efforts put into designing a careful methodology and its longitudinal nature, there were several factors this study did not control for. First, the participants learning the GB accent were instructed by four different teachers.

Although the curriculum was the same for all groups, the impact of the individual differences in teaching styles the teachers may have presented could have been relatively strong. Another limitation of our study is the lack of control for motivation and other related variables, such as grit or general talent for language learning, apart from the musical context. These variables are widely discussed in the field of second language learning and teaching, and their role may have proven very interesting in discussing the results. Finally, the results are based on the data obtained from two recording sessions. An additional recording session after another academic year could have determined whether the gains were retained over time and point to the right direction showing whether the best-performing participants would have still been high-scoring in the delayed post-test.

7. Conclusions

The present study has demonstrated that superior musical hearing is correlated with more accurate production of L2 intonation patterns. Fifty Polish advanced learners of English were recorded reading a series of dialogues focusing on different intonational phrases before and after a two-semester accent training course, supplemented with an English phonetics and phonology course. The participants also completed two musical hearing tests assessing pitch perception and melody discrimination, and a musical experience survey. After comparing the participants' intonation patterns with the model provided by their accent training teachers, we compared their intonation scores with the musical hearing test results and survey responses. We found that superior pitch perception can be related to more native-like L2 intonation as participants with higher scores in the *Adaptive Pitch Test* also produced more accurate intonation contours, similar to those of their teachers. Although we observed that students with higher musical hearing test scores produced more correct L2 intonation patterns, students with poor musical hearing test scores and no musical experience also improved, suggesting that accent training in a formal classroom setting can lead to successful acquisition of L2 intonation regardless of students' musical hearing skills.

Acknowledgements

This research was supported by the National Science Center in Poland, Grant 2014/15/N/HS2/03865. Principal investigator: Mateusz Jekiel. Recipient: Adam Mickiewicz University, Poznań, Poland.

References

Alexander, J. A., Wang, P. C. M., & Bradlow, A. R. (2005). Lexical tone perception in musicians and non-musicians. *Proceedings of Interspeech 2005* (pp. 397-400). https://www.isca-speech.org/archive/pdfs/interspeech_2005/alexander05_interspeech.pdf

Aronsson, B. (2014). Prosody in the foreign language classroom - always present, rarely practised? *Journal of Linguistics and Language and Teaching, 5*, 207-225.

Barbaroux, M., Noreña, A., Rasamimanana, M., Castet, E., & Besson, M. (2020). From psychoacoustics to brain waves: A longitudinal approach to novel word learning. *Journal of Cognitive Neuroscience*, *33*(1), 8-27.

Beckman, M. E., & Elam, G. A. (1997). *Guidelines for ToBI labeling, version 3.0*. The Ohio State University.

Behroozmand, R., Ibrahim, N., Korzyukov, O., Robin, D. A., & Larson, C. R. (2014). Left-hemisphere activation is associated with enhanced vocal pitch error detection in musicians with absolute pitch. *Brain and Cognition, 84*(1), 97-108. https://doi.org/10.1016/j.bandc.2013.11.007

Bidelman, G. M., & Krishnan, A. (2009). Neural correlates of consonance, dissonance, and the hierarchy of musical pitch in the human brainstem. *Journal of Neuroscience, 29*(42), 13165-13171. https://doi.org/10.1523/jneurosci.3900-09.2009

Boersma, P., & Weenink, D. (2022). Praat: Doing phonetics by computer [Computer program]. Version 6.3.03. Retrieved December 17, 2022 from http://www.praat.org/

Brugos, A., Shattuck-Hufnagel, S., & Veilleux, N. (2006). *Transcribing prosodic structure of spoken utterances with ToBI.* MIT Open Courseware. https://ocw.mit.edu/courses/6-911-transcribing-prosodic-structure-of-spoken-utterances-with-tobi-january-iap-2006/

Chapman, M. (2007). Theory and practice of teaching discourse intonation. *ELT Journal 61*(1), 3-11. https://doi.org/10.1093/elt/ccl039

Chen, A., Stevens, C. J., & Kager, R. (2017). Pitch perception in the first year of life, a comparison of lexical tones and musical pitch. *Frontiers in Psychology, 8*(297), 1-8. https://doi.org/10.3389/fpsyg.2017.00297

Chobert, J., & Besson, M. (2013). Musical expertise and second language learning. *Brain Sciences, 3*(2), 923-940. https://doi.org/10.3390/brainsci3020923

Council of Europe. (2001). *Common European framework of reference for languages: Learning, teaching, assessment*. Cambridge University Press.

Dankovicová, J., House, J., Crooks, A., & Jones, K. (2007). The relationship between musical skills, music training, and intonation analysis skills. *Language and Speech, 50*(2), 177-225. https://doi.org/10.1177/00238309070500020201

Demirezen, M. (2009). An analysis of the problem-causing elements of intonation for Turkish teachers of English. *Procedia – Social and Behavioral Sciences*, *1*(1), 2776-2781. https://doi.org/10.1016/j.sbspro.2009.01.492

Derwing, T. M. (2008). Curriculum issues in teaching pronunciation to second language learners. In G. H. Edwards & M. L. Zampini (Eds.), *Phonology and second language acquisition* (pp. 347-369). John Benjamins.

Deutsch, D. (2002). The puzzle of absolute pitch. *Current Directions in Psychological Science, 11*(6), 200-204. https://doi.org/10.1111/1467-8721.00200

Draxler, J. Ch., & Jänsch, K. (2019). *SpeechRecorder – a universal platform independent multi-channel Audio Recording Software* (Version 4.4.50) [Computer software]. https://www.bas.uni-muenchen.de/forschung/Bas/software/speechrecorder/

Dufour, S., & Nguyen, N. (2013). How much imitation is there in a shadowing task? *Frontiers in Psychology, 4*, 1-7. https://doi.org/10.3389/fpsyg.2013.00346

Fenk-Oczlon, G., & Fenk, A. (2009). Some parallels between language and music from a cognitive and evolutionary perspective. *Musicae Scientiae, 13*(2), 201-226. https://doi.org/10.1177/1029864909013002101

Grabe, E., & Karpinski, M. (2003). Universal and language-specific aspects of intonation in English and Polish. *Proceedings of the 15th International Congress of Phonetic Sciences*, 1061-1064. https://www.internationalphoneticassociation.org/icphs/icphs2003

Gussmann, E. (2007). *The phonology of Polish*. Oxford University Press.

Gut, U. (2009). *Non-native speech: A corpus-based analysis of phonological and phonetic properties of L2 English and German*. Peter Lang.

He, X., van Heuven, V., & Gussenhoven, C. (2012). The selection of intonation contours by Chinese L2 speakers of Dutch: Orthographic closure vs. prosodic knowledge. *Second Language Research, 28*(3), 283-318. https://doi.org/10.1177/0267658312439668

Intartaglia, B., White-Schwoch, T., Kraus, N., & Schön, D. (2017). Music training enhances the automatic neural processing of foreign speech sounds. *Scientific Reports, 7*, 1-7. https://doi.org/10.1038/s41598-017-12575-1

Jekiel, M. (2022). L2 rhythm production and musical rhythm perception in advanced learners of English. *Poznan Studies in Contemporary Linguistics, 58*(2), 315-340. https://doi.org/10.1515/psicl-2022-0016

Jekiel, M., & Malarski, K. (2021). Musical hearing and musical experience in second language English vowel acquisition. *Journal of Speech, Language, and Hearing Research, 64*(5), 1666-1682. https://doi.org/10.1044/2021_JSLHR-19-00253

Jentschke, S., & Koelsch, S. (2009). Musical training modulates the development of syntax processing in children. *NeuroImage, 47*, 735-744. https://doi.org/10.1016/j.neuroimage.2009.04.090

Kang, O. (2013). Relative impact of pronunciation features on ratings of non-native speakers' oral proficiency. In J. Levis & K. LeVelle (Eds.), *Proceedings of the 4th Pronunciation in Second Language Learning and Teaching Conference* (pp. 10-15). Iowa State University.

Kurt, B., Medlin, J., & Tessarolo, A. (2014). The perception of prosodically ambiguous intonation patterns by L2 English learners and the effects of instruction. *Concordia Working Papers in Applied Linguistics, 5*, 354-372.

Lemhöfer, K., & Broersma, M. (2012). Introducing LexTALE: A quick and valid Lexical Test for Advanced Learners of English. *Behavior Research Methods, 44*, 325-343. https://doi.org/10.3758/s13428-011-0146-0

Magne, C., Schön, D., & Besson, M. (2006). Musician children detect pitch violations in both music and language better than nonmusician children: Behavioral and electrophysiological approaches. *Journal of Cognitive Neuroscience, 18*(2), 199-211. https://doi.org/10.1162/jocn.2006.18.2.199

Mandell, J. (2009). *Music tests*. Jake Mandell, MD. http://jakemandell.com/

Marie, C., Delogu, F., Lampis, G., Belardinelli, M. O., & Besson, M. (2010). Influence of musical expertise on segmental and tonal processing in Mandarin Chinese. *Journal of Cognitive Neuroscience, 23*, 2701-2715. https://doi.org/10.1162/jocn.2010.21585

Mennen, I. (2004). Bi-directional interference in the intonation of Dutch speakers of Greek. *Journal of Phonetics, 32*, 543-563. https://doi.org/10.1016/j.wocn.2004.02.002

Mikoś, M. J. (1976). Intonation of questions in Polish. *Journal of Phonetics*, *4*(3), 247-253.

Milovanov, R., Pietilä, P., Tervaniemi, M., & Esquef, P. A. (2010). Foreign language pronunciation skills and musical aptitude: A study of Finnish adults with higher education. *Learning and Individual Differences, 20*, 56-60. https://doi.org/10.1016/j.lindif.2009.11.003

Mitterer, H., & Müsseler, J. (2013). Regional accent variation in the shadowing task: Evidence for a loose perception–action coupling in speech. *Attention, Perception, & Psychophysics*, *75*, 557-575. https://doi.org/10.3758/s13414-012-0407-8

Moreno, S., & Besson, M. (2006). Influence of musical training on pitch processing: Event-related brain potential studies of adults and children. *Annals of the New York Academy of Sciences, 1060*, 93-97. https://doi.org/10.1196/annals.1360.054

Ning, L. (2020). Musical memory and pitch discrimination abilities as correlates of vocal pitch control for speakers with different tone and musical experiences. *Proceedings of the 10th International Conference on Speech Prosody 2020*, 611-615, https://doi.org/10.21437/SpeechProsody.2020-125

Nooteboom, S. (1997). The prosody of speech: Melody and rhythm. In J. Laver & W. J. Hardcastle (Eds.), *The handbook of phonetic sciences* (pp. 640-673). Blackwell Publishers.

Ott, C. G. M., & and Jäncke, L. (2013). Processing of self-initiated speech-sounds is different in musicians. *Frontiers in Human Neuroscience*, *7*, 1-15. https://doi.org/10.3389/fnhum.2013.0004

Palomar-García, M. Á., Olcina-Sempere, G., Hernández, M., Parcet, M. A., Mandell, J., & Ávila, C. (2020). The Jake Mandell test as a measure of individual differences in pitch discrimination: Validity and reliability properties. *Revista Electrónica Complutense de Investigación en Educación Musical, 17*, 143-151. https://doi.org/10.5209/reciem.66326

Pastuszek-Lipińska, B. (2008). Musicians outperform nonmusicians in speech imitation. *Lecture Notes in Computer Science, 4969*, 56-73. https://doi.org/10.1007/978-3-540-85035-9_4

Patel, A. D. (2008). *Music, language, and the brain*. Oxford University Press.

Patel, A. D., Foxton, J. M., & Griffiths, T. D. (2005). Musically tone-deaf individuals have difficulty discriminating intonation contours extracted from speech. *Brain and Cognition, 59*, 310-313. https://doi.org/10.1016/j.bandc.2004.10.003

Pijper, J. R. de. (1983). *Modelling British English intonation*. Foris Publications.

Roach, P. (2000). *English phonetics and phonology: A practical course*. (3rd ed.) Cambridge University Press.

Schön, D., Magne, C., & Besson, M. (2004). The music of speech: Music training facilitates pitch processing in both music and language. *Psychophysiology, 41*(3), 341-349. https://doi.org/10.1111/1469-8986.00172.x

Schön, D., Gordon, R., Campagne, A., Magne, C., Astésano, C., Anton, J., & Besson, M. (2010). Similar cerebral networks in language, music and song perception. *NeuroImage, 51*, 450-461. https://doi.org/10.1016/j.neuroimage.2010.02.023

Seashore, C. E., Lewis, D., & Saetveit, J. (1960). *Seashore measures of musical talents*. Psychological Corporation.

Slevc, L., & Miyake, A. (2006). Individual differences in second language proficiency: Does musical ability matter?. *Psychological Science, 17*, 675-681. https://doi.org/10.1111%2Fj.1467-9280.2006.01765.x

Wallentin, M., Nielsen, A. H., Friis-Olivarius, M., Vuust, C., & Vuust, P. (2010). The musical ear test, a new reliable test for measuring musical competence. *Learning and Individual Differences, 20*, 188-196. https://doi.org/10.1016/j.lindif.2010.02.004

Weckwerth, J, Janicka, K., Dziubalska-Kołaczyk K., Scheuer S., Wolfram-Romanowska, D., & Kul, M. (2006). Native standards or non-native ELF: Which

English to teach in the 21st century? In K. Dziubalska-Kołaczyk (Ed.), *IFAtuation: A life in IFA. A festschrift for Professor Jacek Fisiak on the occasion of his 70th birthday* (pp. 235-259). Adam Mickiewicz University Press.

Wells, J. C. (2014). *English intonation: An introduction*. Cambridge University Press.

Willems, N. (1982). *English intonation from a Dutch point of view*. Foris Publications.

Wong, P., & Perrachione, T. (2007). Learning pitch patterns in lexical identification by native English-speaking adults. *Applied Psycholinguistics, 28*(4), 565-585. https://doi.org/10.1017/S0142716407070312

Wong, P. C., Skoe, E., Russo, N. M., Dees, T., & Kraus, N. (2007). Musical experience shapes human brainstem encoding of linguistic pitch patterns. *Nature Neuroscience, 10*(4), 420-422. https://doi.org/10.1038/nn1872

Zarate, J. M., Ritson, C. R., & Poeppel, D. (2012). Pitch interval discrimination and musical expertise: Is the semitone a perceptual boundary? *The Journal of the Acoustical Society of America, 132*, 984-993. https://doi.org/10.1121/1.4733535

Zatorre, R. J., & Baum, S. R. (2012). Musical melody and speech intonation: Singing a different tune. *PLoS Biology, 10*(7), 1-6. https://doi.org/10.1371/journal.pbio.1001372

Zybert, J., & Stępień, S. (2009). Musical intelligence and foreign language learning. *Research in Language, 7*, 99-111. https://doi.org/10.2478/v10015-009-0007-4

APPENDIX

Dialogues presented to participants (based on Wells, 2014)

Dialogue 1

A: What are your plans? Are you going to the concert tonight?
B: Well, not really. I'm going for a jog in the park.
A: Really? It'll rain in a minute!
B: I don't think so. Look, there's still some sun out there. But I'd better take my coat.
A: You'd better.

Dialogue 2

A: What are you drinking?
B: Coffee.
A: Neat! Let me have some.
B: Hands off my drink!
A: I only want to taste it...
B: You're broke again, aren't you?
A: Don't worry, I'll have some money soon.
B: In that case, here you go.

Dialogue 3

A: Hello, sir. How can I help you? Would you like another beer?
B: Thanks. The match is on Saturday, isn't it? (The customer isn't sure)
A: No, I think it was pushed a day ahead.
B: Oh no, so the match is on Sunday, isn't it? (The customer is now sure)
A: You will have to check that.
B: How did you like the football match yesterday?
A: Actually, I don't really watch football.

Dialogue 4

A: John! This is your frog, isn't it?
B: It's not a frog. It's a toad.
A: You know where I found it, don't you?
B: Oh no, was it in the pocket of your jacket again? Is the jacket all right?
A: I've checked it and it's okay. It's a run-of-the-mill jacket anyway.
B: Shall I pay for the cleaning?
A: Actually, let's talk about your homework. Did you finish the essay?
B: I've finished the introduction...