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3aED3. The effect of musical training on auditory perception

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Previous research has shown that musical training affects the type of cues people use to discriminate between auditory stimuli. The current study investigated whether quantity of musical training and musical area of expertise (voice, percussion instrument, non-percussion instrument) affected musical feature perception. Participants with 0-4 years of experience (13 non-musicians), 5-7 years of experience (13 intermediate musicians) and 8 years or more of experience (13 advanced musicians) were presented with pairs of 2.5 s novel music sequences that were identical (no change trials), differed by one musical feature (pitch change, timbre change, or rhythm change), and differed by two musical features (pitch and timbre change, pitch and rhythm change, or timbre and rhythm change). In 64 trials, participants had to report whether they heard a change, as well as classify the specific type of change. Participants in the advanced group (M = 91.2%) and intermediate groups (M = 85.0%) performed significantly better than non-musicians (M = 70.0%). There was no effect of area of musical expertise (voice or instrument) on musical feature change detection. These results suggest that musical training in any area increases the ability to perceive changes in pitch, timbre, and rhythm across unfamiliar auditory sequences.

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I. INTRODUCTION

People are capable of perceiving certain musical events without formal training (Zatorre, Belin, & Penhune, 2002). For example, untrained music listeners are able to perceive musical tensions and relaxations, and anticipate musical events based on subtle distinctions within a prime sequence with performance similar to that of trained musicians (Bigand & Poulin-Charronnat, 2006). However there are elements of music perception for which trained musicians show a distinct advantage, including discrimination of musical sounds.

Some elements of music perception are innate as evidenced by similarities between infants and adults in music perception tasks. Adults and infants have been shown to perform similarly on pitch interval processing and rhythm discrimination tasks (Schellenberg & Trehub, 1996; Trehub & Thorpe, 1989). Infants have also demonstrated the ability to discriminate subtle differences in timbre (Clarkson, Clifton, & Perris, 1988). These studies suggest that the ability to process basic pitch, rhythm and timbre does not require formal musical training.

Formal musical training, however, is necessary for fine perception of musical features involved in such processes as rhythm classification and detection of subtle timbre differences. One such difference includes the concept of accents. Accents are periodic events in music, marked by a change in one of the fundamental features (e.g. pitch, timbre, duration), that give emphasis to a particular part of the melody, and cause listeners to perceive temporal divisions in the music, known as meter. One way in which rhythm perception differs for musicians vs. non-musicians is that they rely on different features of music (pitch vs. a combination of features) to identify accents in the rhythmic structure of a piece of music (Dawe, Platt, & Racine, 1995).

Differences between musicians and non-musicians also appear in timbre perception. In a study by Pitt (1994), musical training enhanced perception of timbre changes in conditions where pitch was changing. Timbre perception differences between musicians and non-musicians also appear when fundamental frequency is kept constant while other features change, and on a task that requires hearing a missing fundamental frequency (Miller & Carterette, 1975; Seither-Preisler et al., 2007).

It appears that informal exposure to music is sufficient for perception of differences in pitch, rhythm and timbre, while formal musical training is needed for more detailed discrimination of these musical features. In the current study we sought to determine whether differences in auditory perception occur between those with formal musical training (advanced and intermediate musicians) and those with no musical training. Additionally, we sought to address whether the type of musical training (percussion instruments, non-percussion instruments, or voice) has an influence on the features musicians are best at discriminating.

We predicted that advanced musicians would perform better overall than intermediate musicians, and that both groups would outperform the non-musicians. Our second hypothesis was that individual differences in performance would occur based on the type of musical training. We predicted that individuals with vocal training would exhibit the highest performance on pitch discrimination compared to the individuals who play instruments. We predicted those who play non-percussion instruments would perform best on timbre discrimination compared to the percussion players and voice musicians. Finally, we predicted that those with percussion experience would have the best performance on rhythm discrimination compared to those who sing or play non-percussion instruments.

II. METHOD

A. Participants

Participants consisted of 13 non-musicians, 13 intermediate level musicians and 13 advanced level musicians. The non-musicians group consisted of RIT students who had between zero and four years of formal music training beyond 6th grade, an age at which typically music classes are no longer required. The intermediate level musicians group consisted of RIT students who either had between five and seven years of music training and played music occasionally, or who had begun music training within the last five years and played on a regular basis. Students with at least eight years of musical training comprised the advanced level group. The criteria for participant categorization were adapted from Seither-Preisler et al. (2007) and Krumhansl and Iverson (1992).

At each level of musical expertise participants were categorized based on their specialty musical instrument. The categories were percussion instruments, non-percussion instruments and voice. Instruments which primarily are used to provide a rhythm in a musical ensemble, such as drums and mallet instruments (e.g. chimes, bells, marimba, and vibraphone), or which are considered accessories (e.g. triangle, suspended cymbals, wind chimes, and woodblocks), were considered percussion instruments. All instruments that did not fall into the percussion category were considered non-percussion instruments, and the voice category applied to participants whose primary musical training was vocal.

B. Materials

The stimuli consisted of 2.5 s sequences of computer generated piano, guitar, flute and saxophone tones (see Figure 1). The sequences were created using the GarageBand program (*Apple,* 2007). The experiment was carried out on a iMac computer using iTunes (*Apple,* 2008) and QuickTime Player (*Apple*, 2007). Koss headphones were used to present the stimuli.

C. Experimental Design

There were two between-subjects variables. The first was level of musical training (no training, intermediate, advanced). The second was musical area of expertise (percussion, non-percussion, voice). There were three within-subjects variables. The first was which auditory feature changed (no change, pitch alone, timbre alone, rhythm alone, pitch and timbre, pitch and rhythm, timbre and rhythm). The second within-subjects variable was session (Session A and Session B). The third within-subjects variable was block. Each session consisted of two blocks of 32 trials. Each block contained 8 trials in which there were no musical feature changes, and 24 trials in which there was a change.

In session A, only one auditory feature changed in each trial (no change, pitch, timbre or rhythm; see Figure 1). There were eight trials for each change condition in each of the two blocks. Session B had the same design as session A, except that there were two auditory features changing in each trial (pitch and timbre, pitch and rhythm, or timbre and rhythm) rather than one.

D. Procedure

Participants were tested individually in a quiet room. Participants sat at a table facing away from the experimenter and were provided with definitions of the three musical features they would be listening for, and a list of possible responses. The possible responses included: *no change, pitch change, timbre change,* and *rhythm change* for Session A, and: *no change, pitch and timbre change, pitch and rhythm change, or timbre and rhythm change* for Session B. Prior to the experiment participants' hearing was tested with Home Audiometer (*Timo Esser*, 2009).

Next, they listened to sample sounds demonstrating the auditory features *pitch*, *timbre*, and *rhythm*. This was immediately followed by a short training phase.

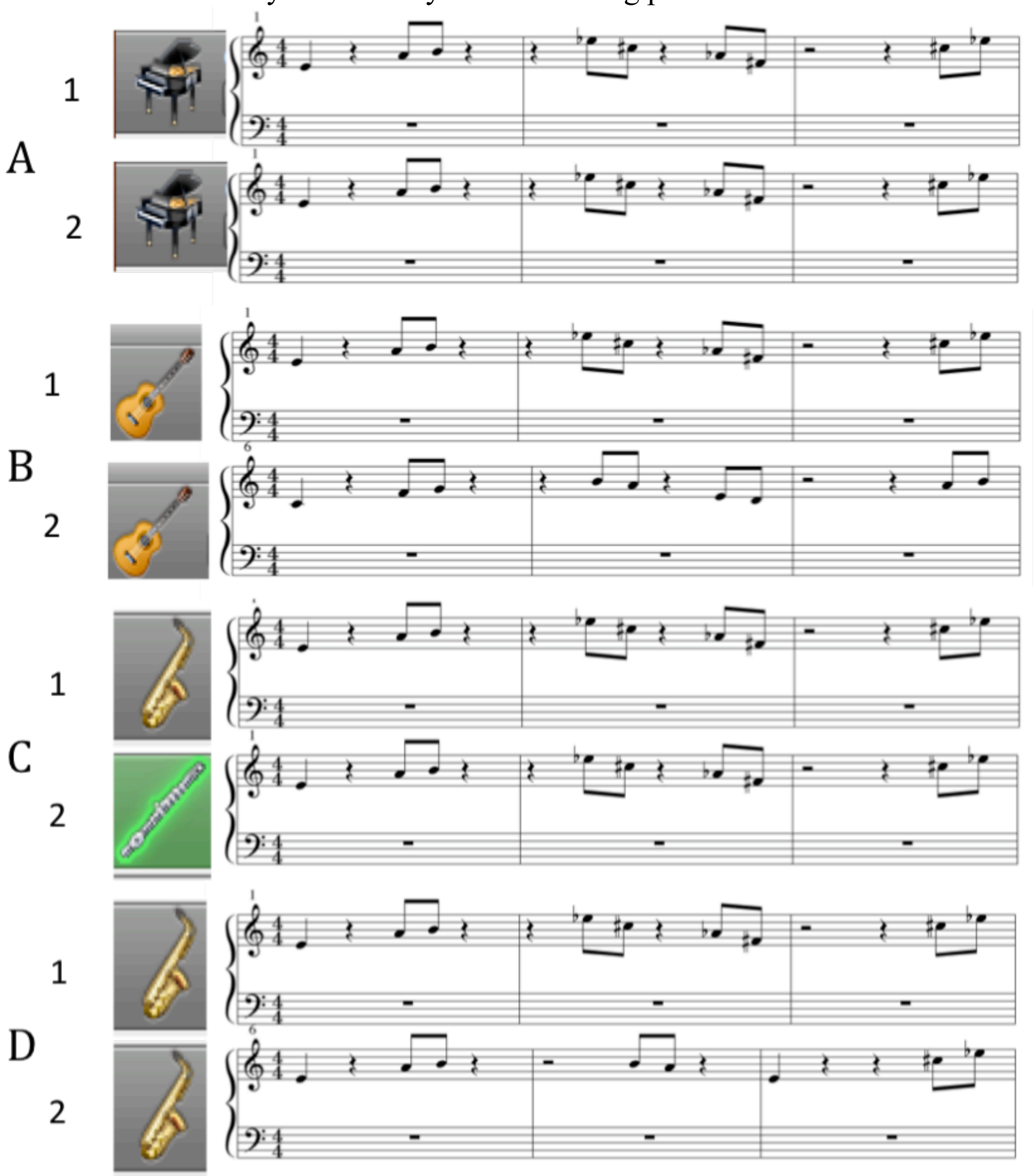

Figure 1. Scores for the four trial types used in Session A. A is an example of a no change trial, B is a pitch change trial, C is a timbre change trial, and D is a rhythm change trial. Participants heard sequence 1 immediately followed by sequence 2.

1. Training

There were two training phases; one that occurred immediately prior to Session A and a second that occurred before Session B. Each training phase contained three trials that represented each of the three types of change conditions that occurred on the test. The specific stimuli in the training trials did not appear on the test. Preceding the training phase participants received instructions to listen to the two consecutive musical sequences for each training trial, signaled by the verbal cues "sequence one" and "sequence two." They were told to verbally respond with a change condition from the list of responses.

2. Testing

In the testing phase participants were presented with two sessions of 64 trials for a total of 128 trials. During Session A they heard a pair of sound sequences for each trial, in which the second sequence was either identical to the first, or varied from the first in pitch, timbre or rhythm. Participants responded verbally with which auditory feature they believe changed. After each response the experimenter provided verbal feedback (correct or incorrect). If the participant was incorrect, the experimenter indicated the correct choice. Session B was the same as session A, with the exception that participants heard musical sequence pairs that were either identical or differed in two musical features, and responded with one of the four choices on the Session B response list.

3. Interview

An interview phase was carried out after each session of the experiment, and an additional final interview was carried out at the completion of the study. During each post session interview participants responded to four questions to explain their perceived difficulty of the trials, their pattern of performance throughout the session and how their prior musical experience and expertise (if any) affected their performance. During the final interview participants were asked to compare the two sessions in difficulty. The entire procedure took 1-1.5 hours to complete.

III. RESULTS

Performance data for all 13 participants at each of the three levels of musical training was analyzed to test the hypothesis that differences in detecting changes would occur between non-musicians, intermediate and advanced level musicians. To test whether area of musical expertise affected performance, each analysis was carried out with nine participants from the advanced and intermediate level musician groups; three from each area of musical expertise. The small size of the sample included in this analysis is due to the limited number of percussion instrument players who were able to participate in the study.

A. Session A

1. Level of Musical Training

A 3 (level: non-musician, intermediate, advanced) × 4 (trial type: no change, pitch change, timbre change, rhythm change) × 2 (block: 1 and 2) analysis of variance (ANOVA) was conducted on the proportion of correct answers made by the participants, with the last two variables as repeated measures. There were main effects of level of musical training, $F\ (2, 36) = 8.29$, $p < .01$, block, $F\ (1, 36) = 10.46$, $p < .01$, and trial type, $F\ (3, 108) = 10.86$, $p < .01$). Both the intermediate (M =84.7%). and advanced group (M =89.4%), performed significantly better than the non-musician group (M =72.5%; Newman-Keuls tests, $p < .01$). However, there was no significant difference between the two musically trained groups. Participants performed significantly better in block two (M = 84.5%) compared to block one (M = 79.9%; Newman-Keuls tests, $p < .01$). Participants performed significantly better on the pitch change, timbre change and no change trials compared to the rhythm change trials (Newman-Keuls tests, $p < .01$), as shown in Figure 2.

2. Instrument Type

A 2 (level: intermediate, advanced) × 3 (instrument type: percussion, non-percussion, voice) × 4 (trial type: no change, pitch change, timbre change, rhythm change) × 2 (block: 1 and

2) ANOVA was conducted on the proportion of correct answers made by the intermediate and advanced level musicians with the last two variables as repeated measures. There was no effect of instrument type. There were main effects of block, $F\ (1, 12) = 5.70\ p < .05$, and trial type, $F\ (3, 36) = 8.51, p < .01$). Participants performed significantly better in block two (M = 89.4%) compared to block one (M = 84.7%; Newman-Keuls tests, $p < .05$). Participants performed significantly better on the pitch change, timbre change and no change trials compared to the rhythm change trials (Newman-Keuls tests, $p < .01$).

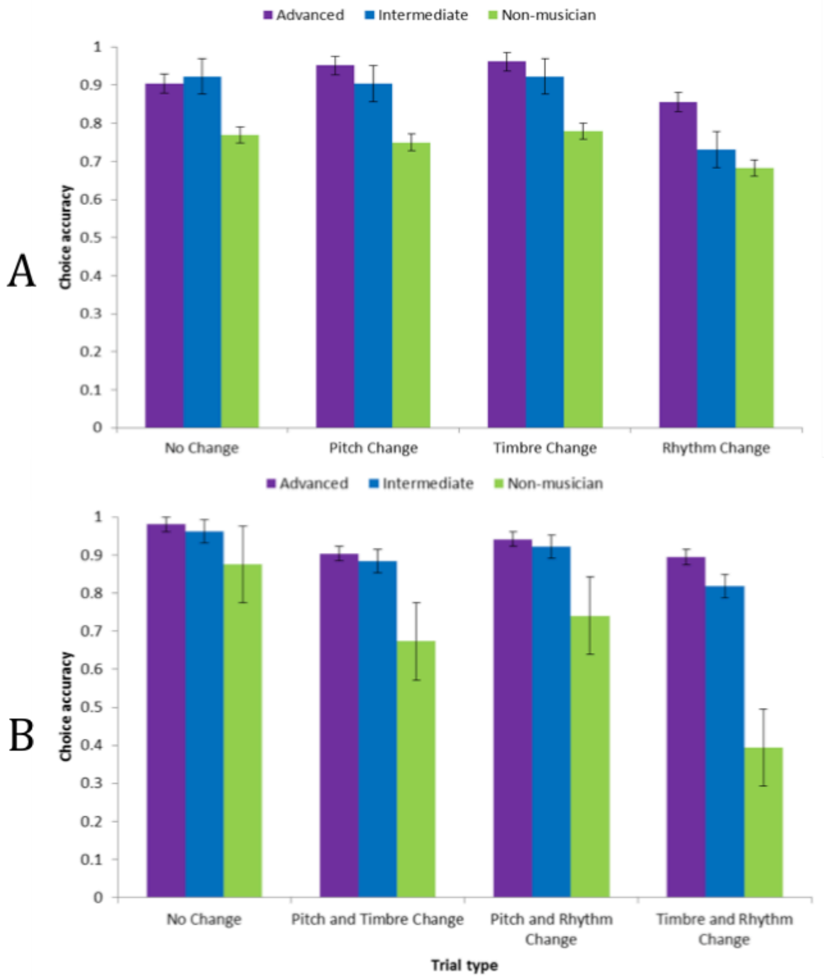

Figure 2. (A) Performance accuracy in Session A. (B) Performance accuracy in Session B. Vertical bars show the standard error.

B. Session B

1. Level of Musical Training

A 3 (level: non-musician, intermediate, advanced) × 4 (trial type: no change, pitch and timbre change, pitch and rhythm change, timbre and rhythm change) × 2 (block: 1 and 2) ANOVA was conducted on the proportion of correct answers made by the participants, with the last two variables as repeated measures. There was a main effect of level, $F\ (2, 36) = 18.88, p < .01$. As in session A, the non-musicians (M = 67.4%) had a significantly lower performance than both the advanced (M = 92.7%) and the intermediate musicians (M = 85.6%, Newman-Keuls, p <.01).

There was a main effect of trial type, F (3, 108) = 41.27, p <.001, and an interaction effect of level of training by trial type, F (6, 108) = 6.88, p <.001. For the advanced musicians, there was no significant difference in performance between trial types. The intermediate musicians performed significantly better on the no change trials (M = 95.1%), pitch and timbre change trials (M = 83.2%), and pitch and rhythm change trials (M = 89.9) compared to the timbre and rhythm change trials (M = 74.0%; Newman-Keuls, p <.05). The non-musicians had the highest accuracy on the no change trials (M =87.5%), followed by the pitch and rhythm change trials (M = 70.7%) and pitch and timbre change trials (M = 70.2%), and the lowest accuracy on the timbre and rhythm change trials (M = 41.3%; Newman-Keuls, p <.001).

There was an interaction effect of block by level of training, F (2, 36) = 3.53, p <.05. The advanced musicians had consistently high performance, and did not significantly improve between block one (M = 92.3%) and block two (M = 93.0%). The non-musicians had consistently low performance, and did not significantly improve between block one (M = 67.8%) and block two (M = 67.1%). The intermediate musicians significantly improved from block one (M = 81.5%) to block two (M = 89.7%; Newman-Keuls, p <.01).

2. Instrument Type

A 2 (level: intermediate, advanced) × 3 (instrument type: percussion, non-percussion, voice) × 4 (trial type: no change, pitch change, timbre change, rhythm change) × 2 (block: 1 and 2) ANOVA was conducted on the proportion of correct answers made by the intermediate and advanced level musicians with the last two variables as repeated measures. As in Session A, there was no effect of instrument type. However, there was a main effect of trial type, F (3,36) = 8.35, p <.001. The participants had higher performance accuracy on no change trials (M = 96.5%) compared to pitch and timbre trials (M = 84.0%) and timbre and rhythm trials (M = 80.2%; Newman-Keuls, p <.01). The participants also performed better on pitch and rhythm trials (M = 92.4%) compared to pitch and timbre trials (M = 84.0%) and timbre and rhythm trials (M = 80.2%; Newman-Keuls, p <.05).

There was also an interaction effect of level by block, F (1, 12) = 5.04, p <.05. Participants in the intermediate group had a significant increase in performance accuracy between block one (M = 80.9%) and block two (M = 88.2%; Newman-Keuls, p < .05). The advanced group had no significant difference in performance between block one (M = 92.3%) and block two (M = 91.7%).

C. Interviews

In the session A interview participants were asked to rank the trial types from easiest (1) to most difficult (4). Timbre change trials were considered the easiest, with 20 participants ranking it first. Pitch change trials was ranked the second easiest (17 participants). The no change and rhythm change trials were more distributed in their rankings. No change trials were ranked third by 10 participants, and fourth (or most difficult) by seven participants. Rhythm change trials was ranked third by 12 participants, and fourth by nine participants.

In the session B interview most participants thought that the no change trials were easiest (19 participants). Ranked in second place were pitch and rhythm change trials (11 participants). However 10 participants indicated that they thought pitch and timbre change was the second easiest trial type. Timbre and rhythm change trials were ranked as the third easiest trial type by

13 participants, and as the most difficult trial type by seven participants. Six participants ranked pitch and rhythm trials as the most difficult.

Of the 26 participants in the musician groups, 11 participants reported that their music experience was more helpful in Session A, 10 said it was more beneficial in Session B, and five found it equally helpful in both sessions. The most common responses participants gave for utilizing their musical expertise more in Session A included that they were unable to use the process of elimination (as they did in Session B). The most common reason participants relied on their musical background more in Session B was that listening to more than one change was more relevant to their musical training. Participants who indicated that musical experience was equally helpful in sessions A and B explained that their specific training helped with discrimination of specific musical feature changes (e.g. timbre and pitch) in both sessions.

IV. DISCUSSION

The present study investigated whether non-musicians, intermediate level musicians, and advanced musicians with different areas of musical expertise performed differently on a musical feature change identification task. As predicted in our first hypothesis, the advanced and intermediate musicians outperformed the non-musicians in both sessions. The second hypothesis was not supported, as there were no significant effects of the musicians' area of expertise (percussion instrument, non-percussion instrument, vocal) on the type of musical feature changes they were best at identifying.

The fact that advanced and intermediate participants performed equally well on both sessions may be due to the criteria used to categorize participants into the intermediate and advanced groups. The requirement of at least 5 years of training for the intermediate group may have resulted in participants who had similar music feature detection and identification skills to the advanced participants. Seither-Preisler et al. (2007) grouped those who had limited musical training and practiced at least 1 hour a week into the amateur musicians group. Krumhansl and Iverson (1992) used five years of experience with an instrument as a criterion for participation in their music study. In the current study students who had between five and 10 years of musical training beyond sixth grade were considered intermediate level musicians.

A major difference between the present study and previous studies is the categorization of the highest level of musical training. Krumhansl and Iverson (1992), and Seither-Preisler et al. (2007) used professional musicians with formal training at a music conservatory. In contrast, for the current study professional musicians were not available. Therefore we created an advanced category instead. Rather than training at a music conservatory, the advanced musicians had a minimum of eight years of any type of individualized musical training. As a result of this, there may have been less of a difference between the advanced and intermediate level musicians in this study and the professional and amateur musicians in the aforementioned studies.

The change in performance from block one (trials 1-32) to block two (trials 33-64). suggests that some auditory perception task learning occurred in this study, but not for all three groups in both sessions. In session A the performance of participants with all levels of musical training improved from block one to block two. Session A was the first session experienced by all participants, so it is reasonable that the largest learning effect occurred during this session. In session B, the advanced participants and non-musicians maintained similar performance across the two blocks; however the intermediate participants improved significantly from block one to block two. This trend could indicate that the advanced group may have been able to detect and identify more than one musical feature changing without an adjustment period. In contrast, the intermediate group may have required training on the specific task to learn how to accurately identify two changes occurring at once.

There was an effect of trial type on accuracy for participants with all levels of training in both sessions. In session A, participants performed worst on rhythm change trials. In addition, participants reported it as one of the most difficult trial types in the interviews. In session B, participants' accuracy was lowest on timbre and rhythm change trials. Overall participants performed most poorly on the trials that included rhythm changes. This is consistent with prior research on detecting multiple musical feature changes. Krumhansl and Iverson (1992) found that timbre and pitch interact in a way that makes it difficult to ignore one while attending to the other. Specifically, more time is required to process these two musical features. The fact that participants were not given a second chance to hear any of the trials limited the amount of time they could have to process the musical features. Bigand and Poulin-Charronnat (2006) found that both musicians and non-musicians perceived an illusion of note changes when a rhythm change occurred in a musical sequence. This illusion may have occurred in the present study.

Another potential reason for poor performance on the rhythm trials is the way these trials were constructed. The rhythms used were created by starting with a series of 16 pitches that ascended for eight notes and then descended for eight notes. Subsequently, pitches that fell on counts that were metric (i.e. on the counts of 1, 5, or 9) were removed selectively, in different places for the four different rhythms, to imitate the non-metric rhythms used in (Handel, 1993). As a result a rhythm change contained pitch changes as well (see Figure 1). In addition, the musical sequence used to demonstrate a rhythm change during the training stage was metric, meaning that notes in the pattern occurred on the expected counts of 1, 5, and 9 (vs. the non-metric rhythm used during the test, for which notes did not occur on those counts). The training rhythm change trial was created in the same way; however it did not have any note changes, because the musical sequence was monotonal.

The fact that there were no significant effects of instrument type (percussion, non-percussion, and voice) on performance accuracy could have been due to the small sample size (only three participants in each group). However, the interview data suggests that more general processes may have overridden instrument specific skills needed to perceive the changes. Seven participants reported using process of elimination during session B. If many participants used this strategy, it suggests that general auditory perception skills were being utilized, rather than instrument specific skills.

In conclusion, musicians are better than non-musicians on an auditory perception task involving short musical sequences. Which musical features are detected most easily does not appear to depend on experience with a specific instrument. Non-metric rhythms appear to be difficult for both non-musicians and musicians to compare. General auditory detection skills are important in musical feature change detection, and may override instrument specific knowledge relevant to a music perception task. Finally, learning effects were observed in this study. After four blocks of training intermediate level musicians were able to detect changes in musical features as accurately as advanced level musicians.

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