Connecting Chord Progressions with Specific Pieces of Music

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Abstract

Musicians can conceptualize harmony in terms of its connection to specific pieces of music. However, research appears to indicate that harmony plays a relatively unimportant role in music identification tasks. The present study examines the ability of listeners of varying levels of musical expertise to identify music from chord progressions. Participants were asked to identify well-known classical and pop/rock pieces from their chord progressions, which were recorded using either piano tones or Shepard tones and were played at six transpositional levels. Although musical training and invariance of surface melodic and rhythmic features were found to have an advantageous effect on the identification task, even some non-musicians were able to identify music from chord progressions in conditions of low invariance of surface features. Implications of these results for our understanding of how listeners mentally represent and remember harmony are discussed.

Keywords: aural skills, harmony, memory for harmony, music identification, musical memory

Connecting Chord Progressions with Specific Pieces of Music

Musicians use a variety of conceptual labels to describe chord progressions. These labels can describe the individual chords (e.g., I-IV-V-I or C-F-G-C), their root motions (e.g., descending-fifth chord progression), or the types of music that use them (e.g., “twelve-bar blues progression,” “Doo-wop 50’s progression”). Musicians can also think of chord progressions in terms of their connection to surface-level features of specific pieces of music (e.g., “The Puff progression” in Shaffer, Hughes, & Moseley, 2014, or “Lady Madonna progression” in Torvund, 2011). Although describing chord progressions in terms of specific pieces of music is sometimes motivated by a desire to aid memory, this type of label can also reflect the way that chord progressions are experienced. A case in point is the common practice of describing the chord progression I-V-vi-iii-IV-I-IV-V in terms of its connection to Pachelbel’s *Canon in D Major*, which can promote the association between harmonic concepts and the surface-level features of a specific piece of music (e.g., a specific melody, tempo, and instrumentation). Descriptions such as “Pachelbel’s Progression” in Shaffer, Hughes, & Moseley, 2014 and Anderson, Miyakawa, & Carlton, 2011, or “Pachelbel’s Canon Progression” in tvtropes.org are often used to refer to any instantiation of that progression, and there is empirical evidence that Western-enculturated listeners, both musicians and non-musicians, can recall Pachelbel’s *Canon in D* after hearing only the first three chords of the progression, regardless of timbre and voice-leading (Jimenez & Rossi, 2013). Although there is some anecdotal evidence about trained musicians’ being able to identify pieces other than Pachelbel’s *Canon in D* from chords alone (Aikin, 2004; Berliner, 1994; Maceli, 2009), this ability has not been empirically tested.

It is thus unclear to what extent factors such as conceptual knowledge and surface-level features play a role in that type of association.

Memory tests with manipulated pitch and rhythm of single melodic lines, without harmonic accompaniment, have often been used to study the way in which pitch and rhythm are mentally encoded and remembered (Krumhansl, 2000). Listeners can easily identify a song or piece of music based on the pitch and rhythmic features of its melody even when the melody is presented with different instrumentation or tempo (Andrews, Dowling, Bartlett, Halpern, 1998; Dowling, Barlett, Halpern, Andrews, 2008; Warren, Gardner, Brubacker & Bashford, 1991), different transpositional level (Cuddy & Cohen, 1976; Bartlett & Dowling, 1980; Takeuchi & Hulse, 1992; Schellenberg & Habashi, 2015; Schellenberg, Stalinski, & Marks, 2014), or without text (Hébert & Peretz, 1997; Prickett, 2000; Vongpaisal, Trehub, & Schellenberg, 2006; Volkova, Trehub, Schellenberg, Papsin, & Gordon, 2014). Only rarely has harmonic information been systematically manipulated in memory tests (Bly, Carrion, & Rasch, 2009; Loui, Wu, Wessel, & Knight, 2009; Jonaitis & Saffran, 2009), and chord progressions have so far been shown to have little effect on the identification of musical pieces (Kuusi, 2009; Povel & Van Egmond, 1993).

The potential effect of musical training

Although musically-trained as well as untrained listeners, both adults and children, can identify and name familiar music with relative ease (for a review, see Halpern & Bartlett 2010), there are reasons to expect that identifying music from chord progressions would be a more challenging task for listeners with no musical training. For instance, connecting an isochronous block-chord progression to a rhythmically more active piece of music in an identification task requires a mental act of “filling in the blanks" (i.e., imagining the missing rhythmic information), a process that may be facilitated by trained musicians' previous experience with embellishing and simplifying textures and rhythms (e.g., composing, improvising, transcribing, and analyzing music). Furthermore, conceptually-based strategies for identifying music from harmony, such as harmonic aural analysis and the pursuit of declarative theoretical knowledge about pieces that use certain chord progressions, likely give formally-trained musicians an edge in this type of task. Music theory textbooks abound with examples of chord progressions using both passages from specific pieces as well as block-chord reductions (Aldwell, Schachter & Cadwallader, 2011; Clendinning & Marvin, 2011; Kostka & Payne, 2008; Roig-Francoli, 2011). It has also become commonplace for articles, books, and online resources specifically aimed at teaching chord progressions to include lists of well-known songs categorized according to their chord progressions (Anderson, Miyakawa, & Carlton, 2011; Biamonte, 2010; Moore, 1992; Reeves, 2001; Rosenberg, 2014; Scott, 2000; Stoia, 2013; Torvund, 2011). Finally, the widespread popularity of YouTube videos such as Rob Paravonian's "Pachelbel Rant" (2006) and Axis of Awesome's "Four Chords" (2008) and their use in educational contexts further increases the likelihood of musicians' possession of declarative theoretical knowledge of specific pieces that use certain chord progressions.

The potential effect of surface features

One of the most important considerations in the study of music identification from chord progressions is that there is no such thing as "chords alone" in a specific musical instantiation. Whereas theoretical concepts exist independently of rhythmic and melodic information, any instantiation of a chord progression requires the use of pitches and durations whose successions tend to be perceived by listeners as melodic voice-leadings and rhythmic streams. Even a progression of isochronous block chords is usually perceived as having an upper melody and a bass line created by the succession of the highest and the lowest notes of the chords, respectively (Cambouropoulous, 2008). Additionally, the succession of isochronous durations creates a rhythmic pattern. For instance, Kuusi (2009) found that participants were better at identifying traditional songs from rhythm alone than when rhythm was played in combination with chords, and concluded that the melody created by the highest notes of the chords provided participants with misleading melodic cues.

In order to avoid providing listeners with a misleading "wrong" melody in the present experiment, we included a condition where the highest note of each chord corresponds to the most distinctive pitch of the melodic segment accompanied by that chord in the original piece. Additionally, we decided to add a second condition using Shepard tones in order to downgrade the clarity of melodic information without overtly providing misleading "wrong" melodic cues. Shepard tones are composed of sine-wave, octave-spaced components over a 7-octave range using an amplitude envelope that tapers off at both low and high ends of the frequency range. They are vague in terms of pitch register, which greatly reduces the clarity of melodic gestures, voicing, lowest and highest pitch, and chord inversions. For this reason, Shepard tones are regularly used to minimize the effects of melodic cues in tasks that examine participants' responses to harmony (Bharucha, 1984; Bharucha & Stoeckig, 1986; Firmino, Bueno, & Bigand, 2009; Kuusi, 2007; Krumhansl, Bharucha, & Kessler, 1982). We expected participants to identify music more easily from chord progressions played in octave-specific tones (piano-tones in our study) than in Shepard-tones because of their stronger melodic cues due to their resemblance to harmonic reductions (Aldwell, Schachter & Cadwallader, 2011; Clendinning & Marvin, 2011; Czerny, 1849; Kostka & Payne, 2008; Roig-Francoli, 2011). However, we also predicted that despite its difficulty, music identification from chord progressions in the Shepard-tone condition is still possible. Participants' success in this task would provide evidence that music identification from harmony is at least partially independent from surface features.

Although listeners can identify a tune regardless of the key, playing a tune in the same key as the original has been found to significantly facilitate identification when the period between familiarization and testing is shorter than one week (Schellenberg & Habashi, 2015; Schellenberg, Stalinski, & Marks, 2014). Previous research has provided evidence that even non-AP (absolute pitch)-possessors are able to store information about the absolute pitch level of a familiar tune in long-term memory (Bergeson & Trehub, 2002; Frieler, Fischinger, Lothwesen, Jakubowski & Müllensiefen, 2013; Hahn, 2002; Halpern, 1989; Levitin, 1994). Studies suggest that pitch memory often has a semi-tone resolution in both AP and non-AP listeners (Levitin, 1994; Miyazaki, 1988; Terhardt & Seewann, 1983; Terhardt & Ward, 1982), and studies demonstrate that non-AP possessors are capable of distinguishing recordings at the original pitch level from recordings shifted by one semitone (Gußmack, Vitouch & Gula, 2006; Schellenberg & Trehub, 2003; Schellenberg & Trehub, 2008; Trehub, Schellenberg & Nakata, 2008; Vitouch & Gaugusch, 2000). Based on the fact that listeners are capable of remembering the specific key of a piece of music and that playing a tune in the same key as the original may facilitate identification, we also decided to test the effect of transposition.

Aim

The present study aimed to test whether music can be identified from harmony, as well as to investigate some of the personal factors (e.g., musical training) and musical factors (e.g., invariance of surface features) that can affect such identification. We predict that musical training and the invariance of surface features (e.g., melodic cues and non-transposition) will facilitate music identification from chord progressions.

Method

Participants

There were 97 participants in the experiment. Of these, 86 were undergraduate students enrolled in music classes at the University of Pittsburgh and received academic credit as compensation. Eleven participants (five composition doctoral or master's students, two music theorists, two instrument instructors, one professional musician, and one amateur musician) volunteered for the project and received no compensation. The participants were divided into four groups according to their musical background. In the group of *professionals* (N = 17; 13 males), the participants were professional musicians or music students, aged 28.29 years on average (range 18–60), with private instrument lessons for an average of 10.9 years (range 4–19). *Serious amateur musicians* (N = 16; 7 males), aged 20.0 years on average (range 19–23), had no professional musical training but had had private instrument lessons for more than five years (8.69 years on average; range 6–11). The group of *amateur musicians* (N = 40, 23 males), aged 20.45 years on average (range 18–58), had either had 5 years or less of private instrument lessons or had played an instrument for more than 5 years (5.89 years; range 1–43). *Non-musicians* (N = 24, 15 males), aged 20.24 years on average (range 18–23), had not studied music (with the exception of music lessons in primary school), nor did they actively play any instrument. One *professional* and one *amateur musician* reported possessing absolute pitch.

Musical selections

Many-progressions-to-one-tune. Songs that are very popular tend to be played by different musicians and in various versions. There is empirical evidence that changing the accompanying chords does not necessarily alter the identity of a tune (Povel & Van Egmond, 1993). However, the "many-progressions-to-one-tune" issue can potentially weaken the association between a given chord progression and a specific tune. It also adds the methodological challenge of having to determine what specific version(s) are accepted as correct identifications. We therefore avoided using songs whose harmonic accompaniment is often changed, choosing instead music that has one well-known recorded version.

One-progression-to-many-pieces. Many pieces share the same or similar chord progressions (Scott, 2000; Stoia, 2013), which can naturally weaken the association between a given chord progression and a specific piece as well as conscious recall of the piece (Frieler and Riedemann, 2011). It thus stands to reason that identifying music from chord progressions would be easier for pieces that are harmonically unique or progressions that are used by a piece that is much more well-known than other pieces that use that progression.

Pieces were selected from 20 popular songs and 20 pieces of classical music tested in a pilot study that was conducted prior to the main experiment. The pieces for the pilot were selected based on their inclusion in studies on music identification (Krumhansl, 2010; VanWeelden, 2012, 2014), a study on implicit absolute pitch (Frieler et al., 2013), a corpus analysis (deClercq & Temperley, 2011), and a CD compilation of popular classical pieces (Parry, 2009); they were also selected based on their popularity among undergraduate music theory students at the University of Pittsburgh, (see Appendix A).

Additionally, HookTheory.com and Last.FM.com were used to verify that our popular music selections had one well-known recorded version and were much more well-known than other pieces that use the same chord progression. Of the 40 pieces, twelve that were most often identified from their chords in the pilot study were selected for the main experiment: The Animals, *House of the Rising Sun*; The Beatles, *Let it Be*; Capital Cities, *Safe and Sound*; Coldplay, *Clocks;* Coldplay, *Viva La Vida;* Daft Punk (feat. Pharrell Williams), *Get Lucky*; Elgar, *Pomp and Circumstance* (graduation march); Led Zeppelin, *Stairway to Heaven*; Nirvana, *Smells like Teen Spirit*; Pachelbel, *Canon in D Major;* Red Hot Chili Peppers, *Snow (Hey Oh);* and Tchaikovsky, *The Nutcracker Suite, Dance of the Sugar Plum Fairy*.

Stimuli

The chord sequences were first composed using Finale 2007 software. The most important pitches for each main change of harmony in the original commercial recording were analyzed and composed into a chord. Durational accents provided a straightforward criterion for choosing most of the pitches. Chord progressions preserved both the contour of the different voices and chord inversions from the original excerpts. Pitches were verified using Sonic Visualiser 2.1 (Cannam, Landone, & Sandler, 2010). The progressions consisted of seven or eight chords from the initial phrase, initial period, or another representative section of the piece. Most progressions had four voices, and all voices had only one note per chord (see figure 1 for an example). For the nine progressions taken from popular songs, the duration of the chords matched the original duration in the most-viewed version of the song on YouTube. For the three progressions taken from classical pieces, the duration of the chords was determined by averaging the duration of every chord in the ten most-viewed versions of the piece on YouTube. The chords' durations varied from 1.04 to 2.09 seconds (average 1.58 seconds), and the duration of the whole progression varied from 7.87 to 16.89 seconds (average 12.41 seconds).

Figure 1. Chord progression representing the first two phrases of Coldplay's *Viva La Vida*.

The piano-tone progressions were recorded using Garage Band 3.0.5 (Apple Inc., 2007) with a digital Orchestra Steinway Piano sound from the extended library of Symphony Orchestra Instruments. The Shepard tones were generated using sounds from the Shepard-Risset Generator by Eduardo Dominguez and were programmed and mapped to corresponding pitches by Matti Strahlendorff. Audio excerpts for the second part of the experiment were extracted from commercial recordings. Excerpts lasted 15 seconds and contained the chord progressions used in the first part of the experiment. Most excerpts from songs included vocals, but no excerpt contained words from the title of the song.

Transpositions

The pitch level of the 30 most-viewed YouTube videos of each piece was identified. With the exception of *Pomp and Circumstance*, each piece was associated with one single pitch level for the majority of videos (70% or more). The graduation march from *Pomp and Circumstance* was always played in either G major or D major. However, we adopted G major as the "typical" pitch level for *Pomp and Circumstance* because that is the key of the first occurrence of the graduation march within the piece. A total of 12 different versions of each chord progression were created using two timbres (piano and Shepard tones) and six pitch levels (original, one semitone down, one semitone up, two semitones down, two semitones up, and tritone), forming a total of 144 stimuli.

Procedure

In the first part of the experiment, the 12 chord progressions were presented using both piano tones and Shepard tones (24 items altogether). Each item was played only once. The participants were asked to respond with expanded naming judgments: the name of the piece, words from the lyrics (not necessarily from the beginning of the piece), or some description of the piece. They were also asked to estimate how clearly the chords reminded them of the piece they were thinking of. Since it was possible that a previous progression representing the piece (even if not identified) might have facilitated or hindered identification of a later version with another timbre (Hébert & Peretz, 1997), half of the items were played using piano tones first and Shepard tones second, while the other half was played in the opposite order. To further minimize the likelihood that listening to a chord progression the first time around would interfere with participants' identification of the piece the second time around, the two versions of a chord progression were also presented at distant pitch levels (e.g., original vs. tritone, one semitone up vs. two semitones down). The transpositions were systematically distributed among participants so that each participant heard a set of 24 stimuli.

In some earlier studies (Moore & Rosen, 1979; Schellenberg, Iverson, & McKinnon, 1999; White, 1960), participants were first given a list of the pieces used in the experiment. However, using this kind of a closed-set identification task can artificially boost the effect of an experimental variable. According to Hébert and Peretz, a closed set allows listeners to activate specific mental representations previous to hearing the stimuli and then to compare them to the heard stimuli—a predominantly top-down strategy that greatly facilitates identification. For this reason, an open-set task was adopted in the present study.

In the second part of the experiment, the pieces were presented as commercial recordings, and the participants were asked to name the pieces. For each participant, the experiment consisted of a total of 36 items (12 piano-tone progressions, 12 Shepard-tone progressions, and 12 commercial recordings). After responding to all items, the participants filled out a questionnaire for background information about their musical studies, instrument playing, music listening, etc. Altogether, the experiment and the questionnaire took about 45 minutes.

In scoring the responses, correct names, correct words from the lyrics, or other correct descriptions of a piece were scored as 1 (identified), and other responses were scored as 0 (unidentified). If a person suggested a piece other than what we had in mind, we checked the response. However, we found no responses in which the melodies and keys corresponded to our melodic reductions and scheme of transposition.

Only pieces that were recognized by a participant from commercial recordings were included in his/her data. The scores were summarized separately for each group of participants, for each of the 12 pieces, and for the two timbres, and were then given as percentages: 75%, for example, indicates that a chord progression was identified by 75% of the participants who identified the piece from the commercial recording.

Results

Figure 2 shows the percentages of identified chord progressions played using two timbres for the four groups of participants. The figure shows that the professional musicians generally identified more pieces from their chord progressions than did the other participants and that there were no differences between the two amateur subgroups. Additionally, the identification from Shepard tones was more difficult than identification from piano tones.

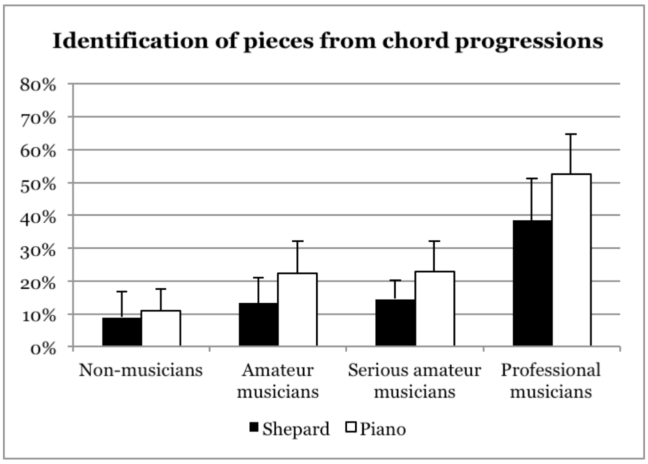

Figure 2. Responses from four participant subgroups. Identification of pieces from chord progressions. Error bars show standard deviations.

ANOVA analysis was made using the two timbres of the progressions and the musical background of the participants as experimental variables. The analysis confirmed the results: the musical training of the participants was statistically very significant ($F_{(3, 190)} = 29.487$, $p < .000$), and timbre was significant ($F_{(1, 190)} = 7.055$, $p = .009$) in explaining the responses. The training * timbre interaction was not statistically significant ($p = .399$). The Bonferroni post-hoc test confirmed that the subgroup of professional musicians differed very clearly from other participant subgroups ($p < .001$) and that there was no difference between amateur musicians and serious amateur musicians ($p = 1.000$). The difference between the group of non-musicians and serious amateur musicians was statistically significant ($p = .032$), and the difference between non-musicians and amateur musicians was marginally significant ($p = .054$). Since the subgroup of professionals and non-musicians differed from the other participant subgroups, but the responses from amateurs and serious amateurs did not differ, the two subgroups of amateur musicians were merged into one group (N = 56; 30 male). All further analyses were made using three participant subgroups: professional musicians, amateur musicians, and non-musicians.

As stated, in half of the items, the piano-tone version was presented before the Shepard-tone version; in the other half, the order was reversed. The responses to the piano-tone versions and those to the Shepard-tone versions, separately for the three participant subgroups, and all participants as one group, can be seen in Figure 3, which shows differences between the two orders of presentation for the group of non-musicians only: if the items were first played using piano tones, they were easier to recognize from Shepard tones but not vice versa; that is, the earlier piano-tone version helped with recognition. The result was confirmed by paired sample T-test analyses, separately for the three participant subgroups, showing statistical significance (p = .039) for non-musicians and Shepard tones only. The p-values for the difference between the two orders for Shepard tones (Shepard first versus Shepard second) varied between .103 and .660. With piano tones (piano first versus piano second), the p-values varied between .083 and .871).

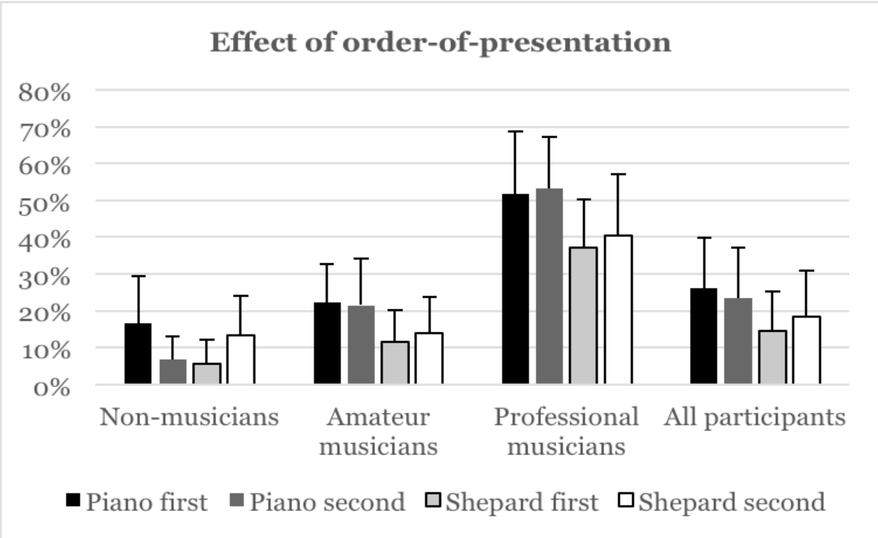

Figure 3. Effect of order-of-presentation on responses; piano tones and Shepard tones. Error bars show standard deviations.

We also analyzed the effect of transposition on piece identification. Figure 4 shows percentages of pieces identified from the six transpositional levels for the three participant subgroups. The figure shows some differences between transpositions for professional musicians, fewer for amateur musicians, and practically none for non-musicians. ANOVA analysis showed that the effect of transpositions was not statistically significant in any of the participant subgroups: professional musicians ($F_{(5,102)}$ = 1.750, p = .131), amateur musicians $F_{(5,333)}$ = 1.161, p = .143), non-musicians ($F_{(5,138)}$ = 0.430, p = .827).

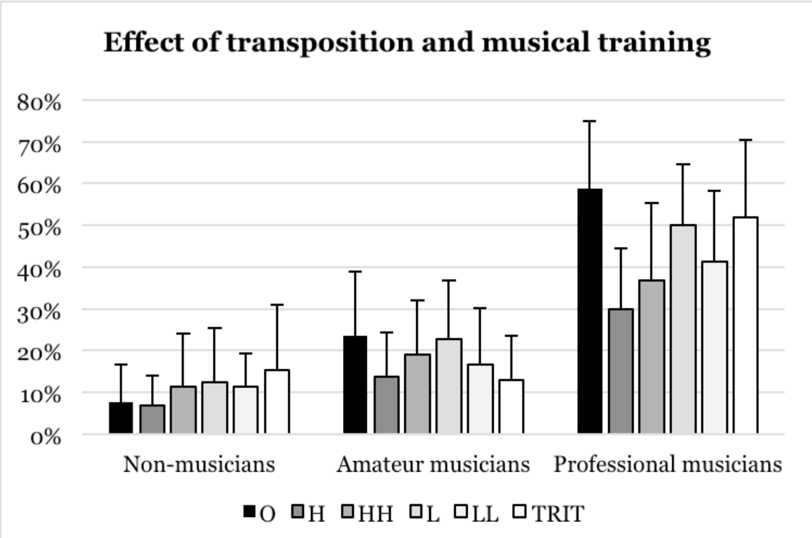

Figure 4. Effect of transposition. Percentages of correct identifications (vertical axis). O = original transposition; H = one semitone up; HH = two semitones up; L = one semitone down; LL = two semitones down; TRIT = tritone. Error bars show standard deviations.

Because Pachelbel's *Canon in D* was the piece that was most often identified from its chord progression in our experiment and because we suspected that the rhythmic resemblance between our slow block-chord stimuli and the beginning of the *Canon* facilitated identification, we decided to analyze the role of rhythmic similarity between the original music and the chord progression on the identification task. Although rhythmic similarity is a complex topic due to its many possible considerations (Cao, Lotstein, & Johnson-Laird, 2014; Forth, 2012; Gotham, 2015; Toussaint, 2013), we only took into account overall rhythmic density. We chose this aspect because of its high perceptual salience, high degree of invariance within each piece, and high degree of variability among our stimuli. In order to calculate rhythmic similarity based on rhythmic density, the number of chords in each chord progression was divided by the number of attacks in the composite rhythm formed by the main melody and the most salient rhythmic pattern in the accompaniment. In other words, we calculated how similar the original rhythm was to our isochronous block chords. These rhythmic similarity values varied between 100% for Pachelbel's *Canon* (the original music had 100% of the same rhythm as the block-chord stimuli) and 11% for Daft Punk’s *Get Lucky* and Red Hot Chili Peppers’ *Snow (Hey Oh)* (see Appendix B). We calculated correlations between rhythmic similarity and the average percentages of piano-tone responses (the easier of the two timbres) for the three participant subgroups and found that there was a statistically significant correlation for all groups ($R(12) = .752$, $p = .005$ for professionals; $R(12) = .872$, $p < .000$ for amateurs and $R(12) = .835$, $p = .001$ for non-musicians). The responses are consistent with the idea that rhythmic similarity does indeed facilitate identification from chord progressions.

Discussion

The present study provided evidence that music can be identified even in an open-set identification task from harmony played using isochronous block chords. Also, as expected, musical training was associated with a greater ability to identify music from chord progressions, professional musicians performing better than amateur musicians, who in turn performed better than non-musicians.

Practicing has been shown to turn processes that initially require conscious control into automatic processes, thus leaving limited attentional resources available for higher-order processes (Jansma, Ramsey, Slagter & Kahn, 2001). For professional musicians, these processes are related to performing and practicing an instrument as well as analyzing and conceptualizing music (van Zuijen, 2006; Kuusi, 2015). Practicing harmonies can enhance both conceptually-based strategies and perceptually-driven mechanisms (Goldstone, 1994) that could facilitate the identification of music from chords. On the one hand, the use of chord labels or other conceptual labels in harmonic analysis can allow professionals to label chords in our block-chord stimuli and associate those labels with declarative knowledge about what pieces use those chords. On the other hand, increasing attention to chord progressions (Cullimore, 1999; Farbood, 2012; Williams, 2004) during practice (e.g., playing chords on an instrument) is likely to increase listeners' general interest in harmony. Additionally, Wolpert (2000) found that musicians not only tend to pay more attention to harmony than non-musicians, but also tend to be more sensitive to it. Heightened attention and sensitivity to harmony may lead to more detailed encoding of harmonic information in everyday listening, even when the listener is not actively labeling chords or chord progressions. If so, music identification from chord progressions for such participants may have been facilitated by auditory memory traces that are particularly detailed in terms of harmonic information. It is also possible that previous engagement with embellishing and simplifying textures and rhythms (e.g., composition, improvisation, and analysis) gives musically trained listeners an edge over other listeners in terms of their ability to imagine a fully fleshed-out song from slow-moving, unembellished chords. However, additional research is needed to better understand the connection between the different aspects of musical training and the ability to identify music from chord progressions.

Even though musically-untrained listeners' ability to complete this type of identification task was low in general, there were individual non-musician participants who recognized up to 44% of the pieces from chords. This indicates that previous experience embellishing and simplifying textures and rhythms, formal training in aural harmonic analysis, and declarative theoretical knowledge about pieces that use certain chord progressions is not indispensable for the identification of music from chord progressions. Although conceptually-based strategies available to musically-trained listeners may have facilitated the identification of music from chord progressions, it is possible for chord progressions to sometimes automatically trigger memories of specific pieces of music via predominantly perceptually-driven processes.

Results from our experiment also provide important information about the role of melodic cues in the identification of pieces from chord progressions. In the piano-sound progressions, chords were voiced in such a way that they avoided providing listeners with misleading "wrong" melodies. However, due to the danger of over-facilitating identification, we also included the Shepard tone version that downgraded melodic information without overtly providing misleading cues. Although identification from chord progressions was significantly more frequent in the piano-tone condition than the Shepard-tone condition, the fact that identification was possible in the Shepard condition is a key finding because it demonstrates that clear melodic cues are not a prerequisite for chord progressions to trigger memories of specific pieces of music.

One of the main challenges in studying how listeners mentally process harmony is not only that harmonic activity always entails some type of melodic and rhythmic activity, but that in most listening scenarios, melody and rhythm tend to be more perceptually salient than harmony (Cullimore, 1999; Farbood, 2012; Halpern, 1984; Mélen & Deliège, 1995; Williams, 2004). The perceptual prominence of rhythm and its influence on the mental processing of harmonic activity has traditionally been minimized in experimental settings by using moderately slow streams of same-duration events. As shown in our study, this kind of isochronous stimuli enhances listeners' association with music that has a similarly slow and homogeneous rhythmic surface. This indicates that even when rhythmic activity is minimized, its influence on the way listeners process harmonic information may still be significant. However, although we found a significant correlation between rhythmic similarity and identification from chords in our experiment that suggests that the resemblance between the original piece and our block-chord representation made that recognition easier, we would hesitate to attribute participants' identification of music from chords solely to rhythmic factors, even in the case where the original music had 100% of the same rhythm as our block-chord stimuli. Hébert and Peretz (1997) found that participants identified famous melodies only 6% of the time when they were asked to identify those melodies from their rhythm alone in an open-set task. Importantly, all of the melodies used in their study had rhythms that were more distinctive (i.e., they formed clear patterns and phrases created by a combination of long and short durations) than the isochronous succession of long durations of our chord stimuli (i.e., durations that do not suggest patterns or groupings at any level of structure). Therefore, considering the use of both isochronous chord stimuli and the an open-set approach in our experiment, it is highly unlikely, even in the scenario of maximum rhythmic similarity (i.e., Pachelbel's *Canon*), that listeners could identify the piece from unpitched isochronous durations in an open-set task. Additionally, participants in our study were sometimes able to identify music from block-chord stimuli even when there was a very low degree of rhythmic similarity to the originals (e.g., Coldplay's *Clocks* and Daft Punk's *Get Lucky,* see Appendix B), demonstrating that strong rhythmic cues are not necessarily required for chord progressions to trigger memories of specific pieces of music.

The order of presentation (Shepard first or piano tones first) had an effect on non-musicians but not on musicians. Non-musicians were less likely to identify music from piano-tone chords when they had previously heard the Shepard-tone version of the progression than when the Shepard-tone version followed the piano-tone version. The fact that non-musicians' recall appeared to be more affected by surface rhythmic resemblance than deeper pitch resemblance (i.e., Shepard-tone and piano-tone versions of the same progression have the same rhythm but not the same pitch structure) may in turn shed light on why non-musicians were less likely than musicians to identify music from harmony in our experiment.

The effects of melodic and rhythmic surface cues can help reveal the learning processes and activation of chord progression schemata (e.g., 12-bar blues progression). Although identifying a piece of music from harmony entails a more specific association than the activation of a harmonic schemata, the mental representations that allow both processes to occur share a similar origin since all schematic musical memories begin with episodic information that is subsequently transformed into schemata (Huron, 2006). Accordingly, our results suggest that the activation of schemata for chord progressions is more dependent on the invariance of surface features (e.g., melody, rhythm, timbre, etc.) for non-musicians than musicians, but that, at least for some non-musicians, surface feature invariance is not a prerequisite for the activation of harmonic schemata. The fact that some chord stimuli identified by non-musicians in the experiment differed considerably from the original songs in terms of their musical surface (e.g., downgraded melodic cues in Shepard-tone stimuli or low levels of rhythmic similarity) also suggests that detailed harmonic information that is at least partially autonomous from surface features can be mentally encoded and implicitly stored in auditory long-term memory.

The influence of transposition was also tested in this study but showed no significant effect on piece identification. This result is consistent with findings from a recent study by Schellenberg and Habashi (2015). Their findings suggest that specific pitch levels tend to be forgotten much sooner than relational melodic information such as contour and melodic intervals.

Although the present study tested conscious full identification of pieces from chord progressions, some participants reported familiarity that was not strong enough to call up any specific details such as lyrics, gender of singer, instrumentation, rhythm, or melodic features. Memory states of semi-activation for a particular song (Chafe, 1994; Snyder, 2009), such as “Recognition without Identification” (RWI) and “Feeling of Knowing” (FOK), have been observed with downgraded musical stimuli (Kostic & Cleary, 2009; Peynircioğlu, Tekcan, Wagner, Baxter, & Shaffer, 1998; Rabinovitz & Peynircioğlu, 2011). Future research can test chord progressions’ potential to semi-activate not only schematic memories related to general musical practices (evident in tonal priming studies, for a review, see Bigand & Poulin-Charronnat, 2009) but also episodic memories related to specific pieces of music.

Our study showed that listeners can identify chord progressions even with limited melodic and rhythmic cues. It appears that the use of harmonic information in music identification is easiest for professional musicians, presumably due to a combination of sophisticated conceptually-based strategies with a formal-training-enhanced perceptually-driven mechanisms. Melodic and rhythmic cues—whether correct or misleading—are important and are always present in chord progressions. The association of a chord progression with a specific song is just one way to show how the interaction of harmony and episodic memory can influence our perception of music, suggesting that the seemingly idiosyncratic task of explicitly identifying music from harmony can improve our general understanding of how listeners make sense of music. Future research on music identification from chord progressions is needed to clarify whether the association of harmony with episodic memory occurs implicitly or not, as well as how such unconscious associations impact our experiences of music.

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References

Aikin, J. (2004). *A player's guide to chords and harmony: Music theory for real-world musicians*. Hal Leonard Corporation.

Aldwell, E., Schachter, C., & Cadwallader, A. C. (2011). *Harmony & voice leading* (4th ed.). Boston, MA: Schirmer/Cengage Learning.

Anderson, Miyakawa, & Carlton. (2011). Common Chord progressions. Retrieved from http://www.hooktheory.com/theorytab/common-chord-progressions

Andrews, M. W., Dowling, W. J., Bartlett, J. C., & Halpern, A. R. (1998). Identification of speeded and slowed familiar melodies by younger, middleaged, and older musicians and nonmusicians. *Psychology and Aging*, 13, 462–471.

Apple Inc. (2007). GarageBand 3.0.5 [computer software]. Cupertino, CA.

Axis of Awesome. (2008). Axis of awesome - 4 four chord song (with song titles) [Video clip]. Retrieved from YouTube. www.Youtube.com, http://www.youtube.com/watch?v=5pidokakU4I

Bartlett, J.C., & Dowling, W.J. (1980). Recognition of transposed melodies: A key-distance effect in developmental perspective. Journal of *Experimental Psychology: Human Perception and Performance, 6*, 501-515.

Bergeson, T. R., & Trehub, S. E. (2002). Absolute pitch and tempo in mothers' songs to infants. *Psychological Science, 13*, 72–75.

Berliner, P. F. (1994). *Thinking in jazz: The infinite art of improvisation*. University of Chicago Press.

Bharucha, J. J. (1984). Anchoring effects in music: The resolution of dissonance. *Cognitive Psychology, 16,* 485-518.

Bharucha, J. J., & Stoeckig, K. (1986). Reaction time and musical expectancy: Priming of chords. *Journal of Experimental Psychology: Human Perception and Performance, 12*, 403-410.

Biamonte, N. (2010). Triadic modal and pentatonic patterns in rock music. *Music Theory Spectrum*, 32(2), 95–110.

Bigand, E., & Poulin-Charronnat, B. (2009). Tonal cognition. *The Oxford handbook of music psychology*, 59-71.

Bly, B. M., Carrión, R. E., & Rasch, B. (2009). Domain-specific learning of grammatical structure in musical and phonological sequences. *Memory & cognition*, *37*(1), 10-20.

Cannam, C., Landone, C., & Sandler, M. (2010). Sonic Visualiser: An open source application for viewing, analysing, and annotating music audio files. In *Proceedings of the 18th ACM Multimedia International Conference* (pp. 1467–1468). New York, NY: ACM.

Cambouropoulos, E. (2008). Voice and stream: Perceptual and computational modeling of voice separation, *Music Perception, 26(1)*, 75-94.

Cao, E., Lotstein, M., & Johnson-Laird, P. N. (2014). Similarity and Families of Musical Rhythms. *Music Perception, 31*, 444-469.

Chafe, W. (1994). *Discourse, consciousness, and time*. Chicago: University of Chicago Press, Chicago, IL.

Clendinning, J. P., & Marvin, E. W. (2011). *The musician's guide to theory and analysis* (2nd ed.). New York: W.W. Norton.

Cuddy, L.L., & Cohen, A.J. (1976). Recognition of transposed melodic sequences. *Quarterly Journal of Experimental Psychology, 28*, 255-270.

Cullimore, J. R. (1999). Harmonic hierarchies as distinctive abstractions that listeners may derive from musical surface structure. Unpublished Master's thesis. Queen's University Kingston, Ontario, Canada.

Czerny, C. (1979). School of practical composition: Complete treatise on the composition of all kinds of music (J. Beshop, Trans.). New York: Da Capo Press. (Reprinted from Die schule der praktischen tonsetzkunst, 1849, Bonn: Simrock)

Dominguez, E. (2011). Shepard-Risset Generator 1.1. Retrieved from https://www.native-instruments.com/en/reaktor-community/reaktor-user-library/entry/show/6403/

deClercq, T., & Temperley, D. (2011). A corpus analysis of rock harmony." *Popular Music 30*, 47–70.

Dowling, W. J., Bartlett, J. C., Halpern, A. R., & Andrews, M. W. (2008). Melody recognition at fast and slow tempos: Effects of age, experience, and familiarity. *Perception & Psychophysics, 70,* 496-502.

Farbood, M. M. (2012). A parametric, temporal model of musical tension. *Music Perception, 29*, 387–428.

Firmino, É. A., Bueno, J. L. O, & Bigand, E. (2009). Travelling through pitch space speeds up musical time. *Music Perception 26*, 205–209.

Frieler, K. & Riedemann, F. (2011). Is independent creation likely to happen in pop music? *Musicae Scientiae, 15*, 17-28.

Frieler, K., Fischinger, T., Schlemmer, K., Lothwesen K., Jakubowski K., & Müllensiefen, D. (2013). Absolute memory for pitch: A comparative replication of Levitin's 1994 study in six European labs. *Musicae Scientiae, 17*, 334-349.

Forth, J (2012). Cognitively-motivated Geometric Methods of Pattern Discovery and Models of Similarity in Music. PhD Dissertation, Goldsmiths University London,

Goldstone, R. L. (1994). The role of similarity in categorization: Providing a groundwork. *Cognition*, *52*(2), 125-157.

Gotham, M. (2015). Meter metrics: Characterizing relationships among (mixed) metrical structures. *Music Theory Online, 21.* http://www.mtosmt.org/issues/mto.15.21.2/mto.15.21.2.gotham.php

Gußmack, M. B., Vitouch, O., & Gula, B. (2006). Latent absolute pitch: An ordinary ability? In M. Baroni, A. R. Addessi, R. Caterina & M. Costa (Eds.), Proceedings of the 9th International Conference on Music Perception & Cognition (pp. 1408-1412). Bologna, Italy: Bononia University Press.

Hahn, K. (2002). Absolute memory for melody: A study with choir singers. In C. Stevens, D. Burnham, G. McPherson, E. Schubert, J. Renwick (Eds.). Proceedings of the 7th International Conference on Music Perception and Cognition (pp. 514-517). Sydney, Australia: Adelaide Causal Productions.

Halpern, A. R. (1984). Perception of structure in novel music. *Memory & Cognition, 12*, 163-170.

Halpern, A. R. (1989). Memory for the absolute pitch of familiar songs. *Memory & Cognition, 17*, 572–581.

Halpern, A. R., & Bartlett, J. C. (2010). Memory for melodies. In *Music perception* (pp. 233-258). Springer New York.

Hébert, S., & Peretz, I. (1997). Recognition of music in long-term memory: Are melodic and temporal patterns equal partners? *Memory & Cognition, 25*, 518–533.

Huron, D. (2006). *Sweet anticipation: Music and the psychology of expectation*. Cambridge, MA: MIT Press.

Jansma, J. M., Ramsey, N. F., Slagter, H. A., & Kahn, R. S. (2001). Functional anatomical correlates of controlled and automatic processing. *Journal of Cognitive Neuroscience, 13*, 730–743.

Jimenez, I. E. & Rossi, V. (2013). The Influence of Instrument, Harmony, and Voice leading on Listeners' Distinction between Popular and Classical Music. Unpublished manuscript.

Jonaitis, E. M., & Saffran, J. R. (2009). Learning harmony: The role of serial statistics. *Cognitive science*, *33*(5), 951-968.

Kostic, B., & Cleary, A. M. (2009). Song recognition without identification: When people cannot "name that tune" but can recognize it as familiar. *Journal of Experimental Psychology: General*, *138*(1), 146.

Kostka, S. M., & Payne, D. (2008). *Tonal harmony: With an introduction to twentieth-century music* (6th ed.). New York: McGraw-Hill.

Krumhansl, C. L. (2000). Rhythm and pitch in music cognition. *Psychological bulletin*, *126*(1), 159.

Krumhansl, C. L. (2010). Plink: "thin slices" of music. *Music perception 27*(5), 337-354.

Krumhansl, C. L., Bharucha, J. J., & Kessler, E. J. (1982). Perceived harmonic structure of chords in three related musical keys. *Journal of Experimental Psychology: Human Perception and Performance, 8*, 24-36.

Kuusi, T. (2007). Interval-class and order of presentation affect interval discrimination. *Journal of New Music Research, 36*, 95–104.

Kuusi, T. (2009). Tune recognition from melody, rhythm and harmony. In J. Louhivuori, T. Eerola, S. Saarikallio, T. Himberg, P-S. Eerola (Eds.), Proceedings of the 7th Triennial Conference of European Society for the Cognitive Sciences of Music (ESCOM 2009), Jyväskylä, Finland. http://urn.fi/URN:NBN:fi:jyu-2009411339

Kuusi, T. (2015). Musical training and musical ability: Effects on chord discrimination. *Psychology of Music, 43,* 291–301.

Levitin, D. J. (1994). Absolute memory for musical pitch: evidence from the production of learned melodies. *Perception & Psychophysics, 56*, 414–423.

Loui, P., Wu, E. H., Wessel, D. L., & Knight, R. T. (2009). A generalized mechanism for perception of pitch patterns. *The Journal of Neuroscience*, *29*(2), 454-459.

Maceli, A. (2009). *Cultivating the imaginative ear for jazz improvisation: A study in three settings*. Unpublished doctoral dissertation, Teachers College, Columbia University, New York, NY.

Mélen, M., & Deliège I. (1995). Extraction of cues or underlying harmonic structure: Which guides recognition of familiar melodies? *European Journal of Cognitive Psychology, 7*, 81-106.

Miyazaki, K. (1988). Musical pitch identification by absolute pitch possessors. *Perception & Psychophysics, 44*, 501-512.

Moore, B. C. J., & Rosen, S. M. (1979). Tune recognition with reduced pitch and interval information. *Quarterly Journal of Experimental Psychology, 31*, 229–240.

Moore, Allan. (1992). Patterns of harmony. *Popular Music, 11(*1), 73–106.

Paravonian, R. (2006). Pachelbel rant [Video clip]. Retrieved from YouTube. www.Youtube.com, http://www.youtube.com/watch?v=JdxkVQy7QLM

Parry, D. (2009). *The 50 Greatest Pieces of Classical Music*. London Philharmonic Orchestra. X5 Music Group. ASIN: B002WMP162.

Peynírcíğlu, Z. F., Tekcan, A. Í., Wagner, J. L., Baxter, T. L., & Shaffer, S. D. (1998). Name or hum that tune: Feeling of knowing for music. *Memory & cognition*, *26*(6), 1131-1137.

Povel, D.J., & Van Egmond, R. (1993). The function of accompanying chords in the recognition of melodic fragments. *Music Perception, 11*, 101-115.

Prickett, C. A. (2000). A Comparison of the Basic Song Repertoire of Vocal/Choral and Instrumental Music Education Majors. *Journal of Research in Music Education, 48*, 5–9.

Rabinovitz, B. E., & Peynircioğlu, Z. F. (2011). Feeling-of-knowing for songs and instrumental music. *Acta psychologica*, *138*(1), 74-84.

Reeves, S. D. (2001). *Creative jazz improvisation*. Prentice Hall.

Roig-Francolí, M. A. (2011). *Harmony in context* (2nd ed.). New York: McGraw-Hill.

Rosenberg, N. (2014). Bach, Beck, and Bjork walk into a bar: Reclassifying harmonic progressions to accommodate popular music repertoire. *Journal of Music Theory Pedagogy, 28*.

Schellenberg, E. G., & Habashi P. (2015). Remembering the melody and timbre, forgetting the key and tempo. *Memory & Cognition*. Published online March 24, 2015 (no offline version available).

Schellenberg, E. G., & Iverson, P., & McKinnon, M. (1999). Name that tune: Identifying popular recordings from brief excerpts. *Psychonomic Bulletin & Review, 6*, 641–646.

Schellenberg, E. G., Stalinski, S. M., & Marks, B.M. (2014). Memory for surface features of unfamiliar melodies: Independent effects of changes in pitch and tempo. *Psychological Research, 78*, 84–95.

Schellenberg, E. G. & Trehub, S. E. (2003). Good pitch memory is widespread. *Psychological Science 14*, 262–266.

Schellenberg, E. G. & Trehub, S. E. (2008). Is there an Asian advantage for pitch memory? *Music Perception, 25,* 241–252.

Scott, R. J. (2000). *Money Chords: A Songwriter's Sourcebook of Popular Chord Progressions*. Bloomington, IN: iUniverse.

Shaffer, Hughes, & Moseley. (2014). Open Music Theory. Retrieved from http://openmusictheory.com/contents.html

Snyder, B. (2009). Memory for music. In S. Hallam, I. Cross, M. H. Thaut (Eds.), The Oxford handbook of music psychology (pp. 107-117). Oxford: Oxford University Press.

Stoia, N. (2013). The common stock of schemes in early blues and country music. *Music Theory Spectrum, 35*, 194-234. doi:10.1525/mts.2013.35.2.194

Takeuchi, A.H., & Hulse, S.H. (1992). Key-distance effects in melody recognition reexamined. *Music Perception, 10*, 1-24.

Terhardt, E., & Seewann, M. (1983). Aural key identification and its relationship to absolute pitch. *Music Perception*, *1*, 63-83.

Terhardt, E., & Ward, W. D. (1982). Recognition of musical key: exploratory study. *Journal of the Acoustical Society of America* 72: 26-33.

Torvund, O. (2011). Guitar chord progressions - Index. Retrieved from http://www.torvund.net/guitar/index.php?page=progressions

Toussaint, G. T. (2013). *The geometry of musical rhythm: What makes a "good" rhythm good?*. Boca Raton, FL: CRC Press, Taylor & Francis Group.

Trehub, S. E., Schellenberg, E. G., & Nakata, T. (2008). Crosscultural perspectives on pitch memory. *Journal of Experimental Child Psychology, 100*, 40–52.

van Zuijen, T. L. (2006). *Sensory auditory processing and intuitive sound detection. An investigation of musical experts and nonexperts*. Doctoral dissertation, University of Helsinki, Finland.

VanWeelden, K. (2012). Classical Music as Popular Music: Adolescents' Recognition of Western Art Music. *Applications of Research in Music Education, 31*, 1–11.

VanWeelden, K. (2014). Preservice Music Teachers' Recognition of Western Art Music Found in Popular Culture. *Journal of Music Teacher Education, 24*, 65–75.

Vitouch, O., & Gaugusch, A. (2000). Absolute recognition of musical keys in non-absolute-pitch-possessors. In C. Woods, G. B. Luck, R. Brochard, S.A. O'Neill, & J.A. Sloboda (Eds), Proceedings of the Sixth International Conference on Music Perception and Cognition. Keele, Staffordshire, UK: Department of Psychology.

Vongpaisal, T., Trehub, S. E., & Schellenberg, E. G. (2006). Song recognition by children and adolescents with cochlear implants. *Journal of Speech, Language, and Hearing Research*, 49, 1091–1103.

Volkova, A., Trehub, S. E., Schellenberg, E. G., Papsin, B. C., & Gordon, K. A. (2014). Children's identification of familiar songs from pitch and timing cues. *Frontiers in psychology*, *5*.

Warren, R. M., Gardner, D. A., Brubacker, B. S., & Bashford, J. A. Jr. (1991). Melodic and nonmelodic sequences of tones: Effects of duration on perception. *Music Perception, 8*, 277–290.

White, B. W. (1960). Recognition of distorted melodies. *The American Journal of Psychology, 73*, 100–107.

Williams, L. R. (2004). *The effect of musical training and musical complexity on focus of attention to melody or harmony*. Unpublished doctoral dissertation, Florida State University, Tallahassee, FL.

Wolpert, R. S. (2000). Attention to key in a non-directed music listening task: Musicians vs. nonmusicians. *Music Perception*, *18*, 225–230.

Appendix A
Sources of Stimuli for Pilot

Song	Year of Release	Krumhansl 2010 *)	Frieler et al. 2013	deClercq & Temperley 2011	Music Theory Students 2010-2014 **)
The Animals, *House of the Rising Sun*	1964	N	N	N	Y
The Beatles, *Yesterday*	1965	N	N	Y	Y
The Beatles, *Hey Jude*	1968	N	N	Y	Y
The Beatles, *Let it Be*	1970	N	Y	Y	Y
Led Zeppelin, *Stairway to Heaven*	1971	Y	Y	Y	Y
The Eagles, *Hotel California*	1973	Y	N	Y	N
Lynyrd Skynyrd, *Sweet Home Alabama*	1974	N	N	N	Y
Nirvana, *Smells like Teen Spirit*	1991	Y	N	Y	N
Radiohead, *Karma Police*	1997	N	N	N	Y
Red Hot Chili Peppers, *Californication*	1999	Y	N	N	Y
Red Hot Chili Peppers, *Otherside*	1999	N	N	N	Y
Coldplay, *Clocks*	2002	N	N	N	Y
Outkast, *Hey Ya!*	2003	Y	N	N	N
Gnarls Barkley, *Crazy*	2006	N	N	N	Y
Red Hot Chili Peppers, *Snow (Hey Oh)*	2006	N	N	N	Y
Coldplay, *Viva La Vida*	2008	Y	Y	N	N
Capital Cities, *Safe and Sound*	2013	N	N	N	Y
Daft Punk (feat. Pharrell Williams), *Get Lucky*	2013	N	N	N	Y
Pharrell Williams, *Happy*	2014	N	N	N	Y
Hozier, *Take me to Church*	2014	N	N	N	Y

*) Y = the song was used in that study; N = the song was not used in that study.
**) Songs popular among undergraduate music theory students at the University of Pittsburgh surveyed between 2010 and 2014. Y = songs mentioned by students; N = songs not mentioned by students.

Classical Piece	VanWeelden 2012/2014 *)	Parry 2009 **)	Other reasons to Include this piece ***)
Elgar, Pomp and Circumstance ("*Graduation March*")	a	Y	NA
Pachelbel, *Canon in D*	a	Y	NA
Beethoven, Piano Sonata No. 14 "*Moonlight Sonata,*" I	a	Y	NA
Beethoven, Symphony No. 9, IV *("Ode to Joy")*	a	Y	NA
Grieg, *Peer Gynt, In the Hall of the Mountain King*	a	Y	NA
Beethoven, *Für Elise*	b	Y	NA
Bach, Orchestral Suite No. 3, Air ("*Air on the G string*")	b	Y	NA
Tchaikovsky, *The Nutcracker Suite, Dance of the Sugar Plum Fairy*	b	N	NA
Bach, *Jesu, Joy of Man's Desiring*	b	N	NA
Arnaud, *Bugler's Dream ("Olympic Fanfare")*	c	N	NA
Dvorák, Symphony No. 9 ("*New World*"), IV	N	Y	NA
Faure, *Pavane*	N	Y	NA
Giazotto, *"Albinoni's Adagio"*	N	Y	NA
Schubert, *Ave Maria*	N	N	Often included in Christmas compilation CDs
Minuet from Anna Magdalena's Notebook	N	N	Often played by piano beginners
Mussorgsky, *Pictures of an Exhibition*, *Great Gate of Kiev*	N	N	Block-chord texture
Bach, *Chaconne for violin*	N	N	Block-chord texture
Beethoven, Piano Sonata No. 8 *"Pathetique,"* II	N	N	Block-chord texture
Chopin, Prelude No. 20 in Cm	N	N	Block-chord texture
Chopin, Prelude No. 4 in Em	N	N	Block-chord texture

*) a = included in VanWeelden, 2012/2014; b = preselected for VanWeelden, 2012 (personal communication with the author); c = included in the internet list used as preliminary source for VanWeelden, 2012; N = not mentioned by VanWeelden.
**) "*The 50 Greatest Pieces of Classical Music*," a selection of classical works recorded by the London Philharmonic Orchestra, with conductor David Parry released in 2009. Y = the piece was included in that compilation of recordings; N = the piece was not included in that compilation.
***) NA = pieces that were selected because of their inclusion in VanWeelden, 2012/2014 and /or Parry, 2009.

Appendix B

Rhythmic Similarity between Chord Stimuli and Original Excerpts

		Non-musicians		Amateur musicians		Professional musicians	
Piece/progression	Rhythmic similarity calculated from density of composite rhythm	ID% from piano-tone chords	ID% from Shepard-tone chords	ID% from piano-tone chords	ID% from Shepard-tone chords	ID% from piano-tone chords	ID% from Shepard-tone chords
Pachelbel, *Canon in D*	100%	75%	78%	88%	72%	100%	94%
The Animals, *House of the Rising Sun*	14%	38%	13%	40%	20%	77%	69%
Coldplay, *Viva La Vida*	18%	0%	12%	14%	16%	36%	43%
Elgar, *Pomp and Circumstance*	45%	33%	8%	50%	13%	69%	27%
Tchaikovsky, *Dance of the Sugar Plum Fairy*	33%	10%	0%	19%	2%	53%	29%
Capital Cities, *Safe and Sound*	13%	0%	0%	0%	0%	0%	0%
Led Zeppelin, *Stairway to Heaven*	27%	0%	0%	13%	4%	62%	15%
Coldplay, *Clocks*	10%	7%	7%	12%	7%	25%	18%
The Beatles, *Let it Be*	25%	0%	9%	5%	12%	47%	33%
Nirvana, *Smells like Teen Spirit*	29%	20%	10%	9%	4%	40%	47%
Daft Punk (feat. Pharrell Williams), *Get Lucky*	11%	5%	6%	6%	0%	33%	17%
Red Hot Chili Peppers, *Snow (Hey Oh)*	11%	0%	0%	3%	0%	20%	13%

*) To facilitate comparison between the different pieces, the rhythmic notation was adjusted so that the harmonic rhythm always corresponds to half-notes. For instance, while the written harmonic rhythm of Pachelbel's Canon and the *Sugar Plum Fairy* in the original score is a quarter note, in this table, their rhythmic notation is doubled; likewise, the written harmonic rhythm of *Viva la Vida*, *Get Lucky*, and *Safe and Sound* in most transcriptions is whole notes, but in this table, their rhythmic notation is halved.

**) The transcription of Pachelbel's Canon in all half-notes does not match the recording used in part II of the experiment. However, it is a reasonable guess that listeners that know Pachelbel's Canon in D have heard versions of that piece that start with the bass or the chords played with no rhythmic elaboration.