Roll Over Beethoven? An Initial Investigation of Listeners' Perception of Chords Used in Rock Music

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Popular mainstream music (hereafter, rock) employs the basic set of chords built on the diatonic scale but also many others (de Clercq & Temperley, 2011; Stephenson, 2002). In an initial investigation of listeners' perception of rock harmony, we adapted a rating task developed by Krumhansl (1990) in her pioneering studies of the common-practice harmonic hierarchy. Participants provided surprise and liking ratings for 35 (major, minor, dominant 7, and control) target chords that followed short key-establishing musical passages (a major scale + tonic major triad, or a major pentatonic scale + tonic major triad) or white noise. Liking ratings for targets that followed a musical passage indicated that listeners prefer some chords that are common in rock, but that lie outside the basic diatonic set, to atypical chords; this effect depended on chord quality and was clearest for major target chords. The findings provide an impetus for further research exploring the harmonic hierarchy in listeners with varying musical backgrounds; it appears to be more inclusive and less differentiated than is commonly thought.

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Listeners' ability to discriminate chords on the basis of their appropriateness for a given musical context is well-documented. In her classic work, Krumhansl (1990) presented target chords at the end of key-establishing musical passages to listeners with music training. Participants rated targets that would be expected, based on the norms of common-practice music, as "better-fitting" than nondiatonic targets. The pattern of ratings also pointed to a within-key harmonic hierarchy, with the tonic I (in major keys) at the top level as the most stable chord, the somewhat less central IV and V chords at the second level down, and lower levels consisting of the other, harmonically less significant chords in the key (ii, iii, vi, and vii°).

Subsequent experiments have verified listeners' harmonic knowledge using both explicit and implicit methods. In *explicit* tasks, such as the one used by Krumhansl (1990), listeners make direct evaluations of target chords. Adults have revealed their harmonic knowledge in these studies by rating how much a given target chord "completes" (Bigand & Pineau, 1997; Tillman & Lebrun-Guillaud, 2006) or "belongs to" a musical sequence (Bigand & Pineau, 1997), or whether a chord sequence generates "tension" (Bigand & Parncutt, 1999; Bigand, Parncutt, & Lerdahl, 1996; Steinbeis, Koelsch, & Sloboda, 2006) or leads them to experience an "emotional reaction" (Steinbeis et al., 2006). Even children as young as three years of age can discriminate diatonic from nondiatonic chords by rating targets as "good" or "bad" (Corrigall & Trainor, 2009, 2010; see also Corrigall & Trainor, 2014; Koelsch, Fritz, Schulze, Alsop, & Schlaug, 2005).

In addition, a large number of studies using *implicit* measures, particularly the harmonic priming paradigm, indicate that virtually all listeners possess at least some tacit knowledge of traditional Western harmony (for reviews, see Bigand & Poulin-Charronnat, 2006; Tillmann, Bharucha, & Bigand, 2000; Tillman, Poulin-Charronnat, & Bigand, 2014). In this paradigm, the hypothesis is that target chord processing will be faster and more accurate when a musical prime context and ensuing target chord are harmonically related than when they are unrelated. Adults with and without music training (Bharucha & Stoeckig, 1986, 1987; Bigand, Madurell, Tillmann, & Pineau, 1999; Bigand & Pineau, 1997; Bigand, Poulin, Tillman, Madurell, & D'Adamo, 2003; Tekman & Bharucha, 1992, 1998; Tillman, Bigand, & Pineau, 1998), children (Schellenberg, Bigand, Poulin-Charronnat, Garnier, & Stevens, 2005), brain-damaged patients who are unable to make explicit ("completion") distinctions between diatonic and

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nondiatonic chords (Tillmann, Justus, & Bigand, 2008), and amusic individuals (Tillmann, Gosselin, Bigand, & Peretz, 2012; Tillman, Peretz, Bigand, & Gosselin, 2007) have all revealed their harmonic knowledge when tested using the harmonic priming paradigm.

This body of work has considerably advanced our understanding of how listeners experience harmonic progressions. Expectations about upcoming musical events appear to be at the heart of aesthetic and emotional response to music (Huron, 2006; Meyer, 1956). However, as Smith (1997) pointed out, "The composer can invite to an expectational dance, but it takes two to tango" (p. 229). The available evidence shows that listeners possess harmonic knowledge that makes it possible for them to participate in the harmonic expectational dance.

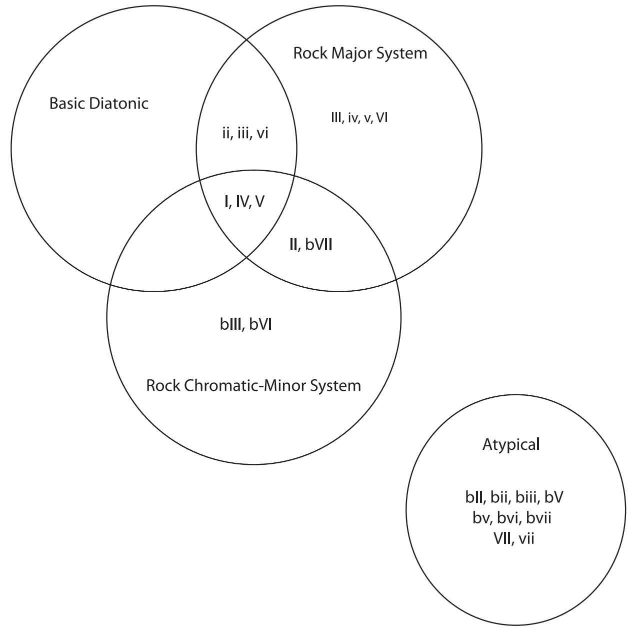

FIGURE 1. A comparison of the basic diatonic chord set with the two rock-based harmonic systems for the major keys, as proposed by Stephenson (2002). Chord roots are specified chromatically relative to the tonic. Following convention, major chords are in uppercase and minor chords are in lower case Roman numerals. Chords that are rarely used in rock or common-practice music are shown as atypical. Note that Stephenson (2002) suggests that major chords in the rock systems may also occur as dominant 7 chords. These are not shown here, but are included in our Rock-typical condition (Table 2).

How extensive is the harmonic knowledge of most listeners? How specific is it? What varieties of mental representation underlie it; is their harmonic knowledge implicit, or is some of it explicit or quasi-explicit? How does this knowledge develop? Despite the progress in this area, these questions continue to be explored (e.g., Corrigall & Trainor, 2014; Tillman, Janata, Birk, & Bharucha, 2008; Tillman et al., 2014). To fully address these matters, we agree with Tillman et al. (2014) that data on "musical expectations in contemporary musical pieces" (p. 111) is needed. To date, research on harmonic expectancies has operationalized chord sequences as "expected" or "less expected" according to the norms of common-practice music. However, many listeners are more familiar with rock music–broadly construed to include most recent popular music–than with art music of the Baroque, Classical, and Romantic periods. Logically, a complete account of listeners' harmonic knowledge requires that we test for their knowledge of rock harmony.

Furthermore, both music-theoretic accounts and corpus analyses suggest that the chords used in rock diverge from the norms of common-practice music. Several music theorists (Moore, 2001; Stephenson, 2002; Tagg, 2009) have made this claim. For instance, Stephenson (2002) argues that rock employs three harmonic systems, each of which differs in some ways from the "basic set" of harmonies from common-practice music, defined by Krumhansl (1990, p. 175) as "the seven triads built on the diatonic scale." The Venn diagram shown in Figure 1 compares the basic diatonic chord set for major keys with the two harmonic systems that Stephenson proposes for rock songs in major keys, which he calls the "chromatic-minor" and the "major" systems. (Whether or not the major/minor key distinction actually has validity for rock is a thorny issue; for a discussion, see Temperley and de Clercq, 2013. For simplicity, we adopt Stephenson's, 2002, position that "in rock, the mode of the piece depends on nothing but the tonic triad," p. 90.)

A recent corpus analysis of rock (de Clercq & Temperley, 2011) provides rather definitive corroborating evidence that rock employs the set of chords from Stephenson's (2002) chromatic-minor and major systems. For a variety of reasons, de Clercq and Temperley (2011) did not attempt to distinguish major and minor keys, and they reported analyses of chromatic relative roots and root motion rather than chord quality (we are not aware of any published rock corpus data—or common-practice music corpus data, for that matter—that distinguishes major and minor triads). Nevertheless, unpublished data from their corpus bears a striking resemblance to Stephenson's proposal (D. Temperley, personal communication, August 13, 2013). A glance at Table 1 reveals that the major and minor chords in Stephenson's chromatic-minor and major systems are, without exception, more common in the rock corpus than each of the "atypical" chords (see Figure 1) that are

TABLE 1. *Chord Frequencies and Stephenson's (2002) Harmonic Categories*

Chord	Rock corpus	Stephenson (2002)
I	0.254	basic diatonic
IV	0.210	basic diatonic
V	0.154	basic diatonic
bVII	0.070	RM and RCM
vi	0.059	basic diatonic
ii	0.039	basic diatonic
bVI	0.036	RCM
bIII	0.020	RCM
iv	0.018	RM
v	0.018	RM
iii	0.013	basic diatonic
II	0.007	RM and RCM
III	0.004	RM
VI	0.004	RM
bII	0.003	atypical
vii	0.002	atypical
biii	0.001	atypical
#IV	0.001	atypical
VII	0.001	atypical
bii	0.000	atypical
#iv	0.000	atypical
bvi	0.000	atypical
bvii	0.000	atypical

Note. Chord roots are specified chromatically relative to the tonic; major chords are in uppercase and minor chords are in lower case Roman numerals. Chord frequencies are unpublished data from the de Clercq and Temperley (2011) rock corpus; these are for all songs and no distinction is made between major and minor keys. RM = rock major system; RCM = rock chromatic-minor system.

rarely used in common-practice music and rock. Thus, the evidence is strong that rock routinely employs a number of chords outside the basic diatonic set.

In addition, a comparison of these rock corpus chord frequencies with Krumhansl's goodness of fit data for major-key contexts (1990; Table 7.3, left column), shown in Figure 2, reveals some patterns worth considering. For instance, IV is both the second most common chord in rock (after the tonic I), and it is also rated as the second best fitting chord. Noting that most music theoretic treatments would predict that V would be rated more highly than IV, Krumhansl (1990) suggests that her participants' high rating for the IV chord may have been an artifact of the musical context that preceded her target chords. Given the corpus data, however, it seems possible that her listeners actually perceived IV as equally or slightly better-fitting than V.

More generally, Figure 2 also shows that although I, IV, and V—thought to be the most structurally significant chords from the basic diatonic set—received the highest fitness ratings, a number of chords outside the basic diatonic set are not far behind. This is particularly salient for major chords (e.g., bVI and bVII received the next-highest ratings). In fact, Krumhansl (1990) reports that for major-key contexts, the correlation between fitness ratings and whether a chord is in the basic diatonic set is nonsignificant. She suggests that a large effect of chord type, with major chords as a group being rated more highly than minor chords, may have masked the relationship between fitness ratings and whether a chord is in the basic diatonic set. Intriguingly, however, Stephenson's (2002) harmonic systems include a large number of major chords outside the basic diatonic set— some (e.g., bIV, bVII), but not all, of these are also quite common in the corpus. It seems plausible that listeners experience some of these chords as harmonically appropriate.

Of course, to say that certain chords outside the basic diatonic set are employed in rock is not to say that these chords never occur in common-practice music. In the absence of corpus data that distinguish major and minor chords in common-practice harmony, it is difficult to know precisely how often chords outside the

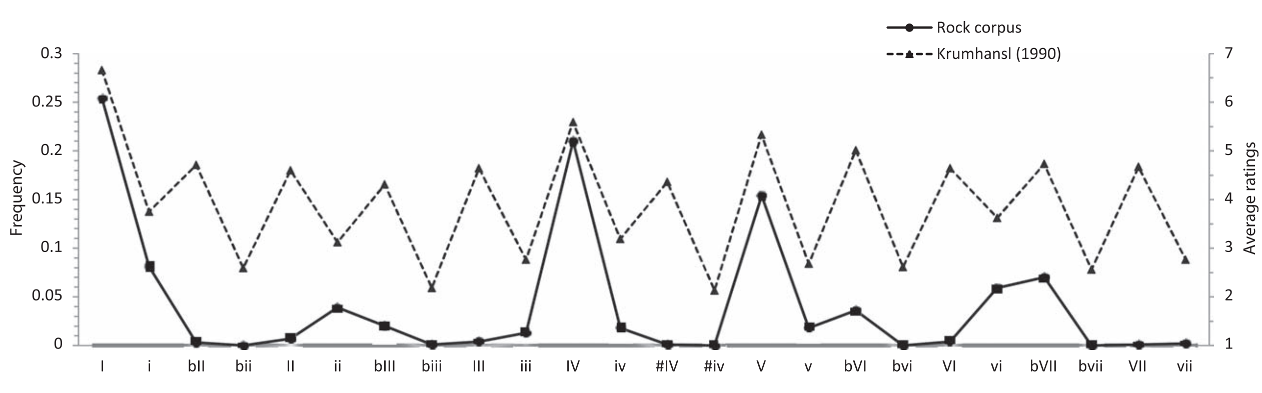

FIGURE 2. Comparison of unpublished chord frequencies from the de Clercq and Temperley (2011) rock corpus (left scale) with Krumhansl's (1990) goodness of fit data for a major key context (right scale). Note that the chord frequency data do not distinguish major and minor keys.

TABLE 2. *Target Chords*

	Chord Quality		
Tonality	Major	Minor	Dominant 7
Basic Diatonic	IV, V	ii, iii, vi	V7
Rock-Typical Diatonic	II, bIII, III, bVI, VI, bVII	iv, v	II7, bIII7, III7, IV7, bVI7, VI7, bVII7
Atypical	bV, VII	bii, biii, bv, bvi, bvii, vii	bV7, VII7

Note. Chord roots are specified chromatically relative to the tonic (C). The "Neapolitan" chord types bII, bII7, and the three chords with the tonic root (I, i, I7) were omitted. Because rock music employs both basic diatonic chords and rock-typical chords, these two conditions were combined in some analyses.

basic diatonic set are used. Stephenson's (2002) comment that "in traditional tonal theory, only chords that fit the major scale constitute the palette of a major key" (p. 94) is probably an overstatement. However, theory textbooks (Aldwell, Schachter, & Cadwallader, 2011; Kostka & Payne, 2009) make it clear that the basic diatonic set is primary—they address this at length before moving on to other harmonies. In addition, the function of chords outside the basic diatonic set appears to be more constrained than is the case in rock. For instance, in common-practice music, major chords outside the basic diatonic set are probably used most often as a "secondary dominants"—brief excursions into another key which then resolve in a highly constrained way. In contrast, Stephenson (2002, p. 94) insists that "it is inappropriate in rock to say that these chords are not normal components of the primary key."

In retrospect—and in light of the music-theoretic considerations and the corpus analysis data reviewed above—Krumhansl's (1990) classic findings suggest the interesting possibility that listeners perceive many chords outside the basic diatonic set as musically appropriate. Why might this be? Perhaps it is because listeners' harmonic knowledge reflects the way that common-practice music sometimes employs these chords. Krumhansl's participants had an average of 11 years of instrumental or vocal study, and thus probably had extensive exposure to music that follows common-practice musical conventions. Another possibility, one that we find particularly plausible, is that Krumhansl's participants—like most Western listeners—were enculturated to rock music that routinely uses these chords. These two explanations do not exhaust the possibilities, nor are they mutually exclusive. In any case, we believe that there is much to be gained by testing whether listeners without extensive music training experience chords outside the basic diatonic set as harmonically valid. The present study is a modest first step in that direction.

TABLE 3. *Liking Ratings for Dominant 7 Chords*

Chord	Mean (SE)
II7	5.25 (0.26)
bIII7	4.08 (0.21)
III7	4.19 (0.22)
IV7	3.82 (0.23)
bV7	3.21(0.17)
V7	3.94 (0.21)
bVI7	3.34 (0.19)
VI7	3.55 (0.19)
bVII7	4.73 (0.24)
VII7	4.44 (0.25)

The Present Study

In the experiment reported below, listeners made surprise and liking ratings to target chords that followed a brief musical passage (establishing a major key) or a nonmusical context (white noise). We presented target chords in three harmonic system conditions: 1) *basic diatonic* chords built on roots from the diatonic major scale using only notes from the scale, 2) *rock-typical* chords that are outside the basic diatonic set but occur in rock, and 3) *atypical* chords that are rarely employed in either rock or common-practice music. Target chords consisted of major triad, minor triad, and dominant 7 chords in each of the three harmonic system conditions (see Table 2).

Of the music-theoretic accounts of rock harmony that might be used to distinguish rock-typical chords from atypical chords (e.g., Moore, 2001; Stephenson, 2002; Tagg, 2009), the proposal by Stephenson (2002) seemed to us to be most straightforwardly testable and also the best supported by the rock corpus data. We thus operationalized the rock-typical condition as including all the chords from Stephenson's rock chromatic-minor and the rock major systems, excluding those which are also included in the basic diatonic set (see Table 2). Because Stephenson implies that virtually any major chord from these two systems may be played as a dominant 7, we included these in the rock-typical condition as well. Finally, although Stephenson's rock harmonic palette is quite a bit more inclusive than that of common-practice music, it does leave out nine chords. These are labelled atypical in Table 2 and Figure 1, and comprise the atypical condition in the present study.

In this initial investigation we employed explicit rating measures, for two reasons. First, although implicit tasks like harmonic priming are clearly more sensitive than many explicit rating tasks, as Bigand and Poulin-Charronnat (2006) point out, explicit tasks may be useful if they "involve fundamental musical intuitions that are understandable by musically trained as well as untrained listeners" (p. 104). For instance, untrained listeners can reliably rate certain combinations of tones as more "pleasant" than others, and these ratings seem to correspond to consonance/dissonance (Guthrie & Morrill, 1928; Johnson-Laird, Kang, & Leong, 2012; van de Geer, Levelt, & Plomp, 1962). Similarly, some studies (Bigand & Parncutt, 1999; Bigand et al., 1996) have successfully obtained "tension" ratings from both musicians and nonmusicians. Perhaps most convincingly, we reasoned that if even young children can reliably distinguish diatonic and nondiatonic targets in a binary task employing "good" and "bad" judgments (Corrigall & Trainor, 2009, 2010; see also Corrigall & Trainor, 2014), then we might expect untrained adult listeners to be capable of making Likert scale liking ratings that reflect their explicit or quasi-explicit harmonic knowledge.

A second reason for using explicit ratings is that this allowed us to measure responses to a large number of target chords. Harmonic priming studies are typically limited to just one "expected" target chord (usually the tonic I) and one "less expected" target (often the subdominant IV). This is understandable—because reaction time data are highly variable, harmonic priming experiments require a large number of trials for each target chord. By using an explicit task, we were able to measure responses to 35 distinct chords during a reasonably short experimental session.

We employed surprise and liking ratings as our explicit measures. To the extent that listeners experience target chords as confirming or violating their expectations, we reasoned that they should be able to report on this reliably with surprise ratings. However, expectations might drive listeners' response to music without necessarily generating the experience of surprise (Margulis, 2007). That is, the unexpectedness of atypical chords may be experienced as ugly, or wrong, or as evoking some emotion other than surprise. Liking ratings seemed like a promising alternative; these might tap musical expectations because they reflect a "prediction effect" (Huron, 2006; see also Hughes, 2011) in which expected chords are experienced as pleasant and unexpected chords are experienced as unpleasant. For instance, we wondered whether dominant 7 chords, despite being more dissonant than major chords (Johnson-Laird et al., 2012), might nevertheless be liked by listeners who are familiar with hearing them in certain styles of rock or blues music.

We also varied what listeners heard immediately prior to each target chord (see Figure 3). On *no-context* trials, listeners heard white noise followed by silence before presentation of the target chord. We expected that surprise and liking ratings in this case would be based on the relative dissonance of the targets. On the basis of the dual-process theory of dissonance (Johnson-Laird et al., 2012), we predicted the following ranked ordering of chords from least surprising/most liked to most surprising/least liked: major triads, minor triads, dominant 7 chords. Listeners also rated the four control chords that were created to sound relatively unmusical and contained the following notes: G-A♭-A-B♭, G-A-B-D♭,

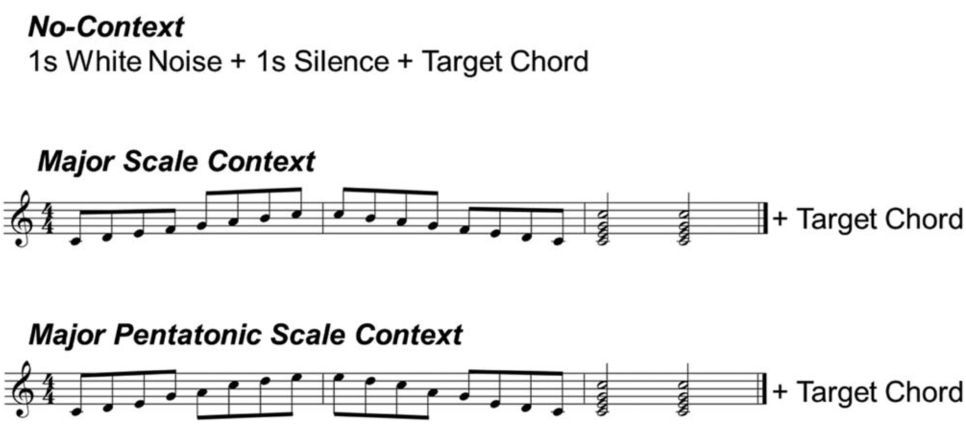

FIGURE 3. Stimuli in the three context conditions.

G♭-G-A♭-A, G♭-A♭-B♭-C. These were included to encourage participants to use the higher (lower) end of the surprise (liking) rating scales, and to test the hypothesis that our participants would find the relatively consonant well-formed triads less surprising and more likable than more dissonant chords.

On *musical context* trials, target chords followed a key-establishing musical passage. On half of these trials, a key-establishing C major scale and a C major triad were presented before each target. The other musical context trials were identical except that the scale played was C major pentatonic (see Figure 3). Because there were no systematic differences in their effect on surprise and liking ratings for target chords, ratings were averaged across the two musical contexts.

The primary goal of the present study was to determine whether listeners are sensitive to rock harmony; that is, whether they hear rock chords as "musically valid" or "appropriate." Our main prediction was that, because they established a specific tonality, the musical context trials would generate lower surprise ratings and higher liking ratings for basic diatonic and rock-typical target chords than for atypical targets. However, many of the chords from the basic diatonic set are very common in rock, and may constitute much of the "core" of rock harmony (de Clercq & Temperley, 2011; Stephenson, 2002; see also Everett, 2004). Because many rock-typical chords are not as common as chords in this basic diatonic core, these may be rated as somewhat more surprising and less liked than target chords in the basic diatonic condition.

Method

PARTICIPANTS

Seventy-one undergraduate volunteers age 18-21 years were tested individually in a 40 min experimental session. A musical background survey revealed that 55 of the participants did not play a musical instrument, three had played for less than 5 years, and 13 had played for more than 5 years. Four participants were able to read musical notation on at least one clef. Three additional participants stated that at one time they had been able to read notation. All of these individuals considered themselves to be amateurs. Although their musical preferences varied, all the listeners had extensive exposure to Western tonal music.

MATERIALS AND APPARATUS

Music training and musical preferences were assessed using a brief questionnaire and the Short Test of Musical Preferences (STOMP; Rentfrow & Gosling, 2003).

We created musical sequences using the classical piano setting in Finale 2010 software. These sound files were edited using Audacity 1.3 software and then converted to WAV format. White noise for the no-context condition was also created using Audacity. SuperLab 4.0 software controlled stimulus presentation and response recording. Participants listened to all stimuli through AKG K181DJ headphones.

STIMULI

In their rock corpus analysis, de Clercq and Temperley (2011) found that 94.1 percent of chords were played in root position. Thus, all chords were presented in root position using closed voicings; for triads, the root was repeated as a fourth tone an octave higher. For this initial investigation, we chose not to employ Shepard tones. All musical excerpts were played at 120 bpm.

The study employed a 3 (context) x 3 (harmonic system) x 3 (chord quality) repeated-measures factorial design. The first factor was the context preceding the target chord (see Figure 3). In the *no-context* condition, participants heard 1 s of white noise, followed by 1 s of silence, then the target chord. In the *major scale context* condition, participants heard an ascending then descending C major scale, followed by two half-note C chords in root position, then the target chord. For most target chords, root motion from the C major tonic chord to the target was ascending; however, because it seemed more ecologically valid, motion from the tonic chord was descending for chords with roots bVII and VII. The *major pentatonic scale context* condition was identical to the major scale context condition, except that participants heard a C major pentatonic scale.

The second factor was the harmonic system that characterized the target chord (see Table 2). *Basic diatonic* chords were built on roots from the C major scale using only notes from the scale—these included major and minor triads and V7. *Rock-typical* chords were those major and minor triads, and dominant 7 chords, that are outside the basic diatonic set but occur in rock (Stephenson, 2002). *Atypical* chords were those that are rarely employed in either rock or common-practice music.

The third factor was chord quality. The 31 target chords generated for the basic diatonic, rock-typical, and atypical harmonic system conditions included 10 major, 11 minor, and 10 dominant 7 chords (see Table 2). Four relatively unmusical control chords were also constructed; these contained the notes G-A♭-A-B♭, G-A-B-D♭, G♭-G-A♭-A, G♭-A♭-B♭-C.

Pilot testing revealed that the tonic C chord was sometimes rated as surprising, but only for the uninteresting reason that listeners expected to hear a change in chord given the nature of the task. Consequently, chords with the tonic as the root were not used as targets. In addition, Neapolitan chords (bII, bII7) were omitted because of their somewhat ambiguous musical function—Stephenson (2002, p. 90) somewhat reluctantly includes N in his chromatic-minor system, but only in parentheses. In jazz, these chords often function as "tritone substitutions" for V7, creating an altered dominant sound that we plan to explore in future studies, but which might muddy the waters in the present initial investigation.

PROCEDURE

After signing an informed consent form, participants began the experiment by completing the music training questionnaire and the STOMP (Rentfrow & Gosling, 2003). Next, participants completed the listening task. We instructed them to listen to each musical sequence and rate how surprising the target chord was and how much they liked it (1 = *not at all*; 10 = *extremely*). They completed three practice trials in the no-context condition before proceeding to the main experiment. The target chord for practice trials was always a C major chord in order to prevent prior exposure to any of the other target chords.

In the main experiment, each participant received a different random order of the 35 target chords in each of the three context conditions. Because both the major scale and major pentatonic scale context conditions strongly established the key of C major, the no-context condition was always presented first. Otherwise, it seemed likely that this key center would carry over into the no-context condition and influence responses. After completing the no-context condition, participants were given a short break. They then completed two more practice trials, one in the major scale context condition and one in the pentatonic scale context condition. Participants then completed two blocks of 35 sequences each in the major scale and major pentatonic scale conditions; the order of these two conditions was counterbalanced across participants. At the end of the experimental session, we thanked and debriefed the participants.

Results

Following Field (2013), for all ANOVAs we used the Greenhouse-Geisser correction for violations of the sphericity assumption when $\varepsilon > .75$, and the Huynh-Feldt correction when $\varepsilon < .75$. Unless otherwise noted, all pairwise comparisons employed the Sidak adjustment for multiple comparisons.

NO-CONTEXT CONDITION

To test the effect of chord quality on listeners' perception of target chords in the absence of a musical context, we conducted one-way repeated-measures ANOVAs on surprise and liking ratings in the no-context condition.

For surprise ratings, there was a significant effect of chord type (major, minor, dominant 7, controls), $F(1.36, 95.2) = 34.41$, $p < .001$, partial $\eta^2 = .33$. Pairwise comparisons revealed that major, minor, and dominant 7 chords were significantly less surprising than the control chords, $p < .001$ (major: $M = 3.95$, $SE = 0.22$; minor: $M = 4.19$, $SE = 2.00$; dominant 7: $M = 4.08$, $SE = 0.19$; control: $M = 5.49$, $SE = 0.28$). No other significant effects were obtained.

Chord type also had a significant effect on liking ratings, $F(2.09, 146.02) = 171.45$, $p < .001$, partial $\eta^2 = .71$. Mean liking ratings followed the predicted pattern (major: $M = 6.66$, $SE = 0.17$; minor: $M = 5.83$, $SE = 0.19$; dominant 7: $M = 5.34$, $SE = 0.19$; control: $M = 3.03$, $SE = 0.19$), and every pairwise comparison was statistically significant, $p < .001$.

The results for the no-context condition are consistent with the hypothesis that without a musical context, major, minor, and dominant 7 target chords would be less surprising and more liked than control targets. This finding is clearest for the liking rating data. The liking ratings also provide strong support for the hypothesis of a rank ordering based on the relative dissonance of chord types.

MUSICAL CONTEXT CONDITIONS

The primary goal of this study was to test listeners' perception of target chords used in rock when these follow a key-establishing musical context. Thus, the next set of analyses examined surprise and liking ratings for the major scale and major pentatonic scale context conditions. Initial analyses indicated that the pattern of responding did not depend systematically on the particular musical context used to establish the key; therefore, data from the two musical context conditions were merged for the analyses reported below.

As a first step, we explored listeners' perception of the complete set of chords used in rock (the three large overlapping circles in Figure 1). To do this, we combined the basic diatonic and rock-typical chords (see Table 2) into a single, inclusive rock harmonic system condition. The mean rating data for this and the other conditions are shown in Figure 4. We conducted two 2 (harmonic system: rock, atypical) x 3 (chord quality:

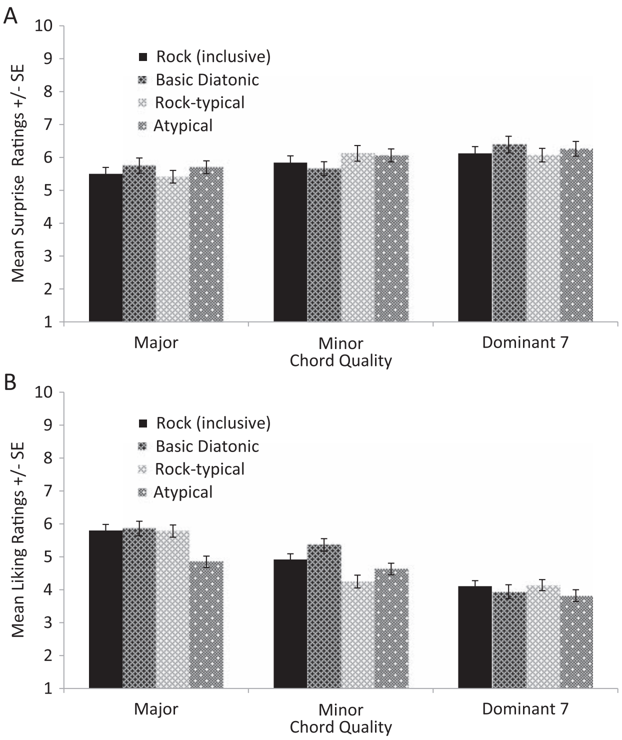

FIGURE 4. Mean a) surprise and b) liking ratings in the combined musical context conditions.

major, minor, dominant 7) repeated-measures ANOVAs, on surprise and liking ratings, respectively. For surprise ratings, the main effect of harmonic system was significant, $F(1, 70) = 5.35$, $p = .02$, partial $\eta^2 = .07$, with listeners rating rock chords as less surprising than atypical chords. This analysis also yielded a significant main effect of chord quality, $F(1.79, 125.40) = 14.87$, $p < .001$, partial $\eta^2 = .18$. Pairwise comparisons indicated that major chords ($M = 5.60$; $SE = 0.19$) were less surprising than both minor chords ($M = 5.95$; $SE = 0.20$), $p = .002$, and dominant 7 chords ($M = 6.18$; $SE = 0.21$), $p < .001$. Minor chords were marginally less surprising than dominant 7 chords, $p = .06$. The Harmonic System X Chord Quality interaction did not reach significance, $p > .05$.

Planned comparisons using paired samples *t*-tests compared mean surprise ratings for rock and atypical chords separately for each chord quality. Only the comparison for minor target chords reached significance, $t(70) = 2.06$, $p = .04$.

For liking ratings, the 2 (harmonic system: rock, atypical) x 3 (chord quality: major, minor, dominant 7) repeated-measures ANOVA yielded significant main effects of harmonic system, $F(1, 70) = 29.59$, $p < .001$, partial $\eta^2 = .30$, and of chord quality, $F(2, 140) = 57.12$, $p < .001$, partial $\eta^2 = .45$. These were qualified by a significant Harmonic System x Chord Quality interaction, $F(2, 140) = 10.16$, $p < .001$, partial $\eta^2 = .13$. Planned comparisons using paired samples *t*-tests showed that for all three chord qualities, listeners liked rock targets more than atypical targets (major chords: $t(70) = 6.73$, $p < .001$; minor chords: $t(70) = 2.24$, $p = .03$; dominant 7 chords: $t(70) = 2.11$, $p = .04$. No other significant effects were obtained.

Although these initial results are suggestive, the ratings in the inclusive rock harmonic condition combined listeners' responses to chords from the basic diatonic set and chords outside the basic diatonic set that are used in rock. We wondered whether the observed differences between rock and atypical chords might be due largely to the influence of basic diatonic chords. As a more conservative test of listeners' response to rock chords, we next compared surprise and liking ratings for all the basic diatonic, rock-typical, and atypical conditions using two 3 (harmonic system: basic diatonic, rock-typical, atypical) x 3 (chord quality: major, minor, dominant 7) repeated-measures ANOVAs. If the effects observed above are due to the influence of basic diatonic chords, they may be absent or reduced in the next analyses.

For surprise ratings, this analysis yielded a main effect of chord quality, $F(1.81, 126.67) = 15.04$, $p < .001$, partial $\eta^2 = .18$. This was qualified by a significant Harmonic System X Chord Quality interaction, $F(2.89, 202.52) = 5.17$, $p = .002$, $\eta^2 = .07$. The main effect for harmonic system was not significant.

A series of planned comparisons using paired samples *t*-tests compared surprise ratings for the three different harmonic system conditions, separately for each chord quality. For major chords, rock-typical targets were less surprising than both basic diatonic targets, $t(70) = 3.07$, $p = .003$, and atypical targets, $t(70) = 2.41$, $p = .02$. For minor chords, rock-typical targets were more surprising than basic diatonic targets, $t(70) = 2.70$, $p = .009$, as were atypical targets, $t(70) = 3.11$, $p = .003$. For dominant 7 chords, rock-typical targets were less surprising than basic diatonic targets, $t(70) = 2.26$, $p = .03$.

For liking ratings, the 3 (harmonic system) x 3 (chord quality) repeated-measures ANOVA revealed significant main effects of harmonic system, $F(1.57, 109.71) = 18.86$, $p < .001$, partial $\eta^2 = .21$, and of chord quality, $F(1.80, 125.91) = 68.59$, $p < .001$, partial $\eta^2 = .50$. These were qualified by a significant Harmonic System x Chord Quality interaction, $F(3.31, 231.63) = 15.13$, $p < .001$, partial $\eta^2 = .18$.

Planned comparisons using paired samples *t*-tests showed that for major chords, listeners liked both the

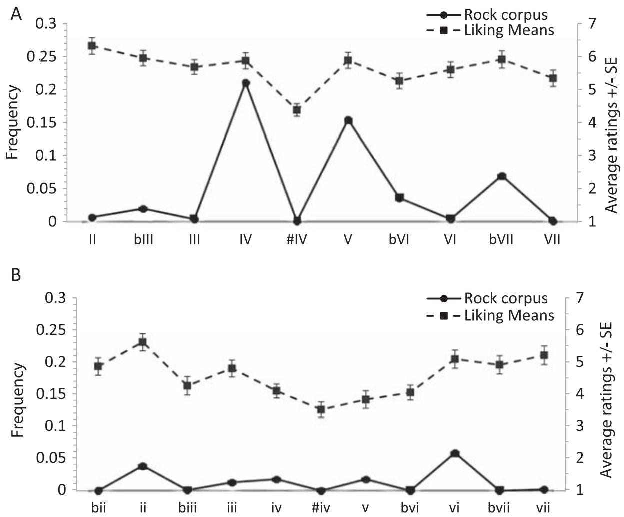

FIGURE 5. Comparison of unpublished chord frequencies from the de Clercq and Temperley (2011) rock corpus (left scale) with mean liking ratings (right scale) for a) major target chords and b) minor target chords.

rock-typical target chords and basic diatonic targets significantly more than atypical targets, $t(70) = 6.56$, $p < .001$, and $t(70) = 5.66$, $p < .001$, respectively. Surprisingly, for minor chords, listeners liked rock-typical chords less than both the basic diatonic targets and the atypical chords, $t(70) = 6.42$, $p < .001$, and $t(70) = 2.29$, $p = .03$, respectively; as expected, however, they liked the basic diatonic chords more than the atypical chords, $t(70) = 5.05$, $p < .001$. For dominant 7 chords, listeners liked rock-typical target chords more than atypical targets, $t(70) = 2.29$, $p = .03$. No other significant differences were found.

Figure 5 compares liking ratings for individual major and minor chords with the unpublished chord frequencies from the de Clercq and Temperley (2011) rock corpus reviewed earlier. A number of similarities are readily apparent; these are discussed below. Liking ratings for individual dominant 7 chords are displayed in Table 3.

Discussion

The present findings for basic diatonic chords fit well with other research that has used explicit ratings to document nonmusician's knowledge of traditional diatonic harmony (e.g., Bigand & Parncutt, 1999; Bigand, et al., 1996; Bigand & Pineau, 1997; Corrigall & Trainor, 2009, 2010, 2014; Koelsch et al., 2005; Steinbeis et al., 2006; Tillman & Lebrun-Guillaud, 2006). Liking ratings in the musical context conditions, in particular, indicate that listeners prefer basic diatonic major and minor target chords to atypical major and minor targets, respectively.

In addition, the present findings are novel in two ways, as discussed below. First, they provide tentative evidence that listeners without extensive music training possess some knowledge of rock harmony. Second, they suggest that this knowledge can be tapped more readily with liking ratings than with surprise ratings.

Our primary goal was to assess listeners' knowledge of rock harmony by measuring their responses to chords used in rock. Liking ratings in the musical context conditions indicate that listeners prefer some chords used in rock over atypical chords. When the entire set of chords known to be used in rock is considered— in Figure 4B, the data labelled Rock (inclusive)— this result holds for all three chord qualities. However, when only rock chords lying outside the basic diatonic set (rock-typical condition) are considered, this effect is limited to major and dominant 7 chords. Surprisingly, in contrast, listeners prefer atypical minor chords to rock-typical minor chords.

Inspection of Figure 5 helps to clarify which of the chords in the various conditions are generating the observed effects for liking ratings. For major chords (Figure 5A), it is clear that both chords from the basic diatonic set (IV, V) received high ratings. However, every single rock-typical chord (II, bIII, III, bVI, VI, and bVII) received comparable ratings. Thus, it does not appear to be the case that a single chord or subset of chords in the rock-typical condition accounts for listener preferences. Furthermore, the effect is not merely an artifact of a preference for major chords, because the atypical #IV chord was clearly rated lower than all others (pairwise comparisons confirm this). On the other hand, the mean rating for the atypical VII chord is similar to those for basic diatonic and rock-typical major chords. This may reflect a general preference for proximity of the target chord to the tonic I chord played at the end of the musical context; consistent with this notion, the rock-typical II chord actually received the highest liking rating, despite occurring with relatively low frequency in the corpus. Note, however, that de Clercq and Temperley (2011) reported that the chord root "II . . . is used in roughly as many songs as bVII and VI, but tends to be used less repetitively, thus resulting in a lower overall count" (p. 60). Perhaps, then, the high rating for II is due to its occurrence in many songs, and the high rating for VII stems from its proximity to I. In any case, the important general point is that listeners' liking for major chords that are outside the basic diatonic set, but used in rock, is highly inclusive.

The pattern of results for minor chords is somewhat different (Figure 5B). Based on their corpus frequencies, one would expect the basic diatonic chords ii, iii, and vi (especially ii and vi) to receive high liking ratings; and indeed, there are discernible peaks in mean liking ratings for each of these chords. The rock-typical chords iv and v, however, are similar in frequency to iii. And yet they received relatively low liking ratings; recall that rock-typical minor chords as a group were liked significantly less than atypical minor chords (bii, biii, #iv, bvi, bvii, and vii). In this case, Figure 5B suggests that liking ratings for atypical minor chords were inflated by a general preference for proximity of the target chord to the tonic I chord played at the end of the musical context. The fact that many of the atypical minor chords are proximate to the tonic— and the rock-typical chords are rather distal from the tonic—might explain the obtained preference for atypical minor chords.

Overall, we find it plausible that liking ratings for major and dominant 7 chords, and perhaps minor target chords, were influenced by both listeners' knowledge of rock harmony and by the proximity of target chords to the tonic I context chord. Together, these two factors could account for the general U-shaped pattern of the liking curves shown in Figure 5 and also for many of the visible peaks and dips in those curves. To test this systematically, future studies might manipulate the last chord in the musical context and observe the effect on ratings for individual target chords. Concurrently, analyses of rock corpora could measure chord transition frequencies for antecedent and consequent chords of all chord qualities (for an example of this type of analysis for chord roots, see de Clercq and Temperley, 2011, Table 3). It would be fascinating to see the extent to which transitional probabilities of major, minor, and dominant 7 chords follow a (physical or musical) proximity principle, and whether listener ratings line up with these probabilities.

A second implication of the present research is that liking ratings may be more efficacious than surprise ratings in tapping musically untrained listeners' harmonic knowledge. This is noteworthy, given the importance of harmonic expectancies in theories of musical response (Bharucha, 1987; Huron, 2006; Margulis, 2007; Meyer, 1956; Narmour, 1990). Surprise ratings may be less useful in capturing harmonic expectations for either of two reasons. First, listeners may be unaware of their harmonic expectations and of violations of those implicit expectations (Margulis, 2007). Alternatively, listeners may be aware when their musical expectations are violated by atypical target chords, but "surprise" may not be the best term for capturing this—perhaps because it connotes a stronger response that typically occurs during music listening. Future studies might try asking participants to rate the extent to which target chords are "expected," "predicted," or "likely." Note that in the present study, surprise ratings for rock chords complemented the results for liking ratings to some extent. For instance, rock-typical major chords were less surprising than atypical major chords.

Concerning liking ratings, it seems plausible that the current findings are, in fact, a consequence of implicit harmonic expectancies that are based on listeners' tacit knowledge of rock harmony. This could occur as a result of either of two well-known types of misattribution effects. The first type occurs when expected chords are processed more efficiently than unexpected (atypical) chords and listeners misattribute this ease of processing as "sounding good"—this is the perceptual fluency/misattribution model (Bornstein & D'Agostino, 1994). Alternatively, Huron (2006) suggests that expected chords trigger a rewarding positive emotional response that is misattributed to the chord—he refers to this as a prediction effect. Of course, we cannot rule out the possibility that there was some other mechanism of aesthetic judgment underlying the obtained effects. On the other hand, it is possible that liking ratings actually underestimate listeners' knowledge—listeners might know that a particular chord occurs in rock, but still not like it. A reasonable goal for future research is to directly compare listeners' surprise and liking ratings with other dimensions that have driven much theorizing, notably "goodness of fit" (Krumhansl, 1990), "degree of belonging" (Bigand & Pineau, 1997), "completion" (Bigand & Pineau, 1997; Tillman & Lebrun-Guillaud, 2006), and "degree of tension" (Bigand & Parncutt, 1999; Bigand et al., 1996; Steinbeis et al., 2006).

The present study is only an initial exploration. Much remains to be investigated. In addition to the suggestions for future research already mentioned, larger studies would make it possible to test participants with a wider range of musical backgrounds. Such studies should employ a variety of stimuli, musical contexts, and response measures to assess the external validity of the effects reported here. Future work might also assess whether listeners possess different harmonic schema for different genres (Huron, 2006). For example, Hughes (2011) found that listeners preferred different chord progressions depending on whether they were first primed with classical or blues music.

In sum, we believe that there is much to be gained by construing harmony broadly to include rock and other musical genres that many people enjoy daily. The present findings suggest that we should look more closely at the content of listeners' harmonic knowledge; it may be more complex than is implied in the literature. First, listeners appear to interpret many chords outside the basic diatonic set as musically valid. In addition, their pattern of response to chords inside and outside of the basic diatonic set is not as hierarchical as is commonly assumed. We hope that these preliminary findings will help stimulate a tripartite approach to further explorations of "everyday" harmony perception. Such an approach would involve further integration of music-theoretic analyses and corpus analyses of popular music, which can then inform psychological studies of how this music is experienced by listeners with varying musical backgrounds.

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