Emotional Connotations of Diatonic Modes

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In this experiment, participants (nonmusicians) heard pairs of melodies and had to judge which of the two melodies was happier. Each pair consisted of a single melody presented in two different diatonic modes (Lydian, Ionian, Mixolydian, Dorian, Aeolian, or Phrygian) with a constant tonic of C; all pairs of modes were used. The results suggest that modes imply increasing happiness as scale-degrees are raised, with the exception of Lydian, which is less happy than Ionian. Overall, the results are best explained by familiarity: Ionian (major mode), the most common mode in both classical and popular music, is the happiest, and happiness declines with increasing distance from Ionian. However, familiarity does not entirely explain our results. Familiarity predicts that Mixolydian would be happier than Lydian (since they are equally similar to Ionian, and Mixolydian is much more common in popular music); but for almost half of our participants, the reverse was true. This suggests that the "sharpness" of a mode also affects its perceived happiness, either due to pitch height or to the position of the scale relative to the tonic on the "line of fifths"; we favor the latter explanation.

Received: June 29, 2011, accepted April 17, 2012.

Key words: emotion, modality, scales, happiness, popular music

A diatonic mode is a pitch framework based on the diatonic scale, in which the tonic, or home pitch, is assigned to a particular position in the scale. The diatonic scale can be represented by the white notes of the piano keyboard; in that case, each mode corresponds to a certain choice of white note as tonic. A tonic of C yields the conventional major scale, or Ionian mode; a tonic of D yields Dorian; E, Phrygian; F, Lydian; G, Mixolydian; A, Aeolian; and B, Locrian (see Figure 1A). An ascending scale (beginning with the tonic) creates a different pattern of whole-steps (W) and half-steps (H) for each mode: for example, Ionian yields W-W-H-W-W-W-H while Dorian yields W-H-W-W-W-H-W. Another way to generate the modes (one that will be important below) is to keep a fixed tonic but change the key signature. With a tonic of C, a one-sharp key signature yields Lydian; no sharps or flats, Ionian; one flat, Mixolydian; two flats, Dorian; three flats, Aeolian; four flats, Phrygian; and five flats, Locrian (see Figure 1B).

The concept of mode as a means of pitch organization has a long and complex history in Western music and music theory (for more detailed discussion, see Powers, 2001). The above-mentioned ethnic names for modes (Ionian, Dorian, etc.) have been attributed to Plato and Aristotle (Mathiesen, 2002); these thinkers used the names to distinguish pitch frameworks that combined scales with a host of other features, including range and rhythmic pattern. Writers in the Middle Ages appropriated these Greek names but applied them in quite different ways, using them for the practical purpose of categorizing liturgical chant melodies. (Today, the term "church mode" is often used synonymously with "diatonic mode," reflecting this early ecclesiastical association.) During this period and continuing into the Renaissance, the identification of the mode of a melody depended chiefly on its last note or "final" (in relation to the diatonic scale) and on its "ambitus" (range). The collection of diatonic modes to which we refer today was codified in the 16th century, beginning with Heinrich Glarean's *Dodechachordon* (1547). By the mid-18th century, the term "mode" had come to mean "a collection of degrees of a scale (and its aggregate intervallic content), being governed by a single chief degree" (Powers, 2001, p. 829). Over the past century, the term has been applied in a variety of ways in music theory and musicology, sometimes referring to non-diatonic pitch frameworks in non-Western music or in twentieth-century Western art music.

Notwithstanding these diverse meanings of the word "mode," we will henceforth use the term only in the limited sense defined in the first paragraph: a diatonic pitch framework with the tonic assigned to a particular position in the scale. The term "scale" will be used to mean an intervallic pattern (or a particular transposition of such a pattern), without commitment to a particular tonal center. The term "pitch framework" will be used broadly to refer to any system of pitch

Music Perception, volume 30, issue 3, pp. 237–257, issn 0730-7829, electronic issn 1533-8312. DOI: 10.1525/mp.2012.30.3.237

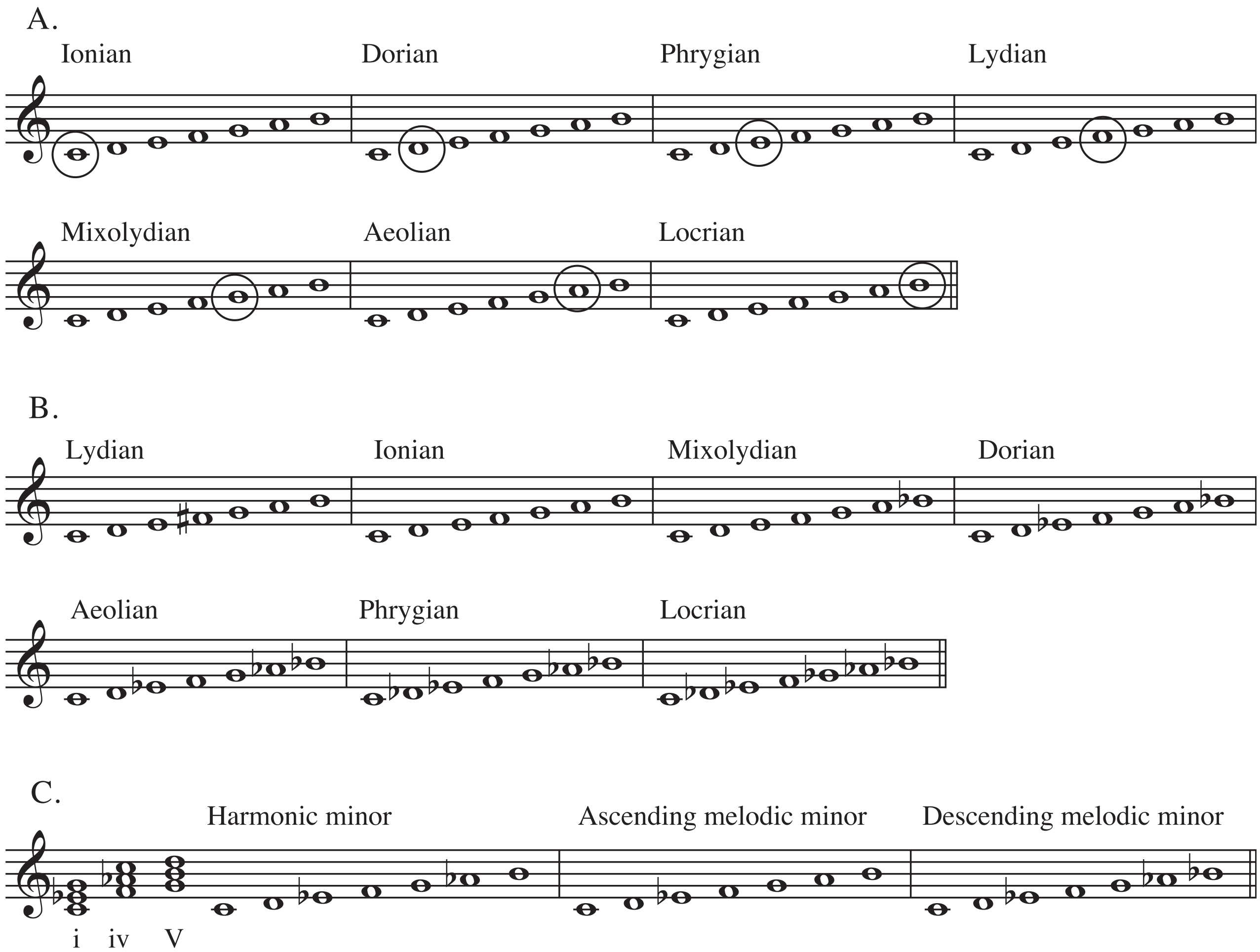


FIGURE 1. (A) The seven diatonic modes, assuming a fixed "white-note" scale (the tonic is circled in each case). (B) The seven diatonic modes, assuming a fixed tonic of C. (C) The three scales of common-practice minor.

organization involving a scale and tonal center, perhaps with other features as well.

In Western art music of the common-practice period (1600 to 1900), pieces are not categorized in modal terms, but rather, in major or minor *keys* (though major and minor are sometimes referred to as modes; henceforth we will refer to these as "common-practice modes"). While common-practice major is more or less the same as Ionian mode, common-practice minor is not equivalent to any diatonic mode (though its key signature corresponds to Aeolian mode). According to modern music theory, common-practice minor involves three different scales: the harmonic minor (representing the primary chords of the minor mode—i, iv, and V), the ascending melodic minor (used in ascending melodic lines), and the descending melodic minor (used in descending lines) (see Figure 1C). Descending melodic minor is equivalent to Aeolian mode; harmonic minor and ascending melodic minor do not match any diatonic mode. Thus, art music of the common-practice period cannot properly be described as modal. However, diatonic modality has been observed in other European music of this period, such as British and Eastern European folk music (Powers, 2001).

Modality has also been widely discussed with regard to modern popular music, particularly rock (Biamonte, 2010; Everett, 2004; Moore, 1992, 1995, 2001; Stephenson, 2002). Here we use the term "rock" in a broad sense—as many authors have done—to include a wide range of late-20th-century Anglo-American popular styles (such as 1950's rock'n'roll, Motown, heavy metal, disco, and 1990's "grunge"). Ionian, Mixolydian, Dorian, and Aeolian are particularly prevalent in rock (Everett, 2004; Moore, 2001). Some have noted that Phrygian is also common in heavy metal and related styles (Biamonte, 2010; Walser, 1993). According to Moore (1992, 1995), even many harmonic progressions that do not appear modal on the surface are based on underlying modal frameworks. Well-known songs in each of the four common rock modes are shown in Figure 2. It should be noted that many rock songs do not remain in a single diatonic mode. For example, in the Beatles "Can't Buy Me Love" (Figure 2E), the melody begins in Dorian (or Aeolian?) mode, containing $\flat\hat{3}$ (the lowered third degree), but the accompaniment features a major I triad, containing $\hat{3}$; in the beginning of the bridge, the melody also shifts to $\hat{3}$. Thus, the degree to which rock reflects modal organization should not be overstated. But the current consensus is that a good deal of rock music shows evidence of modal construction.

THE EMOTIONAL CONNOTATIONS OF SCALES AND MODES

In this study we are particularly concerned with the emotional connotations of diatonic modes and other pitch frameworks. Before examining this issue, we must consider the fundamental relationship between music and emotion. When we say that a piece of music is happy or sad, for example, what does this mean? It could mean simply that we take the piece to indicate or express a certain emotion; this is sometimes known as the "cognitivist" view of musical emotion. Or it might mean that the music makes us feel a certain emotion ourselves; this is known as the "emotivist" view. This issue has been widely discussed in theoretical and aesthetic writing on music (Budd, 1985; Kivy, 1980; Meyer, 1956). Recent experimental research has resolved this issue by recognizing that the cognitivist and emotivist positions pose separate questions, both valid: we do sometimes simply *recognize* emotions in music, yet music can also *induce* emotions in us—that is, make us experience them. (This distinction is sometimes characterized in terms of "perceived" versus "felt" emotion.) Studies of emotional recognition usually involve a descriptive task of some kind, such as choosing between adjectives or assigning ratings on a descriptive scale (Gabrielsson, 1973; Hevner, 1935). Studies of emotional induction often use physiological measures of emotional experience such as heart rate and skin temperature, though verbal reports are sometimes used as well (Bartlett, 1996; Krumhansl, 1997; Pike, 1972). This is not to say that emotional induction and recognition are completely unrelated. Recent research suggests that there is a positive correlation between felt and perceived emotion, but also some independence; that is, music that listeners perceive as happy does not necessarily make them feel happy (Gabrielsson, 2002; Hunter, Schellenberg, & Schimmack, 2010; Evans & Schubert, 2008).

The current study focuses on emotional recognition: our concern is with the emotions that listeners take diatonic modes to indicate or express. Recent discussions of felt versus perceived emotion (Evans & Schubert, 2008; Gabrielsson, 2002) have stressed the importance of designing experiments in a way that clearly distinguishes between the two. Studies of perceived emotion generally direct listeners' attention to characteristics of the music itself rather than to their own internal state; this will be our strategy in the current study as well.

The general idea that pitch frameworks can carry expressive implications is very well established. In the Middle Ages, the notion of modal affect or *ethos* was widely accepted; authors of treatises pertaining to mode would often point to chant examples that exhibited the ethos they described. The specific characteristics associated with each mode changed over time. For instance, the 11th-century theorist Hermannus Contractus deemed Mixolydian "garrulous" (Powers, 2001), while the 16th-century author Stefanno Vanneus considered it a "querulous" mode, one "especially suited to lascivious words mixed in with moderate and pleasant ones, but then also to excited, angry, and threatening ones" (Judd, 2002, p. 375). With regard to non-Western music, pitch frameworks such as North Indian *ragas* and Arabic *maqams*—which combine scales with characteristic melodic patterns and gestures—also carry expressive meaning (Danielou, 1968; Touma, 1996). In common-practice music, it is well-known that major and minor keys have positive and negative connotations, respectively. These connotations have been confirmed by a number of experimental studies, using a variety of populations—musicians, nonmusicians, and children—and a variety of stimulus types: isolated major and minor triads (Crowder, 1984; Heinlein, 1928), naturally occurring pieces of music (Peretz, Gagnon, & Bouchard, 1998), and pairs of pieces constructed or altered to differ only in the major/minor dimension (Gerardi & Gerken, 1995; Hevner, 1935; Kastner & Crowder, 1990; Peretz et al., 1998).

Several explanations for the emotional connotations of major and minor keys have been offered. Helmholtz attributed these connotations to the differing levels of *consonance* between the major and minor triads: in a minor triad, he argued, the strong presence of combination tones that conflict with the notes of the chord give it an effect of "mysterious obscurity or harshness" that is not present in the major triad (1877/1954, p. 216). In a very different vein, Meyer (1956) relates the

FIGURE 2. Excerpts from well-known rock songs. Each song has been transposed to have a tonic of C; in each case, only short representative excerpts are shown. (A) The Who, "The Kids are Alright" (Ionian); (B) U2, "Pride (In the Name of Love)" (Mixolydian); (C) The Bee Gees, "Stayin' Alive" (Dorian); (D) Nirvana, "Smells Like Teen Spirit" (Aeolian); (E) The Beatles, "Can't Buy Me Love" (modally mixed).

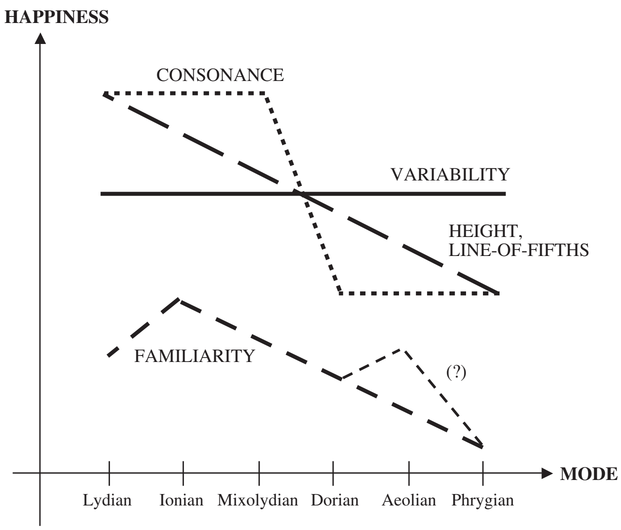


FIGURE 3. Schematic predictions of five theories regarding the emotional connotations of diatonic modes: the consonance theory (Helmholtz, 1877/1954), the variability theory (Meyer, 1956), the height theory (Huron et al., 2010), the line-of-fifths theory (Temperley, 2001), and the familiarity theory.

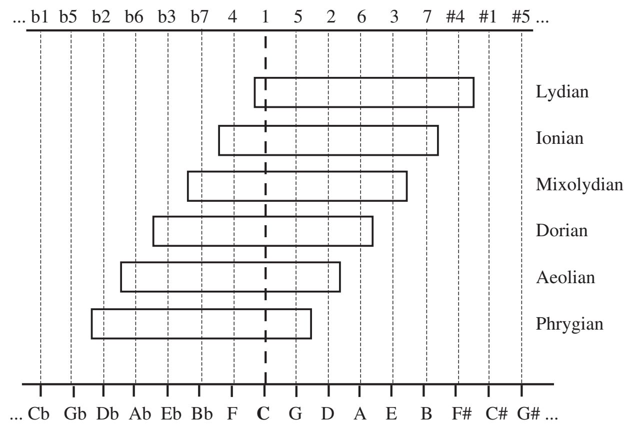


FIGURE 4. The "line of fifths." The horizontal axis represents scale-degrees, as shown at the top; at the bottom these are labeled as pitch-classes, assuming C as tonic. Rectangles indicate the scale degrees contained in each diatonic mode.

expressive difference between major and minor to the greater *variability* of the minor scale (described above), which creates uncertainty and therefore anxiety in the mind of the listener. (It should be noted, however, that this might be regarded as a model of emotional induction rather than recognition.) More recently, Huron, Yim, and Chordia (2010) have suggested that the major/minor difference may be a simple matter of *pitch height*: in speech, lower pitch expresses sadness, and the minor scale (whichever form of the scale one chooses) contains lower pitches than the corresponding major scale. One problem with all of these theories is that they are essentially based on only two data points: common-practice major and minor. Consideration of other pitch frameworks and their expressive implications might allow us to better judge the plausibility of these competing theories.

An interesting opportunity in this regard is provided by diatonic modes. Let us consider what predictions arise from the theories considered above concerning the emotional connotations of diatonic modes. Helmholtz's consonance theory, at least taken without modification, would seem to predict only that the modes with a major tonic triad (Lydian, Ionian, and Mixolydian) would be happier than those with a minor tonic triad (Dorian, Aeolian, and Phrygian); it does not predict any difference in meaning between (for example) Ionian and Mixolydian, or Aeolian and Dorian. Meyer's variability theory appears not to predict any difference in emotion between diatonic modes at all, since each mode—at least as conventionally defined—is based on a single invariable scale. The height theory of Huron et al. makes a clear and interesting prediction: The modes should increase in happiness as flats are removed (or sharps added), since each such alteration creates a rise in pitch (in relation to a fixed tonic). These three predictions are shown in Figure 3. (Locrian mode is excluded for reasons that will be discussed below.)

An additional theory that has been put forth regarding the connotations of modes is that of Temperley (2001). Temperley proposes that pitches are represented cognitively on the "line of fifths," similar to the circle of fifths but extending infinitely in either direction (see Figure 4). A diatonic scale corresponds to seven adjacent positions on the line of fifths; a diatonic mode assigns the tonic to one of these positions. Temperley suggests that the "happiness" of a mode is defined by the position of the tonic in relation to the scale. The further in the "flat" direction the tonic is on the scale, the happier the mode is; if one assumes a fixed tonic, happiness increases as the scale moves in the "sharp" direction (to the right in Figure 4). Temperley points to anecdotal evidence from popular music that supports this theory: in songs that shift from one mode to another (maintaining a constant tonic), the shift often coincides with a change in the mood of the lyrics as the line-of-fifths theory would predict. The line-of-fifths theory makes the same predictions regarding diatonic modes as the "height" hypothesis of Huron et al. (2010): both predict a gradual increase in happiness as the scale moves in the sharp direction on the line of fifths, or equivalently, as sharps are added and flats are removed (compare Figure

3 and Figure 1B). (The line-of-fifths theory also accounts for the case of common-practice major and minor; the minor mode is further in the flat direction than the major mode—whichever minor scale one chooses—and thus is predicted to be less happy.)

A final issue that deserves consideration is familiarity. It is generally accepted that familiarity plays an important role in musical experience. A number of studies have found that the enjoyment of a piece increases with repeated exposure, though continued exposure beyond a certain point may cause enjoyment to decrease (Gaver & Mandler, 1987; Huron, 2006; Szpunar, Schellenberg, & Pliner, 2004). Some have argued, also, that the familiarity of a musical style may affect listeners' enjoyment of it (Krugman, 1943), and that the difficulty that many listeners have with serialism and other 20th-century approaches to pitch organization arises in part from a lack of familiarity (Peel & Slawson, 1984; Thompson, 2006; Daynes, 2010). It should be noted that the abovementioned research on familiarity has mainly focused on emotional induction rather than recognition. Still, as noted above, induction and recognition may influence one another; it seems possible, for example, that a *feeling* of happiness due to the familiarity of a piece may cause the piece to be *perceived* as happy as well. It seems worth considering that possibility here.

Applied to modes, the familiarity theory might suggest that modes that are more familiar should seem happier. The predictions of the theory therefore depend on the familiarity of different modes. Of course, this might vary from one listener to another depending on their musical experience. We might hypothesize that someone who listened primarily to common-practice music would be most familiar with Ionian mode; as noted earlier, Ionian mode corresponds to major while other diatonic modes do not correspond to any major or minor key. Regarding other modes, the predictions are quite unclear. We might predict familarity (and therefore happiness) to decrease with increasing "distance" from Ionian, where distance is defined as the number of scale-degrees that differ; this is shown by the thick dashed line at the bottom of Figure 3. It might also be argued that Aeolian is the most similar mode to common-practice minor and should therefore be relatively familiar to listeners of common-practice music.[1]

[1] Major appears to be somewhat more common than minor in common-practice music overall, though this depends on the period and composer. In Mozart's piano sonatas, Beethoven's piano sonatas, and Mendelssohn's *Songs Without Words*, major keys predominate. By contrast, Bach's keyboard suites show a roughly equal balance between major and minor; in Chopin's Nocturnes, too, major and minor are almost equally common.

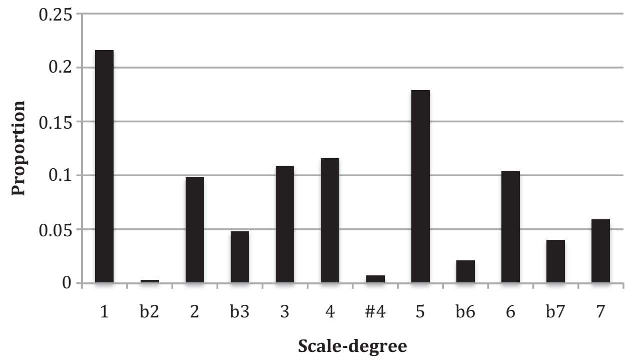


FIGURE 5. A scale-degree distribution for rock, generated from the harmonic analyses of de Clercq and Temperley, (2011b). The vertical axis indicates proportions of the total.

In popular music, the issue is even more difficult. As noted earlier, it is generally agreed that Ionian, Mixolydian, Dorian, and Aeolian are the most common modes in rock, but there has been little discussion of the relative frequency of these modes; it has been suggested that Ionian and Aeolian are more common than others.[2] Some quantitative evidence is offered in a study by de Clercq and Temperley (2011a, 2011b), in which 200 rock songs (from *Rolling Stone* magazine's list of the "Greatest Songs of All Time") were analyzed harmonically. Using these harmonic analyses, and taking each chord symbol to indicate a single occurrence of each scale-degree it contains, we can produce a scale-degree distribution for rock, as shown in Figure 5. This data shows that the seven major-mode degrees occur more frequently than any others, suggesting that Ionian mode is the most frequent in rock. Altogether, then, this complex picture would seem to argue that the familiarity profile for diatonic modes, among modern Western listeners, should reflect a maximum for Ionian mode, possibly with a secondary peak for Aeolian mode, as shown in Figure 3. Note, in particular, that the familiarity theory differs from the height and line-of-fifths theories with regard to Lydian mode. The line-of-fifths and height theories predict that Lydian will be happier than Ionian, while familiarity predicts that it will be less happy.

In what follows, we present an experiment that examines the emotional connotations of diatonic modes. Listeners (nonmusicians) were presented with simple

[2] Temperley (2001) suggests that Ionian mode is most common, while Spicer (2009) gives priority to both Ionian and Aeolian; Everett (2004) gives theoretical primacy to Ionian, though he does not comment on the relative frequency of modes.

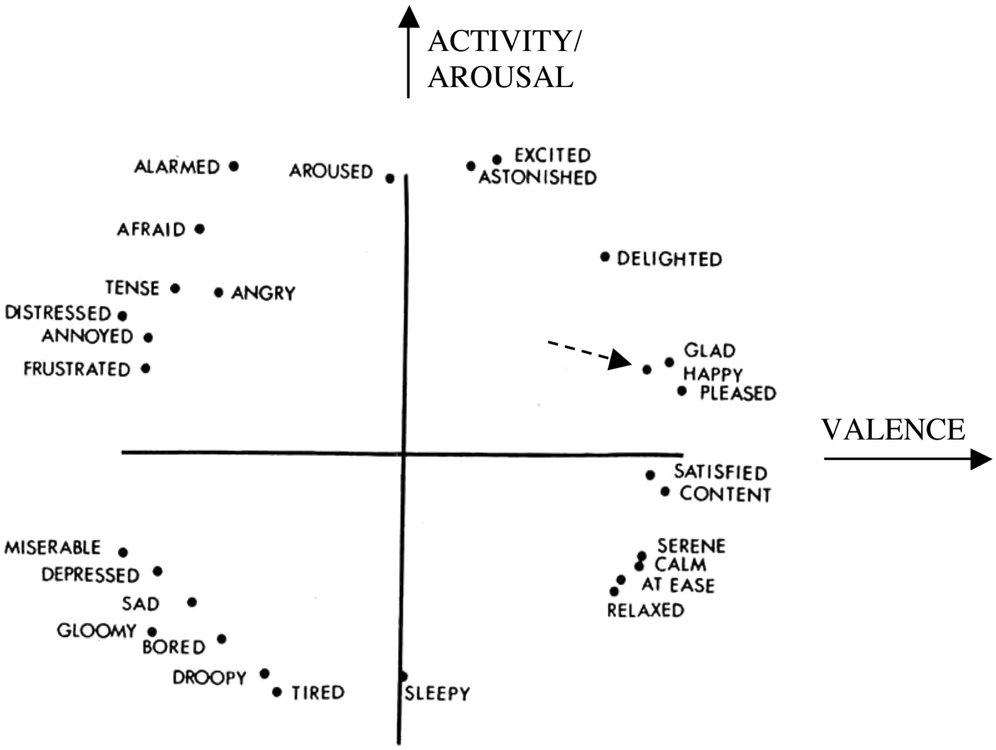


FIGURE 6. A two-dimensional representation of emotions (Russell, 1980). (Axis labels and dotted arrow added by the authors.) © 1980 by American Psychological Association. Reprinted by permission.

diatonic melodies, always with a tonic of C, with the key signature altered to reflect different modes. In each trial, listeners heard the same melody in two different modes, and had to judge which one sounded happier. Given that a good deal of rock music is modal, and given the pervasive presence of rock (broadly defined) in modern American culture, the influence of mode on perceived emotion is an interesting issue in its own right: it relates to the expressive meaning of a large portion of the music that modern listeners actually hear. The current study also relates to the broader issue of the emotional implications of pitch frameworks, and may help us to evaluate the relative plausibility of the various theories described above.

Two possible objections to the current study should be considered. One concerns the use of the term "happiness" to represent the emotional connotations of modes. It may seem simplistic to reduce the rich and complex emotional meanings of music to this single dimension. This approach receives strong support, however, from experimental research on music and emotion. Multivariate techniques have found that emotional responses to music, and indeed emotions in general, can be reduced quite effectively to two dimensions, generally known as *activity/arousal* and *valence* (Gabrielsson & Lindström, 2001; Russell, 1980). Figure 6 shows one such representation. As can be seen from the figure, the valence dimension corresponds roughly to happiness, though not exactly: happiness also appears to involve some degree of positive arousal. There is apparently no term in English that precisely captures the "valence" dimension, but happiness is reasonably close. Previous research has shown that the emotional effects of common-practice mode (major versus minor) lie mainly along the valence dimension. Gabrielsson and Lindström (2001), in a survey of experimental research on music and emotion, note that major mode tends to be associated with happiness and serenity (both positive in valence in Figure 6), whereas minor mode is associated with sadness, tension, and anger (all negative in valence); note that the "major" emotional terms span both sides of the arousal axis, as do the "minor" terms. By contrast, the arousal dimension is affected more by other musical dimensions such as tempo, pitch height, and loudness. According to Gabrielsson and Lindström (2001), a high pitch level is associated with both anger and happiness, both high in arousal but opposite in valence; similar effects are found for both loudness and fast tempo.[3] Since the emotional effects of common-practice modes appear to relate mainly to the valence dimension, it seems reasonable to assume, at least as a starting point, that this will be true of diatonic modes as well.

A second objection concerns our interpretation of the results of the experiment. Our assumption is that a listener's judgment of the happiness of a melody tells us something about the perceived happiness of the underlying mode. But how do we know that the melody is being perceived to be in that mode? As noted earlier, a mode is defined by a diatonic scale with a certain position identified as the tonic. But the identification of tonic is subjective and sometimes ambiguous—certainly in common-practice music and undoubtedly in modal music as well. We believe that this objection is answerable, but is best deferred until after our presentation of the experiment and its results. We should observe, however, that Locrian is particularly problematic in this regard. In our view, it is virtually impossible to compose a melody that "sounds" Locrian—for example, a melody that uses the five-flat key signature but has a tonic of C (see Figure 1B); such a melody will almost always imply an alternative tonic. (No doubt this is partly because scale-degree $\hat{5}$ is absent.) And indeed, Locrian is virtually unknown in any kind of Western music; it is more of a theoretical possibility than a musical reality. For this reason, we excluded Locrian mode from the experiment presented below.

Before proceeding, we should mention one previous study on the connotations of diatonic modes, by Ramos, Bueno, and Bigand (2011). In this study, three melodies were played in all seven diatonic modes, crossed with three different tempi. Participants (Brazilian musicians and nonmusicians) heard individual melodies and had to assign each melody to one of four emotional categories: "happiness," "sadness," "serenity," or "fear/anger." The authors interpret these categories in terms of valence and arousal dimensions in the conventional way, with happiness and serenity positive in valence, sadness and fear/anger negative in valence, happiness and fear/anger positive in arousal, and sadness and serenity negative in arousal. The authors report a general linear trend of increasing valence with increasing mode "height." They report that Ionian was significantly higher in valence than Lydian, and that Lydian and Mixolydian were not significantly different; beyond this, they do not report statistical analyses of pairwise mode differences. Tempo was also found to have a significant effect on valence, with faster tempi being more positive. Because participants were limited to binary (positive versus negative) valence judgments, and because tempo was also varied, it is possible that some of the more subtle differences in valence between modes were not revealed by the data. The forced-choice design of our experiment was designed to highlight such subtle differences.

[3] This point relates to the height hypothesis of Huron et al. (2010), as we discuss further below. We should note, also, that Huron et al. specifically investigated the perceived *sadness* of melodies. It can be seen from Figure 6 that sadness is negative in valence but also involves negative arousal; sadness and happiness are roughly opposite, but not exactly. Thus it is perhaps not quite correct to say that the hypothesis of Huron et al. relates to perceived happiness. To further complicate the matter, it has also been suggested that music can sometimes evoke *mixed* emotions; a piece can seem both happy and sad (Hunter, Schellenberg, & Schimmack, 2010). For the purposes of the current study, however, it seems reasonable to equate happiness with valence, and to consider height as a possible predictor of happiness.

Method

PARTICIPANTS

Seventeen undergraduate students at the University of Rochester (nine females and eight males) participated in the experiment. Each received a payment of $10. None of the participants were music majors. Participants reported an average of 1.9 years of music lessons (including group lessons); none reported more than six years. A questionnaire asked the participants whether they had ever learned about diatonic modes; two participants reported that they had. A further question on the questionnaire asked these two participants a simple question about modes: "A melody using the C major scale with a tonal center of G would be in ____________ mode." Neither participant answered this question correctly. Even students who had learned about diatonic modality would probably not have been taught anything about the emotional connotations of diatonic modes; in our experience, this issue is rarely addressed in undergraduate music courses.

Participants reported listening to an average of 11.7 hours of music per week. A free-response question asked participants to name the styles of music they listened to. Fifteen of the seventeen named "rock" (or some kind of rock, such as "progressive rock" or "classic rock"), seven named "pop," six named "R&B," five named "classical," and five named "jazz." No other style was named by more than four participants.

MATERIALS

Six "basic melodies" were composed in C Ionian mode (C major) (see Figure 7). They ranged from four to eight measures in length, and employed a variety of time signatures. Each melody employed all seven degrees of the C major scale (C, D, E, F, G, A, and B) at least once.

FIGURE 7. The six basic melodies used in the experiment.

The melodies were all relatively simple and might be said to be in the style of traditional European folk melodies or children's melodies.

The melodies were then converted into the five other modes, retaining a tonic of C, by changing the key signature—adding sharps and flats in the manner of Figure 1B. For example, to convert melody 1 in Figure 7 to Mixolydian mode, the B's in the first and second measures were changed to B♭'s. To convert it to Dorian mode, the B's were converted to B♭'s as just described, and in addition, the E in the third measure was changed to E♭. The six modal versions of melody 1 in Figure 7 are shown in Figure 8. Converting all six melodies in Figure 7 into six different modes created a set of 36 melodies. Since each basic melody contained all seven scale-degrees, each of the modal versions of a basic melody was different.

The main challenge that we faced in composing the melodies was that they had to be heard to have a tonal center of C, even when converted to different modes. This is, in fact, a formidable constraint. Experimental and computational studies have found that an important factor in key identification is the particular transposition of the scale that is being used.[4] That is to say, if a melody uses the C major scale (i.e., the diatonic scale of which C is the Ionian tonic), this will be taken by the listener as evidence that the tonal center is C. This is the underlying principle of Longuet-Higgins and Steedman's (1971) pioneering key-finding algorithm. It is also reflected in the influential Krumhansl-Schmuckler key-finding algorithm (Krumhansl, 1990), in which the distribution of pitch-classes in a piece is compared with an ideal distribution or "key-profile" for each key (see Figure 9); it can be seen that the seven degrees of the major mode have higher values in the major key-profile than other degrees. Scales play a similar role in many other key-finding algorithms (see Temperley, 2007, for a review). If melodies are constructed in different modes with a constant

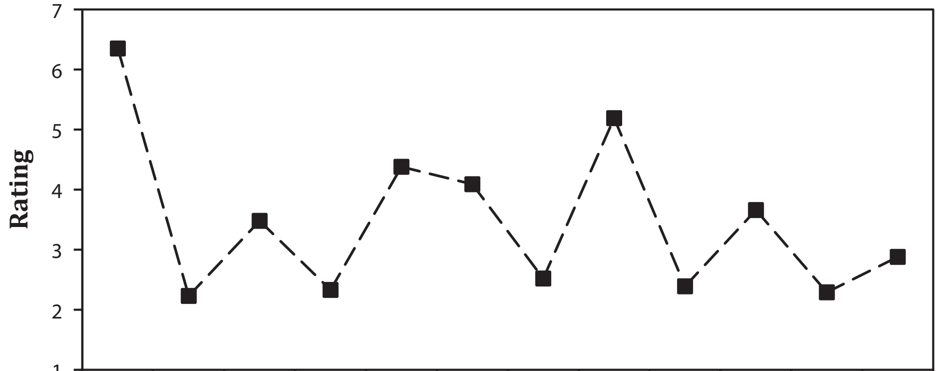
[4] It may seem questionable in this context to draw conclusions from studies of key identification, since these studies are concerned with identifying common-practice keys (major or minor) rather than modes. However, we believe that the basic principles of key identification, such as the importance of the scale and the tonic triad, apply also to the identification of modal frameworks; this is supported by our results, as we will discuss.

FIGURE 8. The six modal versions of basic melody 1.

tonic of C, then each melody will employ a different diatonic scale—for example, a melody in C Mixolydian will use the F major scale—and one might suppose that listeners would simply use the scale to determine the tonic, thus hearing the C Mixolydian melody to have a tonic of F. However, notwithstanding the importance of scale in key determination, there is also evidence that it is not the only factor. In many melodies, a tonal center seems to be strongly established by a pitch set that is contained in several scales, such as a major or minor triad (consider the first six notes of "The Star-Spangled Banner," for example). It has also been shown that the same pitches arranged in different temporal orders can imply different tonal centers (Matsunaga & Abe, 2005), suggesting that the temporal placement of pitches can affect tonality perception. And after all, the whole idea of modes—at least if it is presumed to have any cognitive reality—assumes that the perception of tonic is not simply determined by the underlying diatonic scale.

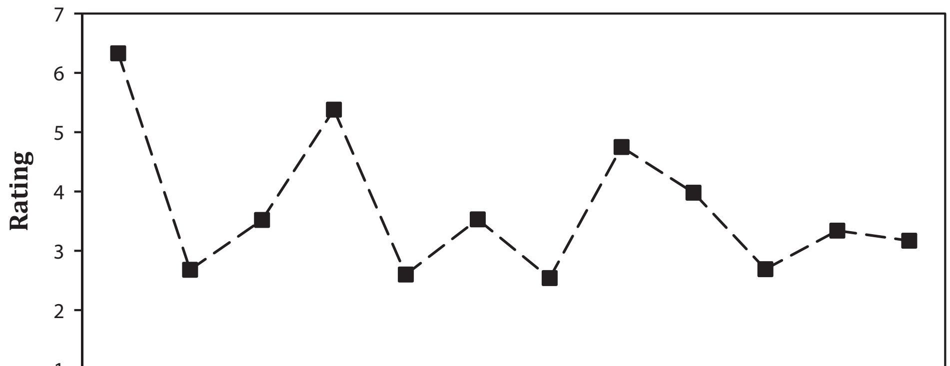
If the scale of a melody is not the sole determinant of its perceived tonic, what other factors are involved? In our view, the primary factor is the emphasis of a particular major or minor triad (whose root is the perceived tonic). This, too, is reflected in the Krumhansl-Schmuckler algorithm: within the major-key profile, the notes of the tonic triad have higher values than other major-mode degrees; the minor key-profile exhibits a similar pattern (see Figure 9). Returning to the excerpts from popular songs in Figure 2, it can be seen that, in each case, C major (I) or C minor (i) is prominent in the accompaniment, occupying as much time as any other harmony or more, and also occurring in metrically accented positions (generally on "hyperdownbeats," that is, the odd-numbered downbeats of the phrase) (Stephenson, 2002). C triads are also emphasized melodically; phrases begin and end on tonic-triad degrees ($\hat{1}$, $\hat{3}/\flat\hat{3}$, or $\hat{5}$) in the great majority of cases, and melodic peaks are generally tonic-triad notes as well. We kept these considerations in mind in composing the melodies in Figure 7. Each melody begins by clearly outlining a C major or minor triad—beginning with a C-triad note and placing C-triad notes on multiple strong beats near the beginning of the melody—and each melody ends on C.

To encourage participants to hear the tonic that we intended, we deliberately maintained the same tonic (C) throughout the experiment—that is, keeping the melodies at the transposition level shown in Figure 8. Our hope was that there would be some "spillover" effect, so that melodies with a relatively clear tonic—in



1	#1/b2	2	#2/b3	3	4	#4/b5	5	#5/b6	6	#6/b7	7
6.35	2.23	3.48	2.33	4.38	4.09	2.52	5.19	2.39	3.66	2.29	2.88

Scale-degree



1	#1/b2	2	#2/b3	3	4	#4/b5	5	#5/b6	6	#6/b7	7
6.33	2.68	3.52	5.38	2.6	3.53	2.54	4.75	3.98	2.69	3.34	3.17

Scale-degree

FIGURE 9. The key-profiles used in the Krumhansl-Schmuckler key-finding algorithm, for major keys (above) and minor keys (below) (from Krumhansl & Kessler, 1982). The vertical axis indicates average ratings for probe tones given a tonal context.

particular, the Ionian mode melodies—would encourage participants to hear other melodies with a tonic of C as well. Despite these measures, we could not guarantee that participants would always hear all the melodies as having a tonic of C, and indeed there is evidence that they sometimes did not do so, as we will discuss below.

The basic (Ionian) melodies were performed on a MIDI keyboard by the first author in a moderate tempo (a metronome was not used), in a musical (but not expressively exaggerated) style. A computer program was then written to convert the MIDI files into different modes, by adjusting the pitch of certain notes, as described earlier. Using this method, the expressive timing and phrasing in each basic melody performance was applied to each modal version of that melody. A uniform dynamic level was maintained throughout.[5]

PROCEDURE

Participants read general instructions indicating that the experiment was about the "emotional connotations" of melodies: "what makes a melody seem happy or sad." They were told that they would hear pairs of melodies, and had to judge "whether the first or the second melody is the HAPPIER of the two." By focusing participants on the qualities of melodies themselves, rather than on how

[5] The stimuli can be heard at www.theory.esm.rochester.edu/temperley/mode-experiment.

the melodies made them feel, we hoped to elicit reports of perceived rather than felt emotions.

In each trial, participants heard a pair of melodies—two modal versions of the same basic melody—separated by a 2-s pause. The six modes were paired in every possible way, creating 15 mode pairs. Every participant heard each of the six basic melodies with each of the 15 mode pairs, or 90 trials in all. Each participant heard the 90 trials in a different random order.

The ordering of modes *within* a trial was handled in the following way. We began by numbering the modes from sharpest to flattest, resulting in the following order: 1 = Lydian, 2 = Ionian, 3 = Mixolydian, 4 = Dorian, 5 = Aeolian, and 6 = Phrygian. A label of "1/5" indicates a trial with mode 1 (Lydian) followed by mode 5 (Aeolian). A canonical ordering of the fifteen possible mode pairs was created, with the lower-numbered mode always placed first: 1/2, 1/3, 1/4, 1/5, 1/6, 2/3, 2/4, 2/5, 2/6, 3/4, 3/5, 3/6, 4/5, 4/6, 5/6. Two arrangements of these pairs were created. In the "first arrangement," the order of each *even*-numbered pair (counting according to the canonical ordering above) was flipped to have the higher-numbered mode first: 1/2, 3/1, 1/4, 5/1, etc. In the "second arrangement," the order of each *odd*-numbered pair was flipped to have the higher-numbered mode first: 2/1, 1/3, 4/1, 1/5, etc. The participants were divided into two "order groups": Group 1 heard the first arrangement on basic melodies 1, 3, and 5, and the second arrangement on basic melodies 2, 4, and 6; Group 2 heard the first arrangement on basic melodies 2, 4, and 6, and the second arrangement on basic melodies 1, 3, and 5. The result was that, for each melody, both orderings of each mode pair were heard by one group or the other; overall, each participant heard a given mode in first position and second position equally often (15 times each); and overall, each participant heard the two orderings of each mode pair equally often (three times each).

The melodies were played on a Macintosh computer using the QuickTime Acoustic Grand Piano sound and were heard over headphones. Participants clicked a link on the screen to hear each trial (melody pair) and listened to each trial only once. They then indicated on paper whether they thought the first or second melody of the pair was happier, by circling "1" or "2."

Results

Our first step in analyzing the data was to explore whether there was a within-trial order effect—that is, a tendency to prefer (judge as happier) the first mode heard or the second. Overall, participants chose the first mode heard on 50.4% of trials, strongly suggesting that there was no order effect. A one-sample t-test across participants examined the number of trials for each participant on which the first melody was favored. The mean (45.3) was not significantly different from an expected mean of 45.0, $t(16) = 0.32$, *ns*. There may have been some more specific order effects, however, as we will discuss below.

To examine the effect of mode on participants' responses, we performed a mixed ANOVA with mode and melody as within-subject factors and order group as a between-subject factor. The dependent measure was the proportion of trials involving a particular participant, melody, and mode, on which that mode was favored. (There were five trials for each participant/melody/mode combination, since each mode was paired with five other modes.) We did not expect any main effect of melody or order group, or any interaction between melody and group, and indeed no such effects were found.[6] A highly significant effect of mode was found, $F(5, 75) = 50.73$, $p < .001$. There was no significant interaction between mode and order group, $F(5, 75) = 0.31$, *ns*, showing that the two groups did not differ overall in their preferences for particular modes. The interaction between melody and mode also (narrowly) fell short of significance, $F(8.8, 132.2) = 1.81$, $p = .07$ (with the Greenhouse-Geisser sphericity correction), suggesting that the perceived (relative) happiness of different modes did not greatly differ across melodies. Also of interest was the three-way interaction between melody, mode, and order group; this indicates whether the within-trial ordering of modes affected the results, since (for a given melody) the two groups heard each mode pair in a different order. This interaction was not significant, $F(25, 375) = 0.83$, *ns*.

The effect of mode on participants' responses was investigated further. Figure 10 shows the proportion of trials involving each mode on which that mode was preferred. Pairwise comparisons were done between the six different modes (as part of the mixed ANOVA

[6] For each melody, group, and melody/group combination, the mean value of the dependent measure must be .5. The reason for this is as follows. Each data point of the dependent measure is a number 0.0, 0.2, 0.4, 0.6, 0.8, or 1.0, representing the proportion of trials (out of five) involving a particular mode M, a melody T, and a participant P on which mode M was chosen. Each of the fifteen trials involving T and P contributes 0.2 to the dependent measure for T, P, and one of the two modes involved in that trial (since each trial involved a forced choice between two modes). Altogether, the fifteen trials involving T and P contribute a total of $15 \times 0.2 = 3.0$ to the six dependent-measure data points for T and P, which means an average of 0.5 for each one, and thus an average of 0.5 for all data points involving a specific melody or a specific participant.

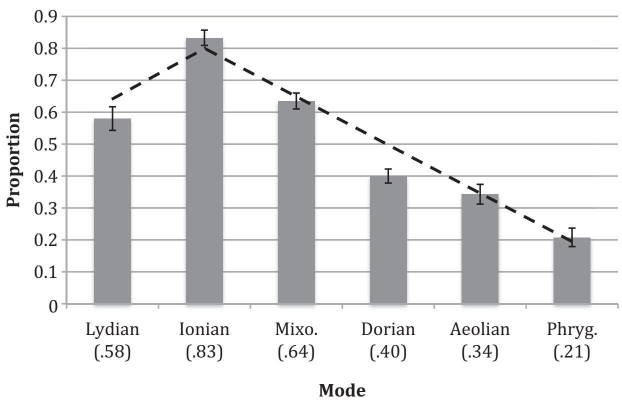


FIGURE 10. Overall preference for each mode. The bar graph shows, for each mode, the proportion of trials involving that mode in which it was judged as happier. The dotted line shows a model that predicts happiness to be linearly related to the number of scale-degrees that are shared with Ionian.

discussed above, with the Bonferroni correction). The results are shown in Table 1. Out of the fifteen pairs of modes, the pairwise differences are significant for all but three: Lydian/Mixolydian, Lydian/Dorian, and Dorian/Aeolian.

With the exception of Lydian mode, the data in Figure 10 reflect a clear pattern: modes get happier as flats are removed and sharps are added. In terms of the numbering of modes suggested earlier (Lydian = 1, Ionian = 2, and so on), this can be viewed as a preference for the "lower-numbered" mode of a pair. It can be seen that, with the exception of Lydian, this rule applies very consistently, not just for adjacent modes (those that differ by just a single scale-degree) but for non-adjacent ones as well. (Even in the one case that the difference is not significant, Dorian/Aeolian, it is still in the direction predicted by the rule.)

One might wonder how consistent this pattern was across participants. To investigate this, we examined, for each participant, the proportion of trials (excluding trials involving Lydian) on which the lower-numbered mode was favored. There were 60 such trials for each participant. These results are shown in Table 2, column 2. It can be seen that every participant favored the lower-numbered mode on more than half of the trials. One-way chi-square tests showed that this preference was greater than chance for all but two participants. We also did a similar test looking only at the 24 trials (per participant) involving adjacent modes (those differing by only one scale-degree) (see Table 2, column 3). In this case, all but one participant (number 12) chose the lower-numbered mode on more than half the trials, and this preference was significant for eight of the seventeen participants.

Discussion

Several conclusions emerge from our study. First, listeners with little or no music training have a strong ability to distinguish melodies in different modes, even those that differ by only a single scale-degree. Our data show significant differences in the perceived happiness of all adjacent mode pairs except one, Aeolian/Dorian. Second, nonmusician listeners have fairly consistent responses to the emotional connotations of modes. Again, the significant differences in perceived happiness between most mode pairs testify to this. And third, these emotional connotations follow quite a consistent pattern: with the exception of Lydian, modes become happier as scale-degrees are raised—that is, as sharps are added and flats are removed.

EVALUATING THE HYPOTHESES

In light of our results, let us reconsider the various hypotheses about the emotional connotations of scales presented in the first section of the article (summarized in Figure 3). The variability hypothesis—proposed by Meyer (1956) to explain the expressive difference between common-practice major and minor—would not seem to predict any difference in connotation

TABLE 1. Comparisons Between Modes.

	Lydian	Ionian	Mixo.	Dorian	Aeolian	Phrygian
Lydian	—	< *	<	>	> *	> **
Ionian		—	> **	> **	> **	> **
Mixo.			—	> **	> *	> **
Dorian				—	>	> *
Aeolian					—	> *
Phrygian						—

Note: The symbol > indicates the row mode was judged as happier on more trials; < indicates the column mode was judged as happier on more trials. * $p < .05$ (with Bonferroni correction); ** $p < .001$ (with Bonferroni correction).

TABLE 2. Results for Individual Participants.

Participant	Proportion of trials (excl. Lydian) on which lower-numbered mode was preferred (out of 60)	Proportion of adjacent-mode trials (excl. Lydian) on which lower-numbered mode was preferred (out of 24)	Proportion of trials involving Lydian on which Lydian was preferred (out of 30)**	Proportion of trials involving Mixolydian on which Mixolydian was preferred (out of 30)**	Proportion of Lydian/ Mixoldyian trials on which Lydian was preferred (out of 6)
1	.72 *	.75 *	**.63**	.57	.50
2	.83 *	.79 *	**.80**	.67	.67
3	.87 *	.75 *	.73	.73	.50
4	.73 *	.79 *	.40	**.43**	.67
5	.73 *	.54	.70	**.80**	.33
6	.90 *	.87 *	.50	**.67**	.33
7	.77 *	.58	.23	**.70**	.17
8	.63	.54	**.57**	.50	.50
9	.78 *	.67	.33	**.60**	.17
10	.93 *	.87 *	.57	**.73**	.33
11	.78 *	.67	.57	**.73**	.17
12	.65 *	.41	.60	**.70**	.17
13	.90 *	.83 *	**.73**	.63	.83
14	.77 *	.67	**.77**	.57	1.00
15	.68 *	.62	**.57**	.53	.33
16	.92 *	.83 *	.63	**.73**	.33
17	.60	.54	**.53**	.50	.50

Note: * Significantly above .5 ($p < .05$) (shown only for columns 1 and 2); ** The larger of the third and fourth columns (within a row) is in boldface.

between diatonic modes; since quite significant differences were in fact found, this hypothesis can be rejected (at least, with regard to diatonic modes). While it is possible that there are differences in variability between the diatonic modes (as they are used in popular music, for example), no theorist has proposed this, to our knowledge.

Helmholtz's consonance theory predicts only a difference between modes with a major tonic triad (Lydian, Ionian, and Mixolydian) and those with a minor tonic triad (Dorian, Aeolian, and Phrygian). Our results are consistent with this hypothesis in a sense, in that the three "major-tonic" modes do have higher happiness ratings than the three "minor-tonic" modes; but the theory does not account for the differences within the major-tonic-triad and minor-tonic-triad groups, several of which are statistically significant, such as Ionian versus Mixolydian and Aeolian versus Phrygian. Thus this hypothesis, too, receives little support from our data.[7]

One might suggest that participants categorized melodies into common-practice modes—major and minor—and then judged their connotations on this basis. But such an explanation seems unable to capture the subtle distinctions between modes reflected in our results. The gradual increase in happiness between Aeolian and Ionian could, perhaps, be explained as arising from "mixtures" of major and minor. But this view has trouble accounting for Phrygian (which is significantly less happy than Aeolian) and Lydian (which is between Ionian and Aeolian in happiness, but is not in any sense a mixture of them). Even Mixolydian is problematic for this view. It is difficult to see Mixolydian as a mixture of common-practice major and minor; in common-practice minor, $\flat\hat{7}$ is used primarily in descending melodic contexts, moving to $\flat\hat{6}$, but $\flat\hat{6}$ is not present in Mixolydian mode. In any case, the assumption that our melodies were perceived entirely within a common-practice framework is belied by our questionnaire, which suggests that our participants listen to rock much more than classical music.

[7] One might say the consonance theory is not especially plausible in any case, since the stimuli in our experiment were all monophonic (involving no chords) and thus were all essentially equivalent in sensory consonance. It is possible, however, that the connotations of modes could be learned from the consonance levels of polyphonic music and then applied to monophonic music. One could also extend the consonance theory to other triads beyond the tonic triad. If all seven triads of a mode are considered, all seven diatonic modes contain the same number of major triads (three), minor triads (three), and diminished triads (one); but by assuming a hierarchy of importance or frequency among the triads, one could construct a consonance theory that assigned a different consonance level to each mode. For example, if one considers just the I, IV, and V triads, then each mode has a unique combination of major, minor, and diminished triads.

Overall, it appears that the hypothesis most strongly supported by our data is the familiarity hypothesis. It was suggested that the most straightforward prediction of the familiarity hypothesis is for a maximum at Ionian mode, with familiarity (and therefore happiness) decreasing as distance increases from Ionian. One could describe this as the "unimodal" version of the theory; a more complex "bimodal" version predicts a secondary peak at Aeolian, since this is the mode closest to common-practice minor and arguably the second-most common mode in popular music (after Ionian). The results of our experiment appear to correspond very closely to the unimodal version of the familiarity theory. Happiness increases in a roughly linear fashion from Phrygian to Ionian and then decreases again from Ionian to Lydian. A quantification of the familiarity theory that predicted happiness as a linear function of the number of scale-degrees shared with Ionian would fit the data quite well (see the dotted line in Figure 10). It was noted earlier, also, that the predictions of the height and line-of-fifths theories align with the familiarity theory for the Ionian, Mixolydian, Dorian, Aeolian, and Phrygian modes, but differ from it with regard to Lydian: unlike the familiarity theory, the height and line-of-fifths theories predict a continued increase in happiness from Ionian to Lydian. The fact that happiness actually decreases significantly from Ionian to Lydian would seem to strongly favor the familiarity theory over the height and line-of-fifths theories.

Further thought suggests, however, that the familiarity theory may not offer a completely satisfactory explanation for our results. In the first place, as was noted earlier, prior research on emotion in music has generally associated familiarity with emotional *induction*: it is believed that listeners find familiar music or musical idioms to be more enjoyable (Gaver & Mandler, 1987; Huron, 2006; Szpenar et al., 2004). But our task specifically probed emotional *recognition*: participants were not asked about how the melodies made them feel, but rather, about the emotional qualities of the melodies themselves. To posit familiarity as an explanation for judgments of emotional recognition is therefore a significant departure from previous thinking about music and emotion. Another point concerns the predictions of the theory for our results. Certainly the familiarity theory predicts that Lydian would be less happy than Ionian; Lydian mode is virtually non-existent in both common-practice and popular music. But what does familiarity predict with regard to the relationship between Lydian and other modes—Mixolydian, for example? While Mixolydian is rare in common-practice music, it is commonly found in popular styles and has been widely discussed by scholars of popular music (Everett, 2004; Moore, 1995; Stephenson, 2002). One could also argue that it is closer to Ionian than Lydian is: Lydian lacks scale-degree $\hat{4}$ while Mixolydian lacks $\hat{7}$, but $\hat{4}$ has been found to be more frequent than $\hat{7}$ in most corpora (Krumhansl, 1990; Temperley, 2007; see also Figure 5) and is also ranked higher in the Krumhansl-Kessler major key-profile (see Figure 9). Thus, going by the familiarity theory alone, one might predict Mixolydian to have a significant happiness advantage over Lydian. But in fact, the difference between the two is small and not statistically significant in our study (see Figure 10 and Table 1).

Given the importance of the Lydian/Mixolydian comparison for teasing apart the familiarity hypothesis and the height/line-of-fifths hypotheses, we investigated this further. Table 2, columns 4, 5, and 6, shows data pertaining to Lydian and Mixolydian, broken down by participant. Columns 4 and 5 show the total number of trials involving Lydian mode on which that mode was favored, and the same for Mixolydian; the greater of the two is shown in boldface. It can be seen that seven of the participants actually favor Lydian more often than Mixolydian; nine favor Mixolydian more often; and one is tied between the two. Column 6 shows the proportion of the six trials involving both Mixolydian and Lydian on which Lydian was favored. Nine participants favored Mixolydian more often, and four favored Lydian more often; one participant favored Lydian on all six of the trials. Overall, this data hardly shows a consistent preference for Mixolydian, as is predicted by the familiarity theory. Rather, it suggests some differences between participants: some participants find Mixolydian to be the happier of the two, while others find Lydian to be happier. We should mention, also, that a pilot version of this experiment was done with eighteen musically trained participants (students at Eastman School of Music); the pilot was identical to the experiment reported here except that within-trial ordering was not systematically controlled. The results were qualitatively very similar to the results of the current experiment, with one difference: Lydian was actually judged to be slightly happier than Mixolydian. (Lydian was favored in 71% of all trials involving that mode, while Mixolydian was favored in 65% of all trials involving that mode.)

We see no possible way to predict a preference for Lydian over Mixolydian via the familiarity theory. Rather, our results suggest that some participants are influenced by a general principle of increasing happiness as scale-degrees are raised, as predicted by the line-of-fifths and height hypotheses. We should note that

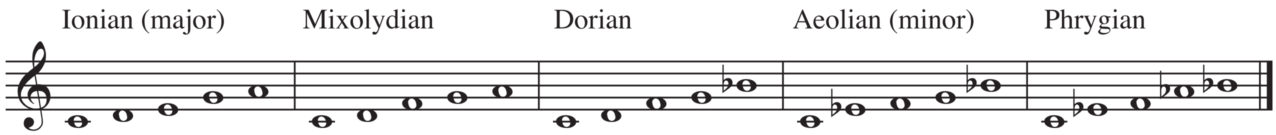


FIGURE 11. The five pentatonic modes, assuming a constant tonic of C.

these two hypotheses also predict that Lydian would be preferred over Ionian. None of our participants displayed an overall preference for Lydian over Ionian (across all trials); however, two participants favored Lydian over Ionian in the six trials that compared them directly, and three other participants were evenly split between the two modes on these trials. This, again, is very difficult to explain from the perspective of familiarity and suggests a pattern of increasing happiness as scale-degrees are raised.

If we accept that either the height hypothesis or the line-of-fifths hypothesis plays some role in the connotations of modal melodies for some listeners, which of these two hypotheses is more plausible? While the two hypotheses make similar predictions for the current experiment, they are very different in character. The height hypothesis is a very general theory about the emotional connotations of music, based on an analogy with speech; the line-of-fifths theory, by contrast, pertains specifically to the cognitive representation of pitches in Western music. It is important to note that the height hypothesis, as advanced by Huron et al. (2010), does not associate happiness directly with pitch height. (This would hardly be plausible; it would predict that, for example, a melody would sound happier in C# minor than in C major, since the pitches of the former are higher, on average.) Rather, the hypothesis relates the happiness of a melody to the height of its *scale*, in relation to some other scale. Common-practice major is happier than minor, by this view, because the third scale degree of minor is lowered in relation to that of major (and possibly the sixth and seventh degrees as well, depending on which minor scale is used). As noted earlier, prior research has indeed found that pitch height plays a role in musical emotion; however, this research has mostly associated pitch height with *arousal* more than valence (Gabrielsson & Lindström, 2001). Thus, we see little *a priori* reason to expect an association between pitch height and valence. Admittedly, there is little *a priori* support for the line-of-fifths theory of musical emotion either. The line of fifths itself is well supported, in that numerous spatial models of the mental representation of pitch have posited a dimension that corresponds to fifth relations, though generally circular rather than linear (for a review, see Krumhansl, 1990). But the idea that this mental representation is used to judge the emotional connotations of scales is, at this point, conjectural.

To differentiate the height and line-of-fifths theories empirically, we require situations where the two theories make different predictions. An interesting case in point is the pentatonic scale. As the term is generally used, the pentatonic scale is a repeating interval pattern of major seconds (S) and minor thirds (T), S-S-T-S-T. As with the diatonic scale, one can generate different modes of the scale by shifting the interval pattern while maintaining a constant tonic (see Figure 11). By far the most common pentatonic modes are the "major" and "minor," shown in Figure 11. Since the other three pentatonic modes do not have well-established names, we apply the names of analogous diatonic modes to these pentatonic modes (and to the major and minor pentatonic modes as well). The line-of-fifths theory predicts the happiness of these modes in the same manner as diatonic modes: a scale is happier if it is further in the "sharp" direction in relation to the tonic. Thus Ionian-pentatonic is happiest and Phrygian-pentatonic is saddest. By contrast, the height theory makes the opposite prediction: unlike the diatonic case, scales in the "flatter" direction are actually *higher* in pitch. (Each move to the right in Figure 11 involves the raising of a pentatonic scale-degree: for example, moving from Ionian-pentatonic to Mixolydian-pentatonic, the third degree of the scale is shifted from E to F.) Thus the line-of-fifths theory predicts that major pentatonic is happier than minor pentatonic, while the height theory predicts the reverse. Discussions of pentatonic scales generally seem to support the line-of-fifths predictions—that is, major pentatonic is said to be happier than minor pentatonic (Tagg, 2003; Wieczorkowska, Synak, Lewis, & Ras, 2005); but there seems to have been no systematic study of this question. This would appear to be an interesting area for experimental work. (The predictions of the familiarity hypothesis are interesting here as well. While both major and minor pentatonic scales are used in popular music, it is by no means obvious that the major pentatonic is more common; we suspect the opposite is true.)

THE PSYCHOLOGICAL REALITY OF MODES

Throughout the discussion so far, we have assumed that listeners can identify modes, and that the judgments of the emotional connotations of melodies in our experiment relied on these mode judgments. This does not, of course, imply that participants *consciously* identified the mode of each melody, but rather that modal categories were operating in their perceptual and cognitive processing of the melodies at an unconscious level. At this point, however, it seems worth examining this assumption. It seems clear that participants identified some kind of difference between, for example, the Ionian melodies and the Phrygian ones, since they very consistently identified the former as being happier than the latter. But is diatonic modality the only way, or even the best way, of explaining these results?

An alternative explanation for our findings is that the melodies were heard not to express modes, but rather, to involve varying degrees of chromaticism, or notes outside the scale. In general, the assertion of a scalar pitch framework for a piece does not imply that all the notes of the piece are within the scale. Chromatic notes are commonplace in common-practice music (to a greater or lesser extent depending on the period and composer); in rock, too, notes and chords are often analyzed as arising from alterations of an underlying scalar framework (Everett, 2004; Moore, 1992, 1995). It has been shown, also, that chromaticism is recognized as expressing negative emotions such as sorrow and anger (Thompson & Robitaille, 1992); thus we might expect more chromatic melodies to be judged as less happy. In our experiment, this "chromaticism" hypothesis is difficult to distinguish from the familiarity hypothesis. If we assume (as we have throughout) that the Ionian mode is the most basic and familiar one, the chromaticism hypothesis would predict decreasing happiness with increasing distance from Ionian, exactly as predicted by the familiarity hypothesis. It is worth emphasizing, however, that the familiarity hypothesis and the chromaticism hypothesis are fundamentally quite different. The familiarity hypothesis (as we have construed it here) assumes that listeners perceive underlying modal pitch frameworks, but judge the happiness of these frameworks by their familiarity. The chromaticism hypothesis, by contrast, assumes that all the melodies in our experiment were heard in C major; each note outside the C major scale was simply heard as an isolated, non-scalar event, not affecting the underlying pitch framework. Overall, we find the familiarity theory more plausible than the chromaticism theory. While major mode may be the most common in popular and classical music, modern listeners are exposed to a great deal of music—especially popular music—that is not built on the major mode; this includes songs in other modes (such as Figure 2B, 2C, and 2D) and songs that do not consistently adhere to any diatonic mode (such as Figure 2E). We see no reason to assume that listeners impose a major-mode framework on everything they hear. But this is an empirical question, deserving further study. (Another possibility would be a "bimodal" version of the chromaticism hypothesis: we might hypothesize that listeners categorize any melody as either Ionian or Aeolian, and treat as chromatic any pitch that does not fit the chosen framework. Again, the assumption would be that chromaticism has negative emotional connotations. However, this model predicts a local happiness "peak" at Aeolian, which is not observed in our data.)

One could imagine an experiment that teased apart the familiarity and chromaticism hypotheses, perhaps using a probe-tone methodology (Krumhansl, 1990). For example, the familiarity hypothesis predicts that a Mixolydian melody (containing $\flat\hat{7}$s rather than $\hat{7}$s) will establish a Mixolydian framework in the listener's mind, such that a following $\flat\hat{7}$ probe-tone should seem to "fit" or "follow" better than $\hat{7}$; by the chromaticism hypothesis, by contrast, the $\flat\hat{7}$s of the melody do not disturb the underlying major-mode framework, so that a $\hat{7}$ probe-tone should still be judged to follow better than $\flat\hat{7}$. Such an experiment might shed light on the psychological reality of modal pitch frameworks.

A further question that might be raised concerns the perception of tonal center. It was noted earlier that our experiment depends crucially on listeners maintaining a constant tonal center of C throughout the experiment. If they are not doing so, then they are not perceiving the melodies in the intended modes, thus the conclusions drawn above about the connotations of modes are unwarranted. (Even the chromaticism hypothesis considered earlier in this section assumes a constant tonal center of C.) Yet it is difficult to be certain that this constant tonality was indeed maintained. As noted earlier, it is generally agreed—at least, with regard to major/minor tonality—that the scale of a melody has some effect on the choice of tonal center. An alternative interpretation of our results might be that participants were judging tonality mainly or even solely by this criterion—treating each melody as Ionian (major), with no chromatic notes, and thus identifying a different tonal center for each (intended) mode: G for the Lydian melodies, C for Ionian, F for Mixolydian, and so forth.

While this "shifting-tonic" hypothesis cannot be completely discounted, it seems highly unlikely to us, for several reasons. First, as observed earlier, there is strong experimental and informal evidence that the identification of tonic is not exclusively governed by the underlying scale, and that the emphasis of a triad can also play an important role. In effect, the shifting-tonic hypothesis implies that listeners cannot hear diatonic modes at all; there seems to be a strong consensus that this is not the case. (The importance accorded to modality in popular music scholarship, for example, seems to imply a belief that diatonic modes have some psychological reality for listeners.) The shifting-tonic hypothesis is also very difficult to reconcile with our experimental findings. If all of the melodies in our experiment were heard as being in "pure" major mode (with no chromaticism), why should they differ in happiness? The shifting-tonic hypothesis might predict that the (intended) Ionian melodies would be happiest; certainly they are the most normative, in that they end on scale-degree $\hat{1}$ (whereas the other melodies, by this hypothesis, end on other scale-degrees). But it has no obvious way of predicting the general pattern of decreasing happiness as flats are added. Why should a melody in F major that ends on $\hat{5}$ (Mixolydian) be happier than one in A♭ major that ends on $\hat{3}$ (Phrygian)?

Thus, we see little reason to give further consideration to the shifting-tonic hypothesis. This does not mean, however, that C was *always* heard as the tonic throughout our experiment; indeed, there is reason to believe that it was not. To explore this, we must revisit the issue of within-trial order effects. As noted earlier, no overall within-trial order effect was found across participants; the absence of a group × mode × melody interaction effect also suggests that within-trial order did not greatly affect the results. However, we wondered if more specific order effects might have been missed by these analyses. Table 3 shows, for each mode pair, the proportion of trials on which the first mode heard was favored. Each mode pair was heard 102 times, and within those trials, each mode of the pair occurred first on exactly half the trials; so in the absence of an order effect, the first mode should have been chosen on half of the trials. One-way chi-square tests (against an expected value of 51) showed that just two of the mode pairs reflected a significant ordering bias: Dorian/Phrygian and Aeolian/Phrygian (see Table 3). In both of these cases, there was a significant tendency to prefer the first mode heard.

TABLE 3. Order Effects by Mode Pair.

Mode pair	Proportion of trials (out of 102) on which the first mode heard was chosen
L/I	.48
L/M	.41
L/D	.47
L/A	.52
L/P	.56
I/M	.46
I/D	.47
I/A	.44
I/P	.48
M/D	.46
M/A	.49
M/P	.48
D/A	.58
D/P	.62*
A/P	.64**

Note: * Significantly above .5 ($p < .05$); ** Significantly above .5 ($p < .01$).

We believe this curious finding may be due to variability in the perception of tonal center. Due to the rarity of Phrygian mode (and particularly scale-degree $\flat\hat{2}$), it seems likely that there will be a particular tendency in this case for listeners to search for an alternative tonic—most likely, the major-mode tonic, or A♭ in our experiment. Consider Figure 12, one of the Phrygian melodies from our experiment; it is not difficult to hear this melody with A♭ as the tonic, and indeed this may be the most natural hearing when the melody is heard in isolation. Recall that the use of a single transposition level throughout was intended to encourage the hearing of a constant tonic of C, and that it was hoped that some "spillover" would occur from the clearly "C-centered" melodies to the more ambiguous ones. A given melody is probably more likely to be affected by such spillover if it is the *second* melody of a pair (separated by the previous melody by only 2 seconds); if it is the *first* of a pair (separated from the previous melody by a somewhat longer period, determined by the participant), it might resist the spillover effect, leading to a preference for whatever tonic is inherently favored by the melody. Thus it is not surprising that a melody such

FIGURE 12. One of the Phrygian melodies used in the experiment.

as that in Figure 12 would sometimes be heard as being in A♭ Ionian rather than C Phrygian, particularly when it was the first of a pair; and this might sometimes cause it to be judged as happier than another modal version, especially a version in one of the "sadder" modes such as Dorian or Aeolian.

In short, while we find it very unlikely that participants were hearing all or most of the stimuli in a "shifting-tonic" fashion, there is reason to suspect that melodies in a small number of trials may have been perceived to have tonal centers other than C. In future studies of mode perception we intend to make greater efforts to address this problem. One possibility would be to maintain a "drone" in the background—a constant pitch of C (or whatever pitch is intended as tonic), perhaps in the bass register—as a way of discouraging the inference of alternative tonal centers.

Conclusions

Our study suggests that listeners without extensive music training are highly sensitive to some quite subtle aspects of pitch organization. In general, they can reliably distinguish one diatonic mode from another, even those that differ only by a single scale-degree. For example, our participants were able to distinguish Ionian from Mixolydian (which differ only in that the seventh degree is lowered in the latter case), and Aeolian from Phrygian (which differ only in that the second degree is lowered in the latter case). Listeners also respond quite consistently to the emotional connotations of diatonic modes, and specifically to their perceived degree of happiness. The "happiest" mode in our study, Ionian (major mode), was favored in 83% of the trials that involved it, while the least happy mode, Phrygian, was favored in only 21% of trials. Listeners' judgments also reflect a clear and consistent pattern; generally, happiness increases as scale-degrees are raised, though Lydian (with a raised fourth) is less happy than Ionian. Thus, it appears that the expressive connotations of pitch frameworks (for modern American college students, at least) go well beyond the conventional dichotomy between major and minor; diatonic modes convey quite subtle gradations of expressive meaning.

We have considered a variety of hypotheses that might explain our results. Overall, the principle that accounts best for our findings is familiarity. The most common mode in both classical and modern popular music, Ionian, was judged to be the happiest in our study, and we found a consistent pattern of decreasing happiness with increasing distance from Ionian. However, some rather subtle aspects of our data suggest that familiarity is not the only factor involved. In particular, familiarity would seem to suggest that Mixolydian would be happier than Lydian, since they are equally distant from Ionian (both differing from it by one scale-degree), and Mixolydian is much more common in popular music. Yet almost half of our participants judged Lydian to be happier than Mixolydian (choosing the former more frequently than the latter). This suggests that, apart from familiarity, the happiness of a mode—for some listeners at least—is influenced by its "sharpness." We considered two possible explanations for this tendency: a "height" hypothesis, which simply equates the happiness of a mode with its (relative) pitch height, and a "line-of-fifths" hypothesis, which attributes the happiness of a mode to the position of the tonic in relation to the scale on the line of fifths; we favor the latter view.

The preceding discussion has pointed to several possible directions for future work. The fact that some participants in our experiment favored Lydian over Mixolydian is of particular interest, as it is not predicted by familiarity; this comparison deserves further study. A study similar to this one using pentatonic modes would also be of value, and might allow better empirical differentiation of the familiarity, height, and line-of-fifths hypotheses. More fundamentally, further research is required to confirm that listeners do indeed perceive modal pitch frameworks at all, as opposed to simply hearing chromatic inflections against an underlying major mode; we have suggested that a probe-tone methodology might be useful in this regard.

The purpose of the current study was twofold. In the first place, we hoped to gain a better understanding of the expressive implications of music that employs diatonic modality, especially popular music. Secondly, we hoped to gain insight into the broader issue of the emotional connotations of scales and how and why these connotations arise. Several of the hypotheses that have been discussed here—such as the variability, consonance, and height hypotheses—were originally proposed to account for the difference between common-practice major and minor. Of course, it is possible that the connotations of diatonic modes and those of common-practice modes (major and minor) are due to quite different factors. Other things being equal, however, an account that explained both sets of phenomena as arising from the same principles would surely gain added plausibility. Given that there remains some uncertainty as to how to account for the case of diatonic modality on its own, we will not attempt to bring common-practice major and minor into the picture as well, but leave this as a topic for future investigation.

It was noted earlier that investigations of the connotations of common-practice major and minor suffer from having only two data points. The addition of diatonic modes adds a few more data points, but more data would certainly be welcome. In this connection, it is worth repeating that pitch frameworks in many other musical idioms have expressive connotations—earlier (pre-common-practice) styles of Western music, as well as non-Western musical styles such as North Indian and Arabic music. Investigations of these frameworks and their expressive implications would be of great interest, both in their own right and as a way of gaining insight into broader issues of musical expression and emotion.

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